Regional Activity Centre for Specially Protected Areas
(RAC/SPA)
Boulevard du Leader Yasser Arafat
B.P. 337 – 1080 Tunis cedes – TUNISIA
E-mail : car-asp@rac-spa.org

Centre d’Activités Régionales pour les Aires Spécialement Protégées
(CAR/ASP)
Boulevard du Leader Yasser Arafat
B.P. 337 – 1080 Tunis cedes – TUNISIA
E-mail : car-asp@rac-spa.org

MEDITERRANEAN SYMPOSIUM ON MARINE VEGETATION

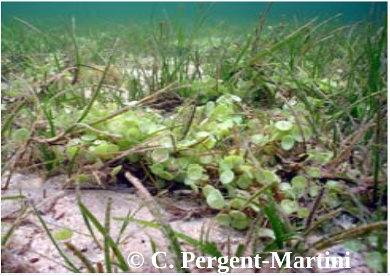
United Nations Environment Programme
Mediterranean Action Plan
Regional Activity Centre for Specially Protected Areas

PROCEEDINGS OF THE 3RD MEDITERRANEAN SYMPOSIUM ON MARINE VEGETATION

27-29 March 2007 – Marseilles

ACTES DU 3ème SYMPOSIUM MEDITERRANEEN SUR LA VEGETATION MARINE

27 – 29 Mars 2007 - Marseille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March 2007

United Nations Environment Programme
Mediterranean Action Plan
Regional Activity Centre for Specially Protected Areas

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Citation : UNEP – MAP – RAC/SPA, 2007. Proceedings of the third Mediterranean symposium on marine vegetation (Marseilles, 27-29 March 2007). C. Pergent-Martini, S. El Asmi, C. Le Ravallec edits., RAC/SPA publ., Tunis : 300p.

PNUE – PAM – CAR/ASP, 2007. Actes du troisième symposium méditerranéen sur la végétation marine (Marseille, 27-29 Mars 2007), C. Pergent-Martini, S. El Asmi, C. Le Ravallec édits., CAR/ASP publ., Tunis : 300p.

AVANT-PROPOS

Suite à une recommandation du Plan d'Action pour la Conservation de la Végétation Marine en mer Méditerranée (adopté par les Parties contractantes à la Convention de Barcelone, en 1999), une série de symposiums scientifiques, dédiée à la végétation marine méditerranéenne, a été initiée en 2000. Cette initiative vise essentiellement à faire le point sur les données scientifiques disponibles et à promouvoir la coopération entre les spécialistes méditerranéens.

Le premier symposium méditerranéen sur la végétation marine (Ajaccio, Octobre 2000) a réuni 43 participants de 15 pays méditerranéens et s'est traduit par 32 communications orales et posters. Lors des tables rondes des sujets d'importance, tels que la taxonomie dans la région et l'utilisation de la végétation marine comme outil de gestion de la zone côtière, ont été abordés. Les recommandations ont permis de promouvoir, dans le cadre du Plan d'Action pour la Méditerranée, une initiative méditerranéenne sur la Taxonomie, s'inspirant de la démarche développée, dans le cadre de la Convention sur la Diversité Biologique, au plan mondial.

Le deuxième symposium (Athènes, Décembre 2003), organisé en collaboration avec le Centre Grec pour la Recherche Marine, a regroupé 67 participants issus de 15 pays méditerranéens. 40 communications orales et posters ont été présentés à cette occasion. Les groupes de travail qui se sont réunis ont mis l'accent sur la nécessité de standardiser les techniques de cartographie et de développer des outils pour la taxonomie de la végétation marine, à l'échelon méditerranéen.

Le troisième symposium, programmé à Marseille, du 27 au 29 Mars 2007, en partenariat avec la Région Provence-Alpes-Côte d'Azur et l'Association Seagrass 2000 (associée au Plan d'Action pour la Conservation de la Végétation Marine en mer Méditerranée), a vu l'inscription de 120 participants provenant de 17 pays méditerranéens. Ce ne sont pas moins de 60 communications orales et posters qui devraient y être présentés.

Le CAR/ASP a souhaité profiter de la présente session pour faire permettre la diffusion des résultats obtenus dans le cadre du programme Interreg III B "Mise en cohérence, développement, harmonisation et validation de méthodes d'évaluation de la qualité du milieu littoral par le suivi de l'herbier à *Posidonia oceanica* - POSIDONIA" à la communauté scientifique méditerranéenne.

Des tables rondes permettront d'aborder des thèmes d'actualité tels que :

- Quelles méthodes de cartographie et de surveillance, pour quels objectifs de gestion ?
- La végétation marine de Méditerranée constitue-t-elle un outil d'évaluation de l'efficacité des stratégies (Directive Cadre sur l'Eau, Directive Stratégie Maritime) et des grands enjeux environnementaux (Horizon 2012, Initiative Horizon 2020) ?
- Comment mettre en place une conservation efficace des « hots-spot » de biodiversité que représentent les formations coralligènes et autres bioconcrétionnements calcaires de Méditerranée ?

Le Directeur du CAR/ASP
Abderrahmen GANNOUN
Tunis, le 15 mars 2007

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Third Mediterranean Symposium on Marine Vegetation

Marseilles, 27-29 March 2007

Region Hall - Standing Committee Room

PROGRAMME

Tuesday 27 March 2007

10:00 – 13:00 *Participants Welcome and Registration*

14:00 – 14:30 **Third Mediterranean Symposium on Marine Vegetation (UNEP/MAP-RAC/SPA) Official Opening**

- Mr. M. VAUZELLE, President of the Provence-Alpes-Côte d'Azur Region
- Mr. A. GANNOUN, Director of RAC/SPA

14:30 – 16:00 **Session 1 - Presentation of the results of the Programme Interreg III B « POSIDONIA » - *Consistency, Development, Harmonization and Validation of Methods Evaluating the Quality of the Coastal Environment through* Posidonia oceanica *Meadows Monitoring***
Rapporteurs: Ms. M.C. BUIA, Ms. C. MIFSUD

- Presentation of the POSIDONIA Programme: Objectives and expected results by Mr. R. KANTIN (Ifremer, France) – 30’
- Results of the MAPPING Group by GIS Posidonie (France) – 30’
- Results of the MONITORING Group by Ms. R.M. BERTOLOTTO (ARPAL, Italy) – 30’
- Results of the BIO-INDICATORS Group by Mr. J. ROMERO (Barcelona University, Spain) and/or Mr. G. PERGENT (Corsica University, France) – 30’

16:00 – 16:20 *Coffee Break*

16:20 – 18:10 **Roundtable and Debate « *Which Mapping and Monitoring Methods for Which Objectives?* »**
Facilitator: Mr. G. PERGENT
Rapporteurs: Mr. R. KANTIN, Mr. R. TURK

- The Action Plan for the Conservation of Marine vegetation in the Mediterranean Sea and the MedPosidonia programme by Ms. S. EL ASMI (UNEP/MAP-RAC/SPA, Tunisia)
- Mapping and monitoring of the marine vegetation: Managers expectations by Ms. V. RAIMONDINO(PACA Region, France) / Mr. R. TURK (Institute of the Republic of Slovenia for Nature Conservation, Slovania)

18:10 – 18:30 Closure of the first day

18:30 *Welcome Cocktail*, offered by the PACA Region to the participants of the Third Mediterranean Symposium on Marine Vegetation (UNEP/MAP-RAC/SPA)

Wednesday 28 March 2007

8:30 – 9:15 **Session 2 - Monitoring of the Mediterranean Marine Vegetation**
Chairperson: Mr. J. ROMERO
Rapporteurs: Mr. A. PEIRANO, Mr. T. BELSHER

- « *The proteomic approach in* Posidonia oceanica *populations: which protein biomarkers for light stress acclimation?*» by: S. MAZZUCA, A. SPADAFORA, D. FILADORO, M. BRACALE, M. MARSONI and A.M.INNOCENTI
- « *Seasonal data on phytoplankton of some Albanian lagoons* » by: S. XHULAJ and A. MIHO
- « *Identification et caractérisation des herbiers à* Posidonia oceanica *par sonar à balayage latéral: vers une base de données méditerranéenne ?* » by: P. CLABAUT, C. AUGRIS, V. PASQUALINI, G. PERGENT and C. PERGENT-MARTINI
- « *Pertinence de la méthode DIVA pour l'interprétation des mosaïques sonar latéral* » by: C. VIALA, C. NOEL, M. COQUET, B. ZERR, P. LELONG and J.-L. BONNEFONT

9:15 – 9:45 Discussion

9:45 – 10:30 **Session 2 - Monitoring of the Mediterranean Marine Vegetation (Continued)**

Poster Session

- « *Exploring the use of rocky shore macroalgae as indicators of environmental condition* » by: M. AZZOPARDI and P. J. SCHEMBRI
- « *Cartographie et caractérisation d'un herbier à Posidonia oceanica de la baie de Sidi-Selem (Bizerte, Tunisie)* » by: I. BEN CHIKH ALMI, A.S. DJELLOULI and Y. MEZGUI
- « *Les peuplements phytobenthiques du Lac Nord de Tunis de 1926 à 2006* » by: N. BEN MAIZ and A. SHILI
- « *The application of the "Carlit method" to assess the ecological status of coastal waters in the Gulf of Naples* » by: M.C. BUIA, L. PORZIO and F. PAOLO PATTI
- « Posidonia oceanica*: a quality element for ecological status assessment* » by: M.C. BUIA, F. SILVESTRE and S. FLAGELLA
- « *Marine habitats atlas of Liguria region (Italy)* » by: S. COPPO and G. DIVIACCO
- « *Developing a conceptual overview of Mediterranean seagrass meadows* » by: G. DI CARLO, M.C. BUIA, S. GOBERT, G. LEPOINT, B. MARTINEZ-CREGO, G. PERGENT, C. PERGENT-MARTINI, G. PROCACCINI, P. RENOM, F. TOMAS, B. VELIMIROV and A. VERGES
- « *Evaluation of the macroalgae communities in the Valencian rocky coasts (SE Spain) for the European Water Framework Directive (WFD)* » by: M. DIAZ-VALDES, E. ABELLAN, A. IZQUIERDO and A. RAMOS-ESPLA
- « *Use of* Posidonia oceanica *(L.) Delile as a pollution indicator Study of a zone situated in Revellata Bay (Calvi Bay, Corsica)* » by: C. DYC, S. GOBERT, G. LEPOINT, J.M. BOUQUEGNEAU, A. CHERY, A. VOLPON and P. LEJEUNE
- « *Evaluation of the status of* Posidonia oceanica *meadows in the Valencian coast (SE Spain) for the European Water Framework Directive (WFD)* » by: Y. FERNÁNDEZ-TORQUEMADA, M. DÍAZ-VALDÉS, F. COLILLA, J.L. SÁNCHEZ-LIZASO and A. RAMOS-ESPLÁ
- « *The state of* Posidonia meadows *along the Albanian coast: general evaluation* » by: L. KASHTA, M. XHULAJ, X. MATO, S. BEQIRAJ and A. GAÇE
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- « *Monitoring the limits of* Posidonia oceanica *meadows using the MDM (Microcartography Diving Method)* » by: A. PEIRANO, S. SGORBINI, S. COCITO and M. MORGIGNI

10:30 – 10:50 *Coffee Break*

10:50 – 11:35 **Session 2 - Monitoring of the Mediterranean Marine Vegetation (Continued)**
Chairperson: Mr. C. F. BOUDOURESQUE
Rapporteurs: Ms. M. PEREZ, Mr. H. MAYHOUB

- « *Monitoring* Posidonia oceanica *in the Mediterranean: A datawarehousing approach*» by: C. LOPEZ Y ROYO, G. PERGENT, C. PERGENT-MARTINI and G. CASAZZA
- « *The* Posidonia oceanica *(L.) Delile meadows' distribution and state of health in Maltese territorial waters* » by: C. MIFSUD, F. CINELLI, S. ACUNTO, D. BALATA, E. LANFRANCO, S.A. MICALLEF, L. PIAZZI, D.T. STEVENS and S. CALVO
- « *The seagrass* (Posidonia oceanica) *meadows in the Catalan coast: Past trends and present status*» by: J. ROMERO, M. PÉREZ and T. ALCOVERRO
- «*Comparison of three seagrass monitoring systems: Seagrassnet, "Posidonia" programme and RSP*» by : G. PERGENT, C. PERGENT-MARTINI, B. CASALTA, C. LOPEZ Y ROYO, B. MIMAULT, M. SALIVAS-DECAUX and F. SHORT

11:35 – 12:05 Discussion

12:10 – 14:00 *Lunch Break*

14:00 – 15:30 **Session 3 - Anthropogenic Impacts on Mediterranean Marine Vegetation**
Chairperson: Mr. F. CINELLI
Rapporteurs: Mr. A. ZULJEVIC, Ms. S. GOBERT

- « *Etude synoptique sur les cultures expérimentations de* Gracilaria verrucosa *en Tunisie* » by: J. KSOURI, F. MENSI, K. SAHLI-HAZAMI and I. CHALLOUGUI
- « *Etude lépidochronologique de quelques herbiers de* Posidonia oceanica *des côtes tunisiennes* » by: Y.-R. SGHAIER, R. ZAKHAMA-SRAIEB and F. CHARFI-CHEIKHROUHA
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- « *Threats to coralligenous assemblages: Sedimentation and biological invasions* » by: F. CINELLI, D. BALATA and L. PIAZZI
- « *Colonization of the Gallinaria island (NW Ligurian Sea) seafloors by* Caulerpa taxifolia *and* C. racemosa*: Implications for a new marine protected area* » by: L. TUNESI, S. AGNESI, T. DI NORA, G. MO and A. MOLINARI

15:30 – 16:20 Discussion

16:20 – 16:40 *Coffee Break*

16:40 – 18:30 **Roundtable and Debate « The *Marine Vegetation as an Environmental Assessment Tool for the Mediterranean?* »**
Facilitator: Ms. G. CASAZZA
Rapporteurs: Mr. P. PANAYOTIDIS, Ms. M. HADJICHRISTOPHOROU

- Regional and international policies and evaluation procedures by Mr. L. TUNESI (ICRAM, Italy) – 10'

Thursday 29 March 2007

8:30 – 9:25 **Session 4 - Biology, Ecology and Inventories of Mediterranean Flora Species and Assemblages**
Chairperson: Mr. M. VERLAQUE
Rapporteurs: Mr. A. BAYED, Ms. S. EL ASMI

- « *Diversité des peuplements phytobenthiques dans les lagunes du Cap Bon (Nord-Est de la Tunisie)* » by: A. SHILI, N. BEN MAIZ and C. F. BOUDOURESQUE
- « *Caractérisation lépidochronologique des différents types d'herbiers de posidonie dans le golfe de Gabes (Tunisie)* » by: M. BEN BRAHIM, H. TERASHIMA and A. HAMZA ASMA
- « *Structure of* Posidonia oceanica *meadows in the vicinity of Ain Al-Ghazala Lagoon (Libya): The « macroatoll » ecomorphosis* » by: G. PERGENT, A. S. DJELLOULI, A. A. HAMZA, K. S. ETTAYEB, A. ALKEKLI, M. TALHA and E. ALKUNTI
- « *Contribution to the study of the marine vegetation of Rhodes Island (Greece)*» by: K. TSIAMIS, P. PANAYOTIDIS and B. MONTESANTO
- « *Shallow, sheltered water populations of* Cystoseira *sp. in Menorca (Balearic Islands)* » by: M. SALES and E. BALLESTEROS

9:25 – 9:55 Discussion

9:55 – 10:30 **Session 4 - Biology, Ecology and Inventories of Mediterranean Flora Species and Assemblages (Continued)**

Poster Session

- « *Chemical composition and trace element concentration of marine algae* Enteromorpha compressa *as a potential food source* » by: M.A.M. ABDALLAH
- « *A preliminary study on selected benthic algae and their epiphytic flora in Izmit Bay (Marmara Sea, Turkey)* » by: Y. AKTAN
- « *Données préliminaires sur la biodiversité phytobenthique du littoral d'El Kala (Est Algérien)* » by: S. BELBACHA, R. SEMROUD, R. DUPUY DE LA GRANDRIVE, M. FOULQUIE and H. SERIDI
- « *Etude préliminaire d'un herbier de Posidonie à Ras Jebel (Nord-Est de la Tunisie) : phénologie et diversité des macro invertébrés* » by: W. BELGACEM, H. GHRAIRI and O.K. BEN HASSINE
- « *Observations sur la phénologie des différents types d'herbiers de Posidonie dans le Golfe de Gabès (Tunisie)* » by: M. BEN BRAHIM[1], T. HIROAKI and A. HAMZA
- « *L'algue rouge* Gelidium spinosum *(S.G. Gmelin) P.C. Silva des côtes de Monastir (Tunisie) : quelques aspects biologiques* » by: R. BEN SAID, M.S. ROMDHANE, A. EL ABED and R. M'RABET
- « *Technique de fixation des boutures de* Posidonia oceanica *(L.) Delile en Méditerranée : adaptation en milieu marin d'un système déjà utilisé sur terre* » by: F.L. CINELLI, F. BOCCALARO, F. CINELLI, M. BURGASSI, L. PIAZZI, F. RENDE and M. ZANELLA
- « *Marine flora and vegetation of South Aegean Sea (Greece)* » by: A. DIAPOULIS and K. TSIAMIS
- « *What remains of the* Posidonium *18 years after?* » by: J. LASSAUQUE, A. MEINESZ and T. THIBAUT
- « *A prospection of Fucales populations in the Ligurian Sea rockpools* » by: L. MANGIALAJO
- « Caulerpa racemosa *(Chlorophyta, Caulerpales) in the Maltese Islands (Central Mediterranean)* » by: C. MIFSUD and E. LANFRANCO
- « *Root morphology of* Cymodocea nodosa *reflects eutrophication gradients* » by: S. OLIVA, O. MASCARÓ, J. ROMERO and M. PÉREZ

- « *Use of exergy to detect and measure perturbations affecting* Posidonia oceanica *(L.) Delile meadows: characterization in the sedimentary compartment* » by: D. PETE, J.M. BOUQUEGNEAU and S. GOBERT
- « *Preliminary phylogeny of the* Cystoseira *genus (Phaeophyceae)* » by: M.L. SUSINI, F. ROUSSEAU, A. MEINESZ, T. THIBAUT
- « *Halophila stipulacea* (Forsskål) Ascherson and Caulerpa racemosa (Forsskål) J. Agardh in Albania » by: M. XHULAJ and L. KASHTA

10:30 – 10:50 *Coffee Break*

10:50 – 11:45 **Session 4 - Biology, Ecology and Inventories of Mediterranean Flora Species and Assemblages (Continued)**
Chairperson: Mr. H. LANGAR
Rapporteurs: Mr. A. DJELLOULI, Mr. L. PIAZZI

- « *Effects of sea urchin grazing on a* Posidonia oceanica *meadow in the Gulf of Oristano (Western Sardinia, Italy)* » by: S. COPPA, I. GUALA, M. BAROLI, M. BRESSAN, S. COMO, G. PIERGALLINI and G. DE FALCO
- « *Cystoseira* communities in the Slovenian coast and their importance for fish fauna» by: R. TURK, M. ORLANDO-BONACA, Ž. DOBRAJC and L. LIPEJ
- « *Nitric oxide effect in transplanted cuttings of* Posidonia oceanica *(L.) Delile* » by: M. CARDILIO, S. NICASTRO, F. RENDE and A.M. INNOCENTI
- « *Early colonization of* Posidonia oceanica *(L.) Delile by epiphytes: Comparison between natural and artificial seagrass leaves* » by: D. PETE, S. GOBERT, J.M. BOUQUEGNEAU, M. POULICEK and G. LEPOINT
- « *Transplantation effects on* Posidonia oceanica *(L.) Delile* » by: S. GOBERT, D. VANGELUWE, J.M. BOUQUEGNEAU, M. EISINGER, M. PASTER, H. SCHUMAKER and G. LEPOINT

11:45 – 12:15 Discussion

12:15 – 14:00 *Lunch Break*

14:00 – 15:10 **Session 4 - Biology, Ecology and Inventories of Mediterranean Flora Species and Assemblages (Continued)**
Chairperson: Mr. N. BEN MAÏZ
Rapporteurs: Ms. Z. DJELLOULI-EL ASMI, Mr. A. HAMZA

- « *Etude biométrique (biomasse et phénologie) de populations à* Caulerpa racemosa *dans la région de Bizerte (Tunisie)* » by : Y. MEZGUI and A. S. DJELLOULI
- « *Phenology and growth dynamics of the seagrass* Cymodocea nodosa *in the Bay of Montazah, East of Alexandria, Egypt* » by: H. M. MOSTAFA, S. H. SHABAKA, H. M. MITWALLY and Y. HALIM
- « *Preliminary report on the evolution of the populations of fucales in the National park of Port-Cros (France)* » by: T. THIBAUT, B. HEREU, M.L. SUSINI, J-M. COTTALORDA, L. MANGIALAJO and E. BALLESTEROS
- « *Change in the phytobenthos settlement along the Santa Liberata Coast (Southern Tuscany, Italy)* » by: M. LENZI, E. FRANCHI, A. GIOVANI, P. MICARELLI, G. PERRA, R. ROFFILLI, D. SOLARI and S. FOCARDI
- « *Invasion of the alien species* Lophocladia lallemandii *in Eivissa-Formentera (Balearic Islands)* » by: E. CEBRIAN and E. BALLESTEROS
- « Caulerpa racemosa *effect on macrophyte assemblages of dead Posidonia beds* » by: J. KLEIN and M. VERLAQUE

15:10 – 15:50 Discussion

15:50 – 16:30 **Debate « *Programme of Work on Protecting the Coralligenous and Other Calcareous Bio-concretions in the Mediterranean* »**

Facilitator: Mr. C. RAIS

Rapporteurs: Mr. G. BITAR, Mr. R. DUPUY DE LA GRANDRIVE

- Presentation of the Programme of Work on protecting the coralligenous and other calcareous bio-concretions in the Mediterranean by E. BALLESTEROS (CEAB, Spain) – 15’

16:30 – 16:50 *Coffee Break*

16:50 – 17:15 **Conclusions and Recommendations**

- Symposium recommendations and scientific objectives of the Fourth Mediterranean Symposium on Marine Vegetation by C. PERGENT-MARTINI (UNEP/MAP RAC/SPA, Tunisia)

Troisième Symposium Méditerranéen sur la Végétation Marine

Marseille, 27-29 mars 2007

Hôtel de Région - Salle de Commission Permanente

PROGRAMME

Mardi 27 Mars 2007

10h00 – 13h00 *Accueil et enregistrement des participants*

14h00 – 14h30 **Ouverture officielle du Troisième Symposium Méditerranéen sur la Végétation Marine (PNUE/PAM - CAR/ASP)**

- M. M. VAUZELLE, Président de la Région Provence-Alpes-Côte d'Azur
- M. A. GANNOUN, Directeur du CAR/ASP

14h30 – 16h00 **Session 1 - Restitution du Programme Interreg III B « POSIDONIA » -** ***Mise en cohérence, développement, harmonisation et validation de méthodes d'évaluation de la qualité du milieu littoral par le suivi de l'herbier à*** **Posidonia oceanica**
Rapporteurs: Mme M.C. BUIA, Mme C. MIFSUD

- Présentation du Programme POSIDONIA: Objectifs et attendus par M. R. KANTIN (Ifremer, France) – 30'
- Résultats du Groupe CARTOGRAPHIE par GIS Posidonie (France) – 30'
- Résultats du Groupe SURVEILLANCE par Mme R.M. BERTOLOTTO (ARPAL, Italie) –30'
- Résultats du Groupe BIO-INDICATEURS par M. J. ROMERO (Université de Barcelone, Espagne) et/ou M. G. PERGENT (Université de Corse, France) – 30'

16h00 – 16h20 *Pause Café*

16h20 – 18h10 **Table Ronde et Débat «** ***Quelles méthodes de cartographie et de surveillance, pour quels objectifs ?*** **»**
Animateur: M. G. PERGENT
Rapporteurs: M. R. KANTIN, M. R. TURK

- Le Plan d'Action pour la Conservation de la Végétation Marine en Méditerranée et le programme MedPosidonia par Mme S. EL ASMI (PNUE/PAM CAR/ASP, Tunisie)
- Cartographie et surveillance de la végétation marine: Les attendus des gestionnaires par Mme V. RAIMONDINO (Région PACA, France) et M. R. TURK (Institut de la République de Slovénie pour la conservation de la nature, Slovénie)

18h10 – 18h30 Clôture du premier jour

18h30 *Cocktail de Bienvenue*, offert par la Région PACA aux participants du Troisième Symposium Méditerranéen sur la Végétation Marine (PNUE/PAM - CAR/ASP)

Mercredi 28 Mars 2007

8h30 – 9h15 **Session 2 - Surveillance de la végétation marine de Méditerranée**
Président: M. J. ROMERO
Rapporteurs: M. A. PEIRANO, M. T. BELSHER

- « *The proteomic approach in* Posidonia oceanica *populations: which protein biomarkers for light stress acclimation?*» par : S. MAZZUCA, A. SPADAFORA, D. FILADORO, M. BRACALE, M. MARSONI et A.M.INNOCENTI
- « *Seasonal data on phytoplankton of some Albanian lagoons* » par : S. XHULAJ et A. MIHO
- « *Identification et caractérisation des herbiers à* Posidonia oceanica *par sonar à balayage latéral: vers une base de données méditerranéenne ?* » par : P. CLABAUT, C. AUGRIS, V. PASQUALINI, G. PERGENT et C. PERGENT-MARTINI
- « *Pertinence de la méthode DIVA pour l'interprétation des mosaïques sonar latéral* » par : C. VIALA, C. NOEL, M. COQUET, B. ZERR, P. LELONG et J.-L. BONNEFONT

9h15 – 9h45 Discussions

9h45 – 10h30 **Session 2 - Surveillance de la végétation marine de Méditerranée (Suite)**
Session posters

- « *Exploring the use of rocky shore macroalgae as indicators of environmental condition* » par : M. AZZOPARDI et P. J. SCHEMBRI
- « *Cartographie et caractérisation d'un herbier à Posidonia oceanica de la baie de Sidi-Selem (Bizerte, Tunisie)* » par : I. BEN CHIKH ALMI, A.S. DJELLOULI et Y. MEZGUI
- « *Les peuplements phytobenthiques du Lac Nord de Tunis de 1926 à 2006* » par : N. BEN MAIZ et A. SHILI
- « *The application of the "Carlit method" to assess the ecological status of coastal waters in the Gulf of Naples* » par : M.C. BUIA, L. PORZIO et F. PAOLO PATTI
- « Posidonia oceanica: *a quality element for ecological status assessment* » par : M.C. BUIA, F. SILVESTRE et S. FLAGELLA
- « *Marine habitats atlas of Liguria region (Italy)* » par : S. COPPO et G. DIVIACCO
- « *Developing a conceptual overview of Mediterranean seagrass meadows* » par : G. DI CARLO, M.C. BUIA, S. GOBERT, G. LEPOINT, B. MARTINEZ-CREGO, G. PERGENT, C. PERGENT-MARTINI, G. PROCACCINI, P. RENOM, F. TOMAS, B. VELIMIROV et A. VERGES
- « *Evaluation of the macroalgae communities in the Valencian rocky coasts (SE Spain) for the European Water Framework Directive (WFD)* » par : M. DIAZ-VALDES, E. ABELLAN, A. IZQUIERDO et A. RAMOS-ESPLA
- « *Use of* Posidonia oceanica (*L.) Delile as a pollution indicator Study of a zone situated in Revellata Bay (Calvi Bay, Corsica)* » par : C. DYC, S. GOBERT, G. LEPOINT, J.M. BOUQUEGNEAU, A. CHERY, A. VOLPON et P. LEJEUNE
- « *Evaluation of the status of* Posidonia oceanica *meadows in the Valencian coast (SE Spain) for the European Water Framework Directive (WFD)* » par : Y. FERNÁNDEZ-TORQUEMADA, M. DÍAZ-VALDÉS, F. COLILLA, J.L. SÁNCHEZ-LIZASO et A. RAMOS-ESPLÁ
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10h30 – 10h50 *Pause Café*

10h50 – 11h35 **Session 2 - Surveillance de la végétation marine de Méditerranée (Suite)**
Président: M. C. F. BOUDOURESQUE
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11h35 – 12h05 Discussions

12h10 – 14h00 *Pause Déjeuner*

14h00 – 15h30 **Session 3 - Impacts anthropiques sur la végétation marine de Méditerranée**
Président: M. F. CINELLI
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- « *Etude synoptique sur les cultures expérimentations de* Gracilaria verrucosa *en Tunisie* » par : J. KSOURI, F. MENSI, K. SAHLI-HAZAMI et I. CHALLOUGUI
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15h30 – 16h20 Discussions

16h20 – 16h40 *Pause Café*

16h40 – 18h30 **Table Ronde et Débat « *La végétation marine outil d'évaluation environnementale pour la Méditerranée ?* »**
Animateurs: M. C. RAIS et Mme G. CASAZZA
Rapporteurs: M. P. PANAYOTIDIS, Mme M. HADJICHRISTOPHOROU

- Les procédures d'évaluations et les politiques régionales et internationales par M. L. TUNESI (ICRAM, Italie) – 10'

Jeudi 29 Mars 2007

8h30 – 9h25 **Session 4 - Biologie, écologie et inventaire des espèces et des communautés végétales méditerranéennes (Suite)**
Président: M. M. VERLAQUE
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- « *Diversité des peuplements phytobenthiques dans les lagunes du Cap Bon (Nord-Est de la Tunisie)* » par : A. SHILI, N. Ben MaIz et C. F. BOUDOURESQUE
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Session posters

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- « *Root morphology of* Cymodocea nodosa *reflects eutrophication gradients* » par : S. OLIVA, O. MASCARÓ, J. ROMERO et M. PÉREZ

- « *Use of exergy to detect and measure perturbations affecting* Posidonia oceanica *(L.) Delile meadows: characterization in the sedimentary compartment* » par : D. PETE, J.M. BOUQUEGNEAU et S. GOBERT
- « *Preliminary phylogeny of the* Cystoseira *genus (Phaeophyceae)* » par : M.L. SUSINI, F. ROUSSEAU, A. MEINESZ, T. THIBAUT
- « Halophila stipulacea *(Forsskål) Ascherson and* Caulerpa racemosa *(Forsskål) J. Agardh in Albania* » par : M. XHULAJ et L. KASHTA

10h30 – 10h50 *Pause Café*

10h50 – 11h45 **Session 4 - Biologie, écologie et inventaire des espèces et des communautés végétales méditerranéennes (Suite)**
Président: M. H. LANGAR
Rapporteurs: M. A. MIHO, M. L. PIAZZI

- « *Effects of sea urchin grazing on a* Posidonia oceanica *meadow in the Gulf of Oristano (Western Sardinia, Italy)* » par : S. COPPA, I. GUALA, M. BAROLI, M. BRESSAN, S. COMO, G. PIERGALLINI et G. DE FALCO
- « *Cystoseira* communities in the Slovenian coast and their importance for fish fauna» par : R. TURK, M. ORLANDO-BONACA, Ž. DOBRAJC et L. LIPEJ
- « *Nitric oxide effect in transplanted cuttings of* Posidonia oceanica *(L.) Delile* » par : M. CARDILIO, S. NICASTRO, F. RENDE et A.M. INNOCENTI
- « *Early colonization of* Posidonia oceanica *(L.) Delile by epiphytes: Comparison between natural and artificial seagrass leaves* » par : D. PETE, S. GOBERT, J.M. BOUQUEGNEAU, M. POULICEK et G. LEPOINT
- « *Transplantation effects on* Posidonia oceanica *(L.) Delile* » par : S. GOBERT, D. VANGELUWE, J.M. BOUQUEGNEAU, M. EISINGER, M. PASTER, H. SCHUMAKER et G. LEPOINT

11h45 – 12h15 Discussions

12h15 – 14h0 *Pause Déjeuner*

14h00 – 15h10 **Session 4 - Biologie, écologie et inventaire des espèces et des communautés végétales méditerranéennes (Suite)**
Président: M. N. BEN MAÏZ
Rapporteurs: M. A. DJELLOULI, M. A. HAMZA

- « *Etude biométrique (biomasse et phénologie) de populations à* Caulerpa racemosa *dans la région de Bizerte (Tunisie)* » par : Y. MEZGUI et A. S. DJELLOULI
- « *Phenology and growth dynamics of the seagrass* Cymodocea nodosa *in the Bay of Montazah, East of Alexandria, Egypt* » par : H. M. MOSTAFA, S. H. SHABAKA, H. M. MITWALLY et Y. HALIM
- « *Preliminary report on the evolution of the populations of fucales in the National park of Port-Cros (France)* » par : T. THIBAUT, B. HEREU, M.L. SUSINI, J-M. COTTALORDA, L. MANGIALAJO et E. BALLESTEROS
- « *Change in the phytobenthos settlement along the Santa Liberata Coast (Southern Tuscany, Italy)* » par : M. LENZI, E. FRANCHI, A. GIOVANI, P. MICARELLI, G. PERRA, R. ROFFILLI, D. SOLARI et S. FOCARDI
- « *Invasion of the alien species* Lophocladia lallemandii *in Eivissa-Formentera (Balearic Islands)* » par : E. CEBRIAN et E. BALLESTEROS
- « Caulerpa racemosa *effect on macrophyte assemblages of dead Posidonia beds* » par : J. KLEIN et M. VERLAQUE

15h10 – 15h50 Discussions

15h50 – 16h30 **Débat «*Nouveau Programme de travail sur la protection du coralligène et autres bioconcrétions calcaires en Méditerranée* »**
Animateur: M. C. RAIS
Rapporteurs: M. G. BITAR, M. R. DUPUY DE LA GRANDRIVE

- Présentation du Programme de travail sur la protection du coralligène et autres bioconcrétions calcaires en Méditerranée Programme de travail par E. BALLESTEROS (CEAB, Espagne) – 15'

16h30 – 16h50 *Pause Café*

16h50 – 17h15 **Conclusions et recommandations du Symposium**

- Recommandations du Symposium et objectifs scientifiques du Quatrième Symposium Méditerranéen sur la Végétation Marine par C. PERGENT-MARTINI (PNUE/PAM CAR/ASP, Tunisie)

ORAL COMMUNICATIONS

COMMUNICATIONS ORALES

Mounir BEN BRAHIM[1], **Terashima HIROAKI**[2], **Asma HAMZA**[1]
[1]Institut National des Sciences et Technologies de la Mer- Centre de Sfax -BP. 1035-3018 Sfax, TUNISIE
[2]Japan International Cooperation Agency

CARACTERISATION LEPIDOCHRONOLOGIQUE DES DIFFERENTS TYPES D'HERBIERS DE POSIDONIE DANS LE GOLFE DE GABES (TUNISIE)

Résumé

La lépidochronologie est une technique fiable pour l'identification des cycles de la production annuelle des feuilles de Posidonia oceanica *(Potamogetenaceae). Ces cycles peuvent être influencés par des paramètres du milieu comme la température, la lumière, l'hydrodynamisme. Cinq stations du golfe du Gabès (Tunisie) ont été prospectées en été 2006, les résultats de l'analyse statistique révèlent que la production annuelle des feuilles dans ces régions semble être tributaire des variabilités que subit l'ensemble de l'écosystème, ni les paramètres intrinsèques de l'herbiers ni les paramètres spécifiques du milieu ont un effet direct sur ce processus.*

Introduction

Le rang d'insertion des pétioles (partie restant attachée au rhizome après la chute foliaire chez la posidonie *Posidonia oceanica* (L.) Delile), leur épaisseur et leur anatomie présentent souvent des variations cycliques pouvant traduire la variabilité des paramètres du milieu ou encore les changements intrinsèques à la population. L'étude de ces variations définie par la méthode dite lépidochronologie permet de rendre compte de l'état de l'herbier et éventuellement du milieu (Pergent-Martini et Pergent, 1994 ; Pergent, 1987 ; 1990).

La présente étude propose une analyse lépidochronologique de différents herbiers de *Posidonia oceanica* dans le golfe de Gabès et de relever par ailleurs les variabilités pouvant être dégagées entre les stations de prélèvement.

Matériels et méthodes

L'analyse lépidochronologique est portée sur 166 rhizomes orthotropes superficiels collectés dans 5 stations du Golfe de Gabès : Kraten, Attaya, Mahres, Zarrat et Ajim et à des profondeurs variant de 5 à 20 m (Fig. 1 et Tab. 1).

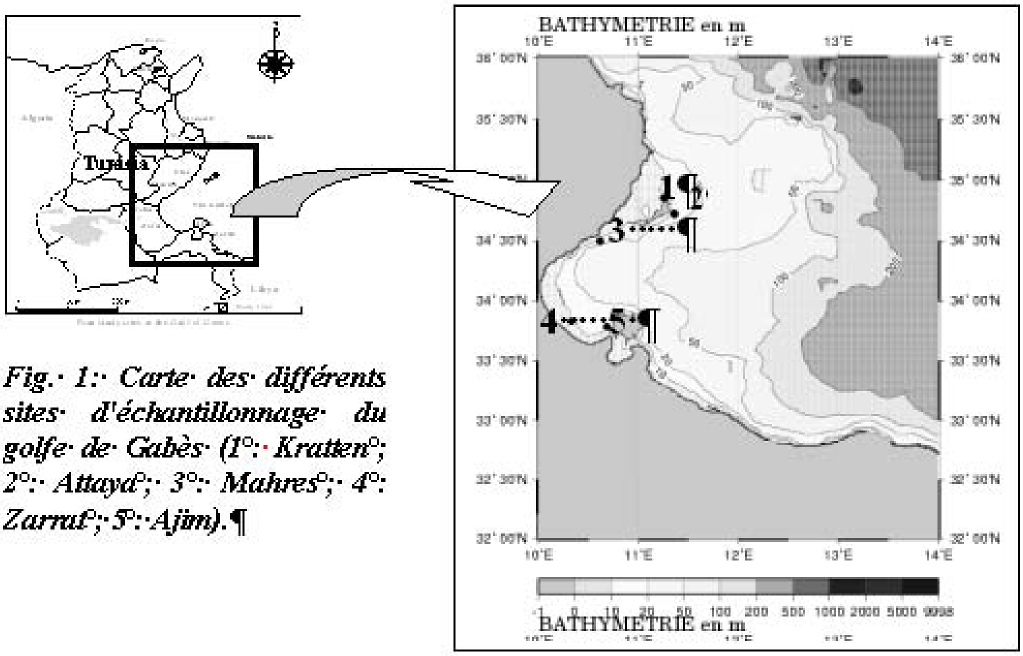

Fig. 1: Carte des différents sites d'échantillonnage du golfe de Gabès (1: Kratten; 2: Attaya; 3: Mahres; 4: Zarrat; 5: Ajim).

Tab. 1 : Nombre de rhizomes analysés, limites inférieure, type d'herbier et profondeur dans chaque station d'échantillonnage.

Stations	Limite inferieure	Type d'herbier	Profondeur	Nombre de rhizomes collectés
Kraten	< - 5m	tigré	-5m	10
Attaya	+ de 20 m	plaine	-5m	20
			-10m	23
			-15m	18
			-20m	24
Mahres	Entre -17 et 20 m	plaine	-5m	10
			-10m	10
			-15m	11
			-20m	10
Zarrat	-5 m	touffe	-5m	14
Ajim	< -5m	touffe	-5m	26

Pour les analyses statistiques, nous avons choisi le **Kruskal-wallis test** (test non paramétrique) du fait qu'il est recommandé dans les situations où on ignore la loi de distribution d'une variable avec un petit nombre d'échantillons. Pour les comparaisons multiples nous avons adopté le **Dunn's test.**

Résultats

Nos prospections des différents herbiers situés en différentes zones du Golfe de Gabès nous ont permis de définir en premier lieu les limites inferieures de ces structures. Cette limite dans les deux stations de Zarrat et d'Ajim se situe à -5m de profondeur dénotant de la notable dégradation de ces régions ; par contre à Mahrès elle atteint -17 et -20 m de profondeur. A la station Attaya l'herbier s'étend à plus de -20 m de profondeur (Tab.1).

L'étude lépidochronologique nous a permis de définir l'âge maximum des rhizomes explorés à 13 ans (1993-2005) pour celui de l'Attaya en toutes les profondeurs. Nous avons aussi remarqué que plus la profondeur augmente, plus les rhizomes plagiotropes tendent à être jeunes.

Le nombre moyen maximum des feuilles produites par an dans l'ensemble des stations et en toutes les années peut atteindre 7,79 f/an. Cette valeur situe nos herbiers comme étant assez productifs puisqu'elle est supérieure à celles observées en d'autres localité, Villasimius (Sardinia) qui est de 7,45 f/an (Didato, 2000) et de 7,12 f/an à l'archipel de Pontino (Dolce *et al*, 1996). Nous remarquons aussi que cette production foliaire semble être indépendante des profondeurs et de la nature des herbiers ; seule une variabilité interannuelle est détectée. *Posidonia oceanica* alternerait deux années de croissance évolutive et une année de repos (Figs. 2, 3, 4, 5 et 6).

L'étude comparative entre les herbiers de différentes zones à la profondeur de -5m nous permet de déceler deux groupes différents, un formé par les structures de Kratten et Ajim et l'autre par ceux de l'Attaya, Mahrés et Zarrat est un groupe intermédiaire, ceci laissant supposer par conséquent des différences génétiques entre les deux populations.

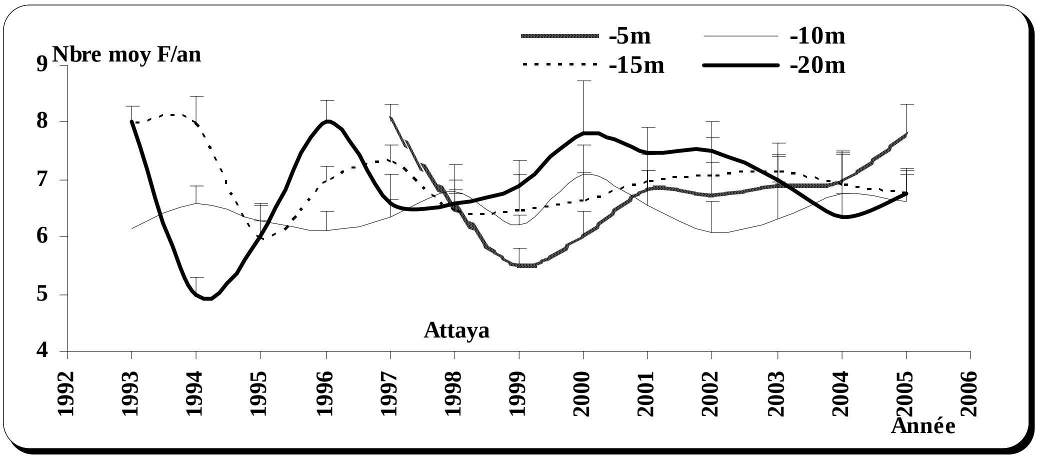

Fig. 2 : Variation de la production annuelle de feuilles à Kerkennah (Attaya) à différentes profondeurs.

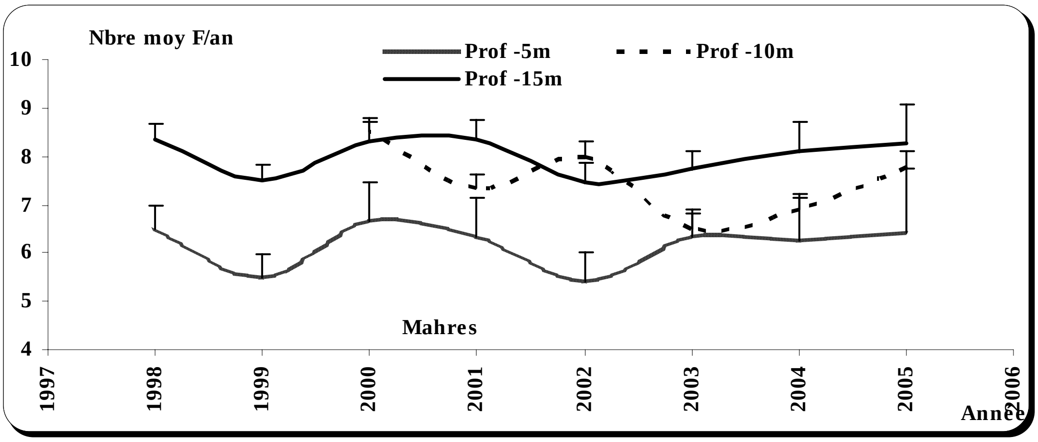

Fig. 3 : Variation de la production annuelle de feuilles à Mahres à différentes profondeurs.

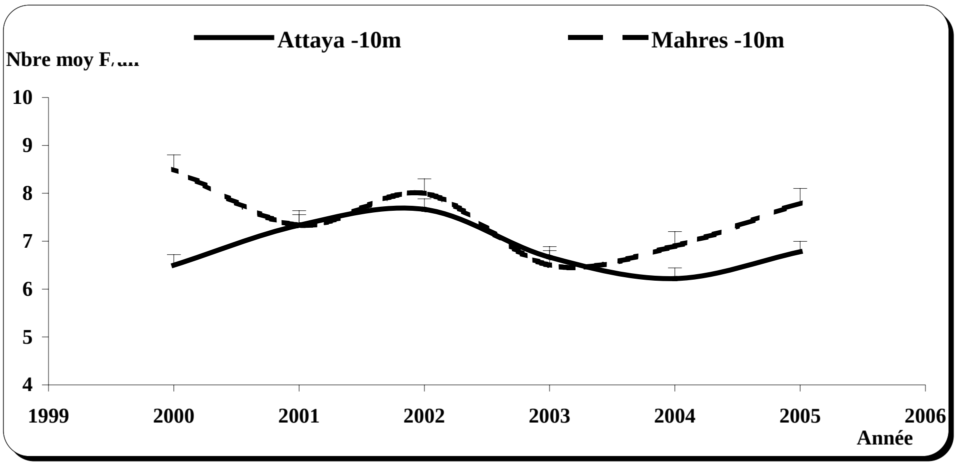

Fig. 4 : Variation de la production annuelle de feuilles à Attaya et Mahres à -10 m de profondeur.

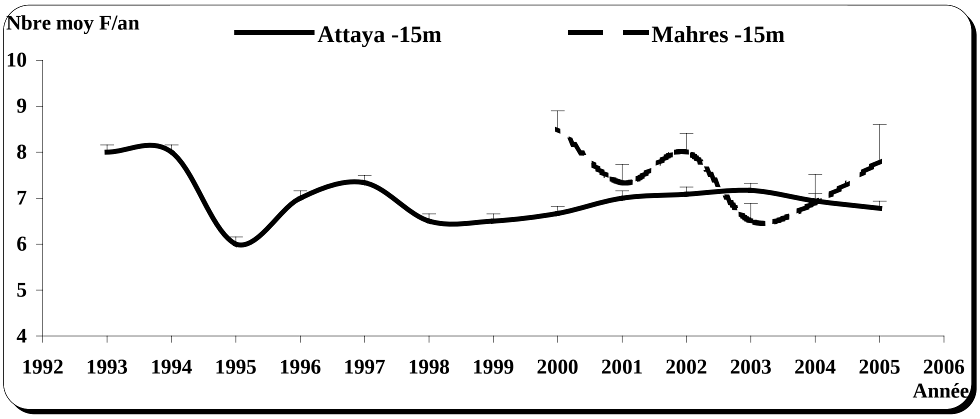

Fig. 5 : Variation de la production annuelle de feuilles à Attaya et Mahres à -15 m de profondeur.

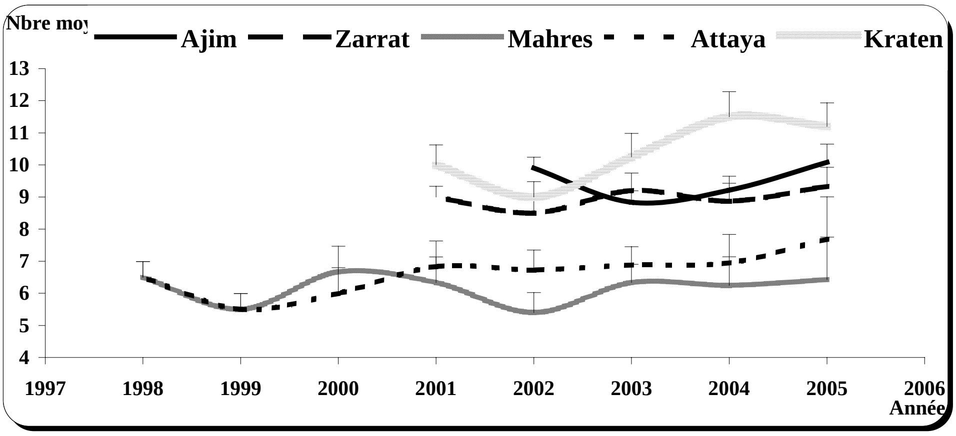

Fig. 6 : Variation de la production annuelle de feuilles dans les différentes station à – 5m de profondeur.

L’analyse statistique menée afin d’évaluer les différences décelables au sein du même herbier ou encore entre ceux des différentes régions nous ont permis de noter les observations suivantes :

- moyennant le Kruskal-wallis test, nous notons que la production foliaire dans les différents herbiers prospectés dans la région pour l'année 2005 à une profondeur de -5m présente une très grande variabilité zonale (P<0,0001) (Tab. 2)
- l'analyse par le Dunn's test nous permet de cibler cette variabilité entre les zones et qui apparaît au niveau des faibles valeurs (Tab. 3)

Tab. 2 : Résultats obtenus par Kruskal-wallis test.

H corrected for ties	27,635
Tied P-Value	<.0001
DF	4

Tab. 3 : Résultats obtenus par Dunns'test.

Ataya-Kratan	0,0002
Ataya-Mahares	0,74
Ataya-Zarat	0,85
Ataya-Ajim	0,0008
Kratan-Mahares	<.0001
Kratan-Zarat	0,219
Kratan-Ajim	0,65
Mahares-Zarat	0,0124
Mahares-Ajim	0,0004
Zarat-Ajim	0,856

Discussions

De ces observations certaines constatations peuvent être dégagées. Dans deux zones éloignées géographiquement, des herbiers de structures différentes et ayant des limites inférieures différentes peuvent présenter la même configuration de la courbe de la production foliaire annuelle et aussi les mêmes variabilités interannuelles (cas Mahres et Attaya). Mais, ces situations ne sont pas exclusives et d'autres alternatives sont aussi observées. L'hypothèse de l'effet de la qualité du milieu ne semble pas être une condition ultime à la variation de la production des feuilles mais certainement d'autres considérations peuvent entrer en jeu.Dans certaines stations, l'effet année et ceci à tous les niveaux a pu être détecté ; en effet, à partir de l'année 2000, les courbes ont tendance à s'aplatir et le nombre de feuilles produites à tendance aussi à s'estomper. On peut envisager l'hypothèse que ces changements seraient générés par les perturbations qu'aurait subit l'écosystème d'une période à une autre.

Conclusion

La production annuelle des feuilles dans la région du golfe de Gabès semble être tributaire des variabilités que subit l'ensemble de l'écosystème, mais les paramètres spécifiques du milieu n'ont pas d'impacts directs sur ce processus. Cette observation rejoint les résultats établis dans d'autres études en d'autres localités méditerranéennes (Didato, 2000) et (Dolce *et al.*, 1996) et confirmés par d'autres analyses statistiques telles le Run-test.

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Monica CARDILIO, Silvia NICASTRO, Francesco RENDE, Anna Maria INNOCENTI
Department of Ecology University of Calabria Ponte P. Bucci cubo 6B 87036 Rende, ITALY
e-mail: innocenti@unical.it

NITRIC OXIDE EFFECT IN TRANSPLANTED CUTTINGS OF *POSIDONIA OCEANICA* (L.) DELILE

Abstract

In the Mediterranean basin a serious, long lasting, seagrass decline occurred, mainly associated with the increasing of anthropogenic pressure along the coastline. The low capability of Posidonia oceanica *to react to external disturbance, unable any possibility of natural recovery of the meadow. Thus transplantation of vegetative material was the primary strategy to remediate sea grass loss in coastal zones. As in transplanted rhizomes N dynamics, utilised either for the growth and in the storage, has been shown essential, the item of the present work was to investigate the effect of sodio-nitroprusside (SNP), which act as NO donor, in P. oceanica cutting. The feedings with SNP, which stimulate adventitious rooting in land phanerogams did not give this expected effect in Posidonia cuttings. In fact this treatment in the seagrass (performed in aquarium at 15 C° from December 2005 to June 2006 and from June to September 2006) stimulated in the first period a significant increase of leaf growth in respect to control cuttings. In the second period, when a large production of new leaves occurred related to leaves abscission, only the feeding 9 µM SNP appeared to be efficacious. Since during the seasonal cycle of Posidonia oceanica leaves lenght increased in summer and decreased in autumn the SNP treatment enhanced, but did not affect the natural plant growth.*

Key-words: *Posidonia oceanica* transplant; Sodionitroprusside, SNP; Leaf growth stimulation.

Introduction

In Mediterranean basin a serious, long lasting, seagrass decline (Krause-Jensen *et al.*, 2004) occurred, mainly associated to the increasing of anthropogenic pressure along the coastline, which enhanced turbidity, sedimentation and pollution (e.g., Neverauskas, 1988; Duarte *et al.*, 2004). As consequence *Posidonia oceanica* shoot density rapidly decreased, up to 50 percent over a few decades and numerous meadows dead (e.g., Orth and Moore, 1983; Giesen *et al.*, 1990). So the different forms of external impact, natural or human induced, started a process which ultimately will lead to the species extinction. Infact in small and isolated populations' homozygosis increases, determining inbreeding depression and loss of fitness and the populations became more fragile and less adaptable to changed conditions (Meffe and Carroll, 1997). The low capability (Raniello and Procaccini, 2002) of *Posidonia oceanica* to react to external disturbance is of large interest, since the meadows rank among the most productive ecosystems (Costanza *et al.*, 1997). In fact this endemic seagrass in the Mediterranean plays a multiple role for marine coastal ecosystems, due to its extension, high productivity and stability being a resource for herbivores (such as Paracentrotus lividus and Sarpa salpa) and indirectly for the high complexity, an habitat for a high diverse community (Duarte *et al.*, 1999; Guidetti, 2000). Its distribution is threatened by several human activities such as species introduction (De Villèle and Verlaque, 1995), aquaculture (Delgado *et al.*, 1997) and anchoring (Duarte *et al.*, 2004; Milazzo *et al.*, 2004). Since there is few possibility of a natural recovery of meadow, the reforestation of impacted sites through transplants has been considered. Hence, many efforts have been focused to study *P. oceanica* adaptability to make transplants very successful. Orthotropic rhizomes cutting were transplanted and their survival followed (Meinesz *et al.*, 1991) and thereafter, to optimize cutting growth, also rhizome length was considered (Meinesz *et al.*, 1991) as well as the depth effect of collection site (Molenaar and Meinesz, 1992). Other studies carried out on other seagrasses considered the local adaptation of plants translocated within the same site rather than transplanted from different sites (Hammerli and Reusch, 2002). More recently researches on the transplants success of *P. oceanica* have been focused on the effect of genetic polymorphism (Procaccini and Piazzi, 2001), of the nutrient content in leaves of transplanted shoots (Vangeluwe *et al.*, 2004) and of the N dynamics of shoots transplanted with or without roots (Lepoint *et al.*, 2004). The item of the present work is to investigate the effect of sodio-nitroprusside (SNP), which act as NO donor, in *P. oceanica* cutting. Namely it is well known that feedings with SNP stimulate adventitious rooting in terrestrial phanerogams (Pagnussat *et al.*, 2003) whereas at present any expected effect in sea grass plants is unknown. To this aim, *P. oceanica* cuttings collected at the depth of 5m-6m, have been submitted to SNP treatment and the phenological parameters have been estimated for ten months at monthly intervals to evaluate the performance of transplanted rhizomes.

Material and methods

Posidonia oceanica cuttings (n= 20) of plagiotropic rhizomes, each bearing four leaf bundles starting from shoot apex, were collected in a meadow located at Diamante (Tyrrhenian cost of Calabria), which has been selected, both for the high phenological performance of plants and for the capability to undergo flower production, from a depth of 6m. The cutting were treated with SNP solution in autoclaved sea water (8, 9 and 10 µM), using a new performed method allowing a local treatment on the cut surface using a Pasteur pipette (Fig.1). A set of five cutting was submitted with 3 ml of SNP solution at different concentration (8 µM, 9 µM and 10 µM). Five cuttings were submitted with only sea water for control. For each solution pH measurements were undertaken, which did not register any variation. Every single rhizome was marked and recorded for the following phenological analysis. Thereafter in the basal portion of each leaves bundle a little hole has been done thus, as Posidonia leaves grow from their base, the hole displacement allowed to calculate both leaf lengthening and new leaves formation. Treated and control rhizomes were transplanted in aquarium with natural seawater at 15 C°. These experiments have been done in two different period of the year (from December 2005 to June 2006 and from June to September 2006) to verify eventual season influence in the treated cuttings. The length of each single leaf has been monthly estimated to evaluate its development and compare leaves growth of treated and control rhizomes. Among each leaf bundle the leaves have been classified as: young intermediate and adult leaf according to Giraud classification (1979).

Fig. 1: Cutting of* Posidonia oceanica *showing the cut surface treated with SNP solution.

Results

The results obtained evidenced that SNP treatment was not active in root production since no adventitious root was observed in the followed period. However our experiments clearly demonstrated a new, effect of SNP on sea grasses where it stimulated both an increasing of leaf growth and/or the production of new leaves in treated cuttings. The effect of this substance change during the year, in fact in the period from December 2005 to June 2006 cutting treated with SNP showed the increase of leaf length overall in juvenile leaves. The increase appeared particularly evident at the treatment concentration 9 µM as shown in Fig.2. Furthermore in the figure can be easily observed that the effect of treatment is function of the concentration utilized. It is also to underline the insignificant effect of treatment in adult leaves, which are less sensible to stimulation.

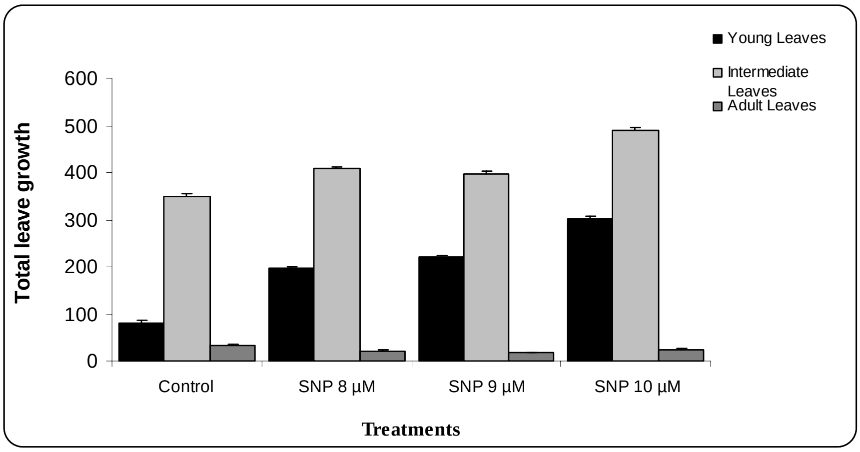

Fig. 2: The effect of SNP treatments at different concentration on the total leave growth, performed in the period from December 2005 to June 2006, is shown in young, intermediate and adult leaves of* P. oceanica *cuttings. The more significant effect has been observed in intermediate leaves.

On the contrary in the experiment lasting from June to September 2006 no significant difference in leave extension was observed at the different treatment concentration. In this case, the growth parameter were also lower than in control (Fig. 3).

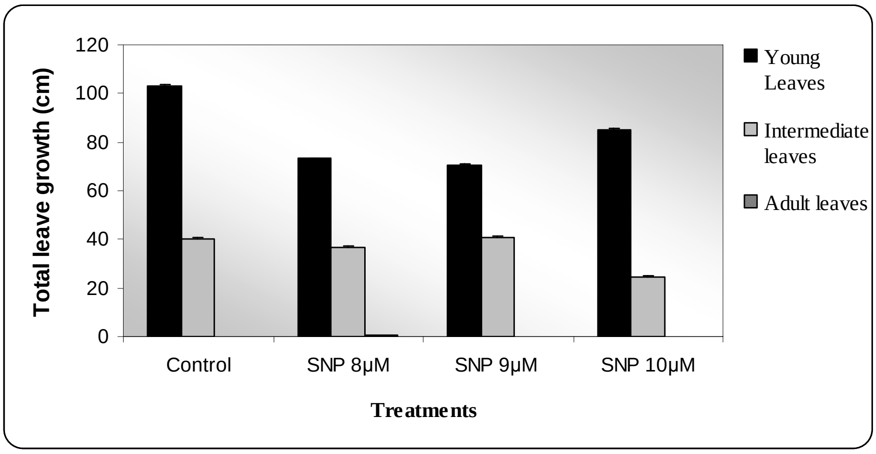

Fig. 3: The effect of SNP treatment at different concentration on total leave growth, performed in the period from June to September 2006 is shown in young and intermediate leaves, whereas in adult leaves no leaf length increase was observed neither in control nor in treated cutting.

However by comparing the results of the experiment in the two year period, we can observe that in the period from June to September when the length stimulation of existing leaves was not effective a larger production of new leaves, with respect to what observed in cuttings treated in the period between December to June was detected (Fig. 4, 5)

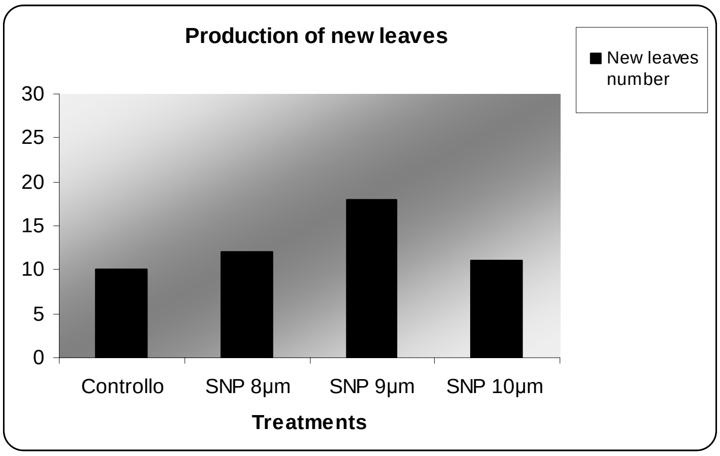

Fig. 4: Number of new leaves produced in the period from December to June 2006 in cutting treated with SNP solution in sea water at different concentration.

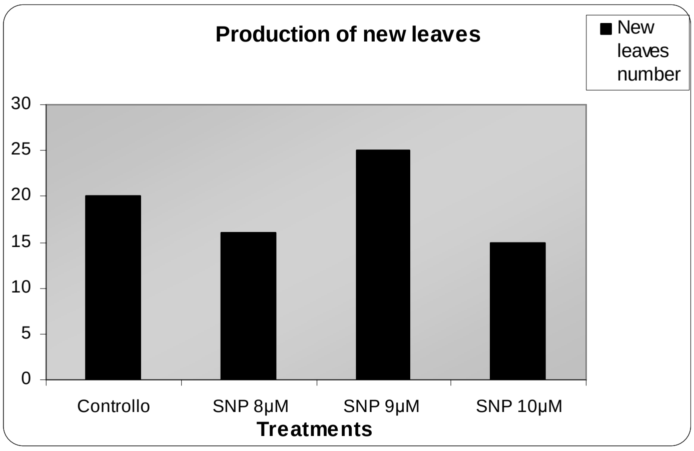

Fig. 5: Number of new leaves produced in the period from June to September 2006 in cutting treated with SNP solution in sea water. In this period plant effort was directed to the new leaves production.

Discussion

The obtained results on stimulation effect of SNP treatment in Posidonia cuttings evidenced for the first time clear difference of reaction between land plant and sea grass, which are phanerogams readapted to water conditions. In fact the treatment, which in land plants stimulated adventitious rooting (Pagnussat *et al.,* 2003), in *Posidonia oceanica* stimulated from December to June the leaf growth and, probably, at 9 µM SNP optimal concentration, also the new leaves production in both the period considered. Thus indicating a different role of SNP submission since, even if it was given on a rhizome section the solution and/or the produced NO was very probably transported and acted in the leaves. However this metabolic pathway localization is not surprising as in nature N absorption in sea grass is overall done at leaf level. Its uptake has been well studied in *Posidonia oceanica* and determined during the year by in situ uptake experiments (Lepoint *et al.*, 2002). In fact this nutrient is acquired and utilised, either for the growth process and stored for subsequent ricycling depending on the plant need (Lepoint *et al.,* 2002a; 2002b) the variation within the year depending on light and temperature conditions (Enriquez *et al.*, 2004). Moreover it is known that the summer is the period when *Posidonia oceanica* show the maximum of photosybthetic capability allowing storage reserves to be utilized both in winter and in the following spring (Alcoverro *et al.*, 2001). In this contest is of large interest to follow during the year the reaction of plant to external stimulations, which could either increase plant performance, without alter the natural cycle of seasonal growth, or disturb long lasting its actual difficult equilibrium.

The first investigations on Posidonia transplants, cultivated under laboratory conditions, survival started many years ago (Ott, 1979) showing that cutting retain the same rhythm of leaf growth than in natural conditions. The presented work also unable to evaluate a seasonal effect of SNP treatment as, in line with the natural biological cycle of *Posidonia oceanica*, we found a major leaf growth stimulation in the period from December to June. The summer, in fact, is the period when this plant shows the maximum of photosynthetic capability allowing the storage of reserves that will be utilized in the period of winter and of the following spring.

Our observations also indicated that the capability of SNP to stimulate leaf elongation is function of the leaf age, namely the effect was maximum in young and intermediate leaves and scarce (Fig.1) or not present (Fig. 2) in adult leaf. The lack of treatment effect in adult leaves is however easy to explain, since adult leaves, from June to September, either have completed their development or are undergoing abscission process. In our opinion also the change of growth strategy of plant development registered in the second experiment clearly indicate the different resource destination of plant towards new leaves production, which would substitute the old leaves detached from rhizome (Fig.4 and 5). However, in conclusion, the treatment of cuttings with SNP solution performed in the present work show the advantage to be local and allow to submit stimulating substance to sea grasses without disturb the water environment. This characteristic has been recently tested also in Posidonia cutting transplanted in the sea and the first results are good, thus indicating the possible use of this procedure to help in same case Posidonia meadows reforestation and surviving.

Acknowledgements

This research received financial support from the “Assessorato all’Ambiente della Provincia di Cosenza- (Italy).

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Emma CEBRIAN*, Enric BALLESTEROS
Centre d'Estudis Avançats de Blanes (CSIC), Acc. Cala Sant Francesc 14, 17300 Blanes, Girona, SPAIN
e-mail address: emma@ceab.csic.es

INVASION OF THE ALIEN SPECIES *LOPHOCLADIA LALLEMANDII* IN EIVISSA-FORMENTERA (BALARIC ISLANDS)

Abstract

The alien red alga Lophocladia lallemandii *(Montagne) F. Schmitz was introduced in the Balearic Islands in 1995 showing a marked invasive behaviour The spread, bathymetric distribution and seasonality in coverage and biomass of* L. lallemandii *in the MPA "Freus d'Eivissa i Formentera" (Balearic Islands) is evaluated hereby visiting fourteen transects on spring and autumn.* L. lallemandii *has a great capacity of rapidly spreading over large distances, and to invade a great range of habitats and substrates, from shallow waters down to 35 meters depth.* L. lallemandii *coverage and biomass were very low or even nil in spring at all communities studied, while they significantly increased everywhere in autumn, representing sometimes more than the 25% of the total community biomass.*

Key-words: *Lophocladia lallemandii*, Invasive species, Spread, Bathymetric distribution, Seasonality.

Introduction

Marine environments are severely affected by the introduction and subsequent proliferation of non-indigenous species (Carlton, 1989, 1996; Carlton and Geller, 1993). The Mediterranean Sea is especially suitable to marine invasions due to, among other causes, an increased maritime transport, the opening of the Suez Channel, and a great development of aquaculture facilities (Zibrowius, 1991; Verlaque, 1994; Ribera and Boudouresque, 1995). Several species of algae have been recently introduced into the Mediterranean (Astraldi *et al.*, 1995; Bianchi and Morri, 2000; Chevaldonné and Lejeusne, 2003), and at least eight species can be assigned to the category of invasive species, being the tropical red alga *Lophocladia lallemandii* one of them (Boudouresque and Verlaque, 2002).

Lophocladia lallemandii (Montagne) F. Schmitz has been probably introduced into the Mediterranean via the Suez Channel (Verlaque, 1994). It is a species with an indo-pacific distribution, but now it is currently distributed throughout most of the Mediterranean Sea with the exception of Morocco and the North Western Mediterranean (Gómez Garreta *et al.*, 2001; Benhissoune *et al.*, 2003).

In the Balearic Islands (Western Mediterranean), *Lophocladia lallemandii* was recorded for the very first time in 1995, and it spread over a coastal area covering more than 20 km of coastline in only three years (Fig. 1) (Patzner, 1998). The rapid spread of *L. lallemandii* in Eivissa suggested a high invasive potential, but up to now no studies have been addressed to assess the invasion rates and the spatial and temporal patterns of *L. lallemandii* invasion. Furthermore, the impact of *L. lallemandii* invasion to native communities is largely unknown.

Here we present the results obtained from different observations devoted to: 1) evaluate the spatial and temporal patterns of expansion; 2) determine the bathymetric distribution of *Lophocladia lallemandii* and, in consequence, the communities most susceptible to invasion; and 3) quantify the seasonal variations on *L. lallemandii* biomass.

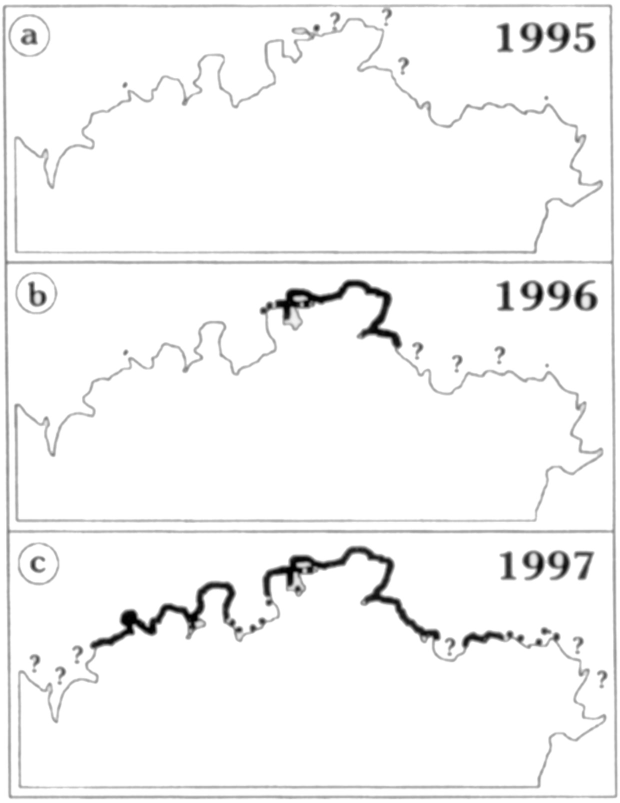

Fig. 1: Spread of* L. lallemandii *within the years 1995 to 1997. Question marks indicate areas not investigated. From Patzner, 1998.

Materials and Methods

Extension of Lophocladia lallemandii

Baseline surveys, which brought information on the colonization patterns of *Lophocladia lallemandii* were conducted around the MPA of "Freus d'Eivissa i Formentera" (Balearic Islands, Western Mediterranean) (Fig. 2) by means of SCUBA diving surveys down to 40 m depth. For the study on the spatial distribution of *L. lallemandii,* fourteen sampling stations were selected covering different substrates, ranges of wave exposure and orientation (Fig. 2; Tab. 1). These stations were visited in October 2000 and 2001, and the presence of *L. lallemandii* was recorded.

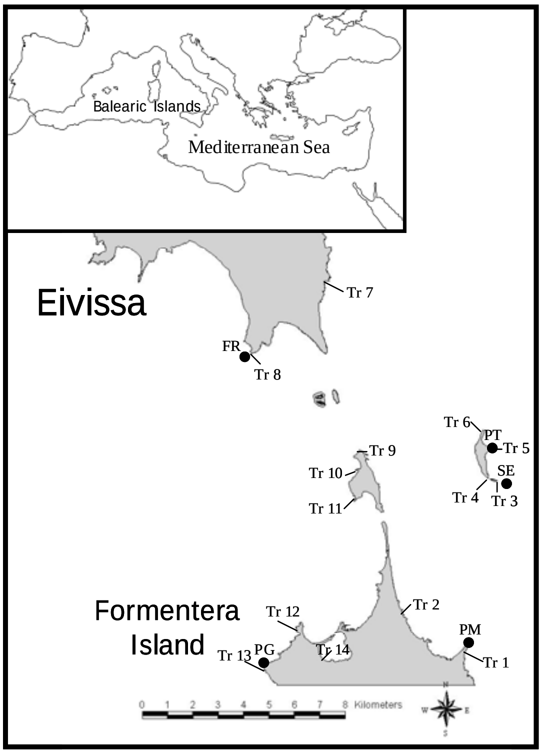

Fig. 2: MPA of "Freus d'Eivissa i Formentera" and transects surveyed during the years 2000 and 2001.

Tab. 1: Transects surveyed in the MPA "Freus d'Eivissa i Formentera" with indication of the depth range. * Localities where biomass sampling has been performed.

Transect	Sampling Station	Depth range (m)
Tr 1	Punta Prima *	0 -27
Tr 2	Ses Salines	0-22
Tr 3	Seca de S'Espardelló *	0 -41
Tr 4	Punta de Fora de l'Espardelló	0 -30
Tr 5	Punta d' En Talaies*	0 -35
Tr 6	Espardelló de Tramuntana	0 -30
Tr 7	Es Cavallet	0 -12
Tr 8	Faralló de Punta de la Rama*	0 -35
Tr 9	Illa dels Porcs	0 -12
Tr 10	Sa Torreta	0 -13
Tr 11	Espalmador (west)	0 -19
Tr 12	Punta Pedrera	0 -26
Tr 13	Estany des Peix	0 -4
Tr 14	Punta Gavina*	0 -28

Bathymetric distribution of **Lophocladia lallemandii**

In order to study the seasonality and bathymetric distribution of *Lophocladia lallemandii*, the same stations sampled for the extension study were visited again in May and November 2005.

A perpendicular transect to shore was performed by two divers at each sampling station. In a first stage (descent) the topographic and bathymetric features of the transect were noted, from the surface to the deepest zone. Different communities were distinguished along the transect according to the dominant species. In a second stage (ascent) every community was carefully checked and coverage of *Lophocladia lallemandii* was quantified by means of 25 cm x 25 cm quadrats, divided into 25 subquadrats of 5 cm x 5 cm (Sala and Ballesteros, 1997; Cebrian and Ballesteros, 2004). At each transect twenty quadrats (total area of 1,25 m^2) were randomly positioned within each 5 meters depth range and the number of subquadrats in which *L. lallemandii* appeared was recorded and used as unit of measure.

Biomass of **Lophocladia lallemandii**

In order to assess the seasonal pattern and the impact of *Lophocladia lallemandii* in native communities, species biomass and species richness were quantified in spring (May) and autumn (November) in severely invaded communities dominated by several species of photophilic algae, *Cystoseira balearica*, *Cystoseira spinosa* or *Osmundaria volubilis* (Tab. 2).

Tab. 2: Localities, communities and depths of the samples used for the biomass study.

Locality	Sampling Station	Depth
Cystoseira balearica		
PP1	Punta Prima	-6m
PP2	Punta Prima	-8m
SE	Seca de S'Espardelló	-8m
PG	Punta Gavina	-8m
Cystoseira spinosa		
SE1	Seca de S'Espardelló	-15m
SE2	Seca de S'Espardelló	-17m
Osmundaria volubilis		
PT	Punta d'en Talaies	-20m
SE	Seca de S'Espardelló	-30m
Photophilic algae		
FR	Faralló de Punta Rama	-10m

Biomass and number of species were quantified after scraping off all organisms from three 20 cm x 20 cm quadrats at each community. Samples were collected and sealed in individual plastic bags and later sorted and quantified in the laboratory. Biomass of algal species was quantified as grams fresh weight. Biomass of the basal encrusting layer of coralline algae and Peyssonneliaceae was not considered.

Results

Extension of **Lophocladia lallemandii**

In year 2000 *Lophocladia lallemandii* was present in most of the transects visited, but was still absent in the western area of Formentera, that is transects 12, 13 and 14. In contrast, during the survey performed one year later (2001), *L. lallemandii* was already present in transects 12 and 13, increasing its extension to almost all the MPA with the exception of transect 14 situated inside a shallow lagoon (Tab. 3).

Tab. 3: Presence of* Lophocladia lallemandii *at the different transects sampled during the years 2000 and 2001.

Transect	2000	2001
Tr 1	X	X
Tr 2	X	X
Tr 3	X	X
Tr 4	X	X
Tr 5	X	X
Tr 6	X	X
Tr 7	X	X
Tr 8	X	X
Tr 9	X	X
Tr 10	X	X
Tr 11	X	X
Tr 12		X
Tr 13		X
Tr 14		

Bathymetric distribution of **Lophocladia lallemandii**

Bathymetric distribution of *Lophocladia lallemandii* is presented in Figure 3.

L. lallemandii was very rare during the survey performed in May without exceeding 10% coverage in any sampled depth. *L. lallemandii* was far more abundant in November, especially between 5 and 20 meters depth, when it reached coverages of 40% approximately (Fig. 3A). *L. lallemandii* decreased its coverage below 20 meters depth although it was always higher than 20%. Coverage of *L. lallemandii* was higher on rocky bottoms than in *Posidonia oceanica* meadows. On rocky bottoms, coverage was very low (<10%) in shallow waters. It substantially increased between five and twenty meters depth where it reached coverages among 50% and 60%, and slightly decreased below (Fig. 3B). In contrast, *L. lallemandii* coverage on *Posidonia oceanica* meadows was constant (around 20 %) at all sampling depths (Fig. 3C).

Biomass

Lophocladia lallemandii biomass was higher in autumn than in spring, for all communities studied (Fig. 4), in agreement with coverage values. Community of photophilic algae was absolutely dominated by native seaweeds in May (99.7%), but *L. lallemandii* represented the main percentage of the total biomass (96.1%) (Fig. 4A) in November. Native seaweeds also dominated the community of *Cystoseira balearica* in May (Fig. 4B), but biomass of *L. lallemandii* increased substantially in November, reaching more than 25% of the total biomass in all sampled sites, except in Punta Gavina, where *L. lallemandii* did not exceed the 12% of the total biomass.

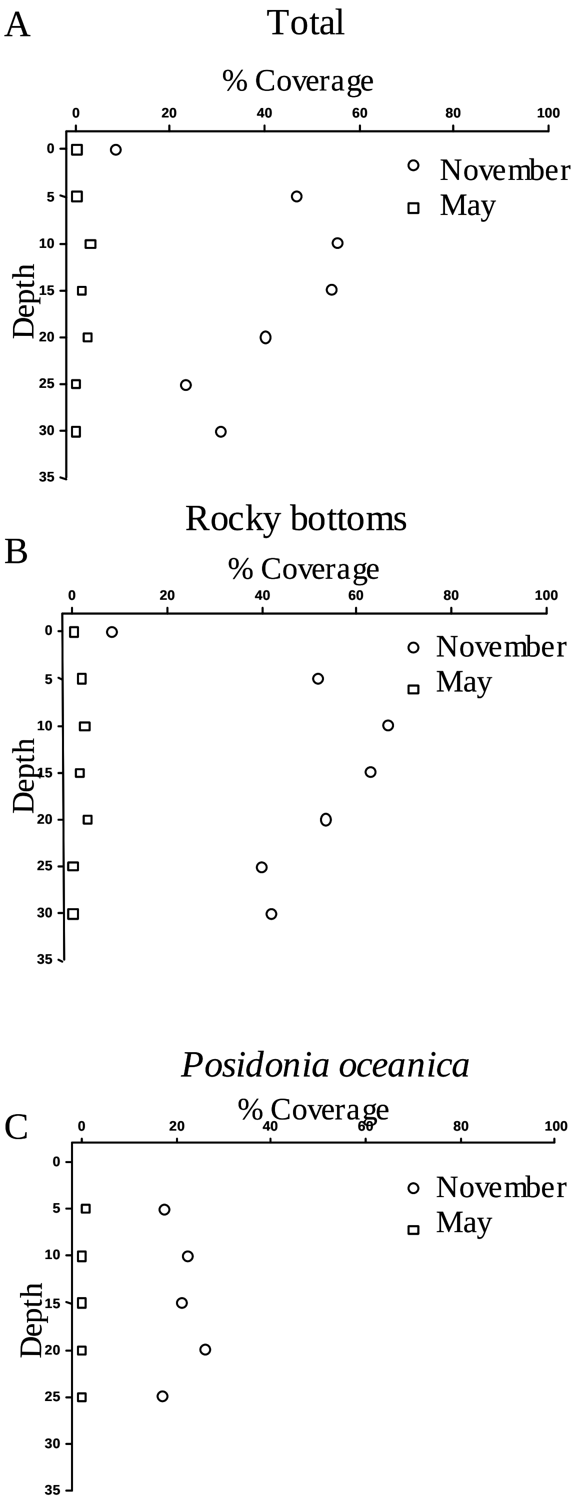

Fig. 3. Seasonal and depth distribution patterns of **Lophocladia lallemandii** *coverage (A); rocky bottoms (B) and* **Posidonia oceanica** *meadows (C).*

The results obtained in the community of *Cystoseira spinosa* follow the same trend: *Lophocladia lallemandii* is absent in May and increases in November. *Cystoseira spinosa* is the most representative species of the community being responsible for the 50-60 % of the total biomass both in May and October. Native species in May and *L. lallemandii* in October constituted the remaining percentage of the total biomass (Fig. 4C).

The community dominated by *Osmundaria volubilis* showed different patterns depending on the depth of the samples. In May, *Osmundaria volubilis* and *Phyllophora crispa* were the main constitutive species of the community and *Lophocladia lallemandii* was absent, in both deep (-30 m) and shallow (-20 m) waters. *O. volubilis* and *P. crispa* were the most abundant species at the two depths sampled in November, but *L. lallemandii* represented the remaining 35.5 % of the total biomass at 20 m, while at 30 m depth it represented only the 3.8% (Fig. 4D).

The total number of species is always at least 2x higher in May than in November; in some cases such as in the *Cystoseira spinosa* community, the number of species in May can be 5x higher than those observed in November (Tab. 4).

Discussion

After its first introduction in northern Eivissa in 1995 (Patzner, 1998), *Lophocladia lallemandii* completely invaded Eivissa and the north of Formentera in only six years, which represents a spread of more than 300 km of coastline. In our study we observed a substantial increase in the geographical distribution of *L. lallemandii* in the MPA “Freus d’Eivissa i Formentera” between years 2000 and 2001.

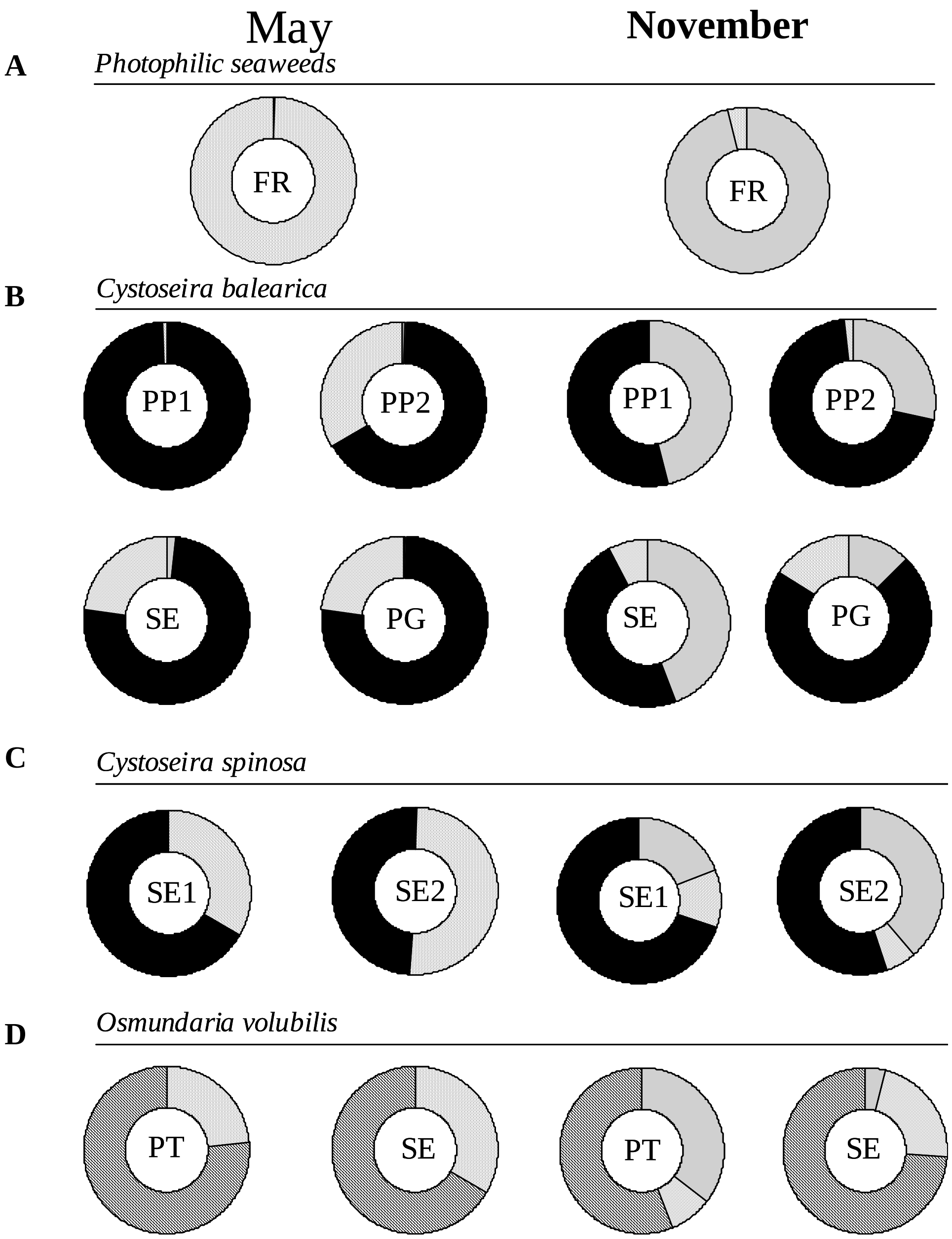

Fig. 4: Percentage biomass of* Lophocladia lallemandii *(grey),* Cystoseira *sp. (black),* Osmundaria volubilis + Phyllophora crispa *(lines) and other native species (points) at all communities sampled. FR: Faralló de Punta Rama; SE: Seca de l'Espardelló; PP: Punta Prima; PG; Punta Gavina; PT: Punta d'en Talaies. See Table 2.

Tab. 4: Mean number of species recorded in May and November at each sampled community.

Comunity	Nº samples	Nº sp (May)	Nº sp (November)
Photophilic algae	1	23	15
Cystoseira balearica	4	43	14
Cystoseira spinosa	2	37	5
Osmundaria volubilis	2	45	12

Considering the bionomic cartography of the MPA (author's unpublished data) and taking into account that *L. lallemandii* normally grows between 5 and 30 m depth (data obtained in the present study) we can estimate that *L. lallemandii* increased its distribution, at least, in more than 450 ha in only one year.

Furthermore, as it has been previously suggested (Patzner, 1998; Boudouresque and Verlaque, 2002; Ballesteros *et al.,* 2007) our results show that *Lophocladia lallemandii* performs as a typical invasive species, concerning macroalgal communities and *Posidonia oceanica* meadows situated between shallow waters and 35 m depth. However, it seems that rocky bottoms covered by native erect algae (*Cystoseira*, *Osmundaria*) are more susceptible to invasion than seagrass meadows, being the rocky bottom communities situated between 5 and 20 meters depth the most heavily impacted. In contrast, although *L. lallemandii* is present over all *P. oceanica* meadows sampled, the affectation seems to be lower in this assemblage than in rocky bottoms, probably because seagrasses are better competitors than algae and thrive in different environments (Den Hartog, 1997). Anyway, *L. lallemandii* effects over *P. oceanica* cannot be undervalued as *L. lallemandii* may drive considerable shoot demise to the seagrass (Ballesteros *et al.,* 2007). On the other hand, the absence of *L. lallemandii* in transect 14 (Estany des Peix), is probably due the lagoonal features of the transect, which probably prevents *L. lallemandii* growth.

Lophocladia lallemandii biomass was very low or even nil in May at all communities studied, while it significantly increased everywhere in November. The lower biomass of *L. lallemandii* in Punta Gavina should be related to its relatively recent colonisation, whilst the low biomass observed at 30 m depth within the community of *Osmundaria volubilis* could be related to the excessive depth, which could limit *L. lallemandii* development.

Lophocladia lallemandii suffers pronounced seasonal changes with a maximum coverage and biomass in autumn, a drastic winter decline and a fast growth in late spring. This growth pattern could be related to the tropical affinities of the genus *Lophocladia*, which is probably inhibited by low water temperatures and enhanced by high water temperatures.

Species richness was always significantly higher in May than in November. Ballesteros (1991) usually finds a larger number of species in autumn than in spring, at least in photophilic algal communities. Perhaps, the small size of the species in autumn may involve an underestimate of the real number of species, although a negative effect of *Lophocladia lallemandii* on the species richness cannot be discarded.

Acknowledgements

This research was financially supported by the "Direcció General de Biodiversitat, Servei d'Espais Naturals" of the "Govern de les Illes Balears". "Vell Marí" Diving Center provided diving facilities.

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Actes du 3ème Symposium méditerranéen sur la végétation marine (Marseille, 27-29 mars 2007)

Francesco CINELLI, David BALATA, Luigi PIAZZI
Dipartimento di Biologia, Università di Pisa, Via A. Volta 6, 56126 Pisa, ITALY, e-mail: lpiazzi@biologia.unipi.it

THREATS TO CORALLIGENOUS ASSEMBLAGES: SEDIMENTATION AND BIOLOGICAL INVASIONS

Abstract

The paper showed results of two different studies describing the species composition of macroalgal coralligenous assemblages in areas subjected to disturbance related to sedimentation and to the spread of the introduced green alga Caulerpa racemosa *var.* cylindracea*. The two studies showed significant differences in species composition and biodiversity between reference and disturbed assemblages. Both the increase of sedimentation rate and the invasion of* C. racemosa *var.* cylindracea *seem to represent serious threats to macroalgal coralligenous assemblages.*

Key words: Macroalgae, Coralligenous assemblages, Sedimentation, Biological invasions.

Introduction

Deep subtidal rocky habitats of the Mediterranean Sea are characterised by assemblages dominated by calcareous organisms, defined as “coralligenous” (Ballesteros, 2006). Coralligenous assemblages are considered among the most important and characteristic habitats of the Mediterranean Sea, in relation to their extension, biodiversity, production and role in carbonate cycle (Hong, 1982; Laborel, 1987; Cocito, 2004; Ballesteros, 2006). As other marine and terrestrial habitats characterized by high diversity related to the maintenance of the steady of physical factors and regulated by biotic interactions, coralligenous assemblages are sensitive to impact, especially if it is caused by human activities (Hong, 1983). Among human-induced disturbance, sedimentation and biological invasions are less investigated than other kinds of disturbances in deep coastal ecosystems.

Sedimentation has increased over the past few decades in many coastal marine areas in relation to the loss of soil due to overuse of land or deforestation, representing a potential threat to littoral communities (Airoldi *et al.*, 2003). Differences in the structures between coralligenous assemblages subjected to different sedimentation rates have been already highlighted (Balata *et al.*, 2005), but photographic methods used in these studies did not allow to evaluate values of biodiversity.

Biological pollution linked to invasions of introduced species is considered a threat to biodiversity in marine habitats (Walker and Kendrick, 1998). In the Mediterranean Sea, invasions of exotic macroalgae have caused serious ecological problems in costal areas (Verlaque, 1994; Boudouresque and Verlaque, 2002). *Caulerpa racemosa* (Forsskål) C. Agardh var. *cylindracea* (Sonder) Verlaque, Huisman *et* Boudouresque represents one of the most significant invasion in the Mediterranean Sea, showing wide colonization across the whole basin (Piazzi *et al*., 2005) and interfering with native assemblages (Piazzi *et al*., 2001).

The aims of this paper are to show results of two different studies that described the species composition and the biodiversity of macroalgal coralligenous assemblages in areas subjected to two different kinds of disturbance and to compare them to reference assemblages. The first study compared assemblages in areas characterised by different turbidity and sediment deposition. In the second study, assemblages in areas invaded by *C. racemosa* var. *cylindracea* were compared to non-invaded native assemblages.

Material and methods

The two studies were carried out along the Tuscany coast in north-western Mediterranean Sea, at a depth of about 30 m. For the study on sedimentation (S), two sites with different average levels of water turbidity were identified (Balata *et al.*, 2005). For study on biological invasion (I), two different conditions were selected: patches dominated by *C. racemosa* var. *cylindracea* and reference zones. In both the studies, two areas were randomly chosen for each condition and in each area 3 replicated samples were collected by scraping a 400 cm² surface on horizontal bottom. Materials were observed under a microscope to identify macroalgal species and to evaluate cover of each species. Species richness of each sample was counted and the Margalef's index of diversity was calculated.

PERMANOVA based on permutations was used to test the hypothesis that macroalgal assemblages differed among the examined conditions (Anderson, 2001). Bray-Curtis dissimilarities for this analysis were calculated using untransformed data. In the studies, the analysis consisted in a 2-way model with Condition (2 levels: disturbed assemblages vs. references) as a fixed factor and Area (2 levels) as random factor nested within Condition. For graphical representation of the data, a two dimensional metric multidimensional scaling (MDS) was carried out. SIMPER test was used to determine which species were responsible for the possible differences between Conditions.

Values of species richness and Margalef's index were analysed by a 2-way ANOVA, utilizing the same factors and levels described for the multivariate analysis. Homogeneity of variances was checked using the Cochran *C*-test (Underwood, 1997).

Results

A total of 77 macroalgal species were found: 8 Chlorophyta, 7 Phaeophyta and 62 Rhodophyta. In reference areas, encrusting layer was well developed and characterized by encrusting corallinaceae, *Peyssonnelia rubra*, *P. squamaria* and *Zanardina typus*. The most abundant erect species were *Flabellia petiolata*, *Halimeda tuna*, *Meredithia microphylla*, *Osmundea pelagosae*. The most common species in the turf were *Pseudochlorodesmis furcellata*, *Dictyota* sp., *Chondria dasyphylla*, *Jania adhaerens*, *Womersleyella setacea*, *Heterosiphonia crispella.*

In both the studies, PERMANOVA analyses detected significant differences between disturbed and reference assemblages (Tab. 1, Tab. 2) and metric MDS ordination showed a clear distinction between areas of the two conditions (Fig. 1, Fig. 2). In S study, the SIMPER analysis showed that assemblages subjected to high sedimentation rates were characterized by high cover of filamentous species such as *Womersleyella setacea* and *Pseudochlorodesmis furcellata*, while many species were less abundant if compared to reference areas (*Zanardina typus*, *Flabellia petiolata*, *Meredithia microphylla*, *Dictyota* sp.) (Tab. 3). In BI study, the SIMPER analysis showed that in areas invaded by *Caulerpa racemosa* var. *cylindracea* encrusting species (*Peyssonnelia* sp, encrusting Corallinaceae and *Zanardina typus*) and several erect (*Halimeda tuna*, *Flabellia petiolata Osmundaea pelagosae*) were less abundance, while *Cladophora prolifera* and *Halopithys incurva* had a higher percentage cover (Tab. 4).

Tab. 1: Results of PERMANOVA on the structure of reference assemblages and assemblages subjected to high sedimentation. Significant effects are indicated in bold.

Source	**df**	**MS**	***Pseudo-F***	***P(perm)***	**permutations**
Condition = (C)	1	15874	5.896	**0.006**	986
Area(C) = A(C)	2	2692.1	1.874	**0.021**	986
Res	8	1436.4			
Total	11				

Tab. 2: Results of PERMANOVA on the structure of reference assemblages and assemblages invaded by C. racemosa var. cylindracea. Significant effects are indicated in bold.

Source	**df**	**MS**	***Pseudo-F***	***P(perm)***	**permutations**
Condition = (C)	1	7471.0	11.1	**0.008**	988
Area(C) = A(C)	2	673.1	2.1	0.074	992
Res	8	317.6			
Total	11				

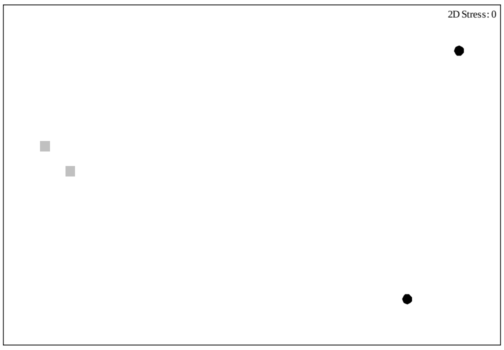

Fig. 1: Metric MDS ordination based on Bray-Curtis dissimilarity coefficient applied to species-samples matrix. Grey Squares = reference areas, Black Circles = high sedimentation areas.

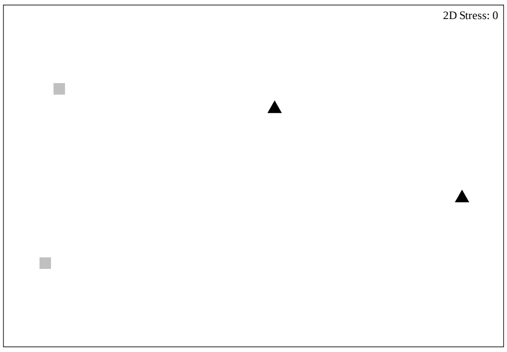

Fig. 2: Metric MDS ordination based on Bray-Curtis dissimilarity coefficient applied to species-samples matrix. Grey Squares = reference areas, Black Triangles = **Caulerpa racemosa** ***var.*** **cylindracea** ***areas.***

Tab. 3: Results of SIMPER test on percentage contributions of taxa to determine significant differences between areas characterized by different sedimentation rates.

Taxa	**Reference areas Av.Abund**	**High sedimentation areas Av.Abund**	**Contrib%**
Zanardinia typus (Nardo) G. Furnari	33.61	0.00	35.71
Flabellia petiolata (Turra) Nizamuddin	14.89	1.23	15.00
Dictyota sp.	13.53	0.89	14.39
Pseudochlorodesmis furcellata (Zanardini) Børgesen	0.37	8.06	8.03
Womersleyella setacea (Wollaston) R.E. Norris	3.27	10.78	7.74
Peyssonnelia rubra (Greville) J. Agardh	5.97	4.06	6.47
Meredithia microphylla (J. Agardh) J. Agardh	2.56	0.18	2.48
Osmundea pelagosae (Schiffner) F.W. Nam	1.18	0.92	1.48

***Tab. 4: Results of SIMPER test on percentage contributions of taxa to determine significant differences between reference areas and areas invaded by* Caulerpa racemosa *var.* cylindracea.**

Taxa	Reference areas Av.Abund	*Caulerpa racemosa* areas Av.Abund	Contrib%
Encrusting Corallinaceae	100.00	40.83	43.32
Flabellia petiolata (Turra) Nizamuddin	44.08	2.92	23.80
Womersleyella setacea (Wollaston) R.E. Norris	12.13	28.54	10.49
Osmundea pelagosae (Schiffner) F.W. Nam	12.78	8.77	5.43
Peyssonnelia rubra (Greville) J. Agardh	9.58	1.75	4.64
Halimeda tuna (J. Ellis et Solander) J.V. Lamouroux	5.33	0.00	3.10
Halopithys incurva (Hudson) Batters	0.00	4.08	2.30
Jania adhaerens J.V. Lamouroux	2.78	5.87	2.19
Cladophora prolifera (Roth) Kützing	0.08	2.48	1.40
Tricleocarpa fragilis (Linnaeus) Huisman et R.A. Towsend	2.12	1.00	1.23
Zanardinia typus (Nardo) G. Furnari	1.47	0.95	0.97

The species number per sample was 35.5±0.9 and 36.8 ±1.1 (mean±SE; n = 6) in reference assemblages, 19.6 ±2.1 in assemblages subjected to high sedimentation rates and 27.8 ±0.5 in assemblages invaded by *C. racemosa* var. *cylindracea* (Fig. 3). The Margalef's diversity index showed values of 7.8±0.1 and 6.7±0.1 in reference assemblages, 5.9±0.3 in assemblages subjected to high sedimentation rates and 5.7 ±0.1 in assemblages invaded by *C. racemosa* var. *cylindracea* (Fig. 4). ANOVA analysis detected significantly higher values of Margalef's index in control assemblages than in disturbed assemblages in both the two studies while differences in the species number per sample resulted significant only for assemblages invaded by *C. racemosa* var. *cylindracea* (Tab. 5).

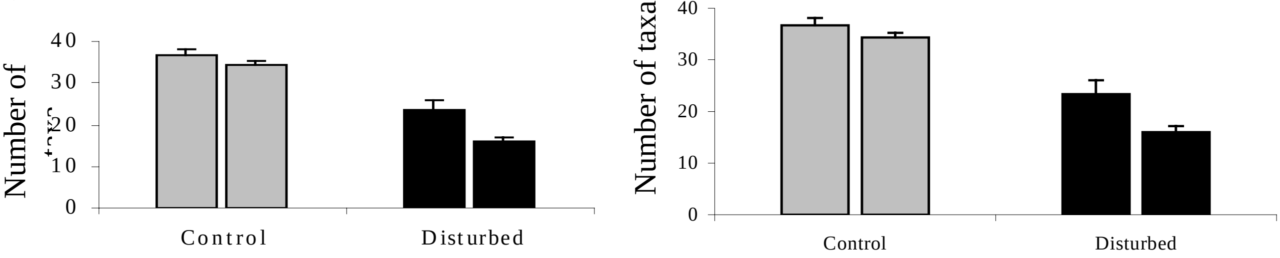

Fig. 3: The number of taxa (mean + SE, n = 3) of coralligenous assemblages. Disturbance is related to sedimentation (a) and to* Caulerpa racemosa *var.* cylindracea *invasion (b).

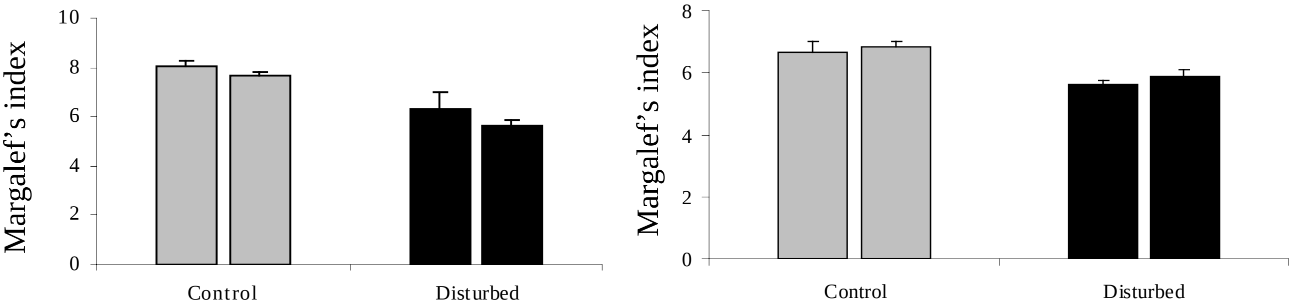

Fig. 4: The Margalef's index (mean + SE, n = 3) of coralligenous assemblages. Disturbance is related to sedimentation (a) and to* Caulerpa racemosa *var.* cylindracea *invasion (b).

Tab. 5: Results of ANOVA on the species number and Margalef's diversity index Significant effects are indicated in bold.

		Species number				**Margalef's index**			
		C. racemosa		**sediment**		***C. racemosa***		**sediment**	
Source	**df**	**MS**	**F**	**MS**	**F**	**MS**	**F**	**MS**	**F**
Condition = C	1	243.00	**58.32**	752.08	16.93	2.82	**35.10**	10.48	**22.32**
Site(C) = S(C)	2	4.17	0.85	44.42	**5.08**	0.08	0.48	0.47	1.23
Residual	8	4.92				0.17		0.38	
Total	11								
Cochran's *C*		0.6610		0.6381		0.6045		0.7448	

Discussion

The two studies showed significant differences in species composition and biodiversity between control and disturbed assemblages. Differences detected between reference and disturbed assemblages are similar to those described for shallower rocky assemblages in relation both to sedimentation increase and *C. racemosa* var. *cylindrace*a invasion (Airoldi, 2003; Piazzi *et al*., 2001). Both the disturbed assemblages showed lower values of species richness and percentage cover of erect macroalgae, while filamentous species increased; thus, similar mechanisms can be suggested to be acting for the effects of sedimentation and *C. racemosa* var. *cylindrace*a colonization. In fact, *C. racemosa* var. *cylindrace*a is able to grow on other algae and to completely cover the invaded areas through a net of ramified stolons (Piazzi *et al*., 2001) causing the death of less tolerant organisms and avoiding spore settlement. Both covering and pre-emption of the substrate are mechanisms of disturbance also described for sediment deposition (Airoldi, 2003; Eriksson and Johansson, 2003).

Although similar mechanisms have been detected between the two studied kinds of disturbances, differences were also highlighted. In fact, sedimentation does not affect encrusting algae that strongly decreased in areas invaded by *C. racemosa* var. *cylindrace*a; moreover, several filamentous species showed different response to the two disturbances. Encrusting forms appeared tolerant to sediment deposition and burial (Airoldi, 2000), while they seem to suffer overgrowth of *C. racemosa* var. *cylindrace*a, probably in relation to the alteration of physical condition due to the presence of wide layers of stolons and trapped sediment. Among filamentous algae, several tolerant species, such as *Womersleyella setacea*, increased in disturbed areas, while other species showed different responses to the stress. *Pseudochlorodesmis furcellata*, for example, appeared affected by the spread of *C. racemosa* var. *cylindrace*a, while in high sedimentation areas it was more abundant than in reference areas. Both the mechanisms of growth and reproduction can be involved in the ability of filamentous species to tolerate disturbance.

Despite these different aspects, both the two studied kind of disturbance seem to strongly affect coralligenous assemblages and they can be considered possible threats to this key Mediterranean littoral system.

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Philippe CLABAUT[1], Claude AUGRIS[2], Vanina PASQUALINI[3], Gérard PERGENT[3], Christine PERGENT-MARTINI[4]
[1]Consultant en Géologie Littorale et Marine, 9, Impasse du Boutillier 62240 Selles, France
e-mail : philippe.clabaut@orange.fr
[2]Ifremer, Département Géosciences marines, Technopôle Brest-Iroise BP 70, 29280 Plouzané, FRANCE
[3]Université de Corse , Faculté des Sciences, BP 52, 20250 Corte, FRANCE
[4]CAR/ASP , Boulevard du Leader Yasser Arafat, BP 337 ,1080 Tunis cedex, TUNISIE

IDENTIFICATION ET CARACTERISATION DES HERBIERS A *POSIDONIA OCEANICA* PAR SONAR A BALAYAGE LATERAL : VERS UNE BASE DE DONNEES MEDITERRANEENNE ?

Résumé

Sur la base de la cartographie des principaux peuplements et types de fonds du littoral de la Corse, réalisée à partir du sonar à balayage latéral pour les zones profondes, un projet de constitution d'une « base d'images sonar des fonds marins », a été envisagé. Outre la position de la limite inférieure, les sonogrammes peuvent fournir de nombreuses informations complémentaires. La base d'images sonar des fonds marins de Corse regroupe 50 fiches descriptives des différents faciès de l'herbier à Posidonia oceanica, des substrats, des figures sédimentaires et des traces anthropiques. Les extraits de sonogrammes sélectionnés traduisent la grande diversité des fonds dans la bande des 0 à 50 m de profondeur autour de la Corse. Au-delà de l'aspect descriptif, les sonogrammes font également l'objet d'une analyse fine des relations entre l'herbier et les substrats, de l'influence de l'hydrodynamisme sur l'extension de l'herbier dans sa partie profonde, et des modelés différents d'herbier au débouché des rivières et ruisseaux. Les différents faciès de l'herbier pourront à l'avenir servir de référence pour l'étude d'autres sites méditerranéens, comme par exemple le littoral Provence Alpes Côte d'Azur (France), où l'herbier est plus réduit et plus affecté par les actions anthropiques.

Mots-clés : Sonar à balayage latéral, *Posidonia oceanica*, Corse, Cartographie, Atlas.

Contexte de l'étude

La Méditerranée abrite plus d'un millier d'espèces végétales marines macroscopiques, qui présentent un fort pourcentage d'endémiques (de 15 à 20 %). Le statut de ces espèces benthiques est souvent mal connu, y compris pour des espèces et / ou des peuplements remarquables comme les herbiers à *Posidonia oceanic*a. En effet, même pour ces dernières, les données disponibles sont fragmentaires et varient d'un secteur géographique à l'autre. Il n'existe donc que très peu d'informations susceptibles de guider les collectivités locales (région, municipalités), les administrations qui ont en charge la gestion des milieux naturels, et bien évidemment les aménageurs. La mise en oeuvre de cartographie apparaît alors comme un objectif prioritaire, notamment dans les secteurs soumis à une forte pression touristique pour lesquels les forts besoins en aménagements littoraux ne doivent pas engendrer de dégradation de la qualité du milieu. En fonction (i) de l'état des connaissances du milieu (e.g. travaux antérieurs), (ii) des objectifs retenus, (iii) de la précision nécessaire, (iv) de l'étendue des secteurs à inventorier, et (iv) des moyens disponibles (humains et financiers), les méthodes de cartographies retenues seront différentes (Walker, 1989).

Le sonar latéral, initialement employé pour l'étude géologique des fonds est fréquemment utilisé, depuis une vingtaine d'années, pour la cartographie des herbiers à *Posidonia oceanica*.
En complément de la cartographie générale des peuplements et types de fonds, présents le long du littoral corse, il s'est avéré intéressant de constituer une « base d'images sonar des fonds marins autour de la Corse », composée d'un ensemble d'extraits de sonogrammes à l'échelle originale localisés, annotés et interprétés. L'atlas ainsi réalisé est représentatif de la diversité des fonds marins côtiers autour de la Corse, et complémentaires des cartes des formations superficielles. Il a pour objectifs (1) de faciliter l'accès aux sonogrammes, qui concernent la partie profonde des herbiers, difficile d'accès, et généralement peu renseignée, (2) de disposer d'un état de référence pour des sites particuliers, notamment dans le cadre du Plan d'Action pour la Conservation de la Végétation Marine en Méditerranée et (3) d'établir progressivement une base de données internationale des faciès côtiers les plus représentatifs. Cet « Atlas » de sonogrammes, qui pourra être régulièrement incrémenté, est de nature à fournir un outil indispensable pour toutes les futures études utilisant cet instrument dans une optique de cartographie des herbiers.

Matériel et méthodes

La cartographie du littoral de la Corse a été réalisée par traitement de photographies aériennes pour la tranche superficielle, et interprétation d'images sonar latéral (sonogrammes), pour la partie profonde (Fig. 1). Le long des côtes corses , 1 280 km de profils sonar ont été réalisés en septembre 1995 et septembre 1996, lors de deux campagnes océanographiques (Fig. 2). Du fait de l'objectif initial des levés, les informations sonar consistent en un profil unique parallèle à la côte (cas de la façade ouest) ou à un nombre limité de profils (cas de la façade Est), permettant d'intercepter la limite inférieure de l'herbier.

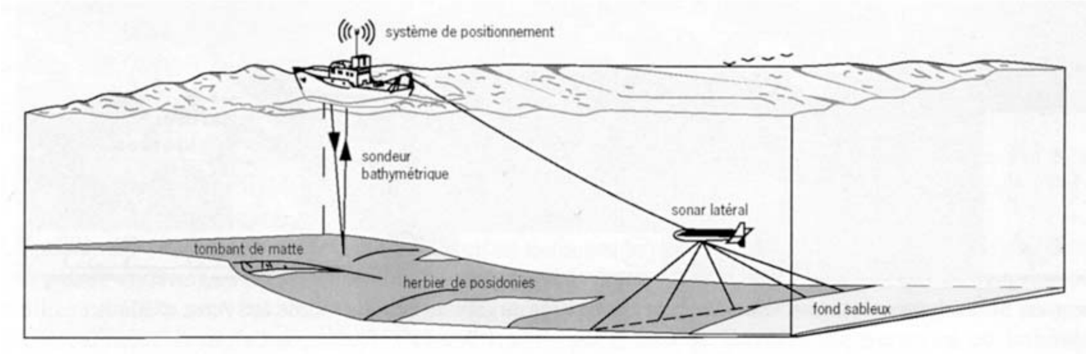

Fig. 1 : Schéma de fonctionnement du sonar à balayage latéral.

La méthodologie d'acquisition des données en mer (Fig. 1) est basée sur l'association de différentes techniques complémentaires (Augris et Clabaut, 2001).

- un sonar à balayage latéral pour la réalisation de la couverture cartographique. Les "images" obtenues, appelées "sonogrammes" permettent de distinguer les types de fond par des teintes différentes, et de les délimiter précisément ;
- un sondeur bathymétrique pour la mesure de la profondeur d'eau, qui révèle le relief du fond à la verticale du navire ;

Le principe du sonar à balayage latéral repose sur la variation du coefficient de rétrodiffusion du fond. Le signal acoustique, de fréquence 110 kHz, émis par les deux transducteurs logés dans le poisson, est renvoyé avec plus ou moins d'intensité selon les caractéristiques de nature et de forme du fond.

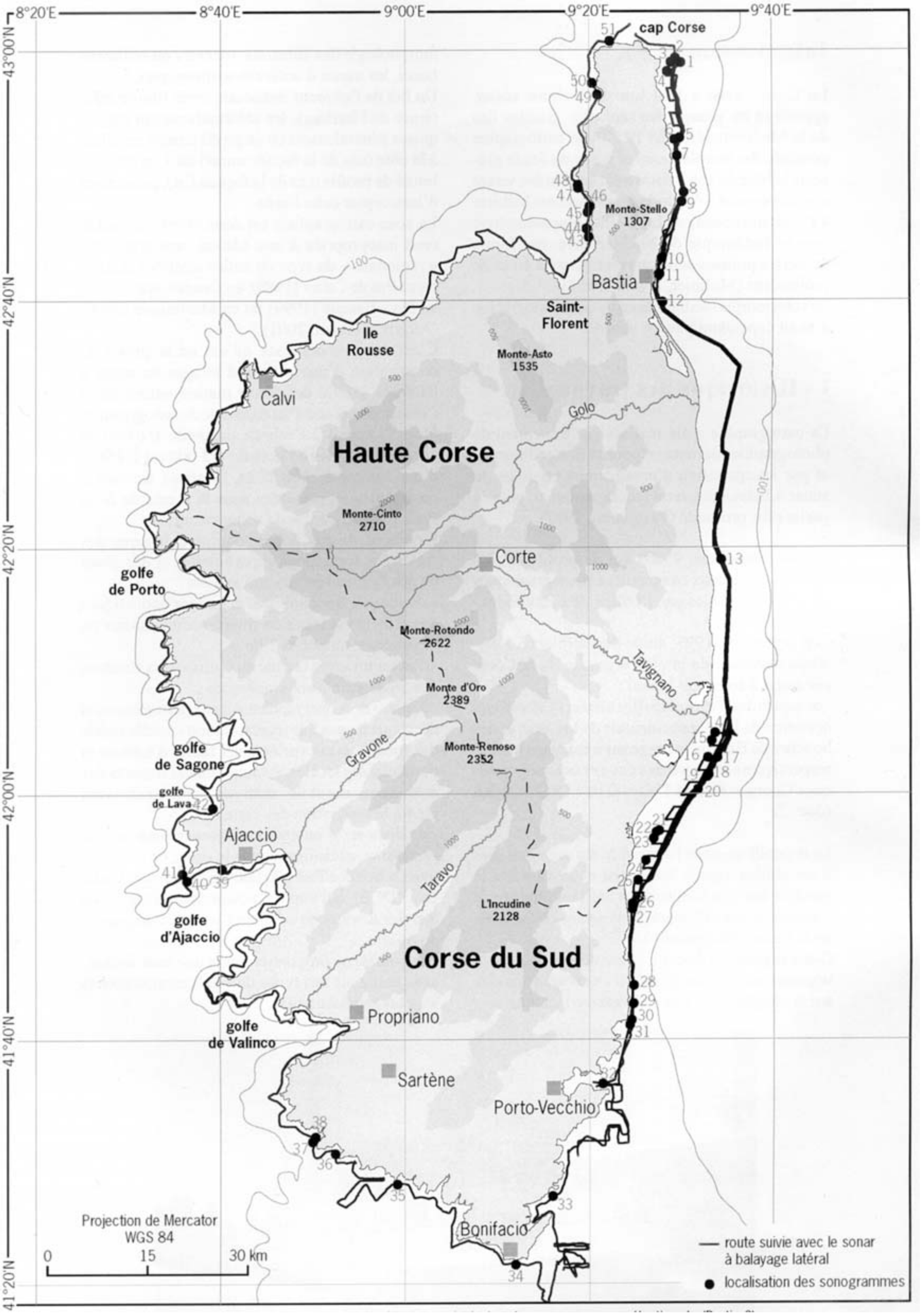

Fig. 2 : Carte de localisation des profils sonar et de l'ensemble des extraits de sonogrammes sélectionnés.

Le positionnement du navire est assuré lors des missions océanographiques par un système de positionnement par satellites (GPS différentiel), d'une précision de quelques mètres.
Le sonar à balayage latéral a une capacité de représentation de larges étendues : environ 1 km^2 par heure à une vitesse de navigation de 5 nœuds (5 milles marins/heure). Autour de la Corse, l'acquisition des 1280 km de profils, couvrant une superficie de l'ordre de 500 km², a été réalisée en 15 jours de travaux à la mer.
Le sonar latéral est adapté à l'identification des limites de faciès (type de fond) et des micro-reliefs. Les enregistrements sont acquis à l'échelle de 1/1 000, avec une définition de l'ordre de 1 m^2. Le sonar latéral n'a par contre aucun pouvoir de pénétration, et ne donne des informations que sur la surface du fond de la mer. Pour des raisons techniques, liées à la sécurité de la navigation de navires remorquant des engins, il ne peut être utilisé que lorsque la hauteur de la tranche d'eau est supérieure à environ 8 m.

Outre la position de cette limite inférieure, les sonogrammes à l'échelle originale 1/1 000 à 1/2 000, donnent de nombreuses informations sur la morphologie fine de l'herbier, la nature et la morphologie des substrats, et les traces d'activités anthropiques. Ils ne sont généralement utilisés que (1) lors des missions, pour le positionnement de points d'observation ou de contrôle (« vérités-terrain ») (2) pour la réalisation des cartes des formations superficielles. Au-delà, ces données de base sont simplement archivées, alors qu'elles constituent une échelle d'information intermédiaire entre l'observation directe sur le terrain (vidéo ou plongée) et les cartes (1/10 000 généralement).
Après visualisation de l'ensemble des sonogrammes (1280 km), une pré- sélection d'une centaine d'extraits de sonogrammes les plus représentatifs a été réalisée dans un premier temps. Parmi ceux-ci, 50 extraits ont ensuite été choisis, et des fiches descriptives réalisées. La réalisation proprement dite des fiches consiste à numériser le sonogramme, à extraire des différents fichiers les positions géographiques et l'information bathymétrique, puis à interpréter ces données.

Résultats

Le document produit (Clabaut *et al.*, 2006) est un document de synthèse sur les levés sonar autour de la Corse, complémentaire des cartographies existantes (Pasqualini, 1997 ; Pasqualini *et al.*, 1997 ; 1998 ; 2000). Il regroupe 50 fiches descriptives des différents faciès de l'herbier à *Posidonia oceanica*, des substrats, des figures sédimentaires.
L'imagerie « sonar » permet généralement de déterminer la présence ou l'absence d'herbier, d'en décrire le faciès acoustique (faciès homogène, ou ondoyant -Fig. 3-, ou encore « strié »), le recouvrement, qui correspond au pourcentage de couverture du substrat par les feuilles de *Posidonia oceanica*, par rapport aux zones non couvertes (sable, matte morte, roche), le caractère continu ou discontinu (on parle alors de faciès « en taches » ou de « mosaïque d'herbier »), la micromorphologie de l'herbier (présence de tombants de matte -Fig.4 -, de taches de matte de taille variable – Fig. 5-, parfois façonnées de mégarides de houle ou de courant)
Des informations peuvent également être recueillies sur la morphologie de la limite inférieure, notamment lorsqu'un abrupt se situe à la base de l'herbier, traduisant une limite érosive. Un passage brusque de l'herbier au fond meuble peut également être différencié d'un passage « progressif »
La profondeur de la limite inférieure est fournie par l'enregistrement bathymétrique. Elle est considérée comme un indicateur de la turbidité moyenne des eaux (Pergent *et al.*, 1995).

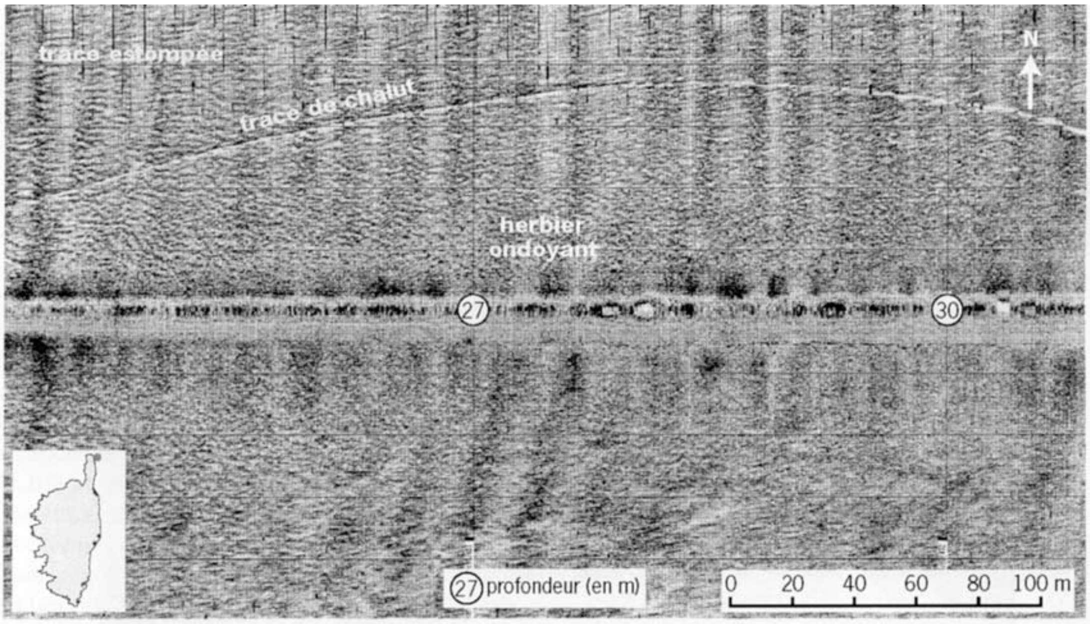

Fig. 3 : Extrait de sonogramme montrant le faciès ondoyant de l'herbier.

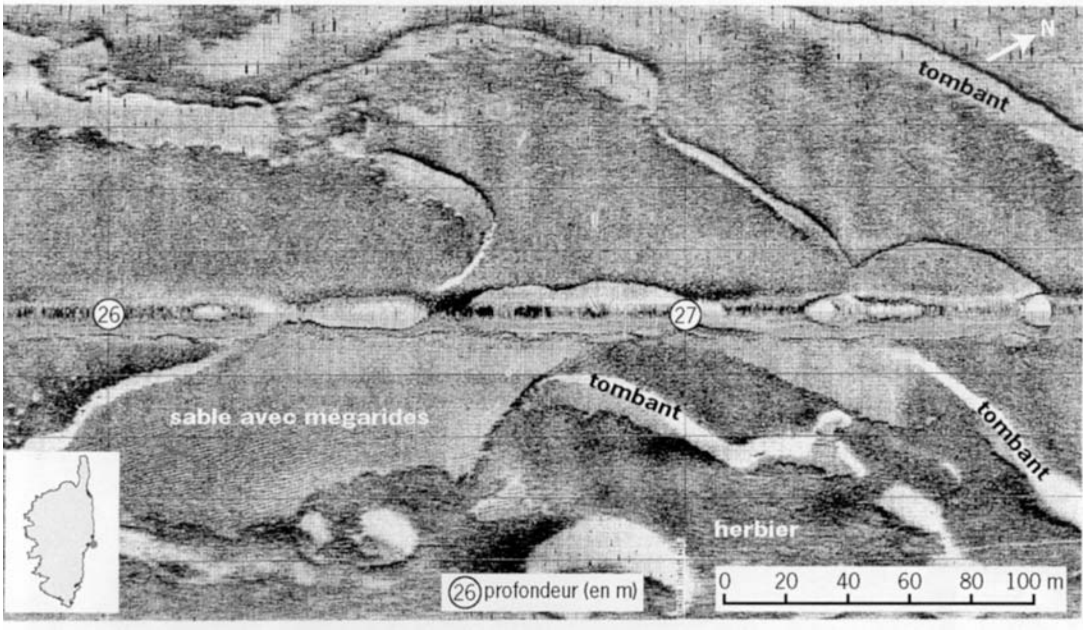

Fig. 4 : Extrait de sonogramme montrant des tombants de matte.

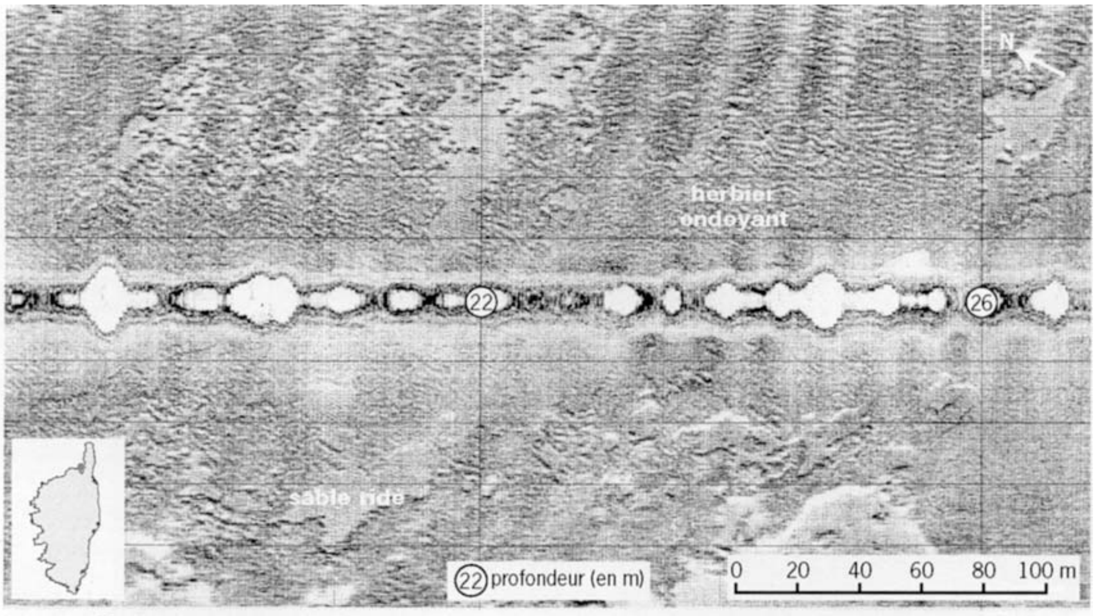

Fig. 5 : Extrait de sonogramme montrant des taches sableuses ridées au sein de l'herbier.

Les informations sur les substrats rocheux sont le relief (ex : platiers, pointements isolés, barres rocheuses, « falaises »), exprimé à la fois par l'imagerie et la variabilité locale de la profondeur, la pente moyenne du fond (profondeur rapportée à la distance à la côte). La nature de la roche elle-même n'est pas indiquée ; elle influe cependant sur la morphologie des affleurements

Les substrats de nature sédimentaire présentent deux types de faciès acoustique : des faciès clairs, pouvant correspondre à de la matte morte de *Posidonia oceanica* , ou à des sables fins à moyens, et un faciès sombre pouvant correspondre à des sables grossiers ou des graviers.

Les figures sédimentaires de taille supérieure au mètre, les mégarides, formées par les houles ou les courants sur les fonds de sables moyens à grossiers, ou de graviers, sont également détectées sur les sonogrammes. La mesure de leur orientation, de leur longueur d'onde, de la profondeur à laquelle elles se forment, peuvent fournir une information indirecte sur l'hydrodynamisme marin. Ces mégarides de quelques mètres de longueur d'onde s'observent soit dans de petites zones au sein même de l'herbier, soit hors de l'herbier

Des informations sur les activités anthropiques peuvent être acquises au travers des traces observées sur le fond. Bien qu'elles soient peu nombreuses et localisées, différents types de traces d'activités anthropiques ont été observées autour de la Corse : des traces d'engins de pêche (soit bien marquées et profondes, avec un impact marqué sur l'herbier - Fig.3 -, soit au contraire moins marquées et diffuses, avec un impact moindre), des traces d'explosifs (trace unique de taille hectométrique ou chapelet de traces décamétriques), comparables à celles observées à l'Est de Porquerolles (Paillard *et al.*, 1993), et sur le Plateau des Chèvres, aux abords de Marseille (Pergent, 2000).

A l'Ouest du Cap Corse, les déblais de la carrière de Canari, exploitée de 1948 à 1965, s'observent au pied de la falaise, à l'aplomb de la carrière. Ils auraient détruit les herbiers initiaux, sur une surface estimée à 230 ha (Pasqualini, 1997). Quelques épaves ont également été identifiées lors des levés.

Discussions et conclusions

Les limites de l'imagerie sonar doivent aussi être soulignées. Il s'agit d'une part de limites techniques (définition maximale de l'ordre 1m, précision du positionnement de l'ordre de 20 m environ, difficulté à travailler à très faible profondeur), d'autre part de limites d'interprétation : le sonogramme ne permet pas, à lui seul, de différencier une limite progressive d'une limite régressive d'herbier (liée à la définition de l'image) ; dans les deux cas, le sonar indique seulement une variation progressive du recouvrement de l'herbier. Lorsque la pente est très forte, l'identification de l'herbier peut devenir problématique. De la même manière, sur le sonogramme, l'herbier présente un façonnement comparable au droit de l'embouchure d'un fleuve côtier et au débouché d'un émissaire.

Les informations tirées des sonogrammes nécessitent une validation de terrain (observation directe ou prélèvement pour les sédiments). Actuellement, seuls quelques prélèvements de sédiment à la benne ont été réalisés, au cours des missions en mer, dans le périmètre du Parc Marin des bouches de Bonifacio. C'est le cas notamment pour un faciès particulier, identifié au large de Solenzara, qui semble correspondre un sédiment sableux plus ou moins induré (beach-rock).

Pour les faciès d'herbier, des observations complémentaires sur le seuil de détection du sonar (recouvrement mesuré sur le fond à partir duquel le sonar identifie l'herbier), et le recouvrement à partir duquel le sonar indique un faciès d'herbier homogène, traduisant un fort recouvrement. De telles intercalibrations entre techniques sont réalisées sur le site de Saint-Raphaël, dans le cadre du programme européen « Posidonia ».

Les informations complémentaires acquises dans le cadre des validations de terrain, ou de levés sonar ultérieurs sur le site, pourraient ensuite être intégrées aux fiches descriptives déjà réalisées.

Le nombre d'extraits de sonogrammes sélectionnés, pour aboutir à un échantillon représentatif de l'ensemble des profils sonar, traduit la grande diversité des fonds dans la bande des 0 à 50 m de profondeur autour de la Corse. Celle-ci est d'abord liée à la nature géologique contrastée des substrats, sableux, faiblement inclinés vers le large et largement colonisés par un herbier de posidonies à fort recouvrement, jusqu'à près de 40 m de profondeur le long de la plaine orientale, à dominante rocheuse et en pente forte sur une large partie occidentale. Les morphologies d'herbier sont également variées, en liaison notamment avec les substrats, et avec l'hydrodynamisme.

Au-delà de l'aspect descriptif, les sonogrammes font également l'objet d'une analyse fine des relations entre l'herbier et les substrats, notamment rocheux, de l'influence de l'hydrodynamisme sur l'extension de l'herbier dans sa partie profonde, et des modelés différents d'herbier au débouché des rivières et ruisseaux, qui reflètent le devenir en mer des masses d'eau dessalées et de leur dérive (notamment en période de crue).

A l'échelle de la Méditerranée, l'herbier de Corse peut être considéré comme un herbier de référence (Pasqualini, 2005), en raison de (1) son extension, révélatrice de la bonne qualité du milieu (près de 50% des fonds entre 0 et 50 m), (2) la profondeur de sa limite inférieure, proche du développement maximal, et révélatrice de la faible turbidité de l'eau, (3) son recouvrement important (témoin d'une bonne santé) et (4) du faible nombre de traces anthropiques, qui traduit un faible impact anthropique.

Les différents faciès de l'herbier pourront à l'avenir servir de référence pour l'étude d'autres sites méditerranéens ; en effet, sur le littoral Provence – Alpes – Côte d'Azur (France) par exemple, où des données comparables sont acquises, et l'herbier est plus réduit et plus affecté par les actions anthropiques.

Remerciements

Les auteurs tiennent à remercier l'Office Environnement de la Corse pour le financement des missions en mer, Genavir et l'INSU/CNRS pour la mise à disposition des moyens à la mer et les équipages des N/O Georges Petit et Thétys II pour leur contribution à l'acquisition des informations.

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Actes du 3ème Symposium méditerranéen sur la végétation marine (Marseille, 27-29 mars 2007)

Stefania COPPA[1,2], Ivan GUALA[1], Maura BAROLI[1], Monica BRESSAN[2], Serena COMO[1], Giuseppe PIERGALLINI[1], Giovanni DE FALCO[1,3]
[1] Fondazione IMC - International Marine Centre - Onlus, Loc. Sa Mardini, 09072 Torregrande, Oristano, ITALY
[2] Università di Padova, ITALY
[3] IAMC-CNR - Istituto Ambiente Marino Costiero, Sezione di Oristano, ITALY
e-mail: s.coppa@imc-it.org

EFFECTS OF SEA URCHIN GRAZING ON A *POSIDONIA OCEANICA* MEADOW IN THE GULF OF ORISTANO (WESTERN SARDINIA, ITALY)

Abstract

Although the interactions between grazers and Posidonia oceanica *have been largely investigated, there are still controversial views about the importance of* Paracentrotus lividus. *This study investigates the effects of different densities of* P. lividus *on* P. oceanica *at leaf and shoot scale. The experiment was conducted in September 2005 and May 2006 on a shallow meadow in the Gulf of Oristano (western Sardinia, Italy). In the field,* P. lividus *individuals were included within cages, according to five different densities: 0, 8, 20, 40 and 80 individuals m^{-2}. It was predicted that (i) under the cages, number and length of leaves, number of shoots and epiphyte biomass would decrease as an effect of sea urchins and that (ii) these effects would be higher at high than at low densities of sea urchins. The number of leaves and epiphyte biomass per surface unit did not change in response to sea urchin grazing, while a response was found in green and brown tissue as well as in the number of broken leaves. The number of shoots completely grazed by* P. lividus *varied for densities higher than 8 ind. m^{-2}; it peaked at the highest densities of sea urchins (i.e. 80 ind m^{-2}) exceeding the 45% of the total number of shoots initially present. The importance of this variable to quantify the grazing effect of* P. lividus *on the meadow is emphasized.*

Key-words: *Posidonia oceanica*, Grazing, *Paracentrotus lividus*, Epiphytes, Caging experiment.

Introduction

The echinoid *Paracentrotus lividus* (Lamarck, 1816) is the most common grazer of the Mediterranean Sea (Palacin *et al*., 1997; Tomas *et al.,* 2004) and one of the main consumers of the seagrass *Posidonia oceanica* (Valentine and Heck, 1991). Generally, *P. lividus* density within *P. oceanica* meadows ranges from 0 to 6 individuals m^{-2} (Tomas *et al*., 2005a; Tomas *et al*., 2005b; Baroli *et al*., 2006) even though higher densities and overgrazing events have been frequently described (Kirkman and Young, 1981; Tomas *et al*., 2005 a). *P. lividus* at densities of 20-40 ind. m^{-2} can remove large patches of the meadow with considerable effects on seagrass biomass and production (Valentine and Heck, 1991; Valentine and Heck, 1999). Verlaque and Nedelec (1984) observed the complete loss of a *P. oceanica* meadow caused by 40-110 sea urchins m^{-2}. The same authors assessed 25-50 ind.m^{-2} to be the critical density beyond which the consumption overcomes the production of the plant. A severe reduction of seagrass shoot density, up to 50% over six months, was reported due to sea urchin grazing, where individuals ranged between 11 and 30 ind.m^{-2} (Ruiz, 2000). On the contrary, other authors indicated that sea urchins grazing seems to be a factor of minor importance for the control of *P. oceanica* production (Cebrián *et al*., 1996), generally regulated by bottom-up factors as light, temperature and nutrients (Alcoverro *et al*., 1995). This hypothesis is supported by the evidence that seagrasses are not a preferential source of food for herbivores because of their high C/N ratios, their high content in cellulose and the presence of chemical deterrents (McMillan *et al.,* 1980; Verges *et al*., 2006). The seagrass unpalatability suggests the potential central role of epiphytes as an alternative or additional food resource for many herbivores (Duarte, 1995; Alcoverro *et al.*, 1997) and in some systems, the interaction between herbivores and seagrass appears to be mediated, at least in part, by epiphytes (Tomas *et al.*, 2005 a). *P. lividus* seems to feed preferentially on the distal portions of seagrass leaves (Nédelec and Verlaque, 1984; Tomas *et al.*, 2005 a) and particularly on the old leaves where the highest epiphytic biomass occurs (Alcoverro *et al.*, 1997). Removing relatively small amounts of leaf standing biomass, *P. lividus* feeds large amounts of epiphytes, and this behaviour could be part of an efficient feeding strategy due to the higher palatability of epiphytes than the host plant (Nédelec and Verlaque, 1984; Alcoverro *et al.*, 1997).

The aim of this work was to estimate, by means of field manipulative experiments, the critical density of *P. lividus* affecting a *P. oceanica* meadow, as well as investigating the grazing activity and its patterns both on leaf and shoot scale. In particular, we tested whether (i) leaf number and length, shoot number and epiphyte biomass per surface unit decreased in the cages as an effect of sea urchins inclusion and whether (ii) such response was dependent on different densities of sea urchins.

Materials and methods

The study site was located in the Gulf of Oristano (39°52.17 N; 008°26.78 E) along the western coast of Sardinia (Italy) (Fig. 1). The Gulf, extending for 150 Km^2 and 15 m depth in the middle, is colonized for 70% by a wide *P. oceanica* meadow (Cancemi *et al.*, 1997; Cancemi *et al.*, 2000). Seagrass shoot density was assessed by taking 10 replicate measurements using a 50x50 quadrat.

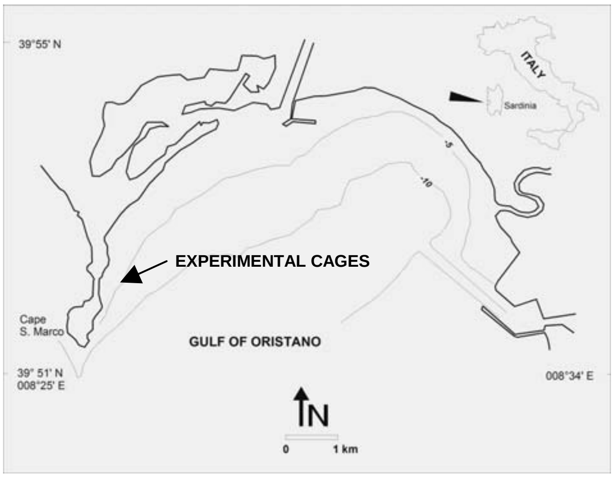

Fig. 1: Sampling site.

The experiment was carried out in September 2005 and May 2006. Fifteen quadrats (50 x 50 cm) were haphazardly selected at 5 m depth and surrounded with an hardware cloth (2.5 cm mesh and 70 cm high) fixed to the substrate with iron bars. Adult sea urchins (diameter ranging from 45 to 55 mm) were introduced inside these cages at different densities (0, 8, 20, 40 and 80 ind. m^{-2}, thereafter I_0, I_8, I_{20}, I_{40}, I_{80}). Each density was replicated three times. Moreover, 3 quadrats (50 x 50 cm), without net were also considered as reference (C) to test for possible artefact effects, due to the presence of cages. Each experiment was limited to a one month period due to the considerable sampling effort required to maintain constant densities of sea urchins within cages. Because of high sea urchins mortality due to gastropods (i.e. *Trunculariopsis trunculus*) predation, inspections to verify the continuous presence of selected density were carried out three times per week. Each time, all sea urchins within I_8, I_{20}, I_{40} and I_{80} were counted and, if necessary, replaced. To achieve this, *P. oceanica* shoots inside the cages were handled to find sea urchins buried among them. To test for possible effects of this manipulation, for the experiment carried out in September, a procedural control (PC) was used. It consisted of three replicate cages without sea urchins where the same operations required to ensure the maintenance of the experimental conditions were simulated.

At the end of both experiments three *P. oceanica* shoots were randomly collected from each quadrat and the following variables were measured for each shoot: (i) number of leaves > 5 cm (old and intermediate), (ii) length of old leaves (cm, distinguishing the green from the brown tissue), (iii) the Coefficient A (CoA) due to *P. lividus* grazing and (iv) the biomass of epiphytes per leaf surface (mg DW cm^{-2}); moreover, (v) the number of shoots completely grazed (Fig. 2) was counted and the ratio with the total number of shoots was calculated for each quadrat. Analyses of variance (ANOVAs) were performed on these grazing variables to test for possible differences between I_0 and other sea urchins density (I_8 I_{20} I_{40} I_{80}, separately) and to evaluate if the grazing effects varied in time (September '05 *vs.* May '06). The artefact effect due to the cage was tested comparing C *vs.* I_8, that was the density closer to the natural one. The comparison between I_0 and PC, to test for possible effects of the manipulation, was carried out only for the first experiment (September 2005). Cochran's test was performed to test for homogeneity of variances and data were transformed when necessary. Post hoc comparisons, by mean of the Student-Newman-Keuls test (SNK), were carried out in case of significant differences in the ANOVA.

***Fig. 2: Shoot completely grazed by* P. lividus.**

Results

P. oceanica density resulted to be 258 ± 9.4 shoots m^{-2} (mean ± standard error). No significant difference, comparing either I_0 *vs.* PC and C *vs.* I_8, was evident for each of the considered variables (Tab. 1). Also, epiphyte biomass per leaf surface and number of leaves per shoot did not change either between densities or between times. On the contrary, the analyses of variance showed significant differences, in the number of shoots completely grazed, starting from the density of 20 ind. m^{-2}; any significant difference was pointed out between September and May.

Sea urchins effect on the green leaf tissue was evident only for 80 ind. m^{-2}, while for the brown part of the leaves the threshold was lower with significant differences starting from the density of 20 ind. m^{-2}; the length of brown tissue varied also between times, with values significantly higher in September than in May. With reference to the Coefficient A, all the densities varied significantly from the control for both sampling times with higher values in May.

Discussion

The contrasts C *vs.* I_8 and PC *vs.* I_0 pointed out that neither the presence of cages nor the operator disturbance had significant effects on all the considered variables. The variable that better describes the effect of *P. lividus* on *P. oceanica* is the number of shoots completely grazed. As expected, the grazing effect is amplified according to increasing sea urchin densities, with the higher value due to 80 ind. m^{-2}; this density, in one month, is able to reduce beyond 45% the initial number of shoots.

Overall, the results highlighted that the density beyond which the effects of grazing are evident, should range between 9 and 20 ind. m^{-2}.

Tab. 1: Mean values (± standard error; n = 3 for the number of shoots completely grazed and n = 9 for all other variables) of the six variables for each treatment and times. Treatments significantly different from the control (C) are represented in bold: * p < 0.05; ** p <0.01; *** p<0.001.

Time	Treatment	Shoots completely grazed (%)	Number of leaves	Green tissue (cm leaf $^{-1}$)	Brown tissue (cm leaf $^{-1}$)	Epiphytes (mg DW cm^{-2})	CoA due to *P. lividus*
September	I_0	0.74 ± 0.37	5.78 ± 0.57	29.56 ± 6.00	13.59 ± 2.72	0.32 ± 0.06	0.00 ± 0.00
	CP	0.34 ± 0.34	5.44 ± 0.47	26.32 ± 2.57	16.91 ± 2.17	0.21 ± 0.03	0.00 ± 0.00
	C	-	5.33 ± 0.53	24.75 ± 2.51	15.2 ± 3.23	0.46 ± 0.05	0.19 ± 0.03
	I_8	2.85 ± 2.85	5.67 ± 0.44	25.79 ± 1.71	16.61 ± 2.29	0.36 ± 0.02	**0.29 ± 0.04 ***
	I_{20}	**10.54 ± 2.68 ***	5.56 ± 0.34	28.06 ± 3.91	**9.24 ± 2.94 ***	0.29 ± 0.02	**0.23 ± 0.04 ****
	I_{40}	**15.68 ± 2.65 ****	5.33 ± 0.41	21.37 ± 2.36	**4.31 ± 1.80 ***	0.25 ± 0.03	**0.45 ± 0.05 ***
	I_{80}	**31.71 ± 3.72 ***	4.67 ± 0.58	**14.04 ± 2.03**	**1.73 ± 1.07 ***	0.27 ± 0.06	**0.50 ± 0.08 ***
May '06	I_0	2.86 ± 1.58	5.33 ± 0.33	41.63 ± 4.24	3.60 ± 1.37	0.21 ± 0.03	0.16 ± 0.05
	C	4.73 ± 1.04	5.22 ± 0.32	37.16 ± 3.48	2.20 ± 0.74	0.32 ± 0.03	0.44 ± 0.06
	I_8	10.03 ± 1.84	5.78 ± 0.28	43.76 ± 1.91	1.45 ± 0.54	0.31 ± 0.04	**0.62 ± 0.04 ***
	I_{20}	**15.78 ± 0.87 ***	4.33 ± 0.47	28.93 ± 5.15	**0.94 ± 0.52 ***	0.30 ± 0.04	**0.82 ± 0.06 ****
	I_{40}	**19.96 ± 2.54 ****	4.78 ± 0.43	27.13 ± 4.18	**0.10 ± 0.10 ***	0.22 ± 0.03	**0.85 ± 0.07 ***
	I_{80}	**45.41 ± 5.32 ***	5.00 ± 0.44	**24.10 ± 2.32**	**0.00 ± 0.00 ***	0.17 ± 0.02	**0.91 ± 0.06 ***

Tomas *et al.* (2005a) did not record any difference in the number of shoots due to the sea urchin inclusion; however, their experimental densities were 5 and 15 ind. m^{-2}, lower than the critical one (20 ind. m^{-2}) we found to have an effect on *P. oceanica*; on the other hand 15 ind. m^{-2} are commonly detected on nearby meadows (S. Coppa, personal observation) without any evident detrimental effect perceived.

For the Mediterranean, a complete lost of shoots due to *P. lividus* grazing is seldom reported, because most of literature documents mainly on sea urchin activity at the leaf scale. Nevertheless, other studies dealing with different latitudes, showed that other sea urchin species, in particular conditions can influence meadows density. For example, Maciá (2000) showed that *Litechinus variegatus* (10-20 ind. m^{-2}) had a significant effect on shoot density of *Thalassia testudinum* along the Florida coasts. Moreover, this author found that sea urchins affected meadow density according to season: in summer sea urchin activity was lower than winter (the critical threshold correspond to 20 and 10 ind. m^{-2}, respectively). In contrast, the present results did not show any significant differences on the number of grazed shoots between September 2005 and May 2006, even if more temporal replicates would be necessary to demonstrate a seasonal grazing pattern.

With reference to the length of green tissue, higher values were found in May 2006, but this effect is probably imputable to the leaf cycle (Mazzella *et al.*, 1986) rather than the grazing activity of sea urchins. Sea urchin influence is evident only at the higher density, indicating that *P. oceanica* does not seem to be particularly attractive, as suggested by McMillan *et al.* (1980) and Verges *et al.* (2006). On the contrary, the brown tissue was more extended in September, also in this case in relation to its seasonal variations rather than the sea urchin grazing (Mazzella *et al.*, 1986). Moreover, the grazing on this tissue portion was already evident for density of 20 ind. m^{-2}; hence, brown tissue is more affected by grazing than the green one, probably in relation to the higher colonization rate of epiphytes as observed by Nédelec and Verlaque (1984), Alcoverro *et al.* (1997) and Tomas *et al.* (2005a).

Data on the bites of *P. lividus* on tips of the leaves (Coefficient A) indicated that grazing effect was already evident at natural density. The coefficient A showed also that grazing was significant higher in May, thus suggesting a more remarkable activity of sea urchins during the spring.

A central role, in the interaction grazers-seagrasses, can be largely ascribed to epiphytes as both green and brown tissues covered by epiphytes are preferred (Boudouresque and Verlaque, 2007 and references therein). Keuskamp (2004) found that the grazers mostly affect the filamentous algae. Alcoverro *et al.* (1997) demonstrated that grazing is one of the factors that contribute to the temporal variability of the epiphyte biomass and that herbivores can be determinant in defining local differences between meadows. Tomas *et al.* (2005a) pointed out a clear effect of sea urchin density on epiphyte abundance and suggested epiphytes as the most limiting resource for sea urchins in *P. oceanica* systems. Our findings did not indicate any significant difference in the epiphyte biomass, calculated per surface unit, due to different sea urchin densities. This suggests that, even if *P. lividus* grazing on epiphytes affects the highly colonised leaf portions (Alcoverro *et al.*, 1997; Boudouresque and Verlaque, 2007), it does not occur independently to leaves consumption.

It is noteworthy that completely grazed shoots were found also within the non-caged plots, characterized by natural sea urchins density and within I_0, probably due to sea urchin grazing before cage installation. This should indicate that, also in natural conditions, *P. lividus* uses two grazing modalities: a complete grazing of the shoot, probably starting from the base of the leaves or, alternatively, the choice of the more palatable portions of the leaves. This hypothesis seems to be confirmed by the absence of effects on the number of leaves per shoot in all treatments.

In conclusion, although the short duration of the experiment could have missed the detection of some grazing effects, especially at lower urchin densities, this research highlighted the importance of assessing the number of shoots grazed in a *P. oceanica* meadow to quantify grazing activity of sea urchins, which would be otherwise underestimated if research focus would be limited to leaf level.

Acknowledgments

This work was carried out with financial support from the MIUR (project STM – nr. 20 Cluster Acquacoltura) and the EU (project EMPAFISH – SSP8-006539). The authors wish to thank Simone Simeone, Andrea Satta, G. Andrea de Lucia, Ettore Lutzu and Enrico Stara for field and logistic assistance. We also thank Giuseppe Di Carlo for improving the English text and an anonymous reviewer for his useful criticism on the manuscript.

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Yasser GENEID, Fekry MOURAD
Marine Ecology Sector, National Institute of Oceanography and Fisheries, EGYPT
yasogin@yahoo.co.uk

LEVELS OF TRACE-METALS IN THE SEAGRASSES OF LAKE BARDAWIL (EASTERN MEDITERRANEAN, EGYPT)

Abstract

*The seasonal variation of lead, zinc, copper and cadmium in the seagrass species (*Ruppia cirrhosa *and* Cymodocea nodosa*) collected from Lake Bardawil (north Sinai, eastern Mediterranean, Egypt) was calculated. The plant materials were collected from four stations representing almost all the lake, which is consederd as one of the most cleanest water mass in the region. In* Ruppia cirrhosa*, the concentration of zinc, cadmium and lead showed a maximum readings in summer, while copper showed a maximum value in Autumn.* Cymodocea nodosa *showed also some variation with seasons; zinc, copper, and lead had their maximum readings in winter, while cadmium was maximum in spring. The mean concentrations of trace-metals in both species at Bardawil lagoon show lower or similar values than those recorded for the same metals measured in seagrasses from other low polluted localities around the Mediterranean Sea.*

Key-words: Seagrasses, Trace-metals, Seasonal variations, Lake Bardawil, Mediterranean Sea, Egypt.

Introduction

Lake Bardawil is a natural depression of the eastern Mediterranean Sea. It harbors large meadows of the seagrass species *Ruppia cirrhosa* and *Cymodocea nodosa* (Geneid and El-Hady, 2006).

The lagoon is an important fishing area for many marine fish and crustacean species mostly of high economic values (sea breams, sea bass, sole fish and shrimps) that use the seagrass beds as nursery and feeding grounds.

The area presents a certain amount of interest, as it is considered as one of the cleanest water masses in the region. Human impact on the Bardawil Lagoon is minimal due to the unexploited surrounding area (Varty *et al.*, 1990); in addition, there is no influence of fresh water from the Nile River or drainage waste water as in the case of other lakes on the Egyptian Mediterranean coast (e.g.: lake Manzala). However, the fishing activities in the lake, mainly the fishing boats used in the shallow lagoon are mostly out-boarding gasoline engines, which may perform some pollution on the pure nature of the Bardawil lagoon.

Seagrasses may serve as heavy metal reservoirs (Nienhuis, 1986; Ward, 1987; Malea, 1994), seagrass leaves play an important role in the cycling of metals, and are probably the main source of metals for seagrass consumers (Ward, 1987; 1989). In addition, seagrasses may be used as indicator organisms for metal contamination and bioavailability (Nienhuis, 1986; Ward, 1987; Tiller *et al.*, 1989). The seasonal variation of metal concentrations in seagrass species from the Mediterranean has been investigated by only a small number of researchers (Malea and Haritonidis, 1989; 1996; Schlacher-Hoenlinger and Schlacher, 1998; Pergent and Pergent-Martini, 1999).

Cymodocea nodosa is one of the most abundant seagrass species along the Mediterranean coasts. This seagraas species was recently recorded and observed to grow in small scattered but dense populations in the middle part of the lake near its opening to the Mediterranean Sea (Geneid and El-Hady, 2006).

The metals measured for the study were selected because Pb and Cd are generally characterized as toxic elements, whereas Zn and Cu are toxic only at high levels (Malea, 1994).

The aim of this study was to investigate the seasonal variation of two essential (Cu and Zn) and two non essential (Pb and Cd) elements and to compare these concentrations with other readings from other parts of the Mediterranean coasts.

Materials and Methods

Study area, seagrass sampling and trace-metal determination:

Lake Bardawil is a shallow hyper-saline lagoon, located along the northern shore of the Sinai Peninsula between longitudes 32^0 $40^{'}$ and 33^0 30' E and latitudes 31^0 03' and 31^0 14' N**.** The lagoon, which is a natural depression, is separated from the Mediterranean Sea by a long, 300-1000 m wide, arrow-shaped sand bar. It has been described as a wetland of major international importance since it is a major bottleneck for migrant water birds passing through the Eastern Mediterranean region where wetlands are scarce (Meinnger and Atta, 1990). Three openings (Boughaz) connect the lagoon to the sea. Two of these are man-made (the western Boughaz I and the Middle Eastern Boughaz II), while the third one is natural (eastern Boughaz III at the Zaranik protectorate). The main water supply of the lagoon comes from the Mediterranean Sea, and flows constantly through these three openings (Ibrahim *et al.*, 1987) (Fig.1).

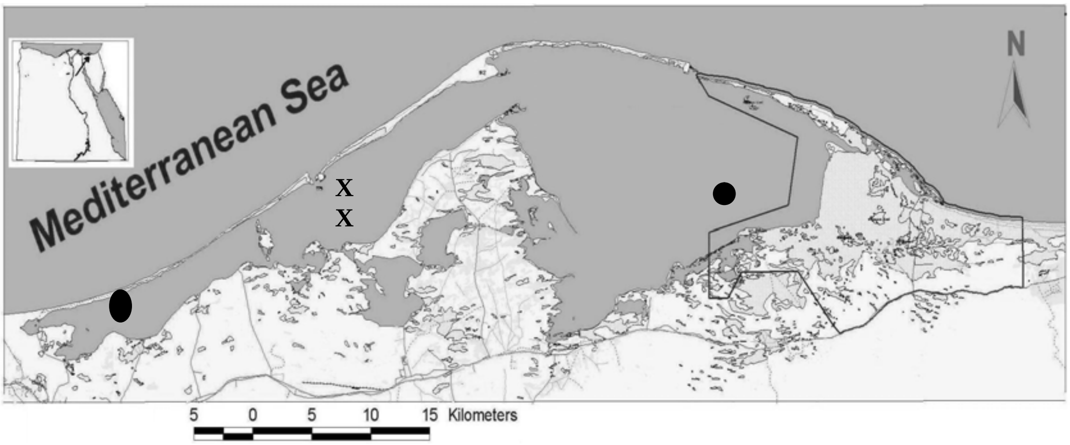

Fig. 1: Map of Lake Bardawil showing the sampling sites (where X shows locations of* Cymodocea nodosa *and* ● *shows locations of* Ruppia cirrhosa*).

From spring 2003 to winter 2004, random samplings of seagrasses were carried out seasonally (April, July, October, 2003 and January 2004) from four sites representing mostly all parts of the lake area.

The lake is very shallow (from 0.5 to 2 m deep), and thus skin diving (snorkeling) was used to collect the plant materials. At each site, a 25x25 cm metal quadrate was used in the collection of plants (both above and underground parts). Five quadrates were sampled from each locality. The seagrass plants were wiped, washed in running water to remove sediments and epiphytes. The plants were air-dried, and then oven dried at 60°C to a constant weight. The dried materials were grounded and homogenized in a porcelain mortar. Random sub samples of homogenates plant materials of each seagrass species were weighted, transferred into glass vials and treated with the method of wet digestion, using mixture of concentrated nitric acid and perchloric acid (AR-grade) with the ratio 2:1 respectively. All the vials containing plant materials were placed on a hot plate and heated till complete digestion. Digested samples were transferred to clean glass vials (25 ml), diluted with deionized distilled water (DDW) to 10 ml, labeled, sealed and stored at room temperature in a dark place till concentration measurements. The concentrations of the elements: Lead (Pb), Copper (Cu), Cadmium (Cd) and Zinc (Zn) were determined by using AAS (Atomic absorption spectrophotometer) in an air- acetylene flame (Perkin – Elmer 2380).

Data statistical Analyses:

Statistical analyses (analyses of variance, ANOVA) were conducted to detect the difference in metal concentrations between the two species. While the statistical tests (Pearson rank correlation coefficient) were performed to detect the similarity between the measured metals using the software SPSS (11.5).

Results

The two seagrass species were collected from four sites in Lake Bardawil. *Ruppia cirrhosa* were found in the eastern and western sides of the lagoon, while *Cymodocea nodosa* (a new species recorded in the lagoon) were found near the opening (Boughaz) connect the lagoon to the sea. The trace-metals (Zn, Cu, Cd and Pb) were measured in the whole plant of the two seagrasses seasonally. Table 1 shows the mean values and standard deviation of the measured metals in *Cymodocea nodosa* .

Tab. 1: Mean concentration and standard deviation of trace-metals measured in* Cymodocea nodosa *(N= number of samples).

Metal	Mean	Std. Deviation	N
Zn	24.16	6.57	24
Cu	6.28	2.03	24
Cd	.66	.45	24
Pb	2.33	1.61	24

The inter-metal correlations between the measured metals are shown in table 2. There is a positively significant correlation between the concentration of Cu and Pb in *Cymodocea nodosa,* while there is a negative correlation between Cd -Cu and Cd-Pb.

Tab. 2: Correlations between metals concentrations measured in* Cymodocea nodosa (*Number of samples: 24).

Metal	Zn	Cu	Cd	Pb
Zn Pearson Correlation	1	.170	.036	.160
Cu Pearson Correlation	.170	1	-.298	.486(**)
Cd Pearson Correlation	.036	-.298	1	-.267
Pb Pearson Correlation	.160	.486(**)	-.267	1

Figure 2 shows the seasonal variation of the measured heavy metals in *Cymodocea nodosa*. The data from each season were summed and the mean was calculated to show the pattern of variation of the metal concentration over the sampling time. It is clear that zinc, copper and lead concentrations in the tissues of the plant are maximum in winter, while the minimum is recorded in Autmn for Zn and Pb, while Cu shows its minimum in Summer. Differntly cadmium concentration was maximum in Spring, and minimum in Summer.

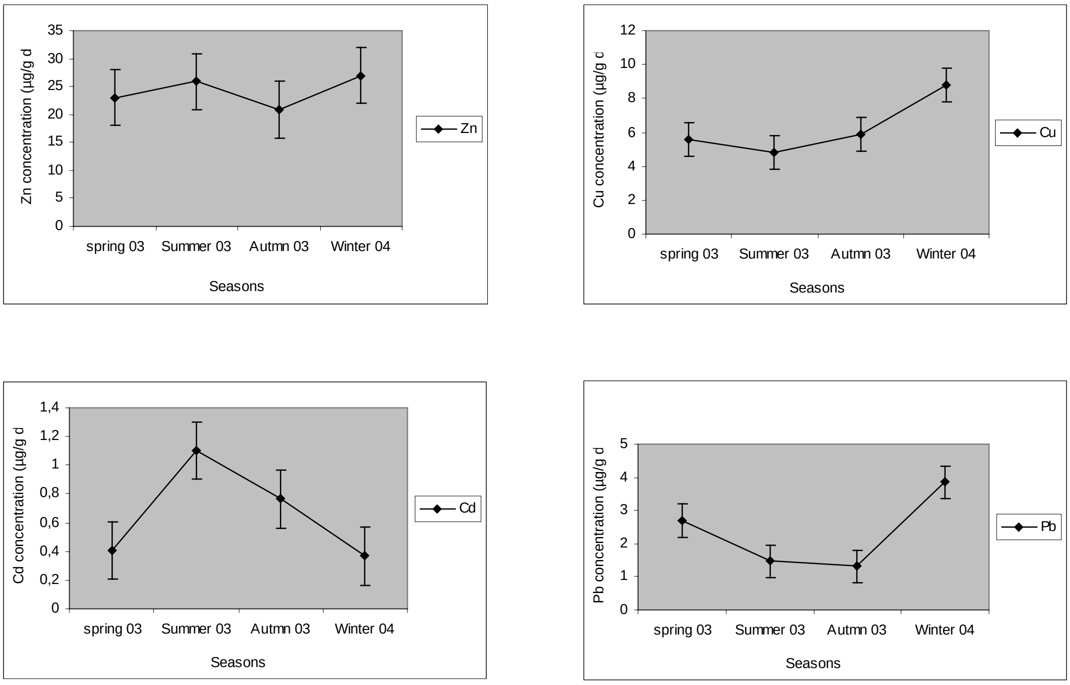

Fig. 2: Seasonal variations of Zn, Cu, Cd and Pb (µg/g dry weight) in* Cymodocea nodosa. *Bars represent the standard error.

The mean concentrations of the measured trace-metals in *Ruppia cirrhosa* didn't differ from those measured in *Cymodocea nodosa.* Only Zn and Cu concentrations were slightly higher than those of *Cymodocea nodosa*, (Tab. 3).

Tab. 3: Mean and standard deviation of different heavy metals measured in* Ruppia cirrhosa. *N= number of samples.

Metal	Mean	Std. Deviation	N
Zn	31.81	15.74	24
Cu	7.94	4.53	24
Cd	.70	.41	24
Pb	2.33	1.39	24

The inter-metal correlation of those measured in *Ruppia cirrhosa* does not exhibit significant correlation in between them (Tab. 4). There was a negative correlation between the concentration of Cd and Pb.

Tab. 4: Correlations between metals concentrations measured in* Ruppia cirrhosa. *Number of samples : 24.

Metal	Zn	Cu	Cd	Pb
Zn Pearson Correlation	1	.152	.254	.371
Cu Pearson Correlation	.152	1	.220	.165
Cd Pearson Correlation	.254	.220	1	-.184
Pb Pearson Correlation	.371	.165	-.184	1

The seasonal variations of metals concentration are illustrated in Fig.3. Zinc concentration in the tissues of *Ruppia cirrhosa* shows its lower reading in summer, while the maximum value is detected in winter. In the same pattern, copper has its minmum concentration in summer, while the maximum was is in Autmn. Lead has a maximum concentration in winter, while the lowest reading is recorded in spring. Cadmium shows an opposite trend than the other metals in its seasonal concentration (high mean value in summer and minimum in spring).

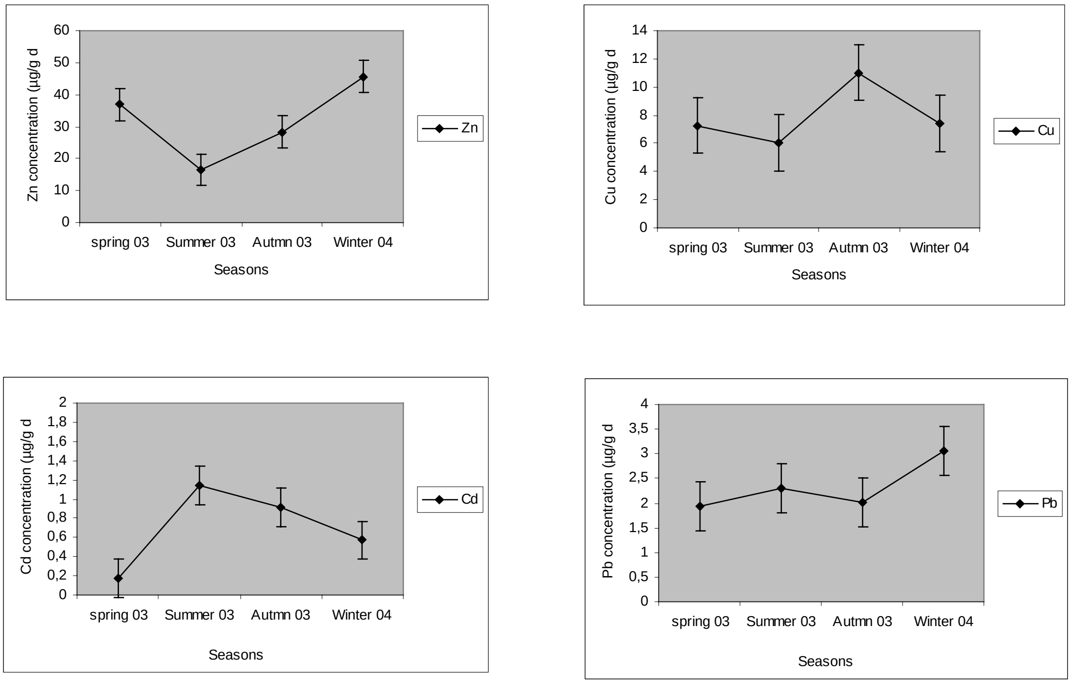

Fig. 3: Seasonal variations of Zn, Cu, Cd and Pb (µg/g dry weight) in* Ruppia cirrhosa. *Bars represent the standard error.

Results of one-way ANOVAs revealed that the mean concentrations of the four studied metals (Zn, Cu, Cd, and Pb) did not show any significant differences between the two species (Tab. 5).

Tab. 5: Results of one way ANOVAs comparing the levels of metals measured in the two studied seagrass species.

Metal	Mean concentrations		F	P value
	Cymodocea nodosa	*Ruppia cirrhosa*		
Zn	24.16	31.81	1.441	.275
Cu	6.28	7.94	1.452	.274
Cd	.66	.70	43.870	.887
Pb	2.33	2.33	.000	.996

It is very clear from table 6 that the trace-metals (Zn, Cu, Cd and Pb) mean concentration in seagrass species collected from Lake Bardawil exhibit lower values than those recorded from other localities around the Mediterranean.

Tab. 6: Comparison of trace-metals mean concentration in seagrass species belonging to the subfamily Cymodoceoideae (**Cymodocea nodosa** ***and*** **Posidonia oceanica*****) from different Mediterranean localities.***

Metals Locality	**Concentrations (µg g^{1} dry wt)**			
	Zinc	Copper	Cadmium	Lead
1) Lake Bardawil, Egypt *(Cymodocea nodosa)*	**24.16**	**6.28**	**0.66**	**2.33**
2) Cote d' Azur, France *(Posidonia oceanica)*	57	22.5	0.7	17.9
3) Marseille, France *(Posidonia oceanica)*	179	12.1	2.4	7.8
4) Isle of Corsica, France *(Posidonia oceanica)*	111	8.6	2.3	6.0
5) Isle of Ischia, Italy *(Posidonia oceanica)*	144	16.2	3.6	4.2
6) Alacaut, Spain *(Posidonia oceanica)*	125	-	1.8	2.0
7) Antikyra Gulf, Greece *(Cymodocea nodosa)*	31.8	16.1	18.8	50.9

1) the present study
2) Romeo *et al.*, (1995)
3) Warnau *et al.*, (1995)
4) Romeo *et al.*, (1995)
5) Schlacher-Hoenlinger and Schlacher, (1998)
6) Sanchiz *et al.*, (1990)
7) Malea and Haritonidis, (1995)

Discussion

The concentrations of Zn, Cu, Cd and Pb were measured seasonally from the seagrasses in Bardawil Lake *Cymodocea nodosa* and *Ruppia cirrhosa*. The variability of metal concentrations in plant tissues can be due to several factors; differences in environmental factors (salinity, pH, temperature, light intensity), metal concentration in the marine environment. It can also be due to different metal uptake in genetically different populations of the species, interspecific differences. Biological conditions may also influence the bioavailability of trace-metals. Moreover, variations of these factors, together with variation in trace-metal load, may influence the seasonal variation patterns (Lyngby and Brix, 1982). The pattern of trace-metals variation with seasons in the species studied in Bardawil lagoon agrees with other reviews dealing with the same subject (Malea and Haritonidis, 1989; 1995). A maximum concentration of Cu and Pb was recorded in winter and lowest in summer and autumn for the seagrass *Cymodocea nodosa*, which is probably associated with the growth dynamics of the plant. It grows most rapidly during April-May and lowest in October through March (Caye and Meinesz, 1985). Maximum Cu and Pb concentrations when biomass was at a minimum, and a distinct decline during the period of maximum growth, were also recorded in other submerged angiosperms (Lyngby and Brix, 1982; Ward, 1987; Malea and Haritonidis, 1989). One other reason for the elevated metal concentrations in winter was given by Schlacher-Hoenlinger and Schlacher (1998), where winter storms act as an important structuring force on the seagrass system, significantly altering grain size distribution of the sediment. During the summer months, the sediment consists mostly of fine sand. When the winter storms set in, it increases rates of sediment resuspension which may lead to higher remobilization rates, and thus possibly bioavailability of metals from the sediment. According to Malea and Harittonidis, 1995, *C. nodosa* mainly absorb Cu, Cd and Pb from the sediment or the interstitial water, which could explain the maximum concentration of these metals in winter. Types of seasonal variations patterns can also be determined by interactions between metals. Concentrations of certain metals in both studied seagrass species display a significant positive or negative correlation, possibly due either to the synergistic or antagonistic interaction with plant tissues (Malea and Hariatonidis, 1995). During this study, it was shown that Cd had antagonistic interaction with Pb for both species and with Cu for *C. nodosa.* The concentrations of these metals showed negative correlations.

The comparison of metal concentrations in seagrass species from different areas around the Mediterranean Sea reveled that the mean levels of all the measured metals in the seagrasses of Lake Bardawil were lower than the other low polluted areas (for example: Island of Corsica, France, Schlacher-Hoenlinger and Schlacher, 1998).

Finally, results of this study indicate clearly that Lake Bardawil still enjoys its pure nature as one of the cleanest water mass in the region, and the seagrass species located in the lagoon could be considered as a background and reference for heavy metals levels to other areas in the Mediterranean Sea.

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Sylvie GOBERT*, Denis VANGELUWE, Jean-Marie BOUQUEGNEAU, M. EISINGER, M. PASTER, H. SCHUMAKER, Gilles LEPOINT
* Oceanology, University of Liège, B6C. Allée de la Chimie Sart Tilman B4000 Liège, BELGIUM

TRANSPLANTATION EFFECTS ON *POSIDONIA OCEANICA* (L.) DELILE

Abstract

A transplantation experiment of the seagrass P oceanica *was launched in September 2001. Biometric parameters were recorded underwater and on samples collected on the transplanted grids. In the best case, the rate of shoot multiplication is 1.4 after 27 months, which could allow reaching the natural shoot density observed in the healthy meadow after 5 years of transplantation. Growth direction shifts from a vertical growth to an horizontal growth. Roots biomass and length increases spectacularly, but leaf length and weight remain clearly inferior to those of reference plant. This implies that root development is of high priority for the plant and that the transplants do not have a sufficient amount of nutrient to ensure adequate leaf growth.* P. oceanica *cuttings, even if they develop a high biomass of roots, continue to be affected by sand patch geo-chemistry a long time after their transplantation on the un-vegetated substrate. This is probably a major cause of transplantation experiment failure. It appears that* P. oceanica *transplants display generally lower N concentrations in their leaves and rhizomes than reference shoot. Storage function of these organs in winter seem to be not realised which probably diminishes the capacity of the plants to ensure an optimal growth during spring and to resist to nutrient shortage periods (summer and fall). The reason of the low elemental concentrations in transplant is more likely linked to difficulties to incorporate nutrient (i.e. lack of roots) as interstitial data shown that the availability of N and P is higher on the transplanted sand patch than on the reference meadow.*

Key-words: Seagrass, Transplantation, Nitrogen, Mediteranean sea, ^{15}N tracer.

Introduction

Endemic to the Mediterranean Sea, *Posidonia oceanica* (L.) Delile forms widespread meadows which exert crucial roles in the coastal waters. Despite their ecological and economical importance, since the sixties, an increasing number of papers show their ongoing loss or regression in all countries. The decline in seagrass meadows and associated communities of plants and animals coverage is generally attributed to anthropic activities (Cambridge *et al.,* 1986; Short and Wyllie-Echeverria, 1996). In the damaged areas, healthy meadows have been replaced with deserts of dead matte, sand or mud.

The natural recolonisation of altered sites is rare but does occur (i. e. Pergent-Martini and Pasqualini, 2000). The recolonizing ability is poor and the process is slow because *Posidonia* are long living species with a low grow and a low occurrence of flowering and success (Boudouresque *et al.*, 1984; Marbà and Duarte, 1998; Marbà and Walker, 1999). Some mechanical *Posidonia* sp transplantations have been conducted with some success and diverse techniques of *P. oceanica* transplantation have been described (Meinesz *et al.*, 1992; Molenaar and Meinesz, 1992; Molenar *et al.*, 1993; Paling *et al.*, 2001). The success of the transplantation varies greatly (Fonseca *et al.*, 1998; Boudouresque *et al.*, 2006) and the processes which influence the performance of the used methodology are generally not discussed.

In this paper, we resume the results of experimental transplantations conducted to put in evidence the factors (biometry, survivorship and multiplication rate of shoots, N dynamics, sediment parameters) influencing the survival of the transplanted *P. oceanica* cuttings (Lepoint *et al.*, 2004; Vangeluwe *et al.*, 2004; Gobert *et al.*, 2005).

Material and method

1. Experimental work was done in the Revellata Bay in front of the oceanographic station STARESO (Calvi, Western Corsica, France) from September 2001 to December 2003 on a sandy patch at 17m depth surrounded by a *P. oceanica* meadow. The transplantation experiment was performed using naturally uprooted shoots (cutting) in order to minimise the impact of transplant collection. These cuttings were collected between 5 and 15 m depth. Shoots with orthotropic rhizomes (maximum 10 cm) were attached on grids ($1m^2$) with 50 or 100 orthotropic shoots.
2. In November 2001, on each cutting, initial maximum leaf length, number of leaves per shoot, rhizome length, length and number of roots were measured before the transplantation. These parameters and the multiplication rates of transplants were also measured, *in situ*, in March, June, September 2002 and in March, June, December 2003. Leaf growth was measured using a modified Zieman technique (Zieman *et al.*, 1974). Furthermore, five shoots were sampled on a reference site in the healthy meadow; biometric parameters were recorded. Leaves, scales, roots and rhizomes were lyophilised for 48 h and weighed to obtain biomass data and for isotopic or elemental measurements.
3. Interstitial pore water was repeatedly sampled in sediment of each grid, on the un-colonised sand patch and in the healthy meadow. Nutrient concentrations (i.e. ammonium, nitrates and phosphates) were measured using an analytical automated chain (Skalar, Netherlands). Results are expressed in µM.
4. In September 2001, to understand Nitrogen dynamic, one hundred cuttings were kept in an aquarium and labelled during two days with a ^{15}N labelled ammonium sulphate solution (Eurisotop, France), were attached on a one square meter grid at 17m depth. Five shoots were regularly sampled (September and November 2001; March, June and September 2002). Isotopic and elemental measurements were performed in lyophilised *P.oceanica* organs with an Optima mass spectrometer coupled to a C-N-S elemental analyser.

Results

After 27 months, the number of cutting decreases (Fig.1, left) to about 20 transplants for the grids with the lowest density (i.e. 35% of the initial number). The grids with 100 transplants show a greater success with about 75 remaining transplants. The loss rate of transplants seems generally more important during fall and winter.

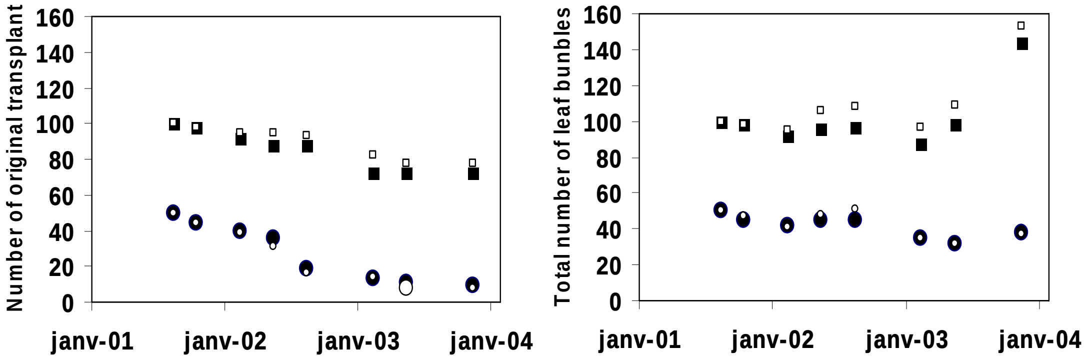

Fig. 1: Temporal evolution of the transplant number (left) and of the leaf number of leaf bundles (right) during the* P.oceanica *transplantation experiment using an initial density of 50 transplant.m^{-2} (black and open circles) and 100 transplant.m^{-2} (black and open square).

After 27 months, the transplants which had originally a vertical growth have change to an horizontal growth. The leaf weight per leaf bundle (Fig.2, left) of transplanted shoots is minimal in December 2003 and maximal in September 2001. It is always lower than that of reference shoots. Both the weights of reference and transplanted shoots show a seasonal variation with a weight increasing in spring and a weight decreasing in fall.

The leaf growth per leaf bundle (Fig.2, right) is minimal in September 2002 for the transplants and the reference shoots. Leaf growth is maximal in June 2003 for the references, but does not show a clear maximum for transplants. Transplant growth is generally lower than that of reference shoots.

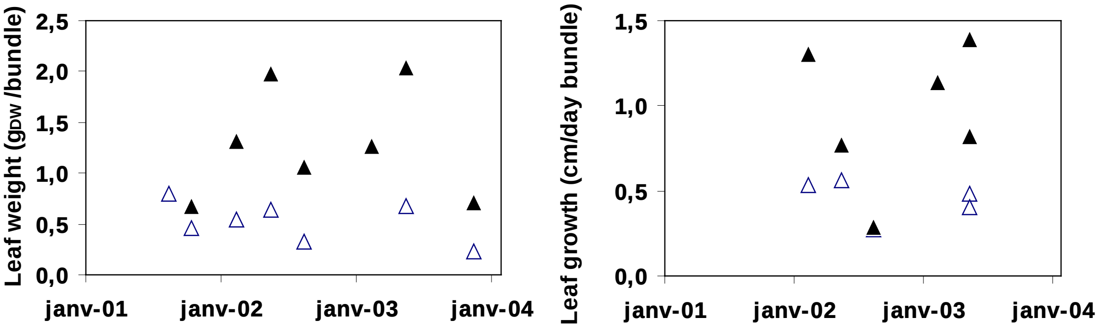

Fig. 2: Temporal evolution of the leaf weight per leaf bundle (left) and of the leaf growth per leaf bundle (right) during the* P. oceanica *transplantation experiment (black triangle = reference site; open triangle: transplanted shoots).

The leaf biomass of transplant represents only 10 to 20 % of the total biomass (Fig. 3) of the transplants. The relative contribution of roots to the total transplant weight increases during this study (from 5% in September 2001 to more than 20% in December 2003). On the contrary, the relative contributions of rhizomes and leaves tend to decrease.

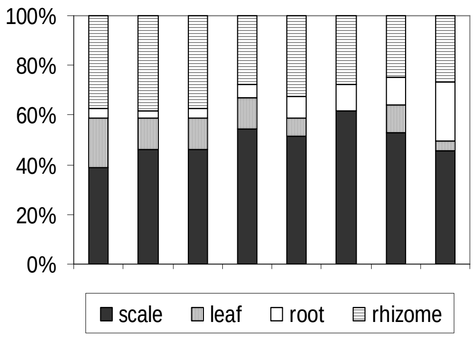

Fig. 3: Temporal evolution (September 2001 to December 2003) of the relative contribution of leaf, root, scale and rhizome to the total transplant weight during a* P. oceanica *transplantation experiment.

Ammonium concentrations in interstitial pore water ranged from 2 to 50µM and were particularly high both on the transplantation grids and the reference sandy patch. The interstitial pore water sampled in the healthy meadow had lower ammonium concentrations than on the sandy patch. Phosphates concentrations ranged from 0.2 to 2µM and were not different in the 4 investigated sites (Fig. 4). Nitrates concentrations varied from 0 to 0.8µM (Fig. 4). They were generally lower on the transplantation grids than in the healthy meadow or in the reference site on the sandy patch.

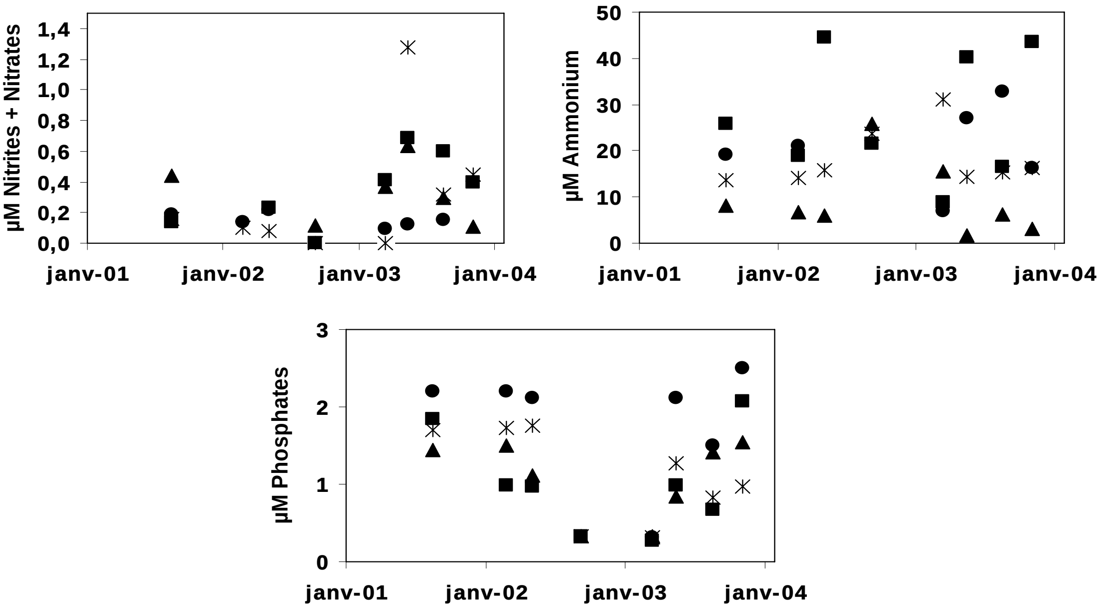

Fig. 4: Ammonium, phosphates and nitrates concentrations (µM) in the interstitial pore water sampled on 100 (asterisk) and 50 (black circle) transplantation grids, in the healthy meadow (black triangle) and in a reference point on the sandy patch (black square). Each point corresponds to five measurements (Standard deviations are not shown for the clarity of the figures).

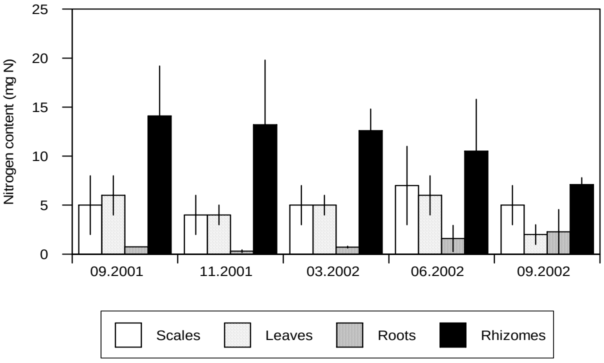

Fig. 5: Temporal evolution of mean values of nitrogen contents in scales, leaves and rhizomes of* P.oceanica *cuttings (September 2001 to September 2002) (Lepoint* et al.*, 2004).

Nitrogen contents in reference and transplanted shoots (mg N shoots^{-1}) of change with time but do not show the same temporal trends. N concentrations of transplant leaves are lower than those of reference leaves data not show). N contents of rhizomes represent between 40 to 50% of the total nitrogen content of the transplant (Fig. 5) constituting the most important stock in the plant and tends to decrease with time. Leaf and root contents are of the same importance but tend to increase in roots with time.

All organs were enriched in ^{15}N (Fig. 6) compared to natural abundance which remains measurable in all organs after one year. The leaves are significantly more enriched in ^{15}N than scales, the roots, the rhizomes and the ^{15}N abundance decrease from November to March sampling, staying quite stable in the following ones. On the contrary, roots ^{15}N contents tend to icrease from September 2001 to September 2002. The ^{15}N contents of rhizomes and scales do not show a significant temporal variation. In September 2002, the 15N contents of rhizomes are the most important stock of ^{15}N in the plant.

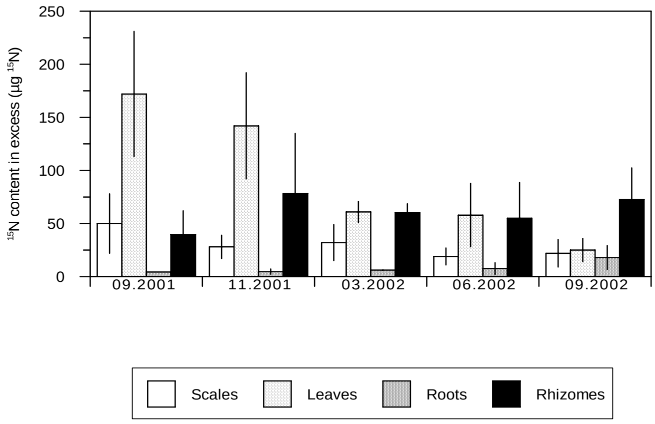

Fig. 6: Temporal evolution of mean values of nitrogen contents in scales, leaves and rhizomes of* P.oceanica *cuttings (September 2001 to September 2002) (Lepoint* et al.*, 2004).

Discussion

The transplanted shoots show strong morphological changes after few months. The growth direction changes from a vertical growth to an horizontal growth. This growth direction is a characteristic of colonising shoots. This change is accompanied by a multiplication of the number of leaf bundle. On the grids supporting an initial density of 100 transplants, the number of leaf bundle is multiplied by 1.4 in 27 months, although 20% of the initial transplant died (or disappeared) during this period. Although these encouraging results, it must be noted that the natural density of the *Posidonia* meadow at 17m depth is about 300 shoot.m^{-2}. Considering a multiplication rate of 1.4y^{-1} (i.e. a rate which is reached the second year of this experiment), this means that the density measured in the natural meadow could be reached after 4-5 years on these grids. This hypothesis should only be correct if the transplant loss decreases with time due to the development of roots and anchoring of shoots.

The initial number of transplant decreases regularly and slowly on the 100 transplant grids. We have identified three major causes for this decrease: firstly a transplant death due to an initial bad health status of natural *Posidonia* cuttings. This death occurs during the first months of transplantation. Secondly, the links used to attach the shoots on the grids got rotten after about one year. Many shoots do not have sufficient roots to anchor themselves in the sediment. Thirdly, because of the lack of roots, the shoots are not able to meet their nutrient requirement which could be also a major cause of death for the transplanted shoots.

The leaf weight and the leaf growth per leaf bundle of transplants are always lower than those of reference shoots. This is partly due to a change in growth orientation and the morphology of transplants, *i.e.* the progressive transition from a vertical (orthotropic) to an horizontal orientation (plagiotropic) which is the colonising form of *P. oceanica* (Meinesz *et al.*, 1993). Plagiotropic shoots generally have a lower leaf weight than orthotropic shoots (Caye, 1980). But this indicates also that the growth conditions are not optimal for the transplants. Leaf growth is minimal in late summer, fall and winter. Late summer and fall are characterised by low nutrient concentrations in the surrounding environment which is limiting for leaf growth. This is also a period of active nutrient resorption from senescing tissues and leaf abscission (Lepoint *et al.*, 2002a). Winter and early spring are periods of low growth but are also periods of nutrient storage occur at very high rate

(Lepoint *et al.*, 2002a; 2002b). Late spring is a period of high growth rate when nutrient reserves stored in the leaves and rhizomes are used to produce new leaf biomass.

The relative contributions of *P.oceanica* organs (i.e. leaves, scales roots and rhizomes) to the total transplant weight vary according to the sampling period. Firstly, we observe an increase of the root contribution which is particularly important in the last sampling. In this study, the roots development is quite spectacular for a species qualified of slow growing species. Roots of *P. oceanica* have two functions: to anchor the shoot in the sediment and to incorporate in the shoot the nutrients from the sediment porewater. It appears that the establishment of these two functions is of high priority for the transplant. Rhizomes weight is quite stable. This does not mean that rhizomes do not grew during the transplantation. The transplants have also produced rhizomes during the transplantation. But, in the same time, old rhizome parts often died and got rotten. In some shoots, this was a cause of initial death of the transplant. In summary, the death (and resorption?) of the old part of rhizome is partly compensate by the growth of the new rhizome part.

Pore water in sand patch and transplant grid sediment is clearly enriched in ammonium compared to the healthy meadow. On the contrary, nitrates and phosphates concentrations are not different in the two environment types. This means that sediment bio-geochemistry (i.e. organic matter content, bacteria, …) of the two sites is clearly different (Gobert *et al.*, 2003). Moreover, it appears that the transplantation grids (and the development of *Posidonia* roots) do not affect the measured parameters. This implies that changes of sediment characteristic (and bio-geochemistry) from un-vegetated to vegetated substrate are long term processes. This also implies that transplants could be affected by anoxic sediment process a long time after the transplantation, even if they have developed a relatively high biomass of roots as in this experiment.

Our data show that transplants display lower nitrogen concentrations than reference plants. Nitrogen could be limiting nutrients for natural stands of *P. oceanica* (Alcoverro *et al.*, 1995) although this species has strategies to uptake or recycle nutrients (e.g. Lepoint *et al.*, 2002b) and display strong physiological integration between connected ramets (Marba *et al.*, 2002). In natural stands, limitation by nitrogen could occur mainly in summer when the concentrations of these elements are relatively low in the environment (Alcoverro *et al.*, 1995). The low N concentrations displayed by the transplants indicate that they could be unable to meet their nutrient requirement. In winter and early spring, transplants do not replenish their N reserves which normally occurs in natural stands of *P. oceanica.*. This winter period is very important for *P. oceanica* N budget because it is a period of high nutrient occurrence in the water column and a period of N incorporation (Alcoverro *et al.*, 2000; Lepoint *et al.*, 2002b). The incorporated nitrogen is not immediately integrated to biomass but is stored as free amino acid in leaves and rhizomes. This nitrogen is re-mobilised in spring when the temperature and the light availability increase, making the environmental conditions optimal for *P. oceanica* growth. The transplanted shoots are unable to store nutrient during the winter and spring. The reason of this could be that the N availability in the environment of transplant is lower than in the healthy meadow. However, nutrient concentrations in the water column are the same and pore water of sediment on the sand patch is enriched in N compared healthy meadow (Fig. 6). Therefore, nutrient availability is not the reason of the low N concentrations observed in this study. A second hypothesis is that the transplants are not able to meet their nutrient needs because they have the capacity to uptake these nutrients. Indeed, the N budget of *P. oceanica* is very complex (Lepoint *et al.*, 2002b). In natural stand of *P. oceanica*, leaves and roots participate to nutrient uptake. Leaves incorporate nutrients of the canopy water but also exploit the nutrient outflux from sediment (Gobert *et al.*, 2002) Therefore, *P. oceanica* uses both the water column and the sediment as nutrient sources. But, the transplants were only rooted in the second year of the experiment. Therefore, in one hand, the transplants, in absence of roots, have access only to the water column as a nutrient source and, in another hand, the development of new roots have increased the nutrient needs of the plant. This explains the observed low concentration of N in our samples and, probably, it is one of the possible cause of death (or poor health status) of transplants.

Tracer experiment shows that the plant is unable to replenish its N reserve during winter, contrary to *P. oceanica* in its natural environment and that the cuttings re-allocate a part of N contained in leaves and rhizomes to the roots formation which seem to be a priority of the plant development.

Conclusions

The establishment from an un-vegetated environment of the sedimentary characteristics of *P. oceanica* meadow needs a very long time, even if a high root biomass is developed by *P. oceanica*. This implies that bio-geochemistry of transplant is primarily (and for a long time) determined by initial sedimentary characteristic of the transplantation site. A consequence of this observation is that it is very important to establish the initial sedimentary characteristics of a potential transplantation site to estimate the long term success of *P. oceanica* transplantation. The biometric measurements done on the transplanted shoots indicated that transplants had lower biomass and leaf growth than reference plant. The elemental measurements indicate also that transplants display lower N concentration than those of reference shoots. This compromises the long term survival ship of *P. oceanica* transplants. Therefore, in future studies, the problem of nutrient incorporation capabilities should be addressed in priority. The use of fertiliser is indadequate to increase the transplantation success, on the contrary, attention to root development and use of specific growth hormones should be a good method to increase the success of transplantation. Our simple transplantation design used allows the recovery of a natural *P. oceanica* density in about 5 years. Nevertheless, this method implies the presence of extensive donor meadows at proximity of transplantation site. In addition, this recovery does not mean that the natural complexity and the high bio-diversity associated to *Posidonia* ecosystem is recovered in the same way.

Acknowledgements

This study was funded by the CEE (EVK3C-T2000-00033) and the FNRS (Belgium) (FRFC 2.4570.97). We wish to thank the staff of STARESO.

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Actes du 3ème Symposium méditerranéen sur la végétation marine (Marseille, 27-29 mars 2007)

Judith KLEIN, Marc VERLAQUE
Centre d'Océanologie de Marseille–Université de le Méditerranée, Parc Scientifique et Technologique de Luminy, case 901, 13288 Marseille cedex 9, FRANCE, E-mail: judith.klein@univmed.fr

CAULERPA RACEMOSA EFFECT ON MACROPHYTE ASSEMBLAGES OF DEAD *POSIDONIA* BEDS

Abstract

The French part of the Mediterranean Sea represents the northern distribution limit of the invasive Caulerpa racemosa *var.* cylindracea. *In the Bay of Marseilles (France, NW Mediterranean),* C. racemosa *grows mainly on dead* Posidonia oceanica *beds between 10 and 40 m depth. The present study investigated the impact of* C. racemosa *invasion on Mediterranean macrophyte assemblages. Two sites, both situated on dead* Posidonia *beds at 17 m depth, were compared. One site was invaded by* C. racemosa *(Invaded) and the other one un-invaded (Control). The study revealed that* C. racemosa *significantly reduced species richness and abundance of macrophytes (*C. racemosa *excluded). Moreover, an increase in total macrophyte cover (including* C. racemosa*) was observed in the Invaded site compared to the Control due to the seasonal development of* C. racemosa*. A shift in the seasonality of the other macrophytes occurred in the presence of* C. racemosa *with a single peak in summer followed by an abrupt drop corresponding to the winter regression of* C. racemosa.

Key-words: Species introductions, Invasion, *Caulerpa racemosa*, France, Mediterranean Sea.

Introduction

The Mediterranean Sea is one of the world's hotspots of marine species introductions. Four to five percent of the Mediterranean flora and fauna are introduced, in total more than 400 species (Boudouresque & Verlaque, 2005).

Caulerpa racemosa var. *cylindracea* (Sonder) Verlaque, Huisman & Boudouresque (Caulerpales, Chlorophyta), introduced from south-western Australia, is spreading in the Mediterranean Sea (Piazzi *et al.*, 2005). In the Bay of Marseilles, this invasive species covers large areas of dead *Posidonia oceanica* (L.) Delile beds between 10 m and 40 m depth. To a lesser degree it colonizes rock, sandy substrates and detritic assemblages and it has been observed in tide pools (S. Ruitton personal comm.). To date, no study has been carried out investigating the impact of *C. racemosa* on macrophyte assemblages in the French part of the Mediterranean Sea, one of the northern range limits of the species. The purpose of the present study was to assess the qualitative and quantitative impact of *C. racemosa* on Mediterranean macrophyte assemblages growing on dead *P. oceanica* beds in the Bay of Marseilles.

Material and methods

The study was carried out in the Bay of Marseilles (France) in the north-western Mediterranean Sea (Fig. 1). Macrophyte assemblages on dead *P. oceanica* beds were studied at 17 m depth. Two sites, one invaded by *C. racemosa* (Invaded) and the other un-invaded (Control), were compared from June 2002 to June 2003.

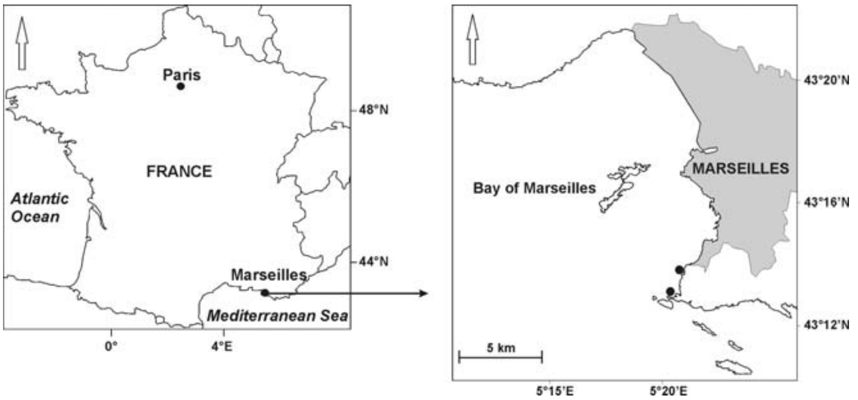

Fig. 1: Map of the study site. Dots indicate the study site. Upper dot: Invaded site; lower dot: Control site.

Five 20 cm x 20 cm quadrates were seasonally sampled at each site by Scuba diving. Samples were preserved in 4 % formaldehyde-seawater until analysis. In the laboratory an exhaustive species list was drawn up using a binocular and a light microscope. For taxonomic purposes the database “algaebase” (Guiry M.D. and Guiry G.M., 2006) was used. Introduced macrophytes were identified according to the checklists of Boudouresque and Verlaque (2002) and Wallentinus (2002). Each species was isolated and its abundance was estimated as the cover of the sampling quadrate. Differences in species numbers and cover were tested by the Student-Newman-Keuls test after a 1-way ANOVA and a test of the homogeneity of variances (Bartlett’s test).
C. racemosa biomass data were obtained from the article by Ruitton *et al.*, 2005.

Results

Caulerpa racemosa shows a seasonal development with highest biomass and 100 % cover in September 2002 and a minimum in April 2003 with zero biomass (Fig. 2). In 2003, a delay in re-growth of *C. racemosa* was observed.

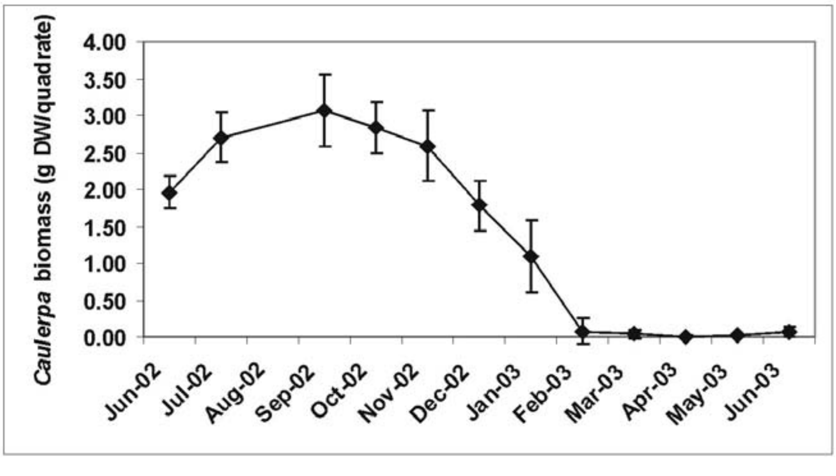

Fig. 2: **C. racemosa** ***biomass (g dry weight per quadrate) from June 2002 to June 2003 in the Invaded site.***

In the Invaded site, macrophyte cover without *C. racemosa* (in cm² per quadrate) was usually lower than in the Control site (Fig. 3), differences were significant, except for December 2002 and June 2003.

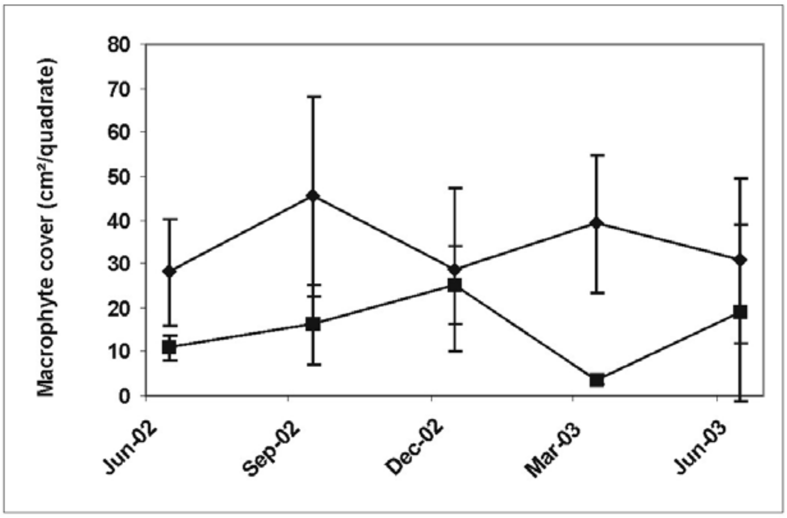

Fig. 3: Macrophyte cover (m ± SD) without* C. racemosa *in the Control and the Invaded site from June 2002 to June 2003. ● = Control; ■ = Invaded.

When *C. racemosa* was included, total macrophyte cover was considerably higher at the Invaded site than in the Control site with 100 % cover during late summer and autumn (September to December) and smaller during the winter and spring months (March to June).

Overall 194 macrophyte taxa were identified: 38 Chlorophyta, 31 Ochrophyta and 125 Rhodophyta. Besides *Caulerpa racemosa* var. *cylindracea*, six other introduced species were identified, the following four of them being potentially invasive: *Acrothamnion preissii* (Sonder) E.M.Wollaston, *Antithamnion amphigeneum* A.J.K. Millar, *Asparagopsis armata* Harvey/*Falkenbergia rufolanosa* (Harvey) F. Schmitz and *Womersleyella setacea* (Hollenberg) R.E. Norris.

The number of macrophyte species was significantly higher at the Control than at the Invaded site throughout the year (Fig. 4).

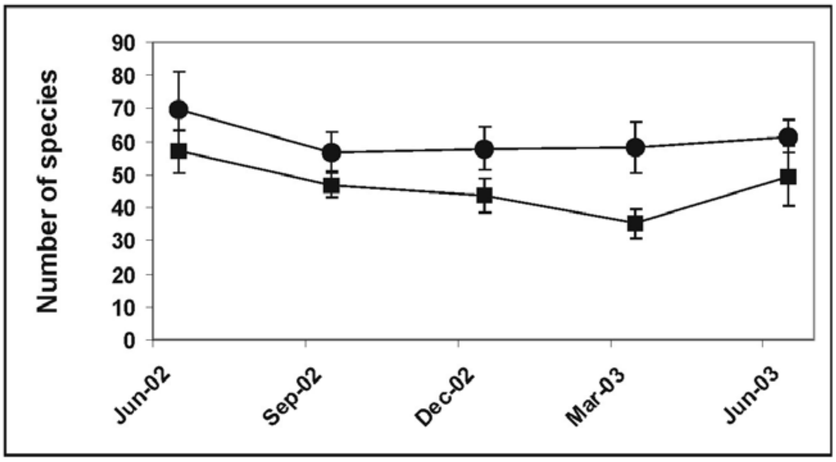

Fig. 4: Number of species (m ± SD) at the Invaded and in the Control site from June 2002 to June 2003. ● = Control; ■ = Invaded.

The number of other introduced species was similar at both sites: Control site (2-4) and Invaded site (2-3). However, their abundance was very low at the Invaded site and high at the Control site, with a maximum in September (Fig. 5). The differences were significant except for June 2002 and June 2003.

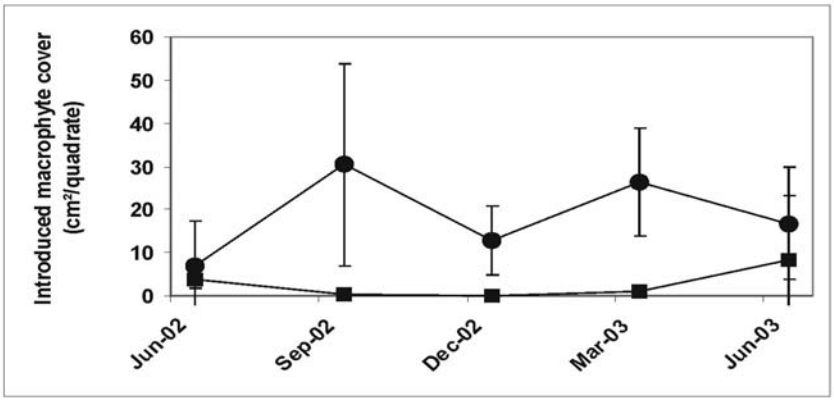

Fig. 5: Introduced macrophyte cover (without* C. racemosa*) (m ± SD) from June 2002 to June 2003. ● = Control; ■ = Invaded.

Discussion and conclusions

In the Bay of Marseilles, the macrophyte assemblages on dead *Posidonia oceanica* beds are dominated by introduced species, especially *Asparagopsis armata, C. racemosa* and *Womersleyella setacea*. *C. racemosa*, which is by far the most abundant, reduced other macrophyte cover and species number. Total macrophyte cover (including *C. racemosa*) was seasonally increased in the Invaded site compared to the Control. This high cover contrasting with the low cover typically observed on dead *Posidonia* beds was due to the development of a continuous *C. racemosa* meadow. Furthermore the cover of other introduced species was reduced, indicating that *Caulerpa racemosa* var. *cylindracea* is competitively superior.

In the macrophyte assemblages of dead *P. oceanica* beds, *C. racemosa* generated a change in the vegetation structure leading to a shift from species growing on rhizomes to a nearly exclusive epiphytic assemblage on *C. racemosa*.

Secondly, in the Bay of Marseilles the seasonal pattern of the vegetation had changed. At the Control site, the macrophyte cover did not show a marked seasonal cycle. On the other hand, at the Invaded site, macrophyte cover (without *C. racemosa*) followed a uni-modal seasonal cycle parallel to the development of *C. racemosa* with a maximum in autumn and a minimum in winter when *C. racemosa* regressed.

Acknowledgements

The authors would like to thank Dr. Sandrine Ruitton, Roland Graille and Frederic Zuberer for field work assistance and Michael Paul for reviewing the English text.

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Jamel KSOURI, Fethi MENSI, Karima SAHLI-HAZAMI, Imen CHALLOUGUI
Institut National des Sciences et Technologies de la Mer, 29 rue Général Khéreddine 2015 Le Kram, TUNISIE.
e-mail : Jamel.ksouri@instm.rnrt.tn

ETUDE SYNOPTIQUE SUR LES CULTURES EXPERIMENTALES DE *GRACILARIA VERRUCOSA* EN TUNISIE

Résumé

Les cultures de Gracilaria verrucosa *ont été réalisées à une échelle expérimentale dans le lac de Bizerte (nord-est de la Tunisie) où l'espèce n'est présente d'une façon notable qu'au niveau de la zone nord-est du lac. Elles ont porté sur la sélection du mode de culture le plus approprié aux conditions du site (boudins de sable), sur l'ajustement des paramètres techniques (poids initial des touffes de 200 g, écartement entre les touffes de 30 cm et distance entre les rangées de 50 cm) et biologiques (évaluation des potentialités de régénération de l'espèce : une seule récolte par an) de culture. Le croisement de ces données a permis une nette amélioration du rendement de culture. En effet, au terme de 46 jours, la culture optimisée entreprise à une densité initiale de 1,4 kg/m² a engendré un accroissement du poids des touffes de 200 à 1280 g, un taux de croissance spécifique de 4,03 %/j et une densité finale de 9,1 kg/m², soit 91 tonnes fraîche/ha.*

Mots-clés : *Gracilaria verrucosa*, Culture, Régénération, Optimisation.

Introduction

Avec une production de 37 000 t en 2001, le genre Gracilaria se présente, à l'échelle mondiale, comme le principal agarophyte (Mc Hugh, 2003). L'ensemencement est réalisé essentiellement à partir de boutures mais peut se faire à partir des éléments reproducteurs (Perez, 1997). Le genre *Gracilaria*, très largement distribué dans le monde, compte prés de 160 espèces caractérisées par la diversité de leurs habitats (Santelices et Doty, 1989).

En Tunisie, les travaux de recherche relatifs à la culture de l'espèce *Gracilaria verrucosa* ont été effectués dans le lac de Bizerte pour sélectionner le mode de culture le plus approprié, ajuster certains paramètres bio-techniques de cette technique, évaluer la capacité de régénération de l'espèce et effectuer une culture optimisée (Ksouri *et al.*, 2005). Le présent travail est un synopsis des principaux résultats obtenus à partir de 1999.

Matériel et méthodes

- Période et zone de culture : les cultures ont été initiées de Mars à Juin au niveau de la zone nord-est du lac à une profondeur moyenne de 1 m.
- Sélection du mode de culture : quatre modes ont été testés : corde tendue décollée du fond, corde tendue sur le substrat, technique des boudins de sable et technique de la bêche.
- Optimisation des conditions de culture : cette optimisation a concerné la distance entre les touffes (30 - 50 - 70 cm), le poids initial des boutures (150 - 200 g) et le potentiel de régénération de *Gracilaria*. Pour l'évaluation de la capacité de régénération, 5 cordes (C1, C2, C3, C4, C5) ont été mises en place. Nous avons suivi, mensuellement par corde et par touffe, les poids et les poids cumulés (Tab. 1); le poids cumulé étant la somme du poids obtenu pour un mois déterminé et des poids enregistrés au cours des coupes précédentes.

Tab. 1 : Suivi des poids et des poids cumulés des touffes de Gracilaria engendrés par les coupes au cours des mois de culture.

Corde	Poids (P) et poids cumulés (PC)	Février	Mars	Avril	Mai	Nombre de coupes
C1	P	a_1	a_2	a_3	a_4	4
	PC		$a_1 + a_2$	$a_1 + a_2 + a_3$	$a_1 + a_2 + a_3 + a_4$	
C2	P		b_1	b_2	b_3	3
	PC			$b_1 + b_2$	$b_1 + b_2 + b_3$	
C3	P			c_1	c_2	2
	PC				$c_1 + c_2$	
C4	P				d_1	1
	PC					

Remarque : le test statistique de comparaison des moyennes portera sur les 10 valeurs des poids (P) et des poids cumulés (PC) engendrés par les coupes successives et qui sont les suivants : a_1, $a_1 + a_2$, $a_1 + a_2 + a_3$, $a_1 + a_2 + a_3 + a_4$, b_1, $b_1 + b_2$, $b_1 + b_2 + b_3$, c_1, $c_1 + c_2$ et d_1

- Culture optimisée : pour le mode de culture adopté, nous avons tenu compte des résultats obtenus à l'INSTM (Ksouri *et al.*, 1999; 2000) et opté comme Sahli-Hazami (2004) pour l'utilisation d'un cordage lesté (Fig. 1).

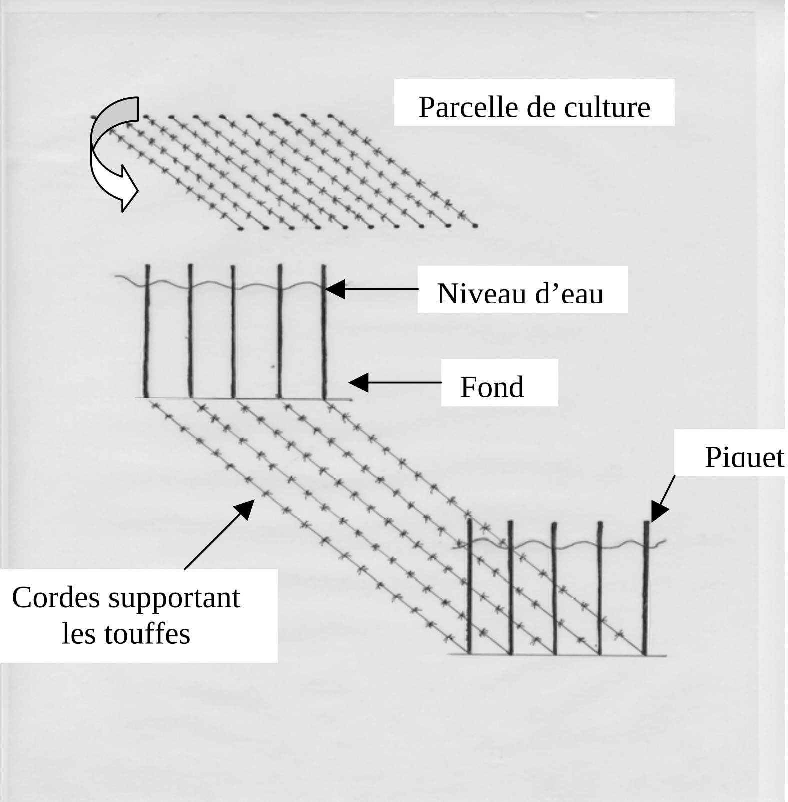

Fig. 1 : Dispositif expérimental de la culture de Gracilaria.

- Expression des résultats : à partir des échantillonnages pratiqués en cours de culture, les paramètres suivants ont été calculés aussi bien pour les périodes intermédiaires qu'en fin de culture: le poids final moyen (g), la densité finale (kg /m²) et le taux de croissance spécifique (TCS).
TCS = 100Ln(Poids final /Poids initial)/Nombre de jours de culture

- Traitement statistique : l'évaluation de l'effet des coupes successives sur le gain du poids a été effectuée par une analyse statistique des données selon la procédure GLM (General Linear Model - Système Statistica).

Résultats et discussion

- Sélection du mode de culture : la technique dite «du boudin de sable» longiligne s'est avérée la plus efficace puisque au bout de 2 mois elle a abouti à des touffes de 1205 g avec une densité finale de 2,7 kg/m² et un taux de croissance spécifique de 3,09%/j.

- Optimisation des conditions de culture.

- Etude de l'effet de l'écartement entre les touffes de *G.verrucosa* mises en culture sur la croissance de celles-ci : à l'expiration de la troisième étape de culture (90 jours), l'analyse statistique montre qu'il n'y a pas de différence significative entre les différents poids enregistrés; ainsi, à la fin de cette période, le poids moyen est de 1025 g. Le TCS moyen est de 2,13%/j. La densité finale a varié entre 2,05 et 3,74 kg/m². Nous pouvons avancer que la récolte des cultures devrait se faire au cours de la première quinzaine du mois de Juin alors que le poids moyen des touffes atteint des valeurs supérieures à 765 g; ceci est en accord avec les observations de Chaoyuan *et al.* (1993) qui préconise que la récolte de *G.verrucosa* est optimale lorsque les touffes atteignent un poids de 700 à 900 g.

- Etude de l'effet du poids initial des touffes de *G.verrucosa* mises en culture sur la croissance de celles-ci : les meilleurs résultats sont obtenus avec les touffes de 200 g au terme des deux premiers mois de culture, soit un passage d'un poids initial de 200 g à 1118 g, un TCS de 1,24%/j et une densité finale de 1,65 kg/m².

- Culture optimisée : en fin de culture (46 jours de culture), le poids moyen des touffes est passé de 200 g à 1280 g. Le taux de croissance spécifique et la densité finale sont respectivement 4,03 %/j et 9,1 kg/m². Le taux de croissance spécifique et le rendement engendrés par notre culture se situent dans la fourchette des valeurs citées par d'autres auteurs (Tab. 2).

Tab. 2 : Comparaison des résultats du présent travail par rapport à ceux d'autres auteurs.

Pays et modes de culture		**Espèce (*Gacilaria*)**	**TCS %/j**	**Récoltes**	**Auteurs**
Taïwan		*sp.*	5-10	40 t (poids sec)/ha en 150 j récoltes fréquentes	CHIANG (1981) *in* MCLACHLAN et BIRD (1986)
Chili	**Monolignes parallèles**	*sp.*	3,21	Récoltes mensuelles ou bimensuelles	SANTELICES ET DOTY (1989)
	Polyculture/ mer ouverte	*chilensis*	7		TROELL *et al.* (1997)
	Cordes suspendues	*chilensis*		53 - 123 t /ha/an (poids frais)	WESTERMEIER *et al.* (1993)
	Bassins	*verrucosa*	4		KIM (1970)
Chine Radeaux flottants		*sp.*	7-7,5		
Hawaï Cages flottantes (élevage crevette)		*parvispora*	8,8-10,4		NELSON *et al.* (2001)
Hawaï Cages (spores)		*parvispora*	2,64		GLENN *et al.* (1998)
Inde Culture cordes au fond- cages - filets		*edulis*	1,75- 3	4 récoltes par an (45 jours)	KHLADRAN *et al.* (1996)
USA Bassins		*folifera*	7,85		ROSENBERG et RAMUS (1981)
Grande Bretagne Bassins		*verrucosa*	1-2,6		JONES (1959)
Philippines Marais		*verrucosa* *salicornia*	4,29-10,02 1,44-4,95		LARGO et *al.* (1989)
France Bassins		*verrucosa*	7,57-13,55		DESTOMBE (1987)
Tunisie Corde sur le fond		*verrucosa*	4,03	1 seule récolte 91t/ha (poids frais)	Présent travail (2005)

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Mauro LENZI[1*], Enrica FRANCHI[2], Andrea GIOVANI[2], Primo MICARELLI[1], Guido PERRA[2], Rugiada ROFFILLI[2], Duccio SOLARI[1], Silvano FOCARDI[2]
[1] Lagoon Ecology and Aquaculture Laboratory OPL srl, v. G. Leopardi 9, 58015 Orbetello (Gr) ITALY, e-mail: lealab2@hotmail.com
[2] Univ. of Siena, Dep. Environmental Science

CHANGE IN THE PHYTOBENTHOS SETTLEMENT ALONG THE SANTA LIBERATA COAST (SOUTHERN TUSCANY, ITALY)

Abstract

Mixed meadows of Cymodocea nodosa, Nanozostera noltii *and* Caulerpa prolifera *lying behind two* Posidonia oceanica *barrier reefs situated along the S. Liberata coast (Southern Tuscany cost, Italy), showed a sudden rarefaction and regression between 2003 and 2005. Two annual surveys (2005 and 2006) were carried out by scuba divers and aerial photography, to define the new settlement and produce a new maps. Four 25m^2 plots were placed in the two areas lying behind the barrier reefs (LB1, LB2), in which the specific covering and macroalgal biomass were estimated, making a distinction in the latter between* Caulerpa racemosa *and all other species. Porosity, bulk density, organic matter, grain size and PAHs were also determined in the sediment of LB1 and LB2 and off those. A floristic list was drawn. In camparison to the past, LB areas showed the disappearance of some species (*C. nodosa, Caulerpa prolifera, Cystoseira barbata, Halimeda tuna, Sphaerococcus coronopifolius, Rytiphloea tinctoria *and* Alsidium corallinum*), while two species were observed for the first time: the Chlorophyta* Caulerpa racemosa *var.* cilindracea *and* Penicillus capitatus. *These two species, in particular* C. racemosa, *showed a high substratum settlement capability between 2005 and 2006. The relative lack of clay in LB areas, allows us to exclude that the regression of mixed meadows is attributable to the construction of an artificial breakwater relatively nearby using earthy matter. Although PAH concentrations in the sediments ranged from 85.6 to 452.3 ng g^{-1}, indicating a homogeneously moderate to high level of pollution, is unlikely that they can be the cause of the recent, sudden vegetation changes as the harbour canal has been open and had the same amount of boat traffic for over thirty year. Finally the lack of organic matter in the two LB areas, suggests that the regression of the mixed meadows is more likely to be due to the recent increase of tourist impact in this stretch of cost, by mechanical disturbance caused by bather.*

Key-words: *Nanozostera noltii, Caulerpa racemosa, Penicillus capitatus,* Anthropic disturbance, Meadow regression.

Introduction

Various factors can contribute to modify coastal phytobenthonic populations. Over the last decades, it has been possible to correlate such changes to various human activities along the coastline, while introduced exotic species and global warming have also contributed more recently. The increasing anthropic influence along the coastline has brought about changes to the coast in the form of residential settlements, ports, breakwaters, docks, etc. Pleasure boating and consequent anchorage in areas covered by flowered marine plats represent another disturbing factor. All this has undoubtedly affected the shrinking of *Posidonia oceanica* meadows, which are now believed to be decreasing significantly throughout the Mediterranean Sea. Finally, the Mediterranean warming by greenhouse effect (Bradley, 2000) may have already caused changes in the phytobenthos populations and favoured allochthonous species that have mainly been introduced and spread by shipping traffic (Boudouresque and Verlaque 2002). *Posidonia oceanica* (L.) Delile barrier reef are Mediterranean endemic formation of high naturalistic importance. They often bring about a reduction of hydrodynamism in areas behind them near the coast, producing particular characteristics that lead to typical phytobenthos settlements (Molinier and Picard, 1952). In the stretch of coast between Villa Domizia and S. Liberata beach (Tuscany Southern cost, Italy; Fig. 1), 600 m wide, there are two barrier reef formations of *Posidonia* meadow, whose behind-meadow areas were home to mixed meadow, high covering of *Cymodocea nodosa* Ucria, *Nanozostera noltii* (Hornemann) Tomlinson et Posluzny and *Caulerpa prolifera* Forsskål (Lenzi, 1987). Rapid rarefaction and regression of this mixed meadow has been noted in recent years. The regression had intensified and in the Santa Liberata stretch culminated in complete disappearance of meadow, except for some small isolated patches of *N. noltii*, in 2005. Several factors may be responsible for this rapid regression. In the past few years, in fact, it has been noted that the waters in this stretch of coast became unusually cloudy and took on a milky appearance during and for several days after rough seas. This may have been caused by the creation of a breakwater 100m from the Santa Liberata barrier reef (Fig. 1), which was built in 1996-1997 with rocks and earthy matter full of clay. It was the last of a set of four breakwaters created to counter the process of erosion that has affected the coast since the 1970s. The pressure of tourism in this stretch of coast has also increased significantly in recent years, further exacerbated along the Santa Liberata beach by the creation of a camper parking area behind the beach. The aim of this study was to establish the new vegetation structure of the two behind-*Posidonia* meadow areas, produce a floristic list and, as far as possible, to establish the cause of mixed meadow sudden regression.

Materials and methods

The study area lies between Villa Domizia and Santa Liberata beach, respectively on the left and on right sides of the sea-mouth canal of the Orbetello Lagoon and the adjoining harbour-canal (Fig. 1).

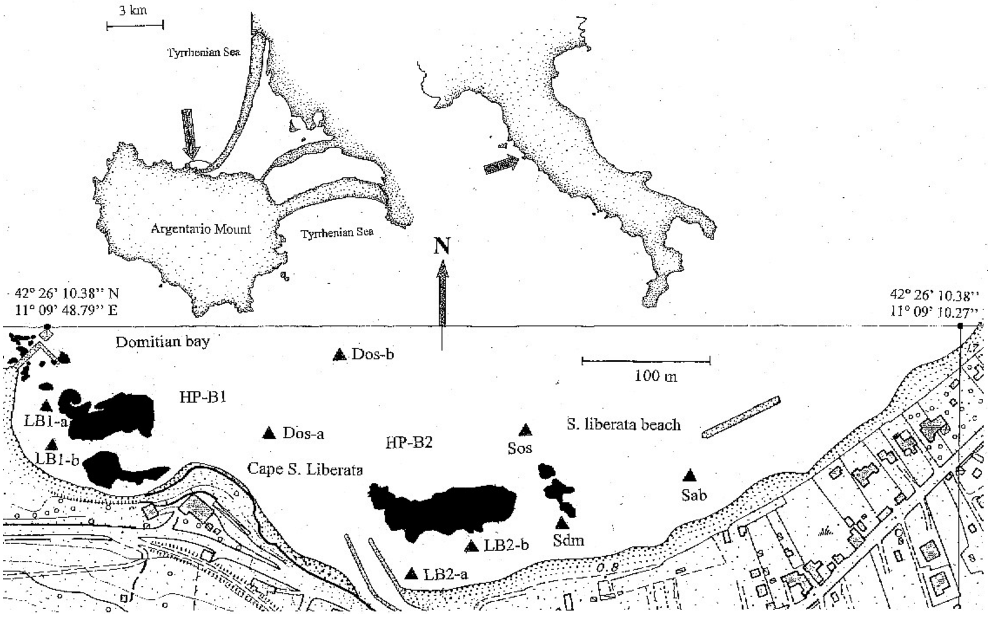

Fig. 1: The study area stretch of Santa Liberata coast (Southern Tuscany). HP-B1 and HP-B2,* Posidonia oceanica *barrier reefs. ▲ sampling stations: LB1-a, LB1-b, LB2-a and LB2-b, stations placed inside the areas lying behind barrier reefs; Dos-a and Dos-b, stations placed off shore in Domitian bay; Sos, station off the HP-B2; Sdm and Sab, stations situated on dead matte on the LB2 border and on the sandy bottom close to the artificial breakwater, respectively.

Two *P. oceanica* barrier-reefs, situated to the left (HP-B1, in Domitian Bay) and to the right (HP-B2, in front of Santa Liberata beach) of the canals, respectively, produce two areas lying behind barrier-reef (LB1 and LB2, respectively) (Fig.1; Lenzi, 1987). Since 2003, an increasing rarefaction and regression of the *C. nodosa – N. noltii –C. prolifera* mixed meadow has been observed by aerial photographiy in the two areas LB1 and LB2. Field research was carried out in the areas LB1 and LB2 between 2005 and 2006. Information collected by aero-photographic surveys over the past twelve years was compared with that collected in the two years study period by ultralight-aircraft (Lenzi and Solari, in press.), in order to locate several homogeneously coloured areas corresponding to different bottom conditions, such as *P. oceanica* meadows, *P. oceanica* dead "matte" with different main vegetation covering, sand inter-matte, "erosion pool" and *C. nodosa-N. noltii-C. prolifera* mixed meadows. These areas were subsequently viewed by scuba divers between August-October 2005 and July-October 2006, in order to determine the actual vegetation assemblages. Nine sampling stations were established between 1m and 5m in depth: two stations were placed inside both the LB1 (LB1-a and LB1-b) and LB2 (LB2-a and LB2-b), two stations were placed offshore from Domitian bay (Dos-a and Dos-b), one station offshore from HP-B2 (Sos), another one on dead matte raised flat of the barrier reef transversal to coastline (Sdm) and the last one on the sandy bottom close to the artificial breakwater (Sab) (Fig. 1). Sediment samples were collected in each station area (three replicates) during 2006, taking away the first 3cm of the sediment surface layer. Where the algal turf was very thick, it was laid bare and the underlying detritus was collected. Samples were stored at –18°C and sediment density (Dsed), porosity (η) and organic matter (OM) were determined afterwards. Measurements of η and Dsed were performed on sediment sub-samples of about 1 cm^3. OM percentages were evaluated as loss on ignition at 400°C for 3 hours. The Sab, Sdm, Sos-a, LB2-b, Dos-a, Dos-b stations were chosen in positions progressively further from the coast and the hypothetical source of pollution, in the form of the earthy matter in the artificial breakwater. Sediment samples were collected in each station area (three replicates) to determine grain size (Shepard, 1954) and polycyclic aromatic hydrocarbon (PAH) (EPA 550 and 3545a). In the stations LB1-a, LB1-b, LB2-a, LB2-b, a 5x5m plot was marked with poles in the four corners and a rope marking the perimeter. During July 2005 and July 2006 samples were taken from these plots to determine the species and vegetal biomass and surveys were carried out to determine the specific covering. In each survey 25 photographs were snapped in each plot of the phytobenthos in a 20x20cm frame, positioning the frame following a fixed scheme. A metric rod was used to maintain the same scheme of frame positioning for the second survey. In each image, the species covering (R_i) was determined by phytosociologic method (Boudouresque, 1971) with the aid of a grid. The average covering for each species (RM_i) was calculated for all plots. 15 samples were collected from a 20x20 cm square (6,000 cm^2 in total) in each plot in July 2005 and July 2006, in order to determine the biomass, taking a different sampling scheme for both the two biomass sampling and vegetal covering surveys. There were many rocks in LB2-a, from which we scraped off the covering of vegetation. Samples were washed to remove impurities and, when possible, each sample was distinguished in two portions, where *Caulerpa racemosa* thalli were isolated from the other macroalgal species. The two macroalgal portions were then oven-dried at 85°C for 24 hours. Sampling stations positions and the main vegetation settlement were geo-referenced (GPS) and transferred to an IGM map. Sediment data and floristic lists were processed by means of PRIMER version 5.0 in order to highlight any similarity among sampling stations. Sediment data were transformed using the arch-tangent function before calculation of the similarity matrix, after which a two-dimensional non-metric multidimensional scaling (MDS) ordination, based on Normalised Euclidean distance, was carried out.

Results and discussion

Tables 1 and 2 show, respectively, the floristic lists with the specific coverage values and the biomass estimates. Although there were no pre-exiting floristic lists for LB1 and LB2 areas studied, Lenzi (1987) describing *P. oceanica* barrier reefs reported besides the phanerogams *C. nodosa* and *N. noltii*, the presence of the macroalgae *Caulerpa prolifera*, *Cystoseira barbata* J. Ag., *Halimeda tuna* Lamour, *Sphaerococcus coronopifolius* (Good.-Woodw.) C. Ag., *Rytiphloea tinctoria* (Clem.) C. Ag. and *Alsidium corallinum* C. Ag. According to Boudouresque (1984), these species belong to the Photophilous-Infralttoral-Thermophilous (PhIT), Photophilous-Infralttoral-Thermophilous-soft bottom (PhISt), Photophilous-Infralttoral-Quiet-environment (PhIQ), Antisciaphilous (AS) and Sciaphilous-Infralittoral-relatively-Quiet-environment (SIQ) ecological groups. The conditions in the LB areas were therefore relatively calm and subject to sensible summer worming. The list produced in this study is also mainly constituted of algal species typical of PhIQ and PhIT and still contains sciophilous elements. In two years of observations, however, none of the species listed by Lenzi (1987), except *N. noltii*, was found. On the contrary, two other species were found that were never before observed along the southern Tuscany coast: *Caulerpa racemosa* var. *cilindracea* (Sonder) Verlaque-Huisman-Boudouresque (Bryopsidales, Chlorophyta), an invasive exotic species, and *Penicillus capitatus* Lamarck (Bryopsidales, Chlorophyta). Both species were observed on the dead matte left by the mixed meadows. *C. racemosa* was widespread with stolons entwined in the low thick algal turfs constituted mainly of *Jania rubens* v. *rubens* (L.) Lamour (Corallinales, Rhodophyta) and *Cladophora prolifera* (Roth) Kutz. (Cladophorales, Chlorophyta), while *P. capitatus* was distributed in isolated patches of a few square metres at most (Fig. 2, Tab. 1).

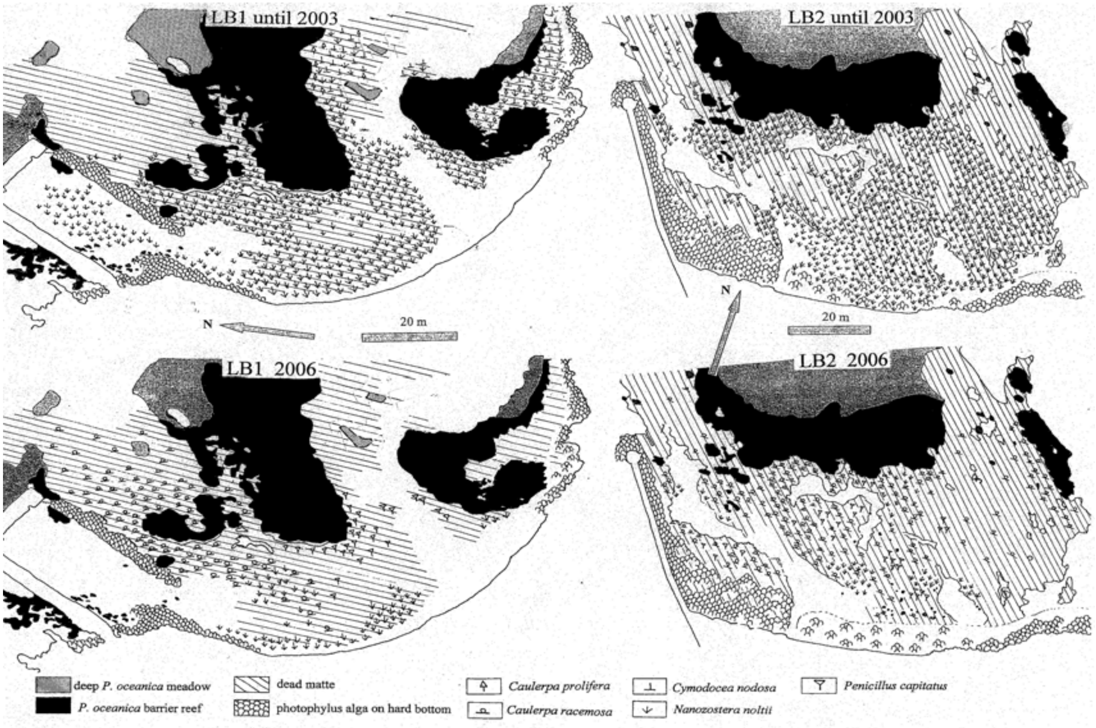

Fig. 2: Phytobenthos settlements in the present (2006) and in the recent past (until 2003) on* P. oceanica *barrier reefs lying behind areas of the Santa Liberata coast (Southern Tuscany). Dead matte without signs of species was covered by photophilic macroalgae.

Tab. 1: List of macrophytes and their covering in the four 25 m2 plots in areas lying behind barrier reefs, in the 2005 and 2006 surveys. + presence; 1 covering ≤5%; 2 covering >5%, ≤25%; 3 covering >25%, ≤50%

	2005				2006			
	LB1-a	LB1-b	LB2-a	LB2-b	LB1-a	LB1-b	LB2-a	LB2-b
Acetabularia acetabulum (L.) Silva				+	+			+
Antithamnion sp.			+					
Caulerpa racemosa var. *cylindracea* (Sonder) Verlaque-Huisman-Boudouresque	1	1	1	1	3	2	2	3
Ceramium sp.			+					
Ceramium codii (H. Richards) Feldmann- Mazoyer	+		+		+		+	+
Chaetomorpha linum (Müll.) Kütz.	+		+				+	
Cladophora albida (Huds.) Kütz.	+				+	+		
Cladophora prolifera (Roth) Kütz.	1	1	1	2	1	1	1	2
Cladophora sp.							+	
Cladostephus spongiosum (Huds.) C. Ag. f. *verticillatus* (Lightf.) Prud'Homme van Reine	+			+	+			+
Dasya rigidula (Kutz.) Ardissone			+		+			
Dictyota dichotoma (Huds.) Lamour.	+	+	+	1	+	+	+	1
Erythrocladia sp.	+							
Erythrotrichia carnea (Dillwyn) J. Agardh			+				+	+
Flabellia petiolata (Turra) Nizamuddin	+	+	+	+	+	+	+	+
Fosliella sp.	+	+	+	+	+	+	+	+
Gracilaria sp.	+		+		+			
Halopteris filicina (Grateloup) Kütz.			+		+		+	
Jania rubens v. *rubens* (L.) Lamour.	3	2	2	3	3	2	2	3
Laurencia obtusa (Huds.) Lamour.	+				+			+
Lomentaria ercegovicii Verlaque-Budouresque-Meinesz-Giraud-Marcot-Coqueugniot			+				+	+
Lophosiphonia sp.			+					
Lynghbya aestuarii	+		+		+		+	+
Lynghbya sp.	+		+		+		+	+
Nanozostera noltii (Hornem.) Tomlinson-Posluzny		2		1		2		1
Padina pavonia (L.) Lamour.	3	1	1	2	3	1	1	2
Penicillus capitatus Lamarck		1	+	1		1	+	2
Polysiphonia sertularioides (Grateloup) J. Agardh							+	
Polysiphonia sp.(I)	+		+		+			
Polysiphonia sp.(II)			+				+	
Rhizoclonium tortuosum (Dillwyn) Kütz.	+		+		+	+	+	
Sphacelaria fusca (Huds.) Gray			+				+	+
Sphacelaria rigidula Kütz.			+				+	+
Spyridia filamentosa (Wulfen) Harvey	+		+		+	+	+	
Stypocaulon scoparium (L.) Kütz.	1		+	+	1		+	
Valonia aegagropila C. Agardh	+		+		+		+	+

Tab. 2: Biomass (gDW m-2) of* Caulerpa racemosa *(C.r.) and other macroalgae (M.) estimates in the 2005 and 2006 surveys in the four 25 m2 plots in areas lying behind barrier reefs.

	C.r. g_{DW} m^{-2}		M. g_{DW} m^{-2}	
	2005	2006	2005	2006
LB1-a	1.08 ± 1.88	74.32 ± 53.21	99.08 ± 70.12	76.79 ± 46.27
LB1-b	1.00 ± 1.00	54.88 ± 36.46	147.50 ± 43.95	344.92 ± 337.32
LB2-a	0.67 ± 1.15	60.39 ± 28.70	240.58 ± 47.30	236.05 ± 104.39
LB2-b	1.00 ± 0.66	58.63 ± 13.56	81.50 ± 55.67	110.86 ± 25.10

Penicillus shape is rare in the Mediterranean Sea and present in only a few areas: it has been observed in Italy on the islands of Elba and Meloria since the 1970s (North Tuscany coasts; Cinelli and Salghetti-Drioli, 1983). *C. racemosa* has been observed on the North Tuscan coast since 1994 (Piazzi *et al.*, 1994).

N. noltii was present in small isolated patches in LB2, while in LB1 the meadow of this species had regressed to two areas: a fringe near the shoreline and a small central meadow (Fig. 2). *C. racemosa* rapidly grew and covered the substrate (Tab. 1, 2). The mean covering (RM) of this species in LB1 e LB2, increased in one year from about 5% to 15-30%; the biomass increased from 0.94±0.18 g_{DW} m^{-2} to 62.05±8.49 g_{DW} m^{-2}. Despite this spread, the other macroalgae (especially *Dictyota dicotoma* (Huds.) Lamour., *Padina pavonica* (L) Lamour. and *P. capitatus*) also increased, from 142.17±71.30 g_{DW} m^{-2} in July 2005 to 192.15±122.72 g_{DW} m^{-2} in July 2006. In one year, in LB1 and LB2 plots, *C. racemosa* biomass increased by 6100% and 6800%, respectively, while all the other macroalgae increased by 71% and 49% (Tab. 2). We can therefore maintain that, following the recent regression of mixed meadows from the substrate, these two areas were ready for fresh colonisation, which is occurring rapidly according to spreading times peculiar of each species. MDS plots distribution concerning the floristic lists showed a great distance of LB1-b from the other plots, likely due to a relatively *N. noltii* high covering and a lower presence of species. MDS distribution of all stations, concerning sediment condition, brought to light an enormous difference between the Sdm and Sab stations and all the others, also for the group of stations for which PAHs were calculated. Excluding Sdm and Sab to highlight the similarity among all the other stations, those in LB1 were distant from those in LB2, and all four LB stations were distant from the rest. OM was particularly abundant in Sdm (8%) due to accumulations of *P. oceanica* leaves detritus close to the coastline. LB1, Dos-a and Sos stations had about 4% of OM, while LB2a,b had the lowest value (Fig. 3).

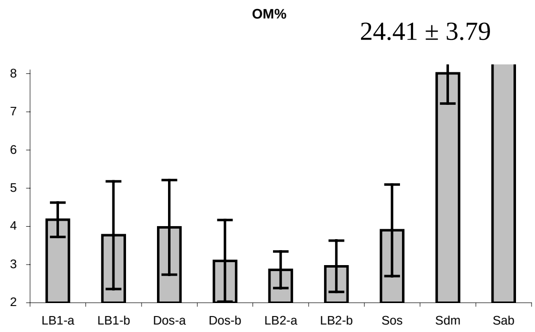

Fig. 3: Distribution of organic matter percentage (OM%) in the sediment of the study area stations.

In Sos, η had the highest values and Dsed the lowest, while in LB stations the Dsed values were amongst the highest and, consequently, those of η were among the lowest. The decline of the mixed *C. nodosa*-*N. noltii*-*C. prolifera* meadow may be mainly caused by the OM reduction in the sediments. This may explain this regression in LB2 in particular, which is the area with the lowest quantities of OM. In fact, these three species establish a system of complementarity in their fixation in the substratum, whose different stratification favours OM and fine sand sedimentation necessary to the settlement structure and produces bottom raising (Meinesz and Simonian, 1983). The stations with the greatest quantities of clay were those furthest from the shore (Dos-a, Dos-b, Sos) (Fig. 4).

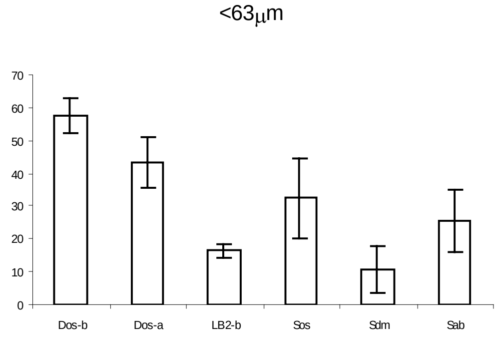

Fig. 4: Distribution of the grain size < 63µm in the study area stations in comparison to an anthropic clay source.

Among the others, Sab, more close to artificial breakwater, had a significant amount of clay (much higher than the LB2 stations), despite being dominated by fine sands (47% of 250 µm) (Fig. 4). Likely, the clay introduced when the breakwater was built was reallocated by the strength of the sea over the years and transported to deeper areas, leaving only relatively small quantities around the source. The areas behind the *P oceanica* barrier reefs didn't seem to have been affected by the phenomenon of transportation, as they have very low quantities of clay (Fig. 4). ΣPAHs values in the sediments ranged from 85.6 to 452.3 ng g^{-1}, increasing near the harbour canal, indicating a homogeneously moderate to high level of pollution (Fig. 5). According to Baumard *et al.* (1998), only LB2-b sediment showed a clear petrogenic origin of PAHs.

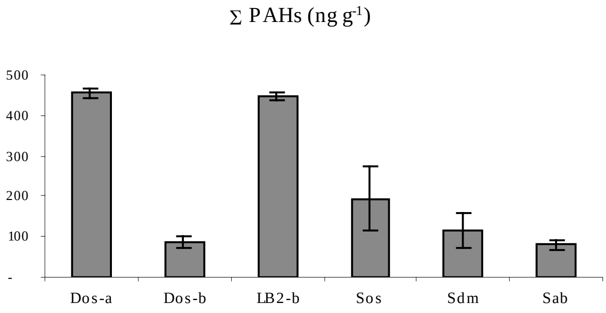

Fig. 5: Total PAH concentration in the sediment of the study area stations.

Conclusions

Although the high ΣPAHs values in LB2-b and in Dos-a, this last station close to LB1 area, it is unlikely that they can be the cause of the recent, sudden changes of the phytobentonic settlement, as the harbour canal has been open and had the same amount of marine traffic for over thirty years. The main cause of the changes in vegetation structure could be the sediment OM decrease, which is very clear in LB2. This decrease coincided with an increase in bathing, which occurred entirely by chance when this particular small stretch of coast became more easily accessible.

The continuous trampling of a greater number of bathers in an already shallow area may have sufficiently disturbed the sediment to bring about a decrease in OM in the area behind the *Posidonia* reef in the space of a few years, by carrying the organic matter produced annually away from the system and using up previous deposits. The edge of LB2 (Sdm) closest to breakwater maintained a more high level of OM than the two inner stations, which may be explained by its relative distance from the bathing zone. Nevertheless, it is not clear because *C. nodosa* and *Caulerpa prolifera* disappeared completely from LB1 and LB2, contrary to *N. noltii*. In fact, these species resulted relatively abundant in deeper area, offshore from the *Posidonia* barrier reefs. The freeing of dead matte consented a restocking by colonising organism, such as *C. racemosa* (arrived in the area recently and certainly subsequently to the regression of the mixed meadows, as it can be deduced from spreading velocity) and *P. capitatus*. The appearance of this last species, which is typical of warm seas and so far confined to a few microenvironments, may be linked to the sea worming. In over 80 years since this species was first observed in the Mediterranean, this is the first time it has been found in this area, despite its vicinity to the island of Elba. Lastly, the high PAH value is alarming and demands further study of both sediments and vegetation tissues the area.

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Cecilia LOPEZ Y ROYO[1,2], Gérard PERGENT[1], Christine PERGENT-MARTINI[3], Gianna CASAZZA[2]
[1]University of Corsica – EqEL, Faculté des Sciences, BP52, 20250 Corte, FRANCE, e-mail: cecilia.lopezyroyo@apat.it
[2]APAT – Agency for Environmental Protection and TS, ITALY
[3] Regional Activity Centre on Specially Protected Areas, Tunis, TUNISIA

MONITORING *POSIDONIA OCEANICA* IN THE MEDITERRANEAN: A DATAWAREHOUSING APPROACH

Abstract

Monitoring is an issue of increasing interest in policies, management strategies and in research on environmental protection and conservation, in particular relatively to biological monitoring and bioindicators. Posidonia oceanica*, commonly accepted as important bioindicator, has been monitored in different regions across the Mediterranean for several years or decades. In order to observe this widespread indicator in a transregional manner, the available data has been collected and stored in a datawarehouse. This* Posidonia oceanica *datawarehouse at the moment contains 578 stations from 18 different regions. A metadata analysis was carried out in order to screen the data and the type of data available, although potential data from a number of regions were not included, at the moment. The characteristics of the monitoring programmes and of the descriptors used have been identified and studied. The analysis highlights a problem of data comparability, due to the different monitoring strategies adopted, the different parameters chosen and the different methods used. Data comparability would be essential not only for a Mediterranean evaluation but also for an effective protection of the seagrass.*

Key-words: Monitoring, *Posidonia oceanica*, Data comparability, Datawarehouse, Metadata.

Introduction

Monitoring is generally defined as a tool used to: be aware of the state of a system, and to observe the situation for any changes which may occur over time or over space. In the environmental context it often refers to measures which indicate the quality or the state of the environment in a specific area at a specific time, and is used to supervise changes, and to be able to identify causes of these changes. Due to an increasingly widespread anthropogenic activity and to the resulting impacts on the environment, the interest in and the use of monitoring for environmental protection purposes has increased exponentially over the last decades. Monitoring, in fact, has become one of the main issues dealt with in legislation, at regional, national, and EU level, as well as a priority for many environmental authorities. Recently biological monitoring and bioindicators, have prevailed over the more traditional chemico-physical monitoring (Vighi *et al*., 2006) and have been adopted or suggested by most of the recent directives and conventions, such as, for aquatic environments, the EU Water Framework Directive (WFD) (Directive 2000/60/EC), the draft "Marine Strategy Directive" (COM 2005/505), certain programmes and protocols of the Barcelona Convention (UNEP, 2005). Indeed, the purpose of the WFD is to protect and enhance the quality of surface waters, with the final objective of obtaining "Good water Status" for all water bodies by 2015. One of the main tools proposed by the Directive towards this aim is monitoring, as defined in article 8 "to establish a coherent and comprehensive overview of water status within each river basin" (Directive 2000/60/EC). This monitoring is based on Biological Quality Elements, as identified in defining the "classification of ecological Status", supported by physicochemical and hydromorphological quality elements.

Seagrass have been described excellent bioindicators (Pergent *et al.*, 1995; Pergent-Martini *et al.*, 2005; Romero *et al.*, in press), due to their high sensitivity to changes in the environment, and specifically to human impacts (Short and Wyllie-Echeverria, 1996). Legal measures for the protection of seagrasses, in general and for some species in particular, are being developed together with legal "technical" requirements for seagrass monitoring, control and analysis (Borum and Greeve, 2004; Boudouresque *et al.*, 2006). The Mediterranean endemic seagrass, *Posidonia oceanica*, has been identified as one of the four biological quality elements of the WFD, used to assess and monitor the ecological status of Mediterranean coastal waters (Casazza *et al.*, in press*)*. It is also an important part of the Action Plan for the Conservation of Marine vegetation in the Mediterranean Sea (RAC/SPA, 2000).

Monitoring of *Posidonia oceanica*, at national and regional level, has been taking place for several years, in particular in the French Riviera where the "Posidonia monitoring Network" was set up in 1984 (Boudouresque *et al.*, 2000) and has, since then, slowly expanded to the rest of the western Mediterranean regions. Due to the influence that all and each coastal region has on the entire Mediterranean coastal ecosystem, it would be interesting to observe and monitor such a widespread bioindicator as *Posidonia oceanica,* in a transnational and transregional manner. The aim of this paper is to identify the different *Posidonia oceanica* monitoring programmes that exist in the Mediterranean, to analyse and compare them, and to identify the difficulties that may arise in drawing a pan-Mediterranean situation.

Materials and Method: a *Posidonia oceanica* monitoring Datawarehouse

The available data and metadata on existing *Posidonia oceanica* monitoring programmes were collected and organised in a datawarehouse, as defined by Inmon (1995): "A warehouse is a subject-oriented, integrated, time-variant and non-volatile collection of data in support of management's decision making process". The software used as Database Management System, is MS Access2000, that allows the creation and management of a relational database. The data is therefore stored in an integrated, relational manner, with a top-down structure, that contains descriptors that range from coastal morphology and pressures to physiological parameters of the plant. The Data present in the datawarehouse have been extracted from publications, grey literature, and reports that are available or have been made available by national or regional administrations, and researchers.

At the moment, the database contains data for 578 stations, from 8 different countries and 18 different regions (Fig. 1). Most of the sites are located in the western part of the Mediterranean basin, in countries such as France, Italy, Malta, Spain, Tunisia and Algeria. Regarding *Posidonia oceanica* in the Eastern Mediterranean (Celebi *et al.*, in press), at the moment, only very little information is publicly available, and as a consequence the datawarehouse contains only a few sites from Greece (3 sites) and from Libya (1 site), as well as two sites on the Ionian coast of Italy. The analysis will thus mainly concentrate on the western Mediterranean basin, although there are some gaps of information in areas in which *Posidonia oceanica* is present, such as the southern regions of Spain (Procaccini *et al.,* 2003), the Balearic Islands (Duarte *et al.,* 2004), and some relevant parts of the Algerian and Tunisian coastline.

Fig. 1: Regions present in the database (only countries and regions present are named).

Results and Discussion: *Posidonia oceanica* monitoring metadata analysis

As previously mentioned the datawarehouse contains data from literature and grey literature, mainly publications, monitoring reports, PhD theses, projects and contracts. The analysis shown here will only consider data that belong to Posidonia monitoring programmes.

a) General Characteristics of the P. oceanica *monitoring programmes*

The following table (Tab. 1), lists the monitoring programmes for which sufficient information was available to compare approaches, and describes general characteristics of each programme.

Tab. 1: Characteristics of the different monitoring programmes.

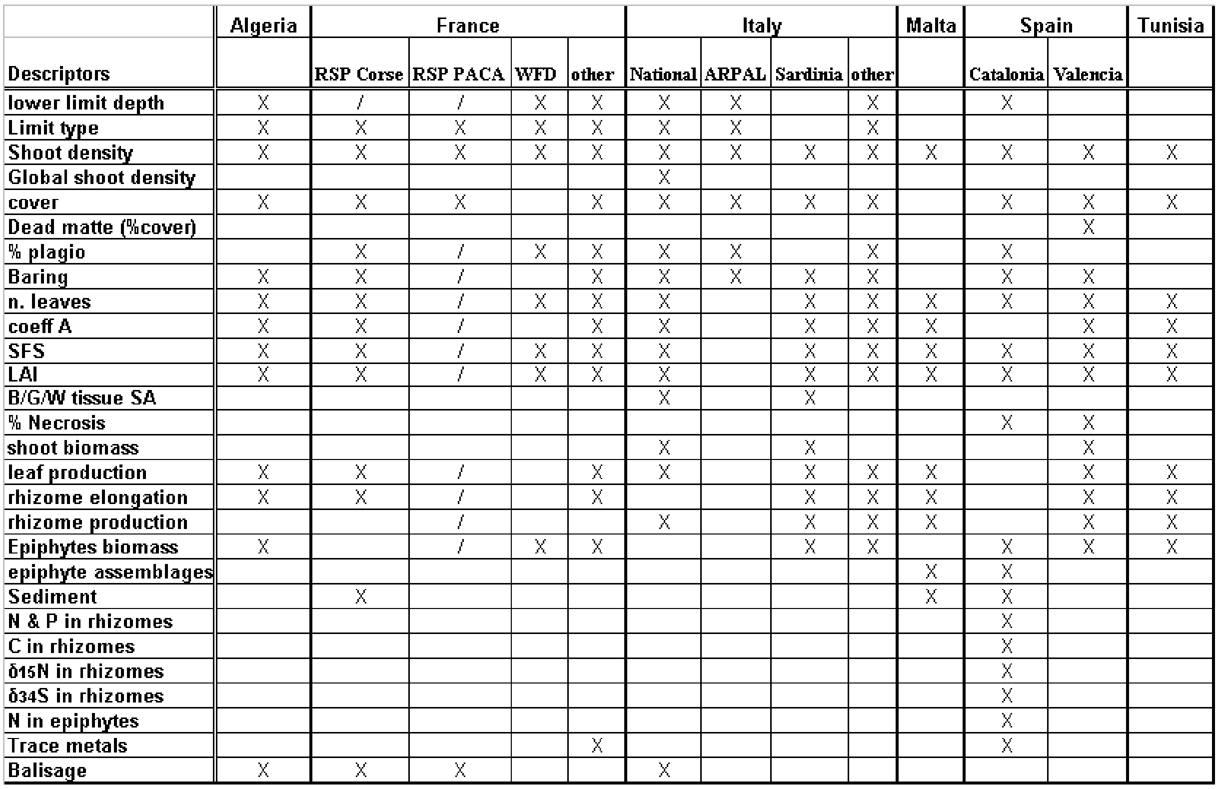
Country	monitoring programme	sampling season	depth of sampling	number of stations	frequency of sampling	Reference
Algeria	El Djamila Monitoring	summer	lower limit (8m)	1	every 3 years	Boumaza & Semroud, 2000
France	RSP Corse	spring - summer	lower limit (24-38m) or upper limit (5-11m)	30	every 3 years	Pergent *et al*, 2005
	RSP PACA	all (not seasonally)	upper limit (2-15m) or Lower limit (14-38m)	33	every 3 years	Cadiou *et al*, 2004
	WFD monitoring	spring	between 4 and 19 m	17	every year	Boissery *et al*, pers.comm.
Italy	National monitoring (Ministry of Environment - MATT)	winter - spring	lower limit (17-37m) or other depths (4-12m)	23	every year	Anonymous, 2001
	ARPAL monitoring	spring - summer	lower limit (15 -28m) and upper limit (3-10m) and central depth (7-19m)	6	once	ARPAL, 2005
	Sardinian coast monitoring	summer	different depths (7-38m)		once	MATT, 2001
Malta	Malta baseline survey	summer	10m	15	once	MEPA, 2002
Spain	Catalan monitoring	summer	between 11 and 18m	27	every year	Romero *et al*, 2005
	Valencia	summer - autumn	between 13 and 22m	17		Ramos Esplà *et al*, 2005
Tunisia	different studies	all	between 1 and 13m		once	Vela, 2006; Sghaier, 2006; Djeloulli Z., 2004;

A preliminary observation is that most monitoring programmes are carried out on a regional basis: characteristics and differences will therefore be tied to a geographical distribution. Characteristics such as season and depth of sampling differ; monitoring in different seasons will create difficulties in data comparability, especially for parameters influenced by seasonal changes. Sampling depth not only differs in depth but also in the type of depth range: the French “Réseaux de Surveillance Posidonies” sample stations on either the lower or the upper limit of the meadow, the Italian national Monitoring samples stations on the lower limit, whereas other monitoring programmes such as the Catalan or the Valencian ones, have chosen intermediate depths to carry out their sampling. These differences in depth range may create difficulties in data comparison due to the parameters’ variability in relation to depth as well as to the different objectives the programmes may have. A monitoring programme that concentrates on the lower limit of meadows generally will tend to assess water quality through the progression, regression or stability of the limit (Boudouresque *et al.*, 2000), whereas a monitoring programme which uses an intermediate depth will tend to assess water quality through a comparable assessment of the meadow status (Romero *et al.*, 2005).

b) Descriptors measured in Monitoring programmes

As illustrated (Tab. 2), each *Posidonia oceanica* monitoring system is based on a specific selection of descriptors. This table also allows some preliminary observations, such as: none of the monitoring systems considered have the same selection of descriptors, and, except for “shoot density”, no other descriptor is shared by all the monitoring systems. These observations seem to anticipate the difficulties that arise when comparing different dataset and analysing metadata.

Tab. 2: Parameters measured in the different monitoring systems (“X”: parameter measured, “/”: parameter not measured always, “blank”: parameter not measured –“%plagio”: percentage of plagiotropic rhizomes, “SFS”:Shoot Foliar Surface, “B/G/W tissue SA”: Surface area of the brown, the green and the white tissue).

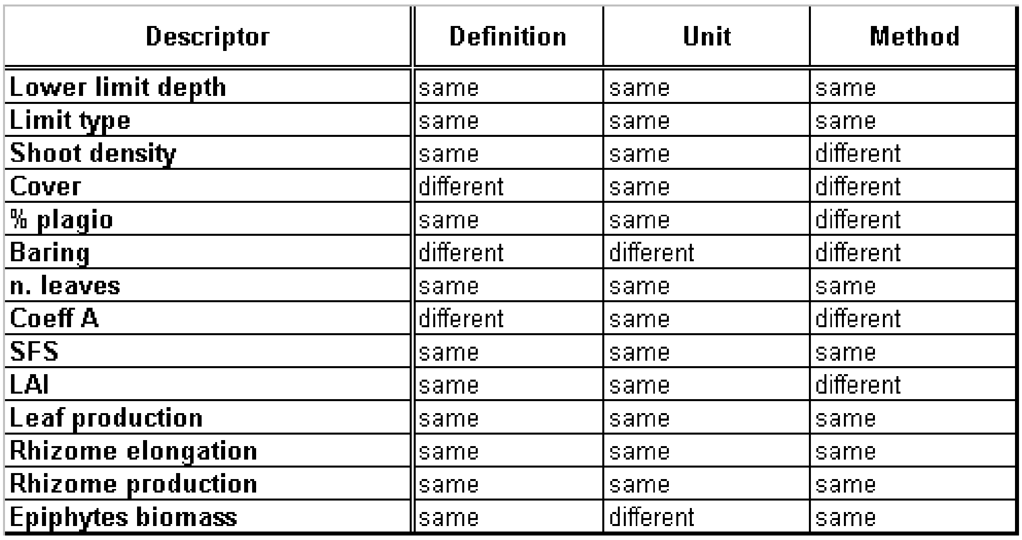


	Algeria	France					Italy				Malta	Spain		Tunisia
Descriptors		RSP Corse	RSP PACA	WFD	other	National	ARPAL	Sardinia	other		Catalonia	Valencia	
lower limit depth	X	/	/	X	X	X	X		X		X		
Limit type	X	X	X	X	X	X	X		X				
Shoot density	X	X	X	X	X	X	X	X	X	X	X	X	X
Global shoot density						X							
cover	X	X	X		X	X	X	X	X		X	X	X
Dead matte (%cover)												X	
% plagio		X	/	X	X	X	X		X		X		
Baring	X	X	/		X	X	X	X	X		X	X	
n. leaves	X	X	/	X	X	X		X	X	X	X	X	X
coeff A	X	X	/		X	X		X	X	X		X	X
SFS	X	X	/	X	X	X		X	X	X	X	X	X
LAI	X	X	/	X	X	X		X	X	X	X	X	X
B/G/W tissue SA						X		X					
% Necrosis											X	X	
shoot biomass						X		X				X	
leaf production	X	X	/		X	X		X	X	X		X	X
rhizome elongation	X	X	/		X			X	X	X		X	X
rhizome production			/			X		X	X	X		X	X
Epiphytes biomass	X		/	X	X			X	X		X	X	X
epiphyte assemblages										X	X		
Sediment		X								X	X		
N & P in rhizomes											X		
C in rhizomes											X		
δ15N in rhizomes											X		
δ34S in rhizomes											X		
N in epiphytes											X		
Trace metals					X						X		
Balisage	X	X	X			X							

c) Descriptors' definitions, units and methods

In order to compare their use in monitoring, descriptors that are present in more than 5 out of the 15 monitoring programmes under study, have been selected for further analysis. The resulting selection of 14 descriptors were: Lower limit depth, Limit type, Shoot density, Cover, % plagiotropic rhizomes, Baring, number of leaves, coefficient A, Shoot Foliar Surface, Leaf Area Index, Leaf production (lepidochronology), rhizome elongation, rhizome production and epiphyte biomass. The definition of these descriptors the units in which they are measured and the method used to measure them, in each monitoring programme, have been identified and summarised (Tab. 3).

Tab. 3: Agreement on definitions, units of measure and methods of measure of the most common descriptors in the different monitoring programmes ("Same": same definition, unit or methods for all monitoring systems that use this descriptor; "Different": At least one of the monitoring systems that use the descriptor, define it or measure it in a different way).



Descriptor	Definition	Unit	Method
Lower limit depth	same	same	same
Limit type	same	same	same
Shoot density	same	same	different
Cover	different	same	different
% plagio	same	same	different
Baring	different	different	different
n. leaves	same	same	same
Coeff A	different	same	different
SFS	same	same	same
LAI	same	same	different
Leaf production	same	same	same
Rhizome elongation	same	same	same
Rhizome production	same	same	same
Epiphytes biomass	same	different	same

Most of the differences between programmes are in the method used to measure a parameter rather than in their definition or unit; although rarer, differences in defining a given descriptors result in much larger implications for data comparability.

"Baring", for instance, is a descriptor present in 10 (of the 15) monitoring systems; most of them agree in defining baring as the distance between the sediment and the rhizome, in the case of plagiotropic rhizomes, or the distance between the sediment and the base of leaves, in the case of orthotropic rhizomes, as defined by Boudouresque *et al.* in 1984. However in the Italian National Monitoring Programme and in the regional Sardinian monitoring, baring is expressed as the percentage of bared rhizomes (Anonymous, 2001). It is evident that data under the heading of "Baring" is definitely not comparable: the differences are thus in definition, concept, and unit (cm or %), and should therefore be considered two different and separate descriptors.

The case of "Cover" is not as evident, as data is expressed in the same unit (%) and in most monitoring programmes the definition is a little vague; nevertheless there are at least two different definitions: the percentage of substrate covered by *Posidonia oceanica* leaves, as in the French monitoring systems (Pergent *et al.*, 2005; Cadiou *et al.*, 2004), or the percentage of substrate covered by *Posidonia oceanica* shoot base as in the Catalan Monitoring system (Romero *et al.*, in press). Again the two types of cover should be considered separately.

The main differences in unit of measure are due to the descriptor "Baring" as described previously, and to the descriptor "Epiphyte Biomass". In the case of epiphyte biomass the unit of measure is different as it can be expressed either in mg/shoot or in mg/cm^2, but the definition of the descriptor is the same in all monitoring programmes and the methods used to measure it are more or less the same. Therefore the data should be comparable, as it should be possible to convert data from one unit to the other.

The differences in the method of measuring a descriptor are a very delicate and controversial issue, and they create also a much wider-spread data comparability problem. Differences can mainly be ascribed to the techniques used to measure the descriptor or to the instruments used. Differences in techniques are, for example, in the evaluation of plagiotropic rhizomes which can be measured in quadrats of different sizes (Pergent *et al.*, 2005; Romero *et al.,* in press) and without a quadrat, on each side of the balises (Cadiou *et al.*, 2004). Another example is given by the estimation of leaf cover, that can be measured by visual estimation, using photographs, using video (Pergent *et al.*, 2005), using a grid (Cadiou *et al.*, 2004). Differences in instruments can be found in “Shoot density” measures, for which the use of quadrats of different sizes (Cadiou *et al.*, 2004; Pergent *et al.*, 2005; ICRAM, 2001; Romero *et al.,* in press) is very discussed among different research groups. These differences in method do not result in a categorical difference between monitoring programmes but they do introduce an error, an additional factor of data variability that is commonly seen as an additional barrier to data comparability.

Conclusions

The *Posidonia oceanica* data warehouse, was created to store data and metadata available across the Mediterranean on *Posidonia oceanica* monitoring programmes, in order to assess whether a “Mediterranean evaluation” is possible. Unfortunately the datawarehouse does not include a number of regions, for which information will hopefully become available soon. However, before analysing the data available across the Mediterranean, an analysis of the metadata was necessary. This study highlighted a number of problems, in particular data comparability, which will have to be understood further, before attempting an analysis of the data contained in the *P. oceanica* monitoring datawarehouse.

When analysing *P. oceanica* monitoring programmes across the western Mediterranean, the most striking fact is probably the heterogeneity of measures and data, this study in fact highlights the importance of data comparability. All monitoring programmes have the same aim: conservation, management and evaluation of the meadows’ status; despite this, each monitoring programme has its own set of descriptors and its own method of measuring them. And, although the *P.oceanica* status across the Mediterranean could be assessed through comparable, even if different, evaluation or classification systems; most monitoring systems considered do not at the moment result in a classification of the meadow or of the water quality. The study, as well as this final consideration, suggests the necessity of agreeing at least on certain parameters, their definitions and the standardisation of their measures. Indeed, most monitoring programmes are carried out on a regional basis resulting therefore in regional differences, but when monitoring a same ecoregion, in particular such as the Mediterranean where all coastal regions influence the ecosystem, it is essential that the seagrass be monitored transnationally, in order to be able to protect and manage it effectively.

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Silvia MAZZUCA[1], Antonia SPADAFORA[1], Dina FILADORO[1], Marcella BRACALE[2], Milena MARSONI[2] , Anna Maria INNOCENTI[1]
[1]Dipartimento di Ecologia, Università degli Studi della Calabria, Ponte Bucci 6b, 87030 Rende, ITALY
[2]Dipartimento di Ambiente Salute e Sicurezza, Università dell'Insubria, Via Dunant 3, 21100 Varese, ITALY
e-mail: s.mazzuca@unical; silvia.mazzuca@virgilio.it

THE PROTEOMIC APPROACH IN *POSIDONIA OCEANICA* POPULATIONS: WHICH PROTEIN BIOMARKERS FOR LIGHT STRESS ACCLIMATION?

Abstract

Posidonia oceanica *meadows show a low capability to tolerate external disturbance, thus to prevent the seagrass loss in coastal zones is of large interest to study its stress acclimation. With this aim we undertake this study by a proteomic approach considering two meadows, where physiological, biochemical an cytological aspects have been previously characterized: (i) a well preserved meadow (site A) under a light daily average value of 300 lux; (ii) a disturbed meadow (site B) subject to a light daily average of 150 lux. The disturbed meadow undergo a physiological acclimation, as demonstrated by phenols accumulation in tissues, plant reduced growth and low meadow density. The obtained results indicated that more than twenty-six protein spots were differentially expressed in the light stress acclimated plants. Ten proteins were univocally identified using MS/MS micro-sequencing and MS MASCOT database searches. As major result, two proteasome subunits (the 26 S proteasome regulatory and the proteasome beta type 1) were up-regulated in the light stress acclimated plants, whereas another proteasome 7 D beta type 1 was down-regulated. Also the level of* the *ribulose-1,5-bisphophate carboxylase (Rubisco) in leaves, seems to be affected by chronic exposure to light stress. Our observations strongly suggested that plants exposed to chronic low light intensity react to this stress changing the protein expression level, which very probably might be related to the reduced plant growth and meadow regression. These protein expression patterns should be compared to those from plants in two selected stations (5 m and 25 m depth) of a continuous meadow, (site C), to establish which proteins could be strictly recognized as light stress indicators.*

Key words: *Posidonia oceanica*, Light stress acclimation, Proteome, Proteasome.

Introduction

Posidonia oceanica meadows are widely recognized as key ecosystems in coastal habitats of the Mediterranean sea (Hemminga and Duarte, 2000). The regression of *P. oceanica* meadows with a resultant loss of biodiversity in the associated species have been reported, according to the ecotoxicological impact (Guidetti and Fabiano, 2000). As a consequence, changes in distribution patterns, density, biomass, growth dynamics have been widely used to obtain an integrated response to disturbances in the coastal ecosystems. Thus *P. oceanica* would appear to be a potentially valuable bio-indicator of water quality and has been used in bio-monitoring programs for the marine environment subjected to stress (Boudouresque *et al.*, 2000). Light is the major limiting factor that affects seagrasses growth and development. In fact, unlike the terrestrial plants, seagrasses are frequently light-limited due to their ecological spreading along the coastal depth gradient or, often, with the occurrence of turbidity that decreases the light penetration in the water column. Quality and quantity of light restricts the distribution of seagrasses to depths where PAR is above 4.5% of the subsurface value (Zimmerman, 2006). However**,** the effects of disturbance attributed to light limitation, trawling, geomorphology changes, anthropogenic waste, are related to the alterations in the growth dynamics and photosynthesis of *P. oceanica* meadows (Ruiz *et al.*, 2003; Ruiz *et al.*, 2001). Recently, many efforts have been focused on gene expression analyses of aquatic organisms under different environmental stress, by the application of proteomics molecular tools, with the aim to add these methodologies into the aquatic bio-monitoring (Andacht and Winn, 2006). In fact, proteomics explore the protein expression and provide results about the changes of cellular pathways in response to the environment stress. The proteomics approach has been utilized in numerous aquatic animal species whereas, in plants, this method is still at a starting phase. This is because plant tissues involve a number of practical challenges that are more problematic than in other organisms. Plant tissues, in fact, are often rich in compounds that strictly interfere with protein separation and analysis, including polysaccharides, lipids and polyphenols and other secondary metabolites. Many authors proposed alternative extraction procedures, respect those developed in the animal tissues, in order to obtained more purified proteins from different tissues and organs in plants (Park, 2004). Previously we reported the extraction methods that allow to obtain the purified protein samples from different tissues and organs of *P. oceanica* (Mazzuca *et al*., 2005; Spadafora *et al*., 2007). Although this method was a time consuming procedure, the benefits of high purity, integrity, great number of proteins in samples and high reproducibility, encourage its routinely use. On these bases the aim of the present study was to characterize differential protein expression profiles induced by chronic low light exposure in the *P. oceanica* meadow in order to identify the potential protein marker of light stress and to contribute to clarify the acclimation mechanisms. To attain this goal, we used the 2-DE analyses followed by mass spectrophotometric *de novo* sequencing of tryptic peptides associated with database search via mass spectrometry-driven BLAST (MS BLAST). Since a coherent pattern between light and photosynthetic capacities subsists, we have also determined the Rubisco levels in stressed and unstressed plants.

Materials and Method

Shoot sampling

P. oceanica shoots were collected in March and June by SCUBA diving in three different sites: two sites (site A= 39°54’28.83’’N - 15°46’.38’’E and site B= 39°48’45.71’’N - 15°47’53.74’’E) along the Tyrrhenian Sea, characterized by a different light intensity (Fig 1) and one site (site C) in Lacco Ameno (Ischia island, Naples) in which meadow is continuously spread along the depth gradient from 5 m to c.a. 30 m. In the site A, plants grow up in the shallow water (approx 10 m) with a daily light intensity of 300 lux average during the year, and it was reported as a well preserved meadow whose density ranges from 331±25.5 to 576±25 (shoots/m^2); in the site B, plants develop at the same depth, but it receive a reduced light daily intensity (150 lux average) due to a persistent water turbidity, with a reduced shoot density than site A, ranging from 303±13.6 to 405±42.4 (Acunto *et al*., 2006). About 20 shoots were collected from each site and adult leaves were separated and immediately frozen in liquid nitrogen and stored at -80 °C for further analyses. Daily light intensity in sites A and B was measured all one week per month for two years by the HOBO® Pendant™ temperature/light intensity Data Loggers (UA-002-xx, Ouset Computer Corporation). Daily light intensities, expressed as lumen/m^2 (lux), were collected and expressed as monthly average values by means of HOBOware software analyses.

Protein extraction and electrophoresis. We performed the protein extraction according to procedures previously described by Spadafora *et al*. (2007). Briefly, 1 g of N_2 frozen leaves was reduced to a fine powder and dissolved in 20% aqueous TCA with 1% PMSF (phenylmethylsulfonylfluoride), as proteases inhibitor. The proteins extraction was made from tissues powder, following the phenol extraction methods described by Wang *et al*. (2003). Then, protein samples were dried and dissolved in Laemmli sample buffer for 1-DE separation or in 2-DE rehydration solution (Spadafora *et al*., 2007; Mazzuca *et al*., 2006). For 1-D separation the Laemmli buffer system was used and proteins were resolved in a Bio-Rad mini-Protean III apparatus. For 2-DE, protein samples were applied in 2-DE rehydration solution by reswelling 13 cm or 18 cm Immobiline DryStrip (Amersham Biosciences, Piscataway, NJ, USA) overnight. IEF was performed in IPGphor system (Amersham). Secondary SDS-PAGE was carried out under constant current. After electrophoresis, proteins were visualized with colloidal CBB.

Western blot. Western blot analysis of purified protein from all sites after 1-DE and 2-DE electrophoreses was performed using a monoclonal anti-Rubisco large subunit (Agrisera) as the primary antibody diluted 1:2000 and the secondary antibody anti rabbit alkaline phosphatase, AP conjugated (Agrisera) at a dilution of 1:3000. The detection was performed using the alkaline phosphatase detection system with the anti-biotin NBT/BCIP (4-nitro blue tetrazolium chloride/5-bromo-4-chloro-3-indolyl-phosphate) reagent kit (Roche). The antibody recognized a protein band at 55 kDa molecular weight as a putative large subunit of Rubisco of *P. oceanica*. The large subunit of Rubisco from spinach (Agrisera) was used as standard purified protein.

Densitometry and Image analysis of 2-DE gels. Each gel was scanned on a densitometer (ImmageScannerTM, Amersham Biosciences) and analysed with the ImageMaster^{TM} 2D Elite software (Amersham). Spot quantity was determined by the area of the spot multiplied by the density and referred to as the spot volume. Each spot was then normalized, as the ratio between the spot volume and the total spot volumes on the same gel and multiplying by the sum of the areas of all spots on the same gel. Then the gels (about 5 gel for each site and sampling) were matched together and spot present at least in three gels were selected for the statistical analysis.
Mean normalized volumes (NV) for each spot were compared between the chronic light stress and control plants. Up-regulation (UR) or down-regulation (DR) correspond to the ratio NV light stress/NV controls. Molecular weight (MW) and isoelectric point p*I* of each spot were calculated on the basis of mean computed values. Protein spots were excised from the gel before tryptic digestion. The proteins were micro-sequenced using nano-electrospray Q-tof 2MS/MS instruments (I.S.B., Milano, Italy). The sequence elements obtained were used to carry out a MS BLAST search to identify proteins by sequence similarity against the available sequence database (NCBI NR database). Each protein was identified with the accession number and MASCOT coverage (%).

Results

Using the proteomic approach, we analysed the response of *P. oceanica* to light reduction, comparing plants in a disturbed meadow *P. oceanica* subject to a light daily average of 150 lux respect to those in a non disturbed meadow under a daily light intensity of 300 lux (Fig 1). A mean of 2400 spots per gels were detected using the colloidal CBB staining and the ImageMasterTM software analysis. We found a high reproducibility of spot patterns in 2-DE gels within population in a site and between populations of two different sites. A high reproducibility of 2-DE analyses was also found in the different times of sampling.

Protein expression profiles and identification

The comparative analysis of adult leaves, evidenced that chronic low light stress induced significant changes in protein expression profiles. A total of 21 protein spots were reported to be differentially expressed with a modified NV from site B respect to site A; 9 spots which NV modification seems to be related to seasonal variations (from March to June) and 11 spots which expression behaviour was not affected by time of sampling. Among the first group, seven spots were over-expressed and only three spots were under-expressed. Among the second group, six spots were significantly over-expressed and only the three spots were under-expressed. For protein spots that had their NV modified by chronic low light, UR were comprised between 1.2 to 6.1 and DR from 1.5 to 14.0.

We excised 16 out of the 21 protein spots that were differentially expressed in chronic low light stress. The other five spots were too weak and/or were too close to other spots to be isolated with assurance. A total of 11 proteins were identified by searching the sequence similarity on the available sequence database (Tab. 1). The remaining 5 proteins could not be identified due to poor MS/MS data.

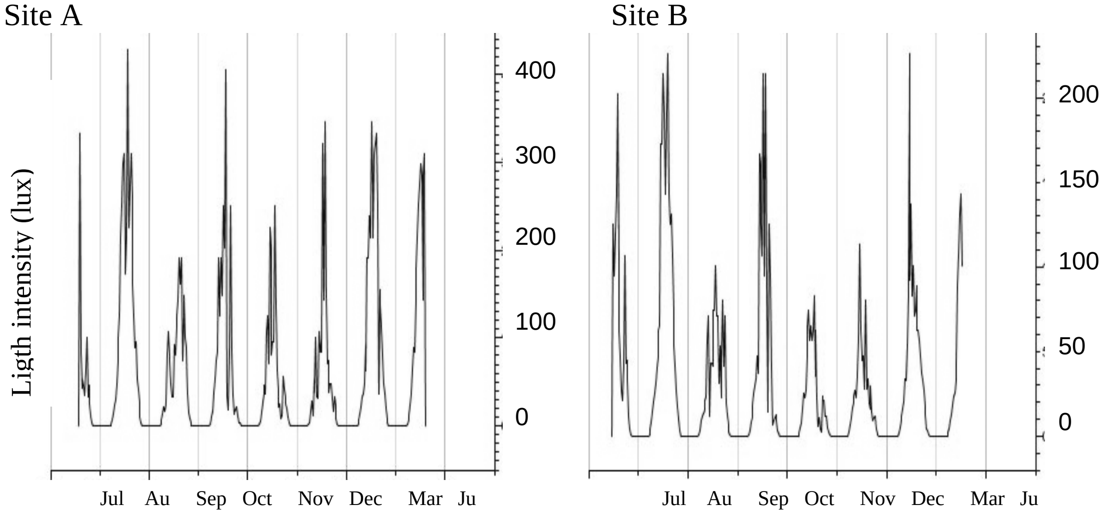

Fig. 1: Light intensity (lumens/m2) reported as mean monthly values from July 2005 and June 2006 in the site A and in the site B.

Tab 1: Up-regulated (UR) and down-regulated (DR) identified protein spots in adult leaves of* Posidonia oceanica *exposed to chronic low light stress and sampled in two different times of year.

Spot num.	MW (kDa)	pI	UR	DR	Accession number	Coverage (%)	Protein identified
351	39	6.1	2.1		gi/62733309	10	Pyridoxine
418*	27	6.1	2.1		gi/34909168	17	Putative alpha 7 proteasome subunit
448*	25	6.3	5.5		gi/17380185	26	Proteasome subunit beta tipe
453*	26	5.3		1.5	gi/66271071	17	Beta 1 proteasome-7D
470	55	5.9	3.6		gi/50938173	3	Beta-amylase
572	15	5.7	1.8		gi/538430	9	Superoxide dismutase
1825	39 30	6.5 6.0	6.1		gi/10800924 gi/46093420	12 8	1-Fructose-bisphosphate aldolase 2-Caffeic acid o-methyl transferase
1865*	50	5.9	4.3		gi/17297987	4	26S Proteasome
1909	20	7.6		1.8	gi/37991674	7	Perchloric acid
2585	16	6.3	1.2		gi/7643788	14	Nucleoside diphosphate kinase

* spots which expression behaviour was not affected by season ($p<0.01$)

Protein induced or repressed by chronic low light stress

Four protein species were identified and significantly related to chronic low light stress to be over or under expressed (Tab. 1). The beta 1 proteasome 7D (spot 453) with a MV of 26 kDa, was significantly down-regulated (DR 1.5; $p<0.01$); on the contrary, three other proteasome subunits were significantly up-regulated and respectively, the Proteasome subunit beta type (spot 448; MV 25; UR 5.5), the Alpha 7 proteasome subunit (spot 418; MV 27 ; UR 2.1), the 26S Proteasome (spot 1865; MV 50; UR 4.3, see also in Fig. 2).

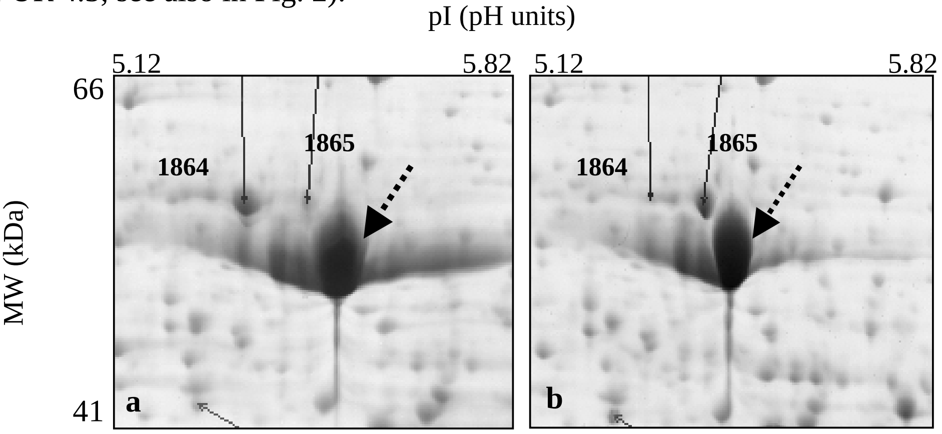

Fig. 2: Magnification of protein spots 1865, 1864 and Rubisco large subunit (dotted arrows), differentially expressed in plants exposed to chronic low light stress (b) respect to unstressed ones (a). The spot 1865 was up-regulated and identified as a 26S proteasome regulatory. The spots 1864 was significantly down-regulated, but not identified by MS micro-sequencing analysis. The NV of Rubisco resulted significantly modified and down regulated in low light acclimated plants.

Other protein identified to be over expressed, but not univocally related to chronic low light stress, were a Pyridoxine (spot 351, MV 39, UR 2.1), a Beta-amylase (spot 470, MV 55, UR 3.6), a Superoxide dismutase (spot 572, MV 15, UR 1.8; a Nucleoside diphosphate kinase (Spot 2585). Five peptides from the spot 1825 allowed to identified two proteins with a different MASCOT Coverage: a 1- Fructose-bisphosphate aldolase and a 2-Caffeic-acido-methyl transferase which were both over-expressed. On the contrary the Perchloric acid soluble translation inhibitor was down-regulated (spot 1909, MV 20, DR 14.0).

Western blot and densitometry evidenced that Rubisco large subunit was down-regulated in light stress acclimated plants. In fact, whatever the sampling time, a significant modified NV was detected (Fig. 2).

Discussion

The proteomic approach developed in the present study provides new and relevantevidences that, in seagrasses, a chronic low light exposure affect the protein expression profiles in leaf tissues. One of the main problems when studying wild population at the proteomic level is the possible genetic disparity that could induce high variability in protein expression profiles. Since vegetative reproduction appears to be the principal means of propagation of *P. oceanica* (Meinesz and Lefevre, 1984), the meadow results structured in the clone patches. However, previous analysis of genetic structures of *Posidonia* populations, reported that the meadows in site A and B were characterized by very low genetic variability (Serra *et al.*, 2006). As expected, we found low variability of spot patterns in 2-DE gels within the population of one site and between populations of two different sites. A highly reproducibility of 2-DE analyses was also found within the sites in the different times of sampling.

Two-dimensional electrophoresis (2-DE), revealed more than twenty protein spots differentially expressed in the light stress acclimated plants. From these spots eleven proteins were identified using MS/MS micro-sequencing and MS MASCOT database searches. As major results the proteasomes seems to be univocally related to chronic low light stress, in fact three proteasome subunits (the 26 S proteasome regulatory, the proteasome beta type 1 and alpha 7 proteasome subunit) were up-regulated in the light stress acclimated plants, whereas another proteasome 7 D beta type 1 was down-regulated. We suggest that light stress generated abnormal proteins in adult leaves, and enabled plant to increase the level of enzymes which degrade these proteins. Thus suggesting that the acclimation of *Posidonia* to low light might be mediated by ubiquitin dependent proteolysis via the proteasome. In addition, acclimation seems to involve important metabolic rearranging as the low expression levels of the large subunit of Rubisco. Although it is not documented in this paper, the depressed level of Rubisco could be establish by the delayed or reduced growth of developing leaves in plants from disturbed meadows (Acunto *et al*, 2006) and closely related with the alterations in photosynthetic capacities in the adult leaves (data not shown). The protein expression profiles have been compared also in plants from 5 m and 25 m depth in the site C. Clear differences in protein expression have been found between plant acclimated to the different light intensities, mainly for a lower level of Rubisco in the deeper plants than in the shallow ones; this results appears to be in agreement with changes in photosynthetic activities found in the same stations of site C (Lorenti *et al.*, 2006).

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Yosr MEZGUI, Aslam Sami DJELLOULI, **Imen BEN CHIKH ALMI**
Département de Biologie, Faculté des Sciences de Tunis, Campus Universitaire – El Manar II 2092 Tunis, TUNISIE
e-mail : mezgui_yosr@yahoo.com

ETUDE BIOMETRIQUE (BIOMASSE ET PHENOLOGIE) DES POPULATIONS A *CAULERPA RACEMOSA* DANS LA REGION DE BIZERTE (TUNISIE)

Résumé

Des mesures mensuelles de la biomasse, effectuées dans la région de Bizerte, sur des échantillons prélevés au sein des populations de Caulerpa racemosa *var.* cylindracea *et de* C. racemosa *var.* turbinata-uvifera *montrent dans les deux cas, un cycle saisonnier marqué par une période de disparition macroscopique totale de l'algue. La biomasse maximale de 34.75g/m^2 (var.* cylindracea*) et 5.1 g/m^2 (var.* turbinata-uvifera*) est enregistrée au mois d'octobre. Ces observations ont été complétées par des mesures phénologiques.*

Mots-clés : *Caulerpa racemosa* var. *cylindracea*, *C. racemosa* var. *turbinata-uvifera,* Biomasse, Phénologie.

Introduction

Le complexe *Caulerpa racemosa* (Forsskål) J. Agardh n'est signalé que depuis peu en Méditerrané (Hamel, 1926) où il ne cesse de s'étendre (Djellouli, 1998). Verlaque (2003) y reconnaît 3 formes : la variété *turbinata-uvifera* (un intermédiaire entre la var. *turbinata* (J. Agardh) Eubank et la var. *uvifera* (C. Agardh) J. Agardh) (Tunisie et Liban), la variété *lamourouxii* (Turner) Weber-van Bosse forme *requienii* (Montagne)Weber-van Bosse (Verlaque et *al.*, 2000) (bassin Est de la Méditerranée : Turquie, Chypre, Syrie et Israël) et la variété *cylindracea* (Sonder) Verlaque, Huisman et Boudouresque (pourtour du bassin occidental, excepté Algérie et Maroc ; et nombreux pays du bassin oriental). La variété *cylindracea* est considérée comme envahissante par de nombreux auteurs (Verlaque *et al.,* 2003 ; 2004 ; Piazzi *et al.,* 2005). Elle est décrite par ailleurs comme colonisant différents substrats à différentes profondeurs et tolérant les températures hivernales, relativement basses du Nord de la Méditerranée. Elle présente toutefois un cycle saisonnier marqué, avec une nette régression en hiver (Piazzi and Cinelli, 1999). Plusieurs hypothèses sont formulées quand à l'origine de cette variété envahissante. Des études génétiques (Durant *et al.,* 2002) suggèrent que les échantillons correspondant à cette variété pourraient être attribués à un hybride récent entre *Caulerpa racemosa* var. *turbinata-uvifera* et une autre souche d'origine non méditerranéenne. En Tunisie, les variétés *turbinata-uvifera* et *cylindracea* sont signalées avec une répartition hétérogène tout le long du littoral (Djellouli, 2000). Dans la perspective de faire le point sur les potentialités de ces souches, nous présentons ici les résultats de leur étude biométrique ainsi qu'une comparaison de leurs caractères morphologiques.

Matériel et méthodes

L'étude est réalisée dans une station localisée dans la baie de Sidi Salem (Bizerte, Tunisie) (Fig. 1) et colonisée par des populations appartenant à la fois à *C. racemosa* var. *turbinata-uvifera* et à la var. *cylindracea*. Les peuplements se développent sur de la matte morte de *Posidonia oceanica* à des profondeurs comprises entre 0,8 m et 1,5 m. Des prélèvements mensuels ont été effectués entre juillet 2005 et juillet 2006. Les récoltes sont réalisées à l'intérieur d'un cadre métallique de 400 cm^2 de surface. Au laboratoire, les thalles sont préalablement soigneusement séparés des débris organiques et des autres végétaux présents dans les relevés. Nous avons par la suite procédé aux mesures des différents paramètres biométriques (diamètre et longueur cumulée des stolons, hauteur des frondes, distance entre les frondes et nombre d'orthostique). Le poids humide des échantillons est évalué après avoir essoré les thalles sur papier. Le poids sec est ensuite déterminé après séchage pendant 48 h à l'étuve à 70°C.

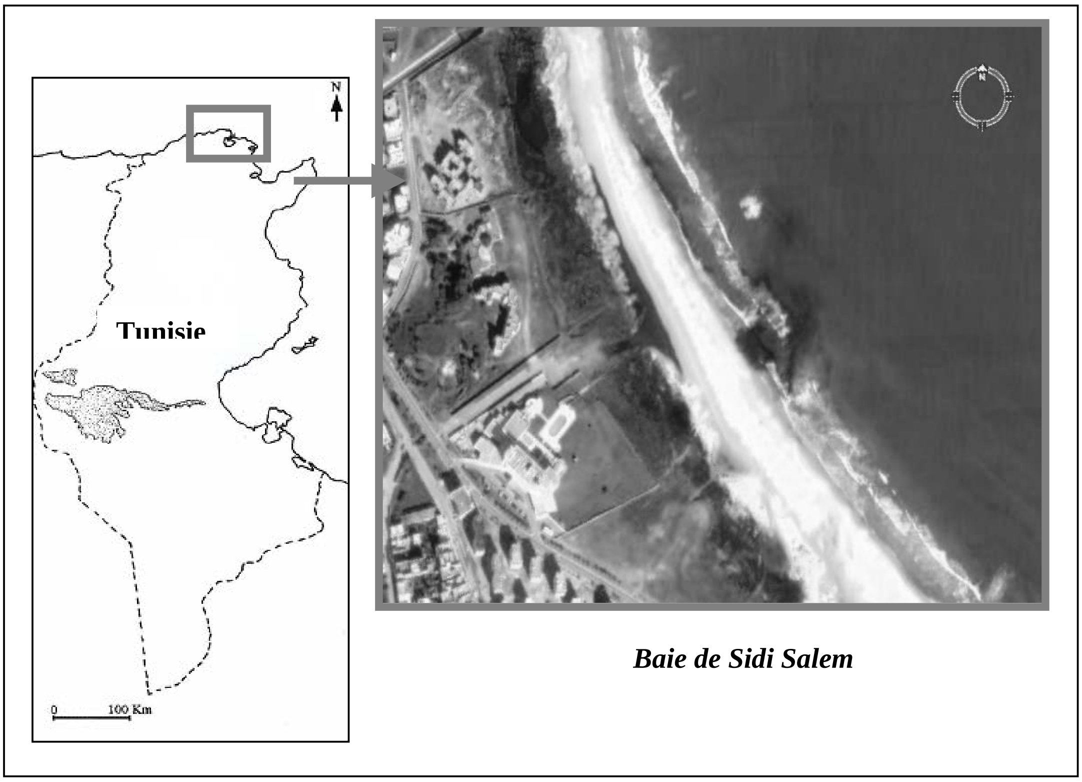


Fig. 1 : Localisation des stations de prélèvement.

Résultats

Observations in situ

Au mois de juillet 2006, au commencement de notre étude, on note une absence totale des thalles appartenant aussi bien à la var. *cylindracea* qu'à la var. *turbinata-uvifera.* Par la suite, au cours de la période allant du mois d'août 2005 au mois de décembre de la même année, on observe un tapis homogène de *C. racemosa* var. *cylindracea*. Dès le début du mois de Janvier 2006, on note une rapide disparition macroscopique et quasi totale de l'algue, qui ne réapparaît que cinq mois plus tard, soit en juin. En ce qui concerne *C. racemosa* var. *turbinata-uvifera*, elle n'est observée qu'à partir du mois d'octobre 2005, où l'on note la présence de quelques touffes éparses (C<10 %) au sein du tapis homogène de la var. *cylindracea*. La var. *turbinata-uvifera* disparaît également au mois de janvier. De ces observations, il ressort que l'ensemble des paramètres biométriques présentent une valeur nulle au cours de la période allant de janvier 2006 à mai 2006.

Biomasse

C. racemosa var. *cylindracea*

Les valeurs de poids sec (Fig. 2) présentent un maximum égal à 34.75g/m^2 enregistré au mois d'octobre 2005. La biomasse diminue par la suite et s'annule au cours de la période allant du mois de janvier 2006 à mai 2006. L'accroissement pondéral maximum est enregistré entre le mois de septembre et le mois d'octobre où il atteint 0.875 g/m^2/24h (poids sec).

C. racemosa var. *turbinata-uvifera*

Elle présente également des variations saisonnières importantes de biomasse (Fig. 3) et le poids sec présente un maximum de 5.1 g/m^2 enregistré en octobre 2005 ; cette valeur tend par la suite à diminuer pour s'annuler en janvier 2006. L'accroissement pondéral maximum est enregistré entre les mois de septembre et octobre où il atteint 0.172 g/m2/24h. Comparé à la variété *cylindracea*, le maximum enregistré pour la variété *turbinata-uvifera* est 6,81 de fois plus faible.

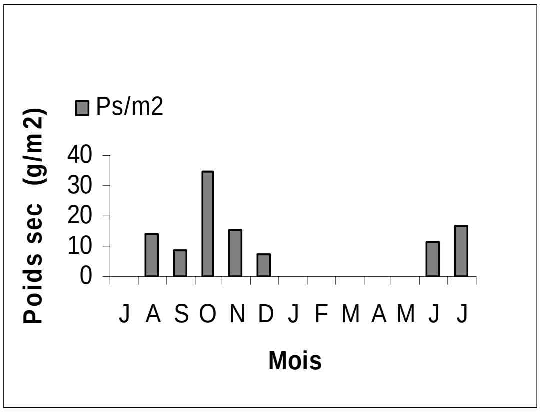


Fig. 2 : Variation du poids sec de* C. racemosa *var.* cylindracea *entre Juillet 2005 et Juillet 2006.

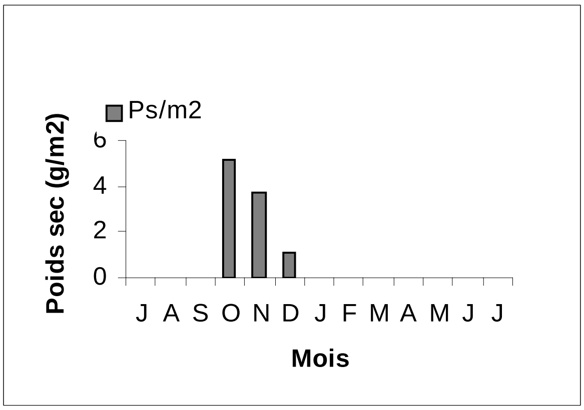


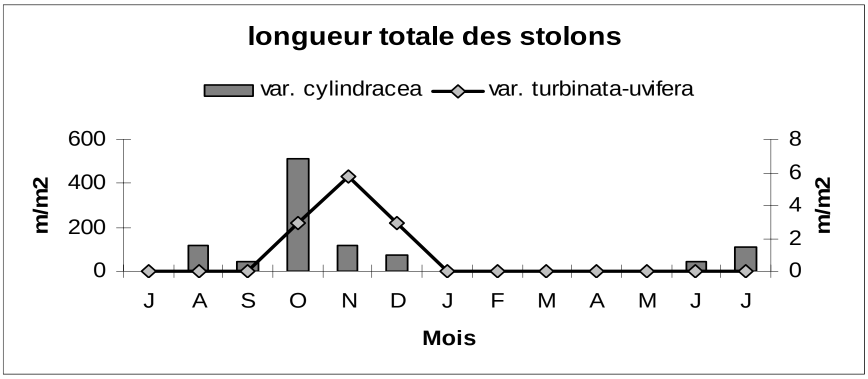
Fig. 3: Variation du poids sec de* C. racemosa *var.* turbinata-uvifera *entre Juillet 2005 et Juillet 2006.

Analyse phénologique

Etude des stolons

Pour la var. *cylindracea*, on note que sur l'ensemble de la période où l'on observe un développement de l'algue, le diamètre des stolons reste constant et présente une moyenne égale à 1 mm. En revanche, la longueur totale cumulée des stolons, nulle au mois de juillet, atteint un maximum de 511.8 m/m^2 au mois d'octobre puis diminue progressivement pour s'annuler de nouveau au mois de janvier (Fig. 4).

Fig. 4 : Variation de la longueur des stolons de C. racemosa var cylindracea et var. turbinata-uvifera entre Juillet (J) 2005 et Juillet (J) 2006.



En revanche, pour la var. *turbinata-uvifera* le diamètre des stolons varie entre 2.25 et 1.5 mm, au cours de la période comprise entre octobre et décembre. La longueur totale des stolons (Fig. 4) enregistre un maximum de 5.75 m/m^2 au mois de novembre, cette valeur étant 89 fois plus faible que pour la var. *cylindracea*.

Etude des frondes

Chez la var. *cylindracea*, le nombre maximum de frondes, observé au mois d'octobre, est de 31375 frondes/m^2. Ce nombre décline par la suite et s'annule au mois de janvier (Fig. 5); la hauteur moyenne des frondes atteint un maximum de 8 mm au mois de septembre (Fig. 6). La distance entre les frondes varie ente un minimum de 9 mm et un maximum de 11, le minimum est enregistré au mois d'octobre (Fig. 7). On note par ailleurs que les ramules sont disposées sur les frondes le long de 2 ou 4 orthostiques.

Chez la var. *turbinata-uvifera,* le nombre maximum de frondes est atteint au mois d'octobre, il est seulement de 510 frondes/m² (Fig 5) ; en revanche, la hauteur de ces dernières atteint un maximum de 15 mm, hauteur largement supérieure à celles observées chez la var. *cylindracea*. La distance séparant les frondes le long du stolon est quasiment constante ici, elle est égale à 4 mm (Fig. 7). Les ramules sont organisés autour du rachis cylindrique, le long de 4, 6 ou 8 orthostiques (Fig. 7).

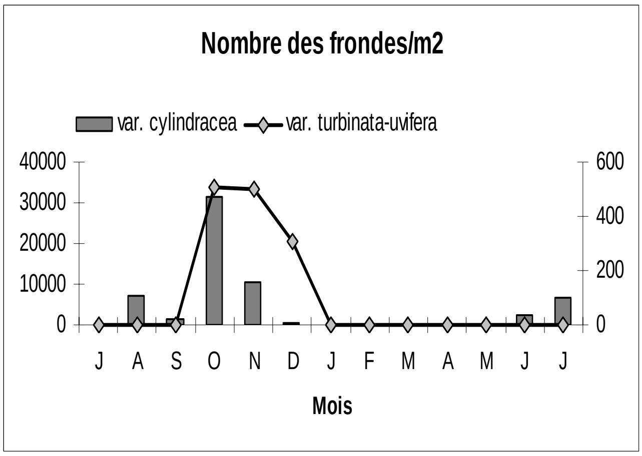


Fig. 5 : Variation du nombre total des frondes de* C. racemosa *var.* cylindracea *et var.* turbinata-uvifera *entre Juillet (J) 2005 et Juillet (J) 2006.

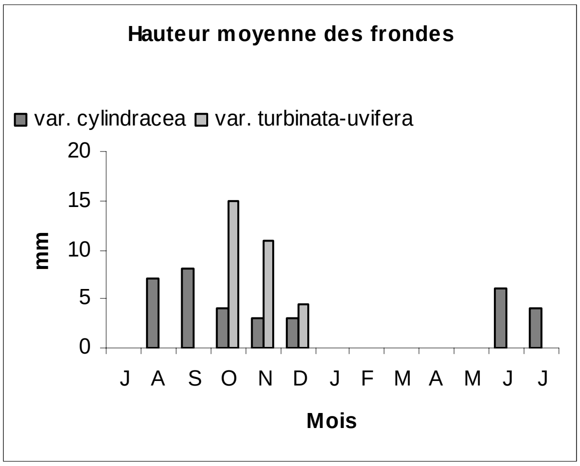


Fig. 6 : Variation mensuelle de la hauteur moyenne des frondes de* C. racemosa *var.* cylindracea *et var.* turbinata-uvifera *de Juillet 2005 (J) à Juillet 2006(J).

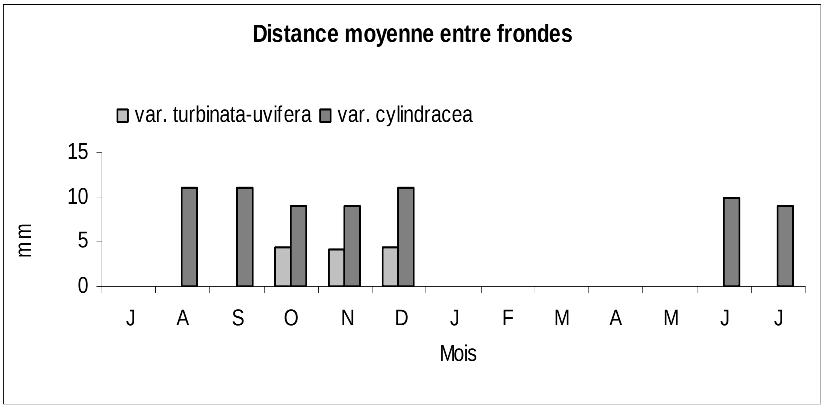


Fig. 7 : Variation mensuelle de la distance entre frondes de* C. racemosa *var.* cylindracea *et var.* turbinata-uvifera *de Juillet 2005 (J) à Juillet 2006(J).

Pour la var. *cylindracea*, la comparaison des paramètres biométriques (Tab. 1 et 2) de nos échantillons avec ceux de populations du nord de la Méditerranée permet de noter les points suivants :

- Quel que soit le paramètre considéré, on note une forte variabilité des valeurs mesurées d'une localité à l'autre.
- Les valeurs maximales de poids sec et de longueur des stolons sont proches de celles enregistrées à Villefranche (France) mais environ deux fois plus faibles que celles observées à Saména (France).
- Le nombre de frondes est bien plus élevé pour les populations tunisiennes que pour les autres populations, la hauteur des frondes est, par contre, comparativement plus faible que pour les autres localités.
- Seules les populations tunisiennes et celle de Cap Croisette disparaissent totalement en hiver.

Tab. 1 : Comparaison des valeurs biométriques maximales de* C. racemosa *var.* cylindracea *en France et en Tunisie. P = profondeur ; Ps = poids sec ; Lg S = longueur totale cumulée des stolons ; Nb F = nombre de frondes.

	France			**Tunisie**
Localité	**Cap Croisette**	**Saména**	**Villefranche**	**Bizerte**
Source	Ruitton *et al.*, 2005	Ruitton *et al.*, 2005	Capiomont *et al.*, 2005	Présent travail
Substrat	Matte morte	Matte morte	Matte morte	Matte morte
P (m)	17	7 - 22	0-3	1
Ps (g/m^2)	1±0.4	81.6±2.6	40.1±16.6	34,75
Lg S (m/m^2)	33±14	1162± 86	572±151	511.8
Nb F au m^2	340±187	20955±1499	8187± 1523	31375
H F m)	8±,3	18±0,2	20.5 ±12.8	8

Tab. 2: Comparaison des valeurs biométriques minimales de* C. racemosa *var.* cylindracea *en France et en Tunisie. P = profondeur ; Ps = poids sec ; Lg S = longueur totale cumulée des stolons ; Nb F = nombre de frondes.

	France			**Tunisie**
Localité	**Cap Croisette**	**Saména**	**Villefranche**	**Bizerte**
Source	Ruitton *et al.*, 2005	Ruitton *et al.*, 2005	Capiomont *et al.*, 2005	Présent travail
Substrat	Matte morte	Matte morte	Matte morte	Matte morte
Pf (m)	17	7 - 22	0-3	1
P s (g/m^2)	0	0.3± 0.1	10.0±1.5	0
Lg S (m/m^2)	0	3± 1	119±58	0
Nb F au m^2	0	35±15	1602±401	0
H F (mm)	0	6±0,1	9.0 ±5.2	0

Conclusion

La variation de la biomasse et des paramètres phénologiques enregistrés chez *C. racemosa* var. *cylindracea* est plus importante que celle enregistrée chez la var. *turbinata-uvifera*, ce qui confirme un caractère envahissant pour les populations tunisiennes de la var. *cylindracea*. Cependant, la disparition totale en hiver des thalles appartenant à cette variété, ainsi que des valeurs de biomasse plus faibles que celles enregistrées à Villefranche, indique une nette différence avec celle-ci. Si la différence au niveau des paramètres biométriques peut être attribuée à des différences de conditions stationnelles, en revanche, l'absence de pérennité doit être attribuée à des facteurs intrinsèques comme un caractère hybride du taxon entre la var. *cylindracea* et la var. *turbinata-uvifera.*, à l'instar de ce que suggère Durand (Durand et *al.*, 2002).

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Carmen MIFSUD[1], Francesco CINELLI, Stefano ACUNTO, David BALATA, Edwin LANFRANCO, Shirley A. MICALLEF, Luigi PIAZZI, Darrin T. STEVENS, Sebastiano CALVO

[1]Nature Protection Unit, Environment Protection Directorate, Malta Environment and Planning Authority, P.O. Box 200, Valletta, CMR 01 MALTA, Email: carmen.mifsud@ mepa.org.mt

THE *POSIDONIA OCEANICA* (L.) DELILE MEADOWS' DISTRIBUTION AND STATE OF HEALTH IN MALTESE TERRITORIAL WATERS

Abstract

The results of a cartographic assessment of the Posidonia oceanica, *Magnoliophyta, meadows around the Maltese Islands carried out between spring and summer 2002 are presented here. Another objective of this baseline survey was to determine the state of health of the meadows, the results of which are also presented here. A comparison was also made between part of the results of the above mentioned survey and those obtained by previous studies.* P. oceanica *colonizes 55.06 km^2 of sea bottom, representing approximately 1.36% of Maltese territorial waters.* P. oceanica *meadows surrounding the Maltese Islands appear to be in a good state of health: in several areas the lower limit of the meadows is greater than 40 m, primary production is normally high; shoot density and LAI values are comparable to those observed along the coasts of Sicily. However, considerable meadow regression has also been observed in some areas, even prior to the 2002.*

Key-Words: Seagrass, Cartography, Phenology, Maltese Islands.

Introduction

The meadows constituted by the seagrass *Posidonia oceanica* (L.) Delile are considered one of the most important ecological assemblages of Mediterranean coastal systems (Mazzella *et al.*, 1992, Pergent *et al.*, 1999; Buia *et al.*, 2000) and have recently been defined as a priority habitat[1] in Annex 1 of the EU Habitats Directive [Natura 2000 Code 1120]. A lot of studies were recently carried out in the whole Mediterranean in order to determine the extent and the characteristics of the meadows (Meinesz *et al.*, 1978; 1988; Colantoni *et al.*, 1982; Falconetti and Meinesz, 1989; Calvo *et al.*, 1993; Pasqualini *et al.*, 1998; Piazzi *et al.*, 2000; 2001). Around the Maltese Islands, only fragmentary information existed on distribution and ecology of *P. oceanica* meadows (Drew and Jupp, 1976), before 1995. But during the last 10 years several surveys were performed improving the knowledge of the *P. oceanica* biological and ecological characteristics and of the assemblages associated to the meadows; moreover, some studies also evaluated the impacts of human activities (Micallef, 1996; Borg, 1995; Borg and Schembri, 1995a; 1995b; Borg *et al.*, 1997; Pirotta and Schembri, 1997a; 1997b; Dimech *et al*., 2000(b); 2002).

Because of the requirements of the EU Habitats Directive, in 2002, the Maltese Government, through the Department of Environment and the Planning Authority, funded an extensive survey in the territorial waters of Malta in relation to the extent and characteristics of *P. oceanica* meadows. The survey was contracted and awarded to G.A.S. s.r.l. (Geological Assistance & Services of

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[1] *Priority habitat types* are defined in article 1(d) of the Habitats Directive as, natural habitat types in danger of disappearance, which are present in the territory of Member States [MS] and for the conservation of which the MS have particular responsibility in view of the proportion of their natural range which falls in their territory.

Bologna, Italy). The aim of this survey was to map the geographic extent of the meadows and the spatial distribution of the morphotypes and to provide details regarding their state of health.
The present paper reports the main results of this survey. Moreover, parts of the results are compared with some previous studies, in order to evaluate any recent changes in the characteristics of the meadows.

Materials and Methods

Malta consists of an archipelago of three main inhabited islands and a number of small uninhabited islets and rocks. The northeast facing seaboards of both Malta and Gozo tend to be gently sloping while the western and southern coastlines are characterised by steep cliffs. The baseline survey was carried out within the whole of the Maltese Islands' territorial waters (12 international units! from the coast, including Hurds bank, which is an 'offshore' reef less then 50 metres deep) up to a maximum depth of 50m, the latter being considered as the depth limit of the *Posidonia oceanica* meadows. The survey was carried out in Spring and Summer 2002.

Geographical survey

Surface positioning throughout the fieldwork was provided by differential GPS (DGPS), whilst underwater positioning was provided using a Simrad HPR 410P hydroAcoustic position reference system. The Navigation system is the software NavPro (Navigator Professional), which is manages two-way serial connections with the external sensors: DGPS, gyrocompass, echosounder, Multibeam, Side Scan Sonar (KLEIN System 2000), HPR. Fixing/logging interval of the vessel position was set every 20 metres for echosounder acquisition and every 25 metres for Side Scan Sonar acquisition. The automatic acquisition of navigation data allowed the processing of the track plot charts, containing all the profiles performed in the areas and the relevant fixes. Navigation data were converted into ASCII format following Quality assurance/Quality Control Manual procedures and prepared for CAD software. The interpretation of the recorded data was performed on charts having a scale of 1:10000; the geo-referenced coastline labelled with the main toponyms was drawn over these charts. The bathymetric data was acquired in continuous mode using a Navisound 210 precision hydrographic echosounder. Side scan sonar equipment was used in order to provide details of seabed features along the surveyed area. The position of the tow fish was determined acoustically and interfaced with the navigation data to ensure correlation between geophysical data sets. Side Scan Sonar data were acquired simultaneously with the bathymetric ones. Range settings of 100m and 150m were used, depending on water depth and survey line spacing.

Biological sampling and data analysis

In order to study the state of health of the beds, fifteen locations around the Maltese Islands were randomly selected and sampled by SCUBA divers (Tab. 1).

Tab. 1:* Posidonia oceanica *was sampled in the following sites [M,C and G stand respectively for Malta, Comino and Gozo Islands].

M1: St. Paul Islands	M6: Gharlapsi	C1: Cominotto
M2: Mellieha Bay	M7:Munxar Reef	C2: St. Marija Bay
M3: L-Ahrax	M8:St./ George's Bay	G1: Ramla Bay
M4: Anchor Bay	M9:Qalet Marku	G2: Dwejra
M5: Fomm ir-rih	M10:Qawra Point	G3: Xatt l-Ahmar

In each location, three sites a 100m apart were chosen and in each site, three areas a few metres apart were sampled. The sampling area was 0.25m² at 10m water depth. The depth chosen is the mean depth of distribution of *P. oceanica*, also reported in similar studies (RTI, 2002; 2004). In each sampling area, shoot density (number of shoots per square metre) was assessed and five vertical shoots were collected for phenological and lepidochronological studies. Samples were preserved in a 4% formalin seawater solution for laboratory observations. A total of 1080 shoots were gathered. In the laboratory, the following phenological variables were calculated: mean number of leaves, mean leaf length and width per shoot and Leaf Area Index (mean leaf surface per shoot/2 X mean shoot density). Coefficient ‘A’ was also determined.

The allocation of primary production devoted to the rhizomes growth of the last five years (1997-2001) was obtained by lepidochronological analysis as described by Pergent *et al*. (1989). Dead sheath thickness minima and maxima were determined using cross sections, localised at 10-12 mm above the base of the dead sheath. The positions of floral stalk remains, inserted between the dead sheaths, were also recorded. The biometry of living leaves (foliar shoots) was determined using the technique of Giraud (1979) Data were analyzed by a 3-way ANOVA with Location (km apart, 15 levels), Site (100m apart, 3 levels) nested in Location and Area (m apart, 3 levels) nested in site considered as random factors; homogeneity of variances was checked before analysis by Cochran C test and data were transformed when necessary (Underwood, 1997).

Results

Meadows Distribution and Morphology

Around the Island of Malta, a dense *Posidonia oceanica* meadow on matte grows in the NE region between Saint Paul’s Islands and Qawra Point and a dense meadow interrupted at times by sand and by the seagrass *Cymodocea nodosa* Ucria Aschers. is present between Qawra Point and Ras il-Qrejten (Fig. 1).

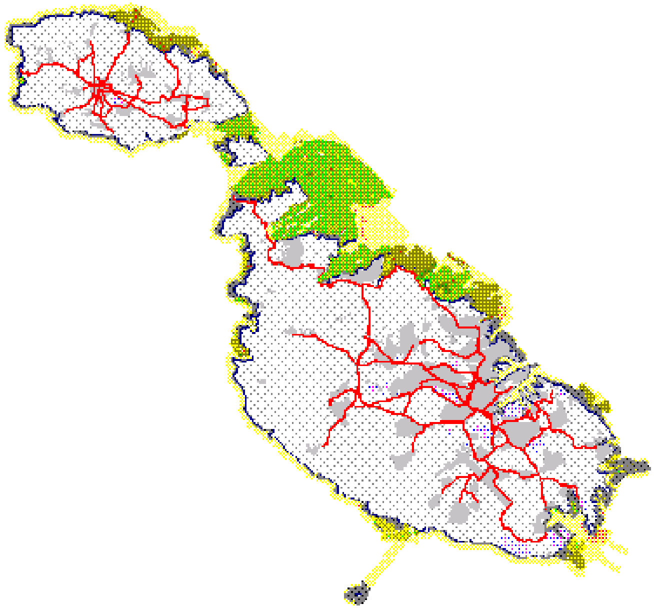

Fig. 1: Distribution of Posidonia oceanica meadows around the Maltese archipelago, as recorded by GAS s.r.l. in 2002.

A relatively dense *P. oceanica* meadow characterizes the seafloor from Ras il-Qrejten to Saint Julian’s bay; here a matte height greater than 2m is common, with erosion channels and areas colonized by *C. nodosa* and by the invasive Chlorophyta *Caulerpa racemosa* (Forsskal) C. Agardh. Rare patches of *P. oceanica* grow on rocks between Saint Julian’s bay and Żonqor point. The meadow reappears at Munxar reef, colonising sand and rocky bottom but matte is also present. Scattered patches of *P. oceanica* characterize the sandy and rocky bottom from Xrobb l-Għagin to Bengħajsa Point and close to Għar Lapsi there are many patches of *P. oceanica* settled on rock. Further north-west *P. oceanica* reappears between Fomm ir-Riħ and Anchor bay, with patches growing on sand and rock. Around the Island of Gozo, *P. oceanica* is widely present along the north-eastern coast. Further west and up to the South-East *Posidonia* is located in two small zones: one at Dwejra (with rare patches) and another just outside the Mgarr harbour, where it grows at a depth of 8-9m and then covers the gently sloping face with a dense meadow at the deeper end. The channels between Gozo and Comino and Comino and Malta are covered by a dense *P. oceanica* growing on matte. The meadow further continues close to the Maltese coast and St. Paul’s Islands.

Phenological and Lepidochronological analysis

The meadow density generally exceeds 400 shoots per square metre (or shoots.m^{-2}), with the exception of the two localities Munxar (M7)and St. George’s Bay (M8) (Tab. 2). The highest densities occur at Qalet Marku (M9), Dwejra (G2), Ramla (G1), St. Marija (C2) and Ghar Lapsi (M6). LAI is highest at Ramla Bay (G1), Xatt l-Ahmar (G3) and Ghar Lapsi (M6) and lowest at Anchor bay (M4). Mean growth rate is highest at Ghar Lapsi (M6) and Xatt l-Ahmar (G3). The lowest mean growth rate is at Anchor bay (M4). Mean Rhizome production is highest at Xatt l-Ahmar (G3) and Ghar Lapsi (M6) and lowest at Anchor bay (M4).

Tab. 2: Mean phonological and lepidochronological descriptors.

Locations	Dens.	LAI	Mean growth Rate (mm/rhizome/year +-s.d.)		Mean Rhizome Pr.production rate (mgdw/rhizome/year +-s.d.)	
M1: St. Paul Islands	494.7	12.87	9.6	3.0	83.8	35.7
M2: Mellieha Bay	482.9	13.22	8.9	3.2	69.3	40.4
M3: L-Ahrax	471.1	13.77	9.3	3.7	71.1	52.9
M4: Anchor Bay	435.1	6.29	4.4	1.7	33.8	17.9
M5: Fomm ir-rih	503.6	14.20	10.5	2.9	84.7	29.4
M6: Gharlapsi	519.6	16.3	17.3	4.9	144.9	56.9
M7: Munxar Reef	331.1	8.23	6.1	2.0	57.4	26.0
M8: St./ George’s Bay	369.3	8.33	5.4	1.9	49.4	31.0
M9: Qalet Marku	627.6	16.14	12.6	4.8	116.8	64.0
M10: Qawra Point	461.3	15.89	8.2	3.0	64.2	26.1
G1: Ramla Bay	541.8	19.47	11.3	2.9	95.8	30.8
G2: Dwejra	583.1	11.55	8.9	3.9	52.7	26.6
G3: Xatt l-Ahmar	468.9	16.4	15.8	5.9	172.0	87.0
C1: Cominotto	517.8	15.6	13.7	5.0	112.5	55.6
C2: St. Marija Bay	532.9	15.45	10.4	2.3	84.6	31.3

Discussion

Results of *Posidonia oceanica* mapping show that meadows are widespread around the coasts of the Maltese Archipelago principally distributed on rock but wide matte structure are also present. These results are in agreement with those of previous data about *P. oceanica* meadows of Maltese Islands (Borg *et al*., 2002). The percentage cover is variable; several meadows appear continuous with no significant patches [M1, M2, M3, M6, M7, M8, M9, M10-refer to Tab. 1]; while the meadows around Gozo [G1,G2,G3] and Comino [C1, C2] and some Maltese meadows [M4 and M5] show a patch structure. Changes in meadow architecture had been observed in some areas, even prior to 2002 [Dimech *et al*., 2002] and some meadows have regressed or have been extirpated altogether [Borg & Schembri, 1995b; Schembri, 1995] The lepidochronological and phenological descriptors indicated that the meadows around the Maltese islands were generally healthy. Density values recorded for the various meadows belong to the normal density class (Pergent *et al*., 1995) except for Munxar Reef that was identified as sub-normal class, with a value of 331 shoots/m^2. Such a low density, at the Munxar reef, may be due to the high currents prevalent in the area, the geomorphology of the seabed and adjacent coast [which is of the more friable middle globigerina limestone type (Mifsud, 1995) and the nearby tuna pen, which may all be causing a greater physical stress on this meadow. However, most of the meadows show quite high densities e.g. at Qalet Marku (M9), Dwejra (G2), Ramla (G1), St. Marija (C2) and Ghar Lapsi (M6). LAI is frequently over 10 m^2/m^2 and quite comparable to values observed along the coasts of Sicily (Calvo *et al*., 1995). The meadows with the higher densities, also generally show higher LAI e.g. Ramla Bay (G1) and Ghar Lapsi (M6). The latter also show the highest mean growth rate and one of the higher mean rhizome production. LAI values, mean growth and mean rhizome primary production are lowest in Anchor bay (M4). Such low values may be due to the sewage outfall present in the area. A comparison with previous shoot density data, for the locality of Anchor Bay done in 1995 (Micallef, 1996) showed higher values than those reported in the present survey, while for certain areas, the latter are in agreement with most of the recent studies (Borg and Schembri, 1995 b; Borg *et al*., 2004).

Mean primary production estimates of orthotropic rhizomes of *P. oceanica* are consistent with the values reported in literature (Pergent-Martini and Pergent, 1994). However, 25% of the meadows have values of primary production that exceed those present in the Mediterranean Sea (Pergent-Martini and Pergent, 1994;1996) and show signs of a high degree of meadow vitality within the temporal range of investigation.

Acknowledgments

Thanks are due to Mr. Alfred Baldacchino (Environment Protection Directorate, Malta Environment and Planning Authority), Mr. Adrian Mallia and Mr. Michael Sant as the national leaders and coordinators of this project. The first author would also like to thank Saviour Formosa, Stephen Conchin, Ashley Farrugia and Carol Agius for their invaluable help in providing the ‘converted’ cartographic maps and other statistical data [% covers] pursuant to the analysis of the 2002 baseline survey.

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Monica MONTEFALCONE[1*], Carlo Nike BIANCHI[1], Carla MORRI[1], Andrea PEIRANO[2], Giancarlo ALBERTELLI[1]
[1] DipTeRis, University of Genoa, Corso Europa 26, 16132 Genoa, Italy
[2] ENEA, Marine Environment Research Centre (La Spezia, Italy)
e-mail: montefalcone@dipteris.unige.it

HUMAN DISTURBANCES AND PHASE SHIFT IN THE *POSIDONIA OCEANICA* ECOSYSTEM OF THE LIGURIAN SEA (NW MEDITERRANEAN)

Abstract

The conservation status of six Posidonia oceanica *(L.) Delile (Angiospermae, Posidoniaceae) meadows and the degree of substitution by other species was investigated by scuba diving in summer 2002 along the Ligurian coast (NW Mediterranean Sea). The values of the Conservation Index (CI), measuring the proportional amount of dead matte relative to live* P. oceanica*, evidenced a generalised state of regression and a wide habitat loss in virtually all of the six meadows. Potential substitutes for* P. oceanica*, namely, the other common Mediterranean seagrass* Cymodocea nodosa*, the Mediterranean green alga* Caulerpa prolifera*, and the invasive green algae* Caulerpa taxifolia *and* Caulerpa racemosa *were found within most meadows. The replacement of* P. oceanica *by these substitutes was measured using the Substitution Index (SI), related to the proportional cover of each substitute. Substitutes were ranked in order of their colonisation potential with respect to* P. oceanica. *The potential of a "phase shift" within Mediterranean seagrass meadows was identified and measured using a new combined index, the Phase-Shift Index (PSI).*

Key-words: *Posidonia oceanica,* Seagrass meadows, Environmental indices, Mediterranean Sea, Phase shift.

Introduction

Posidonia oceanica meadows form one of the most important and productive ecosystems in the Mediterranean Sea, playing a variety of ecological roles in coastal waters. *P. oceanica* meadows are today seriously threatened (Boudouresque *et al*., 2006): their location in shallow coastal waters makes them susceptible to environmental alterations resulting from human disturbances (e.g. land reclamation, eutrophication, trawling, pollution, pleasure boat anchoring).

For assessing the state of health of a *P. oceanica* meadow, Moreno *et al.* (2001) proposed a synthetic environmental index, the Conservation Index (CI), which measures the proportional abundance of dead matte relative to living *P. oceanica*. However, the CI does not discriminate between the dead matte of both natural (e.g. due to the water movement) and anthropic origin (Boudouresque *et al*., 2006).

Regressed meadows have been shown to be more prone to invasion by one or more of the potential substitutes for *P. oceanica* (Bianchi and Peirano, 1995; Montefalcone *et al*., 2006). The substitutes may be the other common Mediterranean seagrass *Cymodocea nodosa* (Ucria) Ascherson, the native Mediterranean green alga *Caulerpa prolifera* (Forsskål) Lamouroux and the two alien green algae *Caulerpa taxifolia* (Vahl) C. Agardh and *Caulerpa racemosa* (Forsskål) J. Agardh. The Substitution Index (SI) was therefore proposed to measure the amount of replacement of *P. oceanica* by these substitutes (Montefalcone *et al*., 2006).

Regression of *P. oceanica* meadows and re-colonization by the substitutes may lead to an ecosystem phase shift from the highly engineering *P. oceanica* (Molinier and Picard, 1952) throughout the earliest appearance of dead matte and to the establishment of substitutes having a lower engineering capacity than *P. oceanica* itself.

In this paper, the conservation status and the substitution of species were described in six *P. oceanica* meadows of the Ligurian Sea (NW Mediterranean) using the Conservation Index and the Substitution Index. A new index, the Phase-Shift Index (PSI), is here proposed to evaluate the potentiality of a phase shift in the seagrass ecosystem.

Materials and methods

The six *P. oceanica* meadows were chosen along the Ligurian coast (NW Mediterranean): Mortola (MO), off Capo Mortola; Gallinara (GA), around Gallinara Island; Cogoleto-Arenzano (CA), between Cogoleto and Arenzano; Pagana (PA), between Prelo and San Michele di Pagana; Manara (MA), off Punta Manara; Monterosso (MM), at Monterosso al Mare (Fig. 1).

The meadows were investigated in summer 2002 by scuba diving along transects. Four to ten transects were described for each meadow, according to its extent, for a total of 47 transects. Transects were positioned randomly within each meadow using a nylon line marked every 5 m laid perpendicularly to the shoreline and directed toward the coast, from the lower to the upper limit of the meadow; transects included, when present, the dead matte areas beyond the actual extent of living *P. oceanica*.

Swimming at about 1 m upon the bottom, two divers independently recorded every 10 m on a 20 cm x 30 cm PVC slate (Bianchi *et al.*, 2004) the percent cover, estimated by eye (Buia *et al.*, 2004), of living *P. oceanica*, dead matte, sand, rock, *C. nodosa*, *C. prolifera*, *C. taxifolia* and *C. racemosa*. The occurrence of dead matte buried by sand was always checked by hand digging.

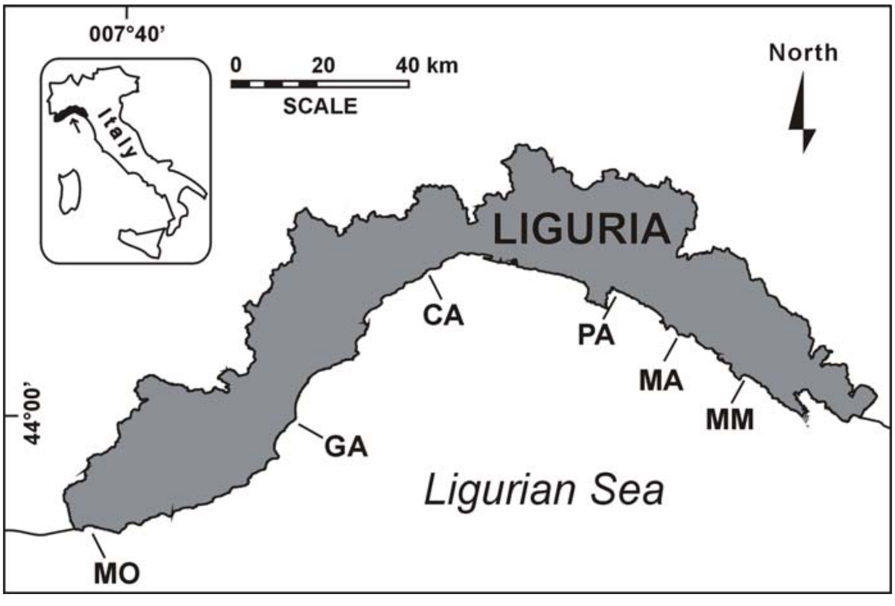

Fig.1: Geographic location of the six meadows studied: Capo Mortola (MO), Gallinara (GA), Cogoleto-Arenzano (CA), Prelo-San Michele di Pagana (PA), Punta Manara (MA), Monterosso (MM).

Based on percent cover data, the Conservation Index (CI) and the Substitution Index (SI) were computed for each transect and then averaged over the whole meadow.

CI is expressed by the formula $CI = P/(P+D)$, where P is the percent cover of live *P. oceanica* and D is the percent cover of dead matte (Moreno *et al.*, 2001). SI is expressed by the formula $SI = S/(P+S)$, where P is the percent cover of live *P. oceanica* and S is the percent cover of the substitutes (Montefalcone *et al.*, 2006).

Based on literature (De Gaillande, 1970; Bianchi and Peirano, 1995; De Villele and Verlaque, 1995; Ruitton *et al.*, 2005; and references therein), a different degree of colonization potential was assigned to the four substitutes and a hierarchical scale, representing six states of the *P. oceanica* meadow, was introduced (Fig. 2): state 0 was assigned to a healthy meadow, state 1 to the occurrence of dead matte, state 2 to the substitution by *C. nodosa*, state 3 to the substitution by *C. prolifera*, state 4 to the substitution by *C. taxifolia*, and state 5 to the substitution by the most invasive *C. racemosa*. This six-point scale must not be interpreted as the sequence of a secondary succession in *P. oceanica* meadows, but it simply ranks the six states of the meadow according to their gravity: the substitution by a highly invasive species should be considered worst than one by a less invasive species.

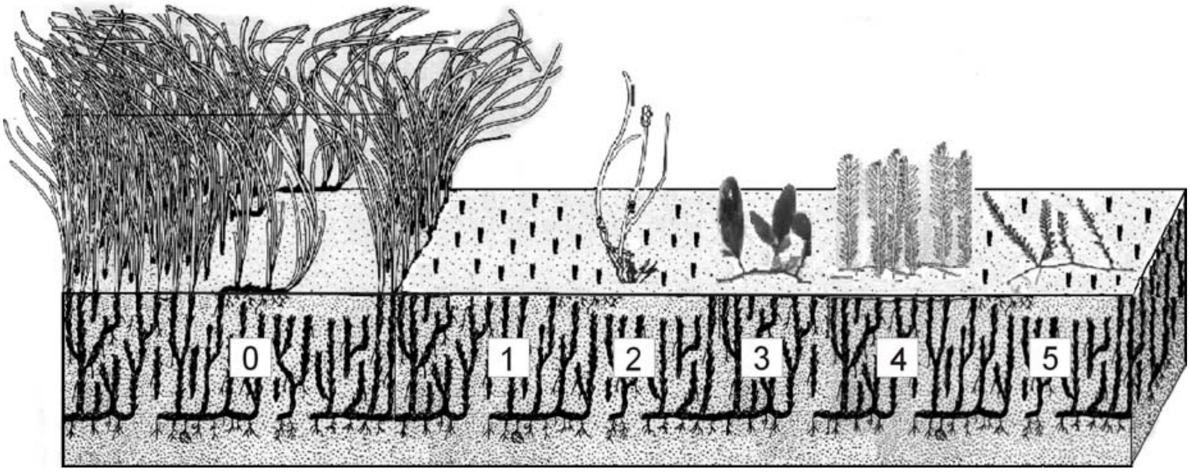

Fig. 2: The six-point scale representing the states of the* Posidonia oceanica *meadow.

This hierarchical scale was combined together with the Conservation Index and the Substitution Index in order to elaborate the Phase-Shift Index (PSI), expressed by the formula:

$$PSI = \{[(1-CI) \cdot 1] + (SI_{Cn} \cdot 2) + (SI_{Cp} \cdot 3) + (SI_{Ct} \cdot 4) + (SI_{Cr} \cdot 5)\}/6$$

where CI is the Conservation Index, SI_{Cn} is the Substitution Index for *C. nodosa*, SI_{Cp} for *C. prolifera*, SI_{Ct} for *C. taxifolia*, and SI_{Cr} for *C. racemosa*. The Phase-Shift Index ranges from 0 (healthy meadow, no dead matte and no substitution) to 1 (when the phase shift had lead to complete substitution by *C. racemosa*).

The following absolute scale for the Phase-Shift Index was finally proposed.

1. PSI > 0 and < 0.08: either the meadow begins to show dead matte areas (however < 50 %) or the percent cover of substitutes, if any, is low; phase shift is therefore still in an early stage.

2. PSI between 0.08 and 0.16 excluded: either the dead matte is dominant (dead matte between 50 % and 100% excluded) or the substitutes cover significant portions of the meadow; phase shift is moderate.
3. PSI between 0.16 and 0.25 included: either the living *P. oceanica* is absent (dead matte = 100%) or the substitutes are very abundant; the level of phase shift is advanced.
4. PSI between 0.25 and 0.5 included: dead matte is always abundant and one or more substitutes are always present and may be dominant; the phase shift is strong.
5. PSI > 0.5: dead matte is always dominant (> 50 %) and either one or more substitutes are always dominant (> 50 %) or have completely replaced the living *P. oceanica*; the phase shift is very strong and could be irreversible.

Results

Conservation status varied greatly according to the individual meadows (Fig. 3 a). Mean CI values ranged from 0.49 (Pagana) to 0.85 (Mortola).

All the four potential substitutes for *P. oceanica* were found in the meadows studied, with mean SI values ranging from 0.06 (Pagana) to 0.28 (Gallinara) (Fig. 3 b). The three westernmost meadows showed the highest degree of substitution, with two substitutes each: *C. nodosa* and *C. taxifolia* at Mortola and Gallinara, *C. nodosa* and *C. racemosa* at Cogoleto-Arenzano. The lowest degree of substitution, by *C. prolifera*, was observed in Pagana meadow, whereas no substitution at all was observed in the two easternmost meadows, i.e., Manara and Monterosso.

Gallinara meadow exhibited a strong phase shift (class 4), with high amount of dead matte re-colonized by *C. nodosa* and/or *C. taxifolia* (Fig. 3 c). The abundance of the same two substitutes determined an advanced phase shift (class 3) at Mortola meadow, notwithstanding the comparatively scarce amount of dead matte. At Cogoleto-Arenzano and Pagana meadows, phase shift was moderate (class 2) and due to both the great amount of dead matte and the low replacement by *C. nodosa* and *C. racemosa* (in the former) or *C. prolifera* (in the latter). Finally, the two easternmost meadows, namely Manara and Monterosso, showed at most an early stage of phase shift (class 1) because of the occurrence of dead matte but of no substitutes yet.

Discussion

CI values were consistent with the basin-wide regressive status for most of the Ligurian *P. oceanica* meadows observed with other approaches during previous large-scale analyses (Bianchi and Peirano, 1995). The use of CI as a synthetic measure of the status of *P. oceanica* seems to be effective in Ligurian Sea meadows, where the occurrence of dead matte areas have already been supposed to be the result of a number of human-induced disturbances that hit the coast of Liguria mostly in the 1960s (Peirano *et al.*, 2005).

Even if the settlement by an individual substitute is to be seen more as a historical episode than as an ecological consequence, the on-going process of substitution, as evidenced by the SI values, seems to be facilitated especially in those meadows that underwent greater regression by cause of human disturbances (Montefalcone *et al.*, 2006; Montefalcone *et al.*, 2007).

PSI values suggested the generalised occurrence of a phase shift in Ligurian Sea meadows. In their pioneer study on Mediterranean seagrasses, Molinier and Picard (1952) already observed that *C. nodosa* may follow *P. oceanica* along a regressive series. The replacement of a “constructional” species like *P. oceanica* by “non-constructional” species like *C. nodosa* and/or the three algae of the genus *Caulerpa* may be seen as a significant community change. A phase shift already begins with the appearance of large areas of dead matte. Dead matte, if not eroded nor buried by sediment, may remain uncolonized or be re-colonized by any of the potential substitutes, thus advancing the level of the phase shift, rather than by *P. oceanica* itself. *P. oceanica* has an extremely low recolonization capacity, so that the recovery of its meadows may require centuries (Meinesz *et al.*, 1991). If it still exists a potentiality of recovery in a meadow showing few and small dead matte areas, a large-scale loss of *P. oceanica* must therefore be considered almost irreversible on human-life time scales. On the contrary, the comparatively fast growth of the substitutes (Borum *et al.*, 2004; Ruitton *et al.*, 2005), can make them to persist in the long term over human-life scales.

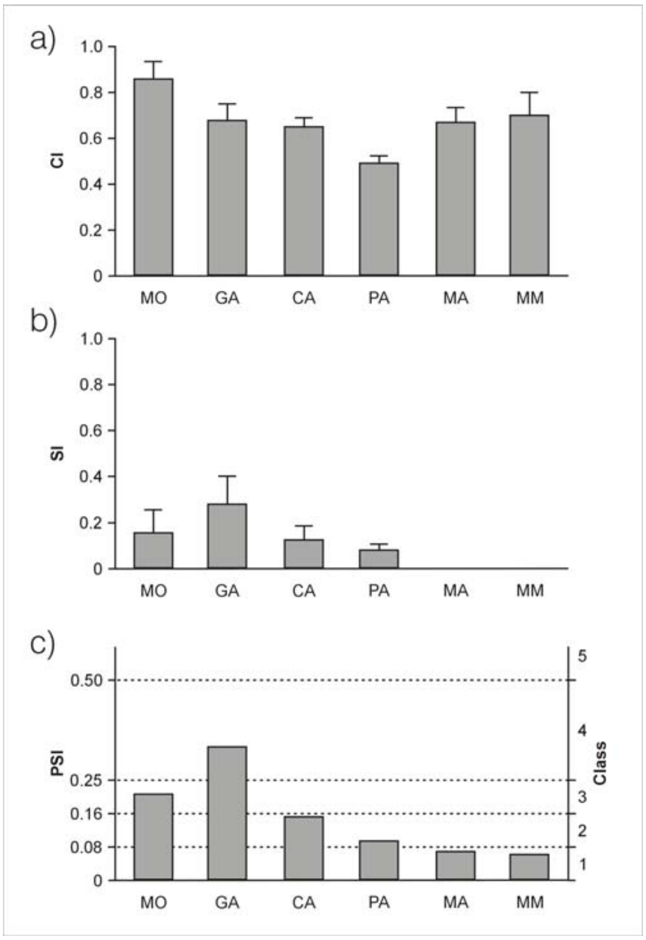

Fig. 3: Mean values (+ se) of the Conservation Index (CI) (a) and of the Substitution Index (SI) (b) and values and classification of the Phase-Shift Index (PSI) (c) in the six* Posidonia oceanica *meadows studied.

Acknowledgments

This work was partially done within the framework of RIPO Project (Italian Ministry for the Environment and CoNISMa).

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Hesham M MOSTAFA[1], Soha Hamed SHABAKA[2], Hanan Mahmoud MITWALLY[1], Yousef HALIM[1]
[1] Department of Oceanography, Faculty of Science, University of Alexandria, EGYPT
[2]National Institute of Oceanography and Fisheries, Alexandria, EGYPT, e-mail: htheprof@yahoo.com

PHENOLOGY AND GROWTH DYNAMICS OF THE SEAGRASS *CYMODOCEA NODOSA* IN THE BAY OF MONTAZAH (EAST OF ALEXANDRIA, EGYPT)

Abstract

Samples of Cymodocea nodosa *are collected every two months during February 2002 to December 2002 from large meadow located within Montazah Bay, Alexandria, Egypt. Different physico-chemical parameters are measured as well as seagrass phenological parameters and associated epiphyte. In general the maximum values of phenological parameters are recorded in late spring (June) and minimum values in winter. Rhizome-root biomass showed an opposite trend. Among the important environmental factors controlling the biomass and abundance of* C. nodosa *are temperature, salinity, light and nutrient concentrations in sediments. In conclusion, although light and temperature are the major factors controlling seasonal growth of* C. nodosa*, during summer, growth is limited by other factors: mainly self-shading and nutrient limitation.*

Key-words: Seagrass meadows, *Cymodocea nodosa,* Montazah, Alexandria, Egypt.

Introduction

The presence of the two pioneer species of Seagrasses *Posidonia oceanica* and *Cymodocea nodosa* along the Egyptian Mediterranean waters is largely documented (Steuer, 1935; Aleem, 1955; Mostafa, 1996). Along the coastal waters of Alexandria, the seagrass meadows of both seagrass species have been badly damaged due to uncontrolled point-sources of pollution mainly sewage and non-point sources of domestic and agricultural runoff (Mostafa, 1996). As a result, seagrasses beds are reduced to scattered patches in inshore semi-closed bays (Mostafa, 1997).

Material and Methods

Cymodocea nodosa was Scuba sampled every two months (three replicates) during February 2002 to December 2002 from large meadow located within Montazah Bay, Alexandria, Egypt (Fig. 1). Physico-chemical parameters were measured in conjunction with seagrass phenological parameters (Leaf density, leaf biomss, shoot density, rhizome-root biomass and epiphytic area, salinity, temperature, pH, TOM and dissolved inorganic nutrients).

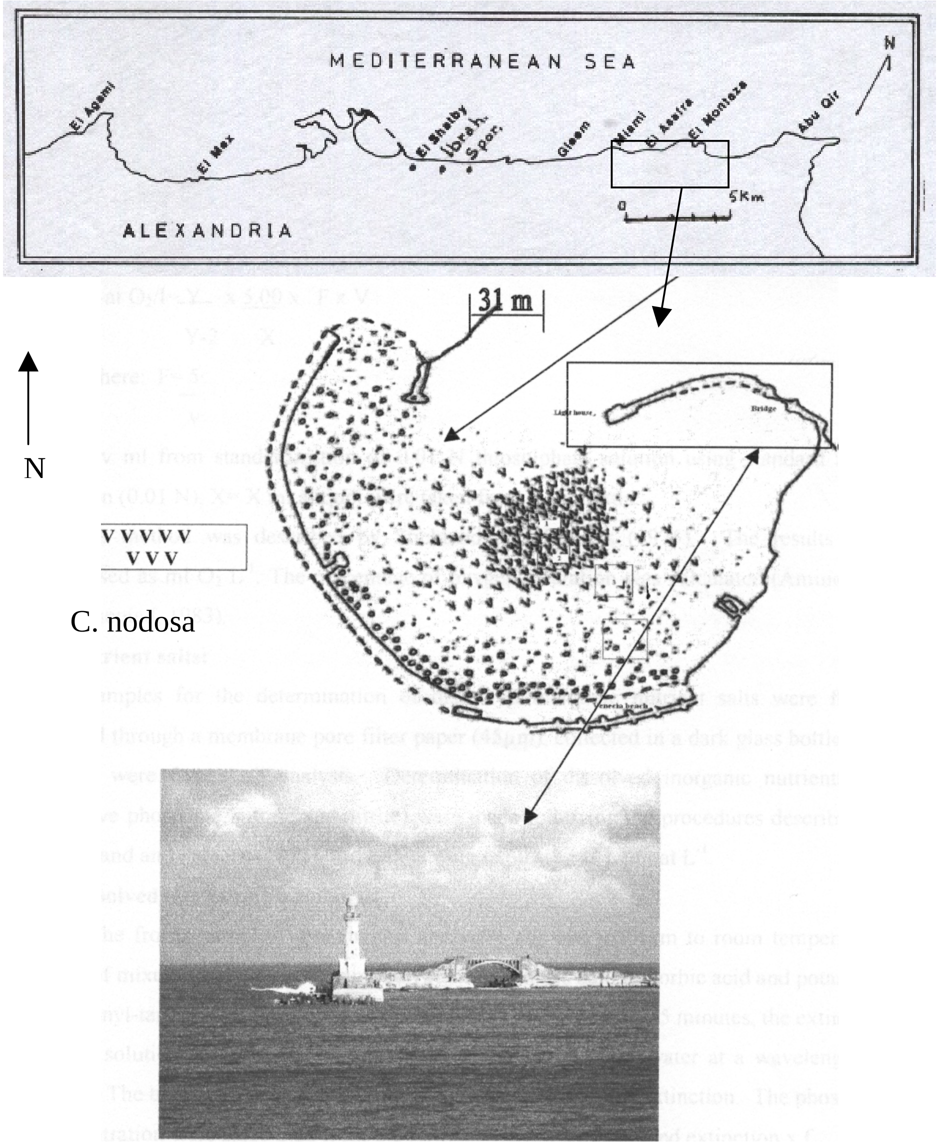

Fig. 1: Showing the sampling site of Montazah bay, East of Alexandria-Egypt.

Results and Discussion

Table 1 summarizes the Physico-chemical parameters during the study period.

Growth of C. *nodosa is* continuous throughout the year with a unimodal cycle. Its foliage started to increase toward spring and became particularly dense in late spring (June), with maximum recorded shoot density (131shootsm^{-2} ± 44) and leaf density (368 leafm^{-2} ± 473). These values decreased towards summer. Minimum shoot and leaf densities were recorded during winter (52 shoot m^{-2} ±8, 113 leaf m^{-2} ±13). Table 2 summarizes the different phenological parameters measured during the present study. Leaf area index, leaf length, epiphytic area, photosynthetic area and leaf biomass showed the same cyclic pattern as shoot and leaf densities.

Tab.1: Physico-chemical parameters during the study period.

Month		Mg O_2 l^{-1}	Salinity (‰)	pH	Reactive P µ gm at l^{-1}	Nitrate µ gm at l^{-1}	Nitrite µ gm at l^{-1}
Feb-02	Mean	8.06	36.71	8.21	0.43	4.93	0.26
	St D	0.09	0.10	0.02	0.25	0.23	0.06
Apr-02	Mean	6.85	36.71	8.14	0.25	0.99	0.20
	St D	0.13	0.20	0.04	0.11	0.03	0.04
Jun-02	Mean	6.57	36.89	8.34	0.37	0.76	0.14
	St D	0.16	0.25	0.10	0.07	0.29	0.10
Aug-02	Mean	6.75	38.78	8.10	0.29	0.67	0.24
	St D	0.42	0.05	0.11	0.02	0.28	0.07
Oct-02	Mean	6.55	39.13	8.12	0.70	3.39	0.39
	St D	0.47	0.10	0.01	0.00	0.13	0.04
Dec-02	Mean	7.21	38.31	8.43	1.08	6.84	1.03
	St D	0.22	0.15	0.06	0.21	1.79	0.09

Tab.2: Different phenological parameters measured during the present study. (LAI= Leaf area index); (PA= Photosynthetic Area); (EA=Epiphytic area).

Month		Shoot density	Number leaf shoot	Leaf density	LAI (m2.m2)	PA (m2.m2)	EA (m2.m2)	Leaf biomass	Rhizome & root biomass
Feb-02	Mean	53.33	2.44	132.00	0.04	0.02	0.01	1.63	23.43
	St D	11.55	0.21	38.16	0.01	0.01	0.00	0.80	5.75
Apr-02	Mean	93.33	3.67	348.00	0.23	0.15	0.08	6.80	18.15
	St D	30.55	0.25	133.63	0.13	0.09	0.04	4.30	4.05
Jun-02	Mean	130.67	3.78	473.33	0.70	0.40	0.30	18.76	4.69
	St D	43.88	0.73	94.85	0.34	0.19	0.16	5.76	1.93
Aug-02	Mean	68.00	3.08	208.00	0.16	0.08	0.08	5.02	15.19
	St D	20.00	0.15	52.46	0.06	0.03	0.03	1.50	2.06
Oct-02	Mean	60.00	2.53	153.33	0.08	0.03	0.05	3.12	21.83
	St D	14.42	0.15	43.88	0.03	0.01	0.02	1.29	5.24
Dec-02	Mean	52.00	2.19	113.33	0.04	0.03	0.01	1.63	22.76
	St D	8.00	0.15	12.86	0.01	0.01	0.00	0.68	4.47

Rhizome-root biomass showed an opposite cyclic pattern to the other phenological parameters, where maximum values were recorded during winter (23.4gm dwm^{-2} t6), and minimum values recorded June (4.7gm dwtn^{-2}±2). Principal component analysis was used for "*C. nodosa* phenological-physicochemical parameters relationship".

Plotting PCl against PC2 (Fig. 2) revealed that phenological parameters of the foliar system had positive correlations with temperature and PH, and negative correlations with dissolved nutrients and salinity and insignificant correlation with total sediment organic matter (TOM).

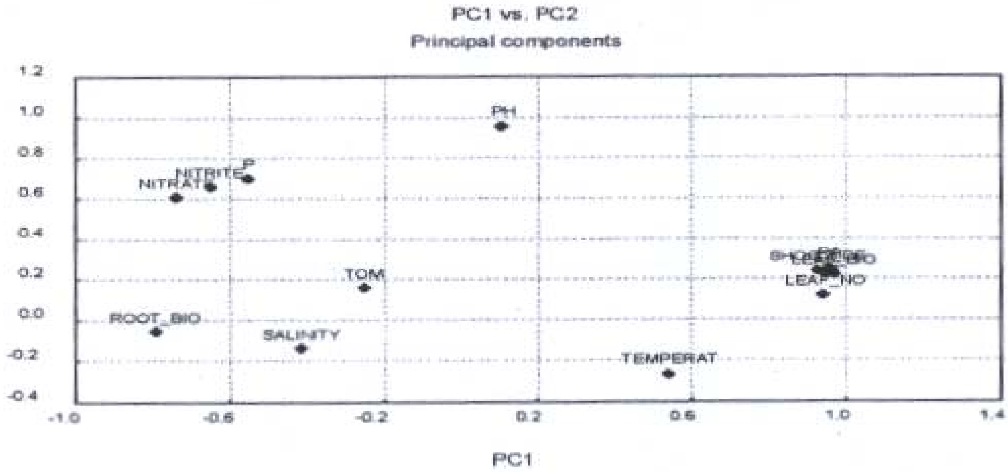

Fig.2: Components loading matrix of phenological and physico-chemical parameters.

Root-rhizome biomass showed completely opposite correlations to those of the foliar system. Seasonal variation of the foliar system of C. *nodosa* could probably be related to changes in temperature and light availability.

Changes in temperature over the year seem to play an important role in the reproduction cycle of C. *nodosa,* which influence the leaf growth and production (Buia and Mazzella, 1991). In the meadow under study, a male flower and seeds were recorded at the end of April.

It seems to be that seeds were dormant, buried in the sediment until germination started in April, coinciding with the rise in water temperature. It was observed that the potential production set by the incoming irradiance and water temperature was not met during summer. This deviation may be attributed to the following reasons: a) Increased epiphytic growth on plant leaves in late spring, b) Self-shading by the plants where maximum leaf length was recorded during late spring. c) Higher turbidity observed in the bay during summer d) Nutrient limitation of summer growth, where minimum dissolved nutrient concentrations was recorded during late spring.

This may be attributed to the active consumption of the seagrass to the dissolved nutrients. The reduction of salinity due to intrusion of fresh water that may carry high concentrations of dissolved nutrients caused the initiation of the foliar system growth in late winter. The opposite correlation between the underground biomass and foliar system biomass may be attributed to the dependence of the rhizome and roots on the extensive foliar system biomass during their growing season in absorption of the nutrients from the surrounding water. After the collapse of the foliar system that occurred in the summer season, rhizome and root system started to increase in biomass to compensate the reduction of dissolved nutrients in seawater by absorption of the nutrients from the sediments.

The sediment is the main source for phosphorus in carbonate sediment seagrasses, the acquisition of phosphorus by both seagrasses *P oceanica* and *C. nodosa* might be limited by sparse supply in water column and their ability of speeding up the uptake of phosphorus from the sediments (Mostafa, 1997). In Montazah Bay, turbidity caused by water sports and seagrass damaging are a threat to seagrass meadows. Despite these destructive factors, *C. nodosa is* a eurybiontic species tolerates considerable fluctuations in environmental variables. This may explain the dominance of *C. nodosa* over the *P. oceanica* when the conditions are unfavorable for the stenobiontic *P oceanica* (Den Hartog, 1970).

Cymodocea nodosa *epiphytic associations*

Among the main floral epiphytes the blue green algae that was represented with the following species: *Anacystis aeruginos* and *Oscillatoria lutea*. The green algae was represented with *Cladophora socialis, Entocladia Jtustrae* and *Ulvella len*. The species of brown algae were: *Giraudia sphacelarioides* and *Myrionema orbiculare*. Red algae showed the higest sepcies abundance: *Audouinella thureiii, A. virgatula, Bangia atropurpurea, Chroodactylon ornatum, Erythrocladia carnea, Nydrolithon farinosum, Melobesia membranacea, Pneophyllum fragile kuetzing, Porphyrostrotnium ciliare, Sahlingia subintegra, Stylonema aslidii* and *S. cornucervi*.

Acknowledgement

The authors wishes to thank Prof. Giusppe Giaccone for the identification of epiphytes.

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Gérard PERGENT[1], Aslam DJELLOULI[2], Abdulmaula Abdelmajed HAMZA[3], Khaled Salem ETTAYEB[4], Ali ALKEKLI[3], Mustapha TALHA[5], Esmaeel ALKUNTI[6]
(1) EqEL, Faculty of Sciences, University of Corsica, 20250 Corte, FRANCE, pergent@univ-corse.fr
(2) University of Tunis-Manar, Tunis, TUNISIA
(3) Environment General Authority, Tripoli, LIBYA
(4) University of Alfateh, Tripoli, LIBYA
(5) Marine Biology Research Centre Tajura, LIBYA
(6) Environment General Authority, Benghazi, LIBYA

STRUCTURE OF *POSIDONIA OCEANICA* MEADOWS IN THE VICINITY OF AIN AL-GHAZALA LAGOON (LIBYA): THE "MACROATOLL" ECOMORPHOSIS

Abstract

The first investigations carried out in Ain Al-Ghazala, a sector of the eastern coast of Libya, revealed a very well preserved environment, presenting a large diversity of benthic populations associated with a biological wealth that is exceptional. The marine magnoliophyta Posidonia oceanica *mainly develops at the entrance of the lagoon in direction of the island of Elba. It forms atoll-shaped structures that can be several dozen metres in diameter, and which emerge when the tide is low. In principle these can be compared to "microatolls"; the difference being that they are here incredibly extensive, and form natural monuments that have never been described before in the Mediterranean. The dynamics of these "microatolls", in conjunction with the fact that* Posidonia oceanica *grows very slowly, suggest that these structures started to form themselves several hundreds of years ago.*

Key-words: Libya, Magnoliophyta, *Posidonia oceanica,* Structure, Dynamics.

Introduction

This study is part of a project of the Action Plan for the Conservation of Marine Vegetation in the Mediterranean Sea, adopted at the 11th Ordinary Meeting of the Contracting Parties to the Barcelona Convention (Malta, October 1999) and implemented by the Regional Activity Centre for Specially Protected Areas (United Nations Environment Programme – Mediterranean Action Plan). Bearing in mind the length of Libya's coastline (over 2,000 km), and the supposed presence of vast meadows of marine and lagoon magnoliophyta, the Regional Activity Centre for Marine Protected Areas, in partnership with the Libyan Government, initiated several assignments along this coastline. After the study on Farwa Lagoon (west coast, Pergent *et al.*, 2001), it seemed necessary to acquire information on another site of major ecological interest, the Ain Al-Ghazala lagoon (east coast).

Marine magnoliophyta meadows, particularly *Posidonia oceanica* meadows, constitute specific structures according to the environmental conditions (depth, light, hydrodynamics, sedimentation); several morpho-structural types are described in the literature on the subject (Boudouresque *et al.*, 2006). Among these structures, two are identified as « threatened marine landscapes » in the Gérard Vuignier Red Book on threatened plants, populations and landscapes in the Mediterranean, edited by the United Nations Environment Programme (Boudouresque *et al.*, 1990): the barrier reefs and the striped meadows. These *Posidonia oceanica* meadow structures are both fairly shallow (between the surface and 4-5 metres depth), and for this reason are particularly vulnerable to the impact of human activity. Although barrier reefs have been described throughout the Mediterranean (Spain, France, Italy, Turkey, Egypt, Tunisia, Algeria), striped meadows on the other hand have only been reported in the southern area of the basin ,and in particular around the Kerkennah Islands in Tunisia

(Boudouresque *et al.*, 1990). "Microatolls" are originally formed from a very shallow, more or less circular, patch; as the meadow develops, the central part dies away while the outside ring grows, producing a crown of 3-6 metres in diameter (Boudouresque *et al.*, 2006).

In the context of the investigations carried out on the coastline of Ain Al-Ghazala, we were mainly interested in collecting information on the distribution and structure of the main plant formations in the area, in particular regarding the marine magnoliophyta meadows.

Material and methods

The scientific fieldwork took place from the 7th to the 12th of May 2006.

Seven transects were placed within the lagoon, in direction of the island of Elba; more precise investigations were also carried out at the entrance of the lagoon on a specific area of major ecological interest (Fig. 1). This fieldwork enabled the main populations and types of substrate to be identified and precisely located (GPS Garmin 276C).

The field data was transferred onto a SPOT 5 satellite image with a 2.5 m resolution, taken on the 10th of March 2006 at 9.24 a.m., in order to map the main populations and types of seabed. To this end, image processing was done with Multiscope (Matra Cap Systemes ©) software according to the protocol of Pasqualini *et al.* (1997) – dynamic adaptation, analysis into main composants, classification by generalized hypercube from the training plots, homogenization and surface calculation. For the parts of the image that were hidden by dead *Posidonia oceanica* leaves (litter), the use of Google Earth 2006 pictures was very useful before going on to a manual extrapolation using Photoshop (Adobe©) software.

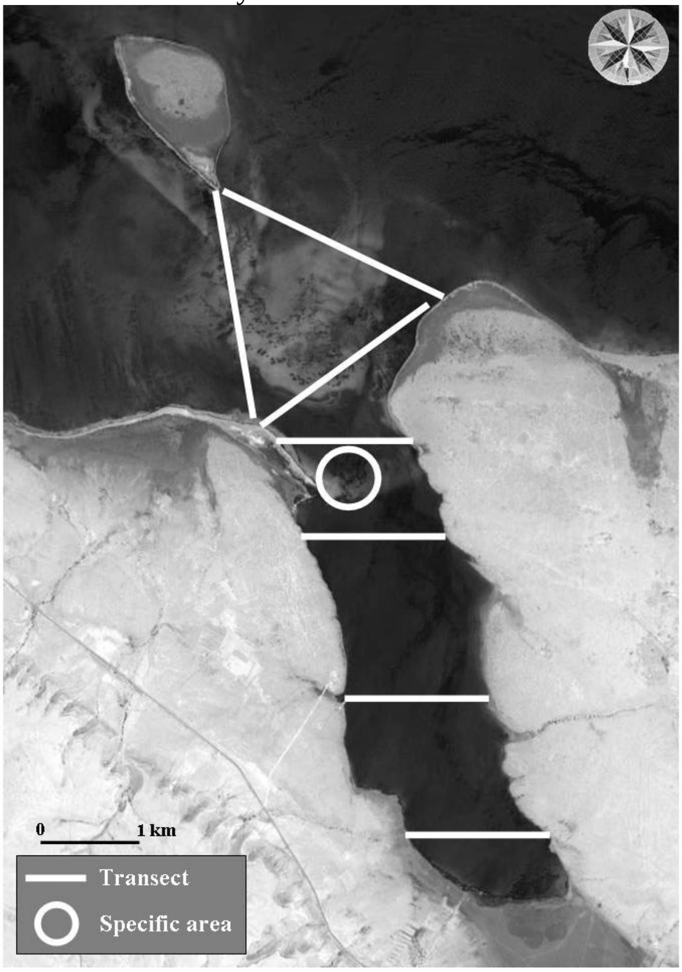

Fig. 1: Locating the investigations carried out in the Ain Al-Ghazala sector (Google Earth 2006)

Results and discussion

The investigations carried out in the Ain Al-Ghazala lagoon and out at sea up to the island of Elba allowed to draw a first map of the main populations and substrate types (Fig. 2) present, and it revealed three main plant formations:

- the *Cymodocea nodosa* meadow that covers most of the bed of the lagoon,
- the *Posidonia oceanica* meadow that is present at the mouth of the lagoon and in open sea,
- the photophilous populations on the edges of rocky shores.

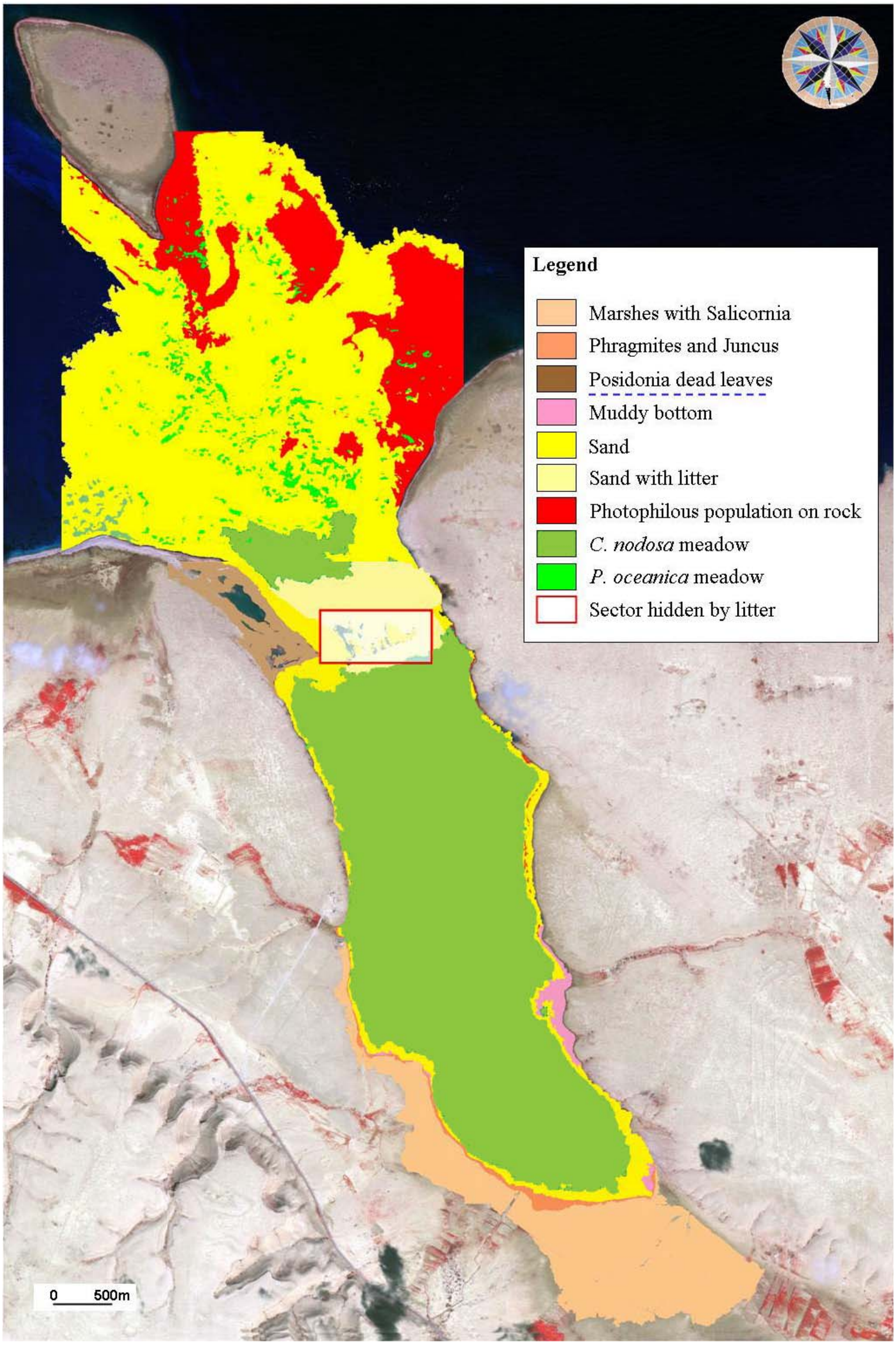

Fig. 2: Map of the main populations and substrate types in the Ain Al-Ghazala lagoon.

Due to its sensitivity to low salinity (salinity is lowered in winter by small coastal rivers) and to high temperatures, *Posidonia oceanica* is absent from the Ain Al-Ghazala lagoon, which has the characteristics of an enclosed environment. This plant in fact, is only found at the entrance of the lagoon (north) and in open sea (in direction of the island of Elba). The *Posidonia oceanica* meadow can be found in three distinct forms: (i) meadow on rocks, (ii) meadow on deeper matte, and (iii) atolls, generally emerging at low tide.

The *Posidonia oceanica* meadow develops on a rocky substratum, mainly to the north-east of the entrance to the lagoon and around the island of Elba (Fig. 2). These two sectors are vast superficial rocky areas, mainly covered by a photophilous population on rocks, characterized by an important presence of *Cystoseira mediterranea*, alternated by a few local patches of *Posidonia oceanica* with relatively short leaves. East of the island of Elba the depth increases (4 to 5 metres) and the meadow shows a more “traditional” development on matte. At greater depths, the *Posidonia oceanica* meadows probably cover considerable areas, as suggested by the accumulation of dead leaves along the coast and around the island of Elba. These banks of dead *Posidonia oceanica* leaves are several dozen metres wide and often over one meter high. As well as offering protection against erosion, these formations are also the basis of a specific trophic chain that is rich in detritus-eating crustaceans (Bellan-Santini *et al.*, 2003 ; Boudouresque *et al.*, 2006). Furthermore, on the island of Elba, such banks of dead leaves are used by the yellow-legged gull (*Larus michahellis*) for nesting. The eggs and chicks have a protection (homochromy) that is extremely useful against predators.

Posidonia oceanica atolls have been identified at the entrance of the Ain Al-Ghazala lagoon (Fig. 3) and in the direction of the island of Elba (Fig. 4).

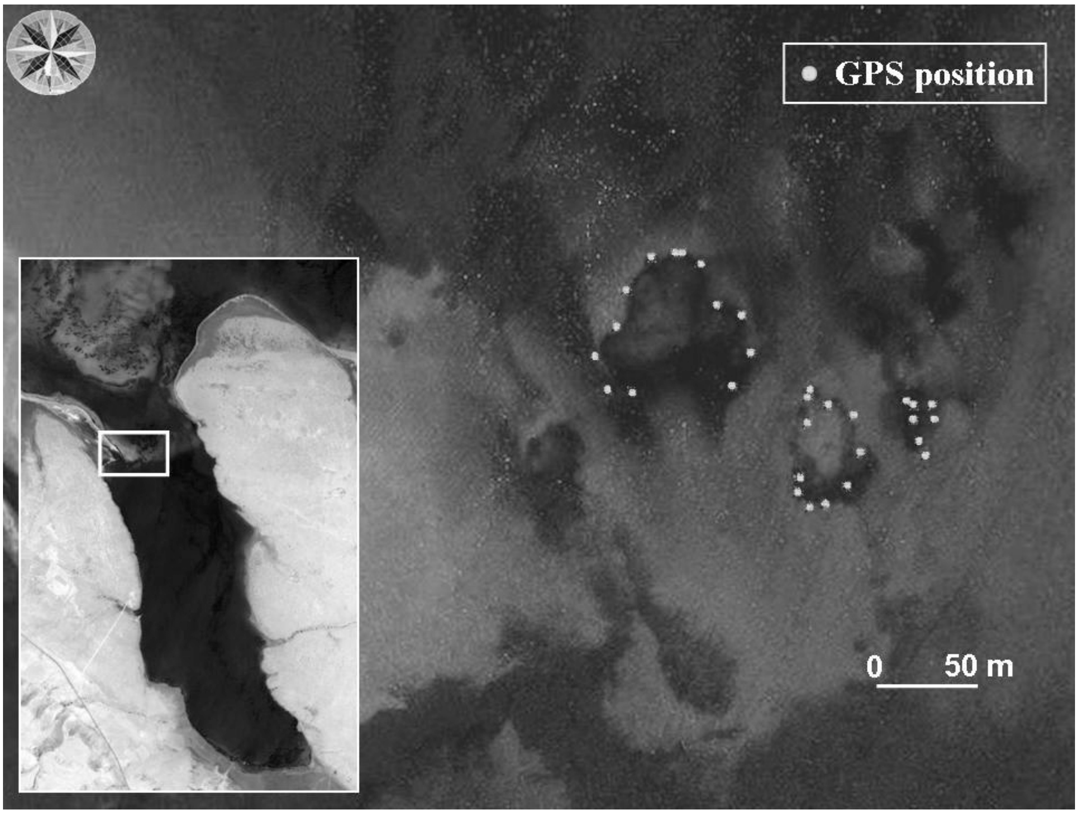

Fig. 3: GPS location of* Posidonia oceanica *atolls at the entrance of the Ain Al-Ghazala lagoon (GoogleEarth 2006).

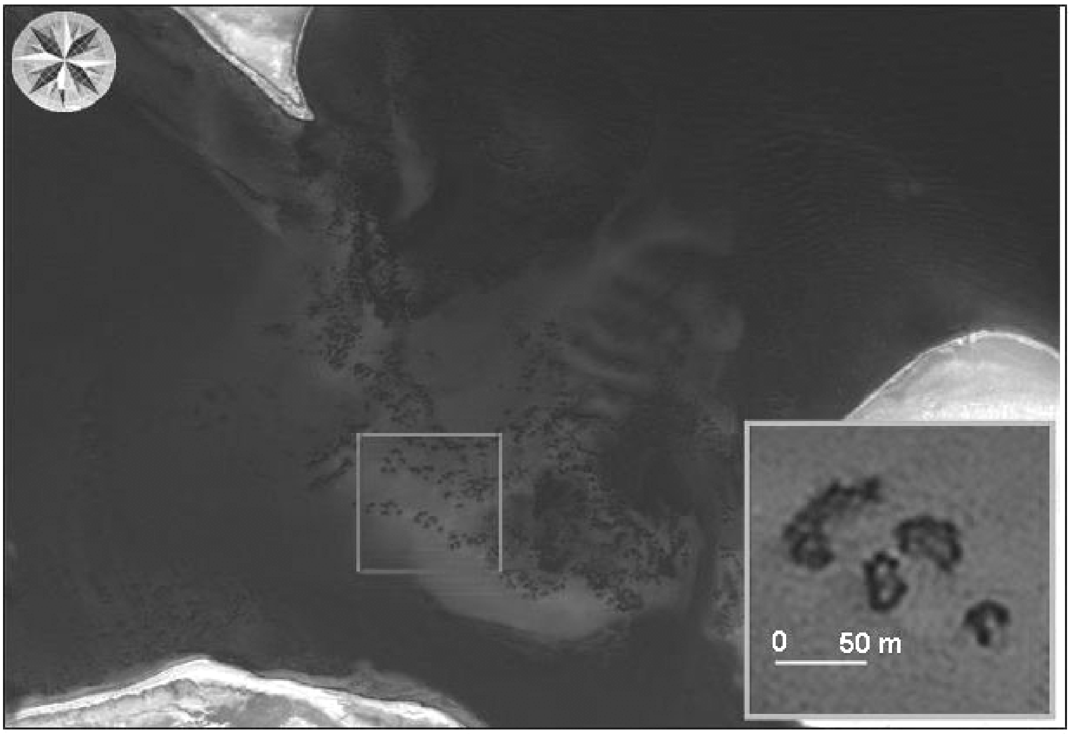

Fig. 4: Structure of* Posidonia oceanica *atolls between the island of Elba and the Ain Al-Ghazala lagoon (SPOT Image 2006).

These formations are particular because of their size and the structure of their crown. Indeed usually atolls are hardly larger than a few metres in diameter, whence the term "microatolls". Here, in this case, they are uniquely extensive: the diameter of these atolls is on average 20-30 metres and can reach almost 70 metres in several sectors (Fig. 3 and 4). Furthermore, the crown that forms these atolls can itself be made up of several "microatolls", which can be criss-crossed by "channels" that may be up to one or two metres wide. The presence of patches and atolls of various sizes and at different evolutionary stages, as described by Boudouresque *et al* (2006), seems to corroborate the hypothesis that the dynamics of these formations are similar to other "microatolls" observed in several parts of the Mediterranean. However, the size of many of these structures implies that their development, in all likelihood, took place over several centuries, or even thousands of years ago.

The growth of the rhizomes of this magnoliophyta is relatively low (a few centimetres per year in optimum conditions, *in* Caye, 1980) and there are regular phases of advance and decline in the building up of a meadow (Mateo *et al.*, 1997). Although the observations made at Ain Al-Ghazala confirm that the outside of the crown really is made up in great part of plagiotropic rhizomes, even colonizing the substratum, several sectors present obvious signs of decline (dead shootss). What is more, the violence of the currents between the channels when the tide changes, and the hydrodynamics, encouraged by the shallowness, are likely to slow down the advance of the meadow. Starting from a theoretical growth of plagiotropic rhizomes of approximately 5 cm per year, the dynamics of the biggest atolls observed, that are some sixty metres in diameter, probably started at least 600 years ago. This however would be relative to an optimum continuous advance of the meadow, in the absence of any episode of decline.

The presence of such structures that are unique in the Mediterranean, and whose destruction would be irreversible given the time required for their developement, enhances the ecological interest of the Ain Al-Ghazala site from the point of view of the conservation of marine vegetation in the Mediterranean Sea. Although at present no specific threat seems to hang over these atolls, due to the isolation of this site and the small numbers of activities carried out in the area, the setting up of a structure to protect these natural monuments must be a priority.

Acknowledgements

This work was done in the context of the Memorandum of Understanding concluded, between the Environment General Authority of Libya (EGA) and the Regional Activity Centre for Specially Protected Areas (RAC/SPA). It takes place with a global approach focussing on the inventory and characterization of the most important seagrass meadows in Libya (MedPosidonia Program, granted by Fondation d'Entreprise Total pour la biodiversité et la mer). The authors wish particularly to thank the SPOT Image Company and the ISI programme (Encouragement for the Scientific Use of SPOT Images) for the acquisition of satellite pictures without which the project could not have been carried out.

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Gérard PERGENT[1], Christine PERGENT-MARTINI[2], Bérangère CASALTA[3], Cecilia LOPEZ Y ROYO[1], Benoit MIMAULT[3], Maylis SALIVAS-DECAUX[1], Frederick SHORT[4]
[1] EqEL, Faculty of Sciences, University of Corsica, 20250 Corte, FRANCE
e-mail: pergent@univ-corse.fr
[2] RAC-SPA, Boulevard du Leader Yasser Arafat, BP 337, 1080 Tunis cedex, TUNISIA
[3] GIS Posidonie – Corsica Agency, Faculty of Sciences, University of Corsica, 20250 Corte, FRANCE
[4] Jackson Estuarine Laboratory, University of New Hampshire, 85 Adams Point Road, Durham, New Hampshire 03824, USA

COMPARISON OF THREE SEAGRASS MONITORING SYSTEMS: SEAGRASSNET, "POSIDONIA" PROGRAMME AND RSP

Abstract

Three different Posidonia oceanica *monitoring systems have been set up in the bay of Calvi (Corsica). The aim of this study is to define the reference conditions of the meadow (status zero) in this area and to compare the different protocols and descriptors used. These different programmes should allow us to monitor, in the long term, the evolution of the* Posidonia oceanica *meadows' status (extension, quality) and/or to use this seagrass as biological indicator of the overall water quality. The advantages and limits of these different approaches are analysed with the purpose of optimising the tools available for an overall monitoring strategy of the mediterranean basin.*

Key-words: *Posidonia oceanica*, Monitoring network, Corsica.

Background

Many monitoring networks today, in different regions of the biosphere, are based on the use of organisms. This is the case of “Mussel Watch”, a monitoring network based on molluscs, developed and in use in the USA since 1986 (Goldberg and Bertine, 2000), later extended to many Mediterranean countries (CIESM, 2002) or of “Seagrass Watch” based on the use of seagrass (McKenzie *et al.*, 2000). The latter international monitoring programme studies the state of seagrass meadows around the world, as well as the threats that weigh on these ecosystems. Initiated in 2001 in the Western Pacific, it is composed of 48 sites in 15 countries. It is based on a standardised protocol which may be applied in different regions of the biosphere (Short *et al*., 2005). Data collection is carried out in each season by local scientists, although public participation is highly considered in this initiative, and the results are gathered in online database (www.seagrassnet.org) for consultation by the different actors.

As for the mediterranean, it may be considered a pionneer in the matter as the Réseau de Surveillance Posidonies (RSP), the french Posidonia monitoring network, was the first monitoring network based on a seagrass: *Posidonia oceanica* (L.) Delile. Set up initially in the french mediterranean riviera (Provence-Alpes-Côte d’Azur, PACA) in 1984 (Boudouresque *et al.*, 2000), and regularly improved, the RSP was then extended (i) in the Euro-Mediterranean region (Greece, Italy and Spain) through the COST 647 (Boudouresque *et al.*, 1990) and (ii) in the mediterranean basin through the initiatives of the Regional Activity Centre for Specially Protected Areas (RAC-SPA) of the MAP, in particular since 1999 with the adoption of the Action Plan for the Conservation of Marine Vegetation in the Mediterranean Sea (RAC/SPA, 2000). Today this network involves seven countries in the mediterranean basin and will involve three additional countries in the next few months with “MedPosidonia”, a RAC-SPA project in partnership with the Fondation Total.

The adoption of a European Community policy in the field of water, Directive 2000/60/EC of the European Parliament and of the Council, commonly called the Water Framework Directive (WFD), has moreover highlighted the necessity of monitoring seagrass meadows and has lead several regions (Catalonia – Spain, PACA and Corsica – France, Liguria – Italy) to work on the harmonisation of the methods of monitoring seagrass by establishing a common approach through the Interreg IIIB programme “Posidonia”. The aim of this project is to (i) create comparable databases that may be integrated by all concerned regions, (ii) develop an optimal monitoring strategy, and (iii) identify and select the most significant descriptors.

In general terms, the objective of these different programmes is to monitor, in the long term, the evolution of seagrass meadows’ state and/or to use these meadows as biological indicators of the overall quality of coastal waters. The aim of this paper is to describe and compare these three approaches on a single study site, the bay of Calvi (Corsica) in order to identify their advantages and limits, as well as to evaluate whether they can validate operational tools that may allow an overall Mediterranean monitoring strategy.

Monitoring systems set up

The bay of Calvi (8°45 E, 42°35 N) is located on the North-Western coast of Corsica. The meadows of *Posidonia oceanica*, main segrass present, extend from the surface to approximately 40m depth (Gobert, 2002). According to the requirements and objectives of each programme, several stations were defined (Fig. 1):

The SeagrassNet is based on three transects, lined up in front of the Station de Recherche Sous-marine et Océanographique (Stareso). These transects are situated at the three different depths: behind the upper limit (9m), at an intermediate depth (24m) and before the lower limit (37m).

The “Posidonia” programme considers three different stations (Punta Bianca, Stareso and Les Cages) and two different depths: an intermediate depth (15m) and the lower limit (between 27 and 38m, according to the station).

The RSP is placed on a station on the upper limit in the Eastern part of the Bay of Calvi (13m) and on a station on the lower limit in front of Stareso (38m).

The field work was carried out between April and August 2006; and consisted in the set up of a reference state, and eventually of its successive observations according to the protocols. Thus, if the SeagrassNet requires seasonal observations every three months (Short *et al.*, 2005), the RSP only requires observations every three years and no following observations have been foreseen for the “Posidonia” programme.

The **SeagrassNet**, requires that two ballasts be placed at an interval of 50 metres, parallel to the coastline, at the three depths defined by the protocol (Short *et al.*, 2005). The measures *in situ* (cover, density) and the sampling (12 shoots, two sediment cores) are carried out at a precise distances along the transects. Light (for 15 days each season) and temperature (for 3 months) variations are registered on the upper limit (transect A) and on the lower limit (transect C), whereas salinity is measured at the sampling date. Density is measured in 25x25cm quadrats and cover is estimated in 40x40cm quadrats by using video images. The shoots collected are divided in three parts: leaf, rhizome (maximum length of 10cm) and sheathes. The length of the longest leaf determines the canopy height. Each shoot part is then dried and weighed in order to measure the biomass.

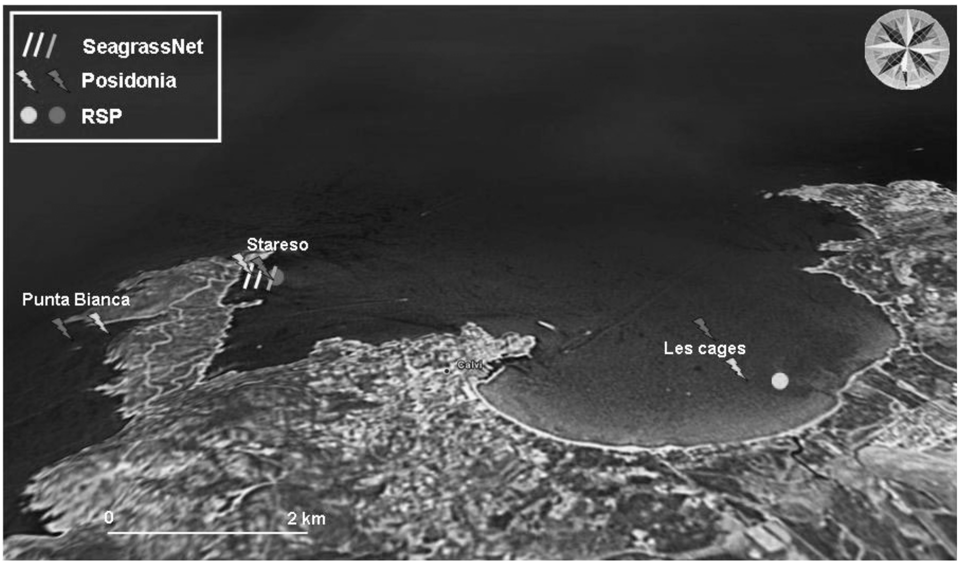


Fig. 1: Location of the stations studied in the different programmes.

The "**Posidonia**" programme does not require any fixed structures. Density (40x40cm quadrat at 15m and 20x20cm quadrat on the lower limit), cover (by video along two 20m orthogonal transects) are measured randomly. The number of plagiotropic rhizomes and shoot baring are evaluated in the quadrats, when measuring density. 20 to 25 shoots are collected in order to analyse, in the laboratory, their phenology (Giraud, 1979) and lepidochronology (Pergent, 1990). Chemical analyses are carried out on the 2nd order adult leaf, to measure chlorophyll concentration, Carbon and Nitrogen content, trace metals concentration (cadmium, lead, mercury and silver). The compactness of the matte is estimated by extracting five sediment cores (12cm diameter, 15cm height); the necromasse, grain size and organic matter content are measured in the laboratory.

The **RSP** consists in setting eleven fixed landmarks every five metres, on the edge of the upper and lower limit of the meadow, in order to follow any changes (progression or regression) or evolution (Pergent *et al.*, 2005; Boudouresque *et al.*, 2006). The precise position of each landmark is recorded (microcartocraphy), while density (40x40cm quadrat on the upper limit and 20x20cm quadrat on the lower limit), cover (1m^2 quadrat), percentage of plagiotropic rhizomes and shoot baring are measured. Horizontal and vertical views are taken by video in order to have an as precise as possible representation of the limit (Pergent *et al.*, 2005). On the upper limit, a general mapping of the site (approximately 1 km^2) is carried out by processing 1/5000 aerial photographs. Two shoots are collected at the back of each landmark (for a total of 22 shoots) and a sediment core is extracted centrally. Phenology and lepidochronology are measured in the laboratory, as well as grain size and organic matter content of the sediment.

Reference Condition of the meadow

SeagrassNet

Density and cover decrease with depth (Tab. 1). The mean density (±SE) is respectively of 326.7 ± 51.5 shoots.m^{-2} (transect A), 178.0 ± 19.1 shoots.m^{-2} (transect B), and only 37.3 ± 10.5 shoots.m^{-2} (transect C). Cover is of 100% for both transects A and B, and only of 6% for transect C. The mean (±SE) canopy height is of 859.0 ± 56.9 mm for transect A, 854.5 ± 44.1 mm for transect B and 386.7 ± 27.7 mm for transect C. For a given tissue, the biomass also decreases with depth (Tab. 2).

Tab. 1: Density and cover for each transect (A : -9m ; B : -25m ; C : -37m).

A (distance in m)	**2**	**7**	**8**	**16**	**18**	**25**	**26**	**33**	**38**	**40**	**44**	**46**
Density (m^2)	120	384	560	248	168	432	192	424	320	176	544	352
Cover (%)	100	100	100	100	100	100	100	100	100	100	100	100
B (distance in m)	**9**	**10**	**15**	**17**	**22**	**25**	**28**	**31**	**35**	**37**	**39**	**45**
Density (m^2)	256	136	176	176	56	192	272	184	88	216	136	248
Cover (%)	100	100	100	100	100	100	100	100	100	100	100	100
C (distance in m)	**5**	**7**	**10**	**18**	**19**	**22**	**26**	**34**	**35**	**38**	**43**	**44**
Density (m^2)	80	48	0	0	16	112	48	32	0	0	48	64
Cover (%)	25	5	5	0	5	5	5	5	0	0	10	5

Tab. 2: Mean biomass (in g DW±SE) of each tissue in the different transects.

	Transect A	**Transect B**	**Transect C**
Leaves	1.15 ± 0.10	1.08 ± 0.13	0.42 ± 0.05
Sheathes	2.06 ± 0.16	1.73 ± 0.09	0.98 ± 0.10
Rhizomes	0.93 ± 0.10	0.59 ± 0.05	0.41 ± 0.08

Between the 20th and the 30th of July, the mean light intensity, estimated in relation to the intensity measured on the surface (278.1 ± 34.9 L.sf^{-1}), is of 30% at 9m (92.9 ± 9.5) and of 10 % at 37 m (23.2 ± 2.6). The temperature variations where not considered, as the sensor on the lower limit collected in October 2006 was damaged.

"Posidonia" Programme

Density, percentage of plagiotropic rhizomes and shoot baring, are always higher at the intermediate depth than on the lower limit, in all 3 stations studied (Tab. 3). At the same depth (15m), density and shoot baring are not significantly different between stations, whereas the percentage of plagiotropic rhizomes is. Phenological data (Tab. 4) equally is higher at intermediate depth, except for leaf width.

Tab. 3: Structure of the meadow at the six stations studied in April 2006 (mean ± SE).

Intermediate depth	**Punta Bianca (-16 m)**	**Stareso (-15 m)**	**Les cages (-15 m)**
Density (shoots.m^{-2})	334.9 ± 21.0	310 ± 27.9	285.4 ± 22.6
Plagiotropic rhizomes (%)	25.0 ± 5.1	6.7 ± 4.2	45.8 ± 5.1
Baring (cm)	10.4 ± 1.8	13.3 ± 2.2	12.5 ± 1.8
Lower limit	**Punta Bianca (-27 m)**	**Stareso (-38 m)**	**Les cages (-36 m)**
Density (shoots.m^{-2})	325.0 ± 22.4	155.0 ± 14.6	245 ±34.8
Plagiotropic rhizomes (%)	1.4 ± 1.4	1.4 ± 1.4	36.8 ± 4.2
Baring (cm)	3.2 ± 0.5	1.0 ± 0.0	3.0 ± 0.6

The number of leaves produced annually (number of sheathes per cycle) and the rhizome growth rate vary significantly between stations (Tab. 5).

Tab. 4: Leaf biometry and phenological indices (adult + intermediate leaves; mean ± SE).

Intermediate depth	**Punta Bianca (-16 m)**	**Stareso (-15 m)**	**Les cages (-15 m)**
Mean no. of leaves. shoot.$^{-1}$	6.2 ± 0.3	6.2 ± 0.4	5.7 ± 0.4
Mean length (mm)	676.9 ± 39.9	587.9 ± 42.9	604.4 ± 58.2
Mean width (mm)	10.4 ± 0.2	9.6 ± 0.3	9.1 ± 0.2
Coefficient A (%)	47.2 ± 7.2	15.4 ± 8.7	25.7 ± 8.1
Shoot Foliar Surface(cm^{2}.shoot.$^{-1}$)	433.2 ± 25.0	352.5 ± 37.7	317.9 ± 33.4
Lower limit	**Punta Bianca (-27 m)**	**Stareso (-38 m)**	**Les cages (-36 m)**
Mean no. of leaves. shoot.$^{-1}$	5.5 ± 0.4	4.9 ± 0.3	4.9 ± 0.2
Mean length (mm)	485.8 ± 36.4	180.2 ± 14.5	214.3 ± 18.9
Mean width (mm)	10.5 ± 0.2	9.9 ± 0.2	8.9 ± 0.2
Coefficient A (%)	13.6 ± 6.8	11.4 ± 7.5	6.1 ± 4.2
Shoot Foliar Surface(cm^{2}.shoot.$^{-1}$)	280.7 ± 27.7	88.5 ± 8.8	95.3 ± 5.5

Tab. 5: Lepidochronological analyses on the Posidonia oceanica shoots (mean ± SE).

	Punta Bianca		**Stareso**		**Les cages**	
	-16 m	**LL**	**-15 m**	**LL**	**-15 m**	**LL**
No. of leaves (leaves.year^{-1})	8.4 ± 0.5	7.7 ± 0.6	8.8 ± 0.6	7.3 ± 0.9	7.4 ± 0.4	7.4 ± 0.6
Rhizome growth rate (mm)	11.4 ± 4.0	8.9 ± 2.2	14.7 ± 4.8	4.3 ± 1.1	7.0 ± 1.4	5.2 ± 1.9

Chlorophyll concentration and carbon content values are the highest in Punta Biance and the lowest in Les Cages, at whichever depth considered (Tab. 6); whereas Nitrogen content values are the highest in Les Cages.

Tab. 6: Chlorophyll concentration, Carbon and Nitrogen Content in adult leaves (2nd order) (mean ± SE).

	Punta Bianca		**Stareso**		**Les cages**	
	-16 m	**Lim. Inf.**	**-15 m**	**Lim. Inf.**	**-15 m**	**Lim. Inf.**
Chlorophyll a (mg.g-1)	6.2 ± 1.4	6.2 ± 0.7	5.5 ± 0.1	4.5 ± 0.1	4.5 ± 0.2	3.5 ± 0.1
Chlorophyll b (mg.g-1)	3.6 ± 0.7	3.5 ± 0.3	3.4 ± 0.2	2.5 ± 0.6	2.7 ± 0.1	2.5 ± 0.1
Total Carbon (%)	33.5 ± 3.3	39.4 ± 2.6	27.0 ± 1.0	34.1 ± 4.7	27.2 ± 1.7	32.1 ± 1.4
Total Nitrogen (%)	2.8 ± 0.1	3.5 ± 0.1	2.9 ± 0.1	3.6 ± 0.1	3.2 ± 0.1	4.0 ± 0.1

Trace metals concentration along the lower limit are higher for Silver and lower for Cadmium (Tab. 7). Mercury concentration is comparable in all sites. On a general point of view, metal contamination exhibits the highest values in Punta Bianca.

Tab. 7: Trace metals concentration (in μg.g^{-1}) of adult leaves (2nd order) of* Posidonia oceanica *(mean ± SE).

	Punta Bianca		**Stareso**		**Les cages**	
	-16 m	**Lim. Inf.**	**-15 m**	**Lim. Inf.**	**-15 m**	**Lim. Inf.**
Ag	0.57 ± 0.03	0.73 ± 0.07	0.47 ± 0.03	0.70 ± 0.06	0.37 ±0.03	0.75
Cd	4.52 ± 0.36	4.41 ± 0.14	3.37 ± 0.21	2.40 ± 0.14	4.62 ± 0.19	2.55
Hg	0.045 ± 0.015	0.043 ± 0.013	0.036 ± 0.016	0.033 ± 0.013	0.038 ± 0.018	0.057 ± 0.014
Pb	3.77 ± 0.54	3.40 ± 0.06	2.60 ± 0.17	2.90 ± 0.31	2.40 ± 0.06	1.80

RSP

On the upper limit, the mapped area allows to distinguish a large meadow of *Posidonia oceanica* in the northern part and sedimentary substrate in the southern part (Fig. 2). The limit between these two elements is sharp and stretches perpendicularly to the coastline. Within the meadow, a large patch of sand, parallel to the shore and several intermattes can be identified. On the edge of the beach, a little banquette of dead leaves of *Posidonia oceanica* can be observed, as well as large quantities of dead leaves are visible at a very superficial depth where it conceals the underlying sand. A representative area of this meadow limit has been mapped, in microcartography, when placing the landmarks.

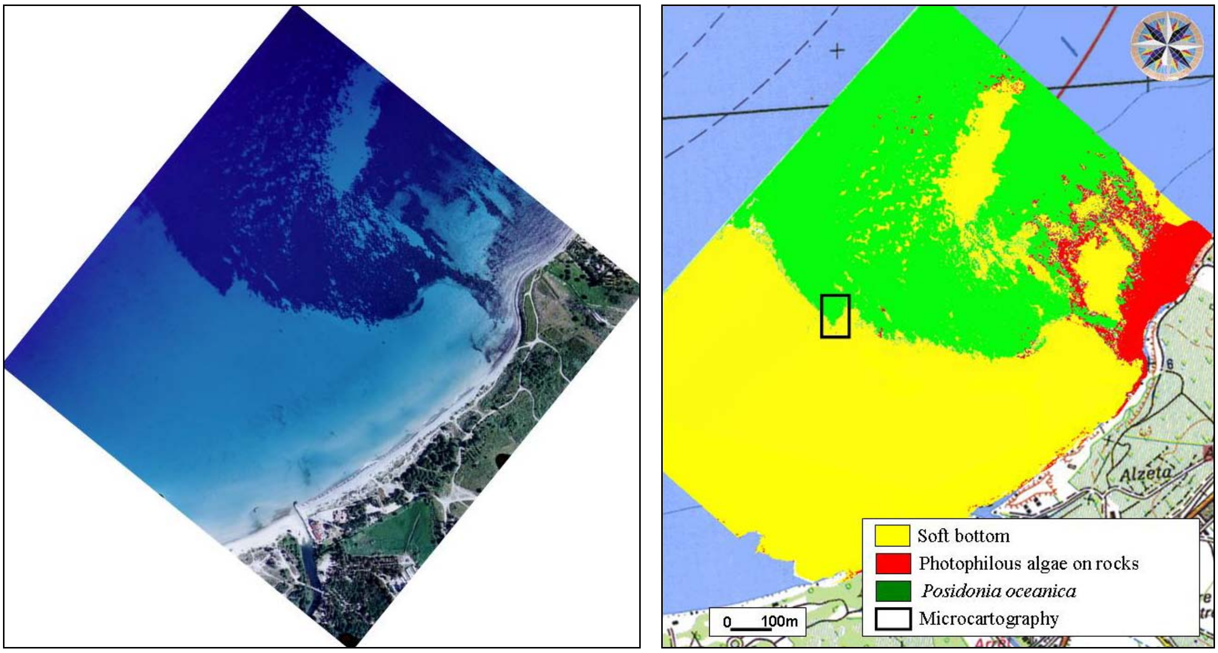


Fig. 2: Aerial photograph of the upper limit in the bay of Calvi (left) and mapping of the corresponding Posidonia oceanica meadow (right).

Mean density (± SE) is of 483 ± 23 shoots.m^{-2} and cover of 100%. Shoot baring is high (10.4 ± 1.4 cm) although variable, with maximum values in the areas of high hydrodynamic activity (landmarks 1, 5 and 9). This meadow is essentially composed of orthotropic rhizomes (79.5 ± 4.6 %). The shoots collected behind the limit, have been analysed in the laboratory for their phenological (Tab. 8) and lepidochronological parameters.

Tab. 8: Leaf biometry and phenological indices (adult + intermediate leaves; mean ± SE).

	Upper limit	**Lower Limit**
Mean no. of leaves. shoot.$^{-1}$	5.6 ± 0.2	4.4 ± 0.2
Mean length (mm)	708.6 ± 47.9	285.2 ± 17.9
Mean width (mm)	9.4 ± 0.1	9.1 ± 0.2
Coefficient A (%)	48.0 ± 5.2	26.6 ± 6.0
Shoot Foliar Surface(cm^2.shoot.$^{-1}$)	380.8 ± 19.0	115.5 ± 8.6

The sediment analysis on grain size results in a “unimodal” histogram, the mean size of the sediment is 0.79mm, which corresponds to coarse grained sediment. This sediment is well classed and very well sorted, with the highest class on the side of coarse matter. The sorting kurtosis suggests a mesokurtic sediment. The organic matter content is 6.25 % for the 0.063 mm fraction.

The ballasts on the lower limit, situated on average at 38.6 m depth, follow a sharp limit on sand, with a low cover according to the classification of Pergent *et al.* (2005) (Fig. 3).

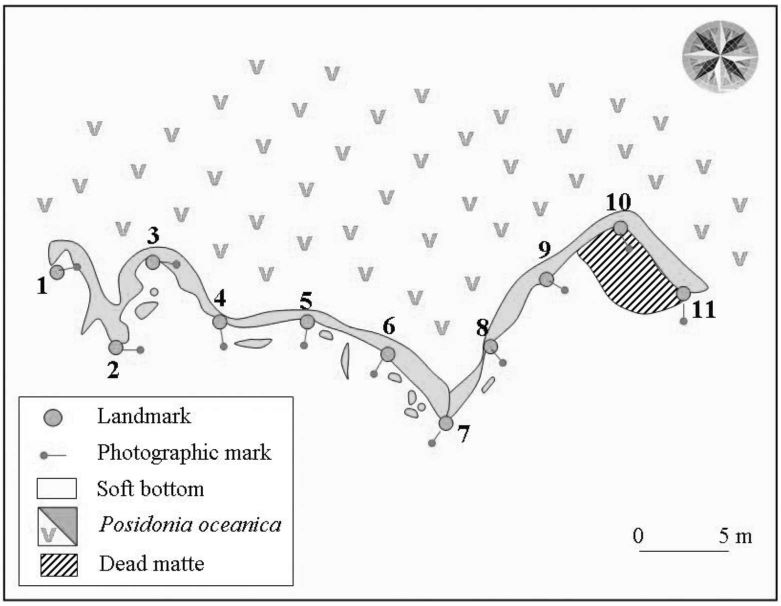


Fig. 3: Map of the ballasts on the lower limit of Calvi.

The estimated cover is of 24%. Density is evaluated at the back of each ballast with a 1 m^2 quadrat, subdivided in 20x20cm quadrats; the measures are taken and recorded for defined sub-quadrats (Fig. 4). It is then possible to measure density in clusters where the number of shoots per quadrat is superior to 2 (98.3 ± 7.1 shoots.m^{-2}) or on the entire lot of quadrats (51.1 ± 6.3 shoots.m^{-2}). The estimated percentage of plagiotropic rhizomes is of 77.3 ± 7.6% and the shoot baring is very low (1.4 ± 0.2 cm).

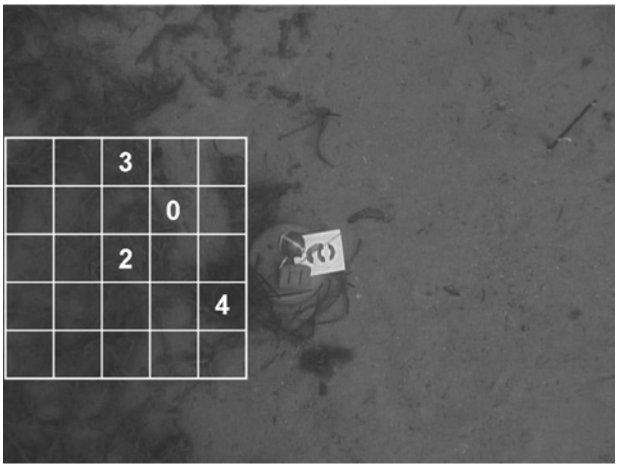


Fig. 4: Density measures taken at the back of each ballast.

The sediment analysis on grain size results in a “unimodal” histogram, the mean size of the sediment us 1.6mm, which corresponds to coarse sand. This sediment is well classed and very well sorted. The organic matter content is 7.5 % for the 0.063 mm fraction.

The phenological data (Tab. 8) of shoots collected at the back of the ballasts show higher values on the upper limit than on the lower limit, except for leaf width. The number of leaves produced annually is on average of 7.4 ± 0.5on the upper limit and of 8.1 ± 0.4 on the lower limit. The rhizome growth rate is of 9.1 ± 1.3 mm.year^{-1} on the upper limit and of 3.8 ± 0.7 mm.year^{-1} on the lower limit.

Summary and future development

The number of descriptors considered in these three monitoring systems varies between 10 for SeagrassNet and 15 for the "Posidonia" programme (Tab. 9). The temporal interval between observations is also very variable, as it is of only three months for SeagrassNet and of at least three years for the other two systems. Furthermore the objectives of the three systems differ slightly:

- Evaluate and follow the quality of the meadow for SeagrassNet
- Evaluate de quality of the environment, using the meadow (bioindicator) for "Posidonia"
- Evaluate and follow the quality of the meadow and the quality of the environment for RSP.

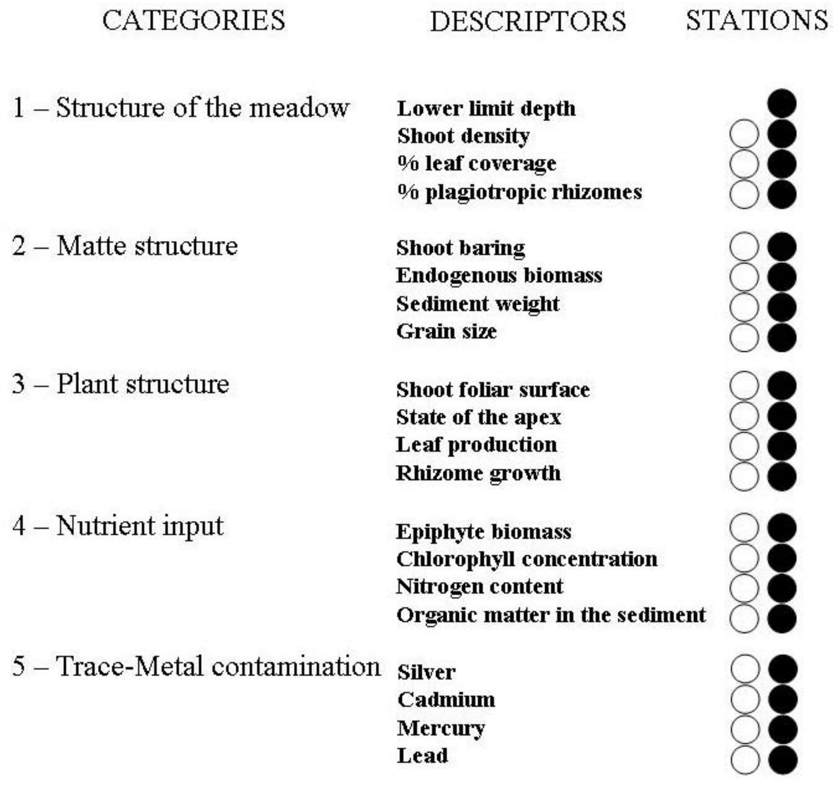
Tab.9: Main parameters considered in each of the monitoring systems set up. The number of samples is indicated for each depth; -: parameter not measured.

	SeagrassNet	**Posidonia Programme**	**RSP**
Station	Stareso	P. Bianca, Stareso, Cages	Cages, Stareso
Depth	9 m, 25 m, 37 m	15 m, 27 to 38 m	13 m, 38 m
Light	15 days per season	-	-
Temperature (°C)	All year	-	-
Salinity	Every season	-	-
Lower limit	Depth	Depth, type	Depth, type, mapping
Upper limit	Depth		Depth, type, mapping
Density	12 measures/transect	5 measures	11 measures
Plagiotropic rhizomes (%)	-	5 measures	11 measures
Baring (cm)	-	5 measures	11 measures
Cover (%)	12 measures/transect	4 transects (10 m) Video	Transect (50m) Video
Phenological/canopy analyses	12 measures/transect	20 to 25 shoots	20 shoots
Lepidochronological analyses	-	20 to 25 shoots	10 shoots
State of the apex	-	20 to 25 shoots	20 shoots
Biomass (g DW)	Leaves	Epiphytes	-
Necromasse	Sheathes, rhizomes	5 measures	-
Grain size	-	5 measures	1 measure
Organic Matter (%)	-	5 measures	1 measure
Chlorophyll a and b (%)	-	3 measures	-
C and N content (%)	-	3 measures	-
Trace metals (µg.g PS)	-	Ag, Cd, Hg, Pb	-
Observations	Every 3 months	Every 3 to 6 years	Every 3 years

Although the majority of the parameters are common to the three systems, it is also true that the method used (protocols) differ, which often leads to different results in relatively close stations. Thus, density, measured on the lower limit in front of Stareso, is estimated at 37.3 ± 10.5 for SeagrassNet, at 155 ± 14.6 for the "Posidonia" programme and between 51.1 ± 6.3 and 98.3 ± 7.1 for the RSP, depending on the protocol followed. Although there is a certain amount of natural variability within the meadow (Panayotidis *et al.*, 1981), it cannot explain the large differences that exist between the measures. In this example, taking into account whether shoots of *Posidonia oceanica* are present or not when placing the quadrat, is decisive (pre-defined placement or random placement within the meadow's shoot clusters). On the other hand, parameters which follow a precise protocol (phenological and lepidochronological analyses) show much more similar results (Tab. 4 and 8).

The use of overall methods that may be applied to seagrass in general, as for SeagrassNet, offer an undeniable advantage in terms of reproducibility, comparison and standardisation of the protocol (Short *et al.*, 2006). However, the strong ecological differences (depth, salinity, substrate, morphology, growth…) lead to an adaptation of the protocol to the specific characteristics of each species studied and therefore to differences between species in methods used. It would probably be more relevant to integrate a minimum number of precisely defined parameters (minimum protocol) and to complete them with measures that are specific for each species.

The definition of an overall index of the meadow quality, and therefore of the environment in which it grows, would be the final purpose. The WFD favours this approach, the concept of a global index, through the assessment of the distance from a reference situation (reference values) that should be an existing situation, past or present. This evaluation of a situation in relation to an optimum may be obtained from different descriptors, hence the existence of several indices proposed by different Mediterranean countries (e.g. POMI, CARLIT). The main objective being that, for whichever index applied, the result be the same and that the evaluation be reproducible over time. The aim of the "Posidonia" programme is to verify whether this evaluation, using different parameters, is possible and could lead to an intercalibration on common sites between the POMI index and the POSID index under development. Whereas the POMI index is oriented towards an overall approach (Romero *et al.* 2005), the POSID (POsidonia Status InDex) identifies five categories of descriptors ("Structure of the meadow", "Structure of the matte", Structure of the plant", "Analysis of the plant", "Chemical analysis"); each descriptor has its own evaluation scale in five classes, which allows to asses the level of each category (Fig. 5).



CATEGORIES	DESCRIPTORS	STATIONS
1 – Structure of the meadow	**Lower limit depth**	●
	Shoot density	○ ●
	% leaf coverage	○ ●
	% plagiotropic rhizomes	○ ●
2 – Matte structure	**Shoot baring**	○ ●
	Endogenous biomass	○ ●
	Sediment weight	○ ●
	Grain size	○ ●
3 – Plant structure	**Shoot foliar surface**	○ ●
	State of the apex	○ ●
	Leaf production	○ ●
	Rhizome growth	○ ●
4 – Nutrient input	**Epiphyte biomass**	○ ●
	Chlorophyll concentration	○ ●
	Nitrogen content	○ ●
	Organic matter in the sediment	○ ●
5 – Trace-Metal contamination	**Silver**	○ ●
	Cadmium	○ ●
	Mercury	○ ●
	Lead	○ ●

Fig. 5: POSID evaluation index under development, in the "Posidonia" programme. White circles: intermediate depth; black circles: lower limit.

Therefore, in the perspective of an overall evaluation of the quality of the environment, the category "chemical analysis" will have more weight in the assessment of the quality of the meadow itself; whereas the categories "Structure of the matte" and "Structure of the meadow" will be important elements in the assessment of the fragility of the meadow.

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Dorothée PETE, Sylvie GOBERT, Gilles LEPOINT, Mathieu POULICEK, Jean-Marie BOUQUEGNEAU
Laboratoire d'Océanologie, MARE Centre, Université de Liège (ULg), Institut de Chimie, B6c, Allée de la Chimie 3, Sart-Tilman, 4000 Liège, BELGIUM, e-mail: Dorothee.Pete@ulg.ac.be

EARLY COLONIZATION OF *POSIDONIA OCEANICA* (L.) DELILE BY EPIPHYTES: COMPARISON BETWEEN NATURAL AND ARTIFICIAL SEAGRASS LEAVES

Abstract

Posidonia oceanica *is an important marine Magnoliophyta of the Mediterranean coastal zone that can form dense meadows. The leaves of this seagrass are colonized by a lot of organisms, from bacteria to polychaetes and algae. However, the early stages of colonization are not well known.*
A preliminary is proposed to examine the nine first days of colonization by epiphytes on natural leaves and on Artificial Seagrass Units (ASUs). Aims of this work were to understand which species are the first to set up, to compare colonization on both leaves and to determine the interest of ASUs in ecological studies.
It was shown that the setting up of epiphytes on the bases of both leaves is rapid (first algae on the second day) but the number of organisms increases quicker on ASUs than on natural leaves and on the smooth faces than the rough ones. Shannon-Wiener diversity and evenness were higher for the P. oceanica *leaves and the use of Bray-Curtis similarity index showed that colonisation is not similar (between 20 and 30 % similarity) on both leaves for the same day. It can be explained by the lower colonization rate of natural leaves. This lower rate is probably due to a less developed biofilm on natural leaves than on ASUs, to a difficult access to the bases of* P. oceanica *leaves for epiphytes and microoganisms, and the production of phenol compounds by the plant. Even if ASUs used here do not seem to be similar to natural leaves in early stages of colonization, they could be used in ecological studies thanks to their rapid covering by epiphytes.*

Key-words: *P. oceanica*, ASUs, Epiphytes, Colonization.

Introduction

In the Mediterranean coastal zone, one can find dense meadows form by the marine Magnoliophyta *Posidonia oceanica*. This seagrass plays important roles like trapping particles in suspension, stabilizing the sediment, attenuating hydrodynamism of the waves, importing and exporting an important vegetal biomass and producing a large amount of oxygen. These meadows are also involved in many food webs and represent a place of nursery, reproduction and predation for a lot of ecological and economical interesting species. Thanks to that, they are sensitive to environmental perturbations and are often used as a pollution descriptor (Boudouresque and Meneisz, 1982; Gobert *et al.*, 2005; Pergent-Martini *et al.*, 2005; Procaccini *et al.*, 2003)

There are lots of different organisms on *P. oceanica* leaves. These epiphytes are as diverse as bacteria, diatoms, macro-algae, bryozoans, hydrozoans, foraminifera or annelids and represent 20 to 40 % of the biomass of seagrass leaves (Gobert *et al.*, 1995; Lepoint *et al.*, 1999). They take also actively part in total primary production of the meadows (27,5 %; Dauby *et al.*, in prep.) and to many food webs (Bell *et al.*, 1984; Lepoint *et al.*, 2000; Mazzella *et al.*, 1995).
Early stages of colonization by those epiphytes are not well known because only very few studies were realised on this subject, despite the importance of those species, especially on the ecological point of view (De Troch *et al.*, 2005; Novak, 1984; Virnstein and Curran, 1986). Indeed, epiphytes

are useful in pollution studies because they react more quickly to environmental perturbations than the plant itself thanks to their rapid turnover (Delgado *et al.*, 1999; Pergent-Martini *et al.*, 2005; Piazzi *et al.*, 2004; Ruiz and Romero, 2001).

To study the colonization by epiphytes, the use of ASUs seems interesting because they can be put anywhere, whatever the conditions (Barber *et al.*, 1979; Lee *et al.*, 2001) and because it is a non destructive method. It also has the advantage to make possible the control of parameters like the number of leaves, the shoot density, leaves length and width, as well as the surface available for colonization (Bologna and Heck Jr, 1999; Trautman and Borowitzka, 1999).

For all these reasons, aims of this study are (1) to understand the setting up of epiphytes during the first days of colonization on the bases of *P. oceanica* leaves and on ASUs, (2) to compare the colonization on both types of leaves and (3) to determine the interest of ASUs in ecological studies.

Material and methods

This study was realised in the port of the oceanographic research station STARESO, Revellata Bay, Calvi Gulf (42° 35’ N, 8° 43’ E), Corsica, France.

This site is characterized by a continuous *P. oceanica* meadow which present a shoot density from 400 to 700 shoot/m^2 at 10 m (Soullard *et al.*, 1994) and a relatively low hydrodynamic regime (Bay, 1984). This meadow presents low anthropic perturbations because of the sewage of the station. However, the discharge was not important during this study (from March 6th to 15th 2005) because of the low frequenting rate in March.

The study was led at 10 m depth. Each ASU was made of a PVC band of 1 cm width and 50 cm length with a float at the extremity, fixed on a ballasted PVC tube and positioned inside the meadow. At the same time, *P. oceanica* shoots were marked with Zieman’s method (Zieman and Wetzel, 1980) to compare adequately data on both types of leaves.

Each day of the study, one ASU and one marked natural shoot were taken by scuba diving. For the *P. oceanica* shoot, only the younger leave was taken. The all length of ASUs was observed with 50x magnification, separating data from rough faces and smooth ones, in order to determine the number of colonizing epiphytes by cm^2. The same observations were done with parts of natural leaves situated underneath the hole made by the Zieman’s method.

Data coming from determinations of organisms were also used to calculate Shannon-Wiener diversity index, Pielou’s evenness and Bray-Curtis similarity with PRIMER 5 (Clarke and Warwick, 2001; Jørgensen *et al.*, 2005).

Results

The basal parts of both leaves were compared according to the density of organisms. This density increases with time and reaches until 15 organisms/cm^{2}on *P. oceanica* leaves and 249 org./cm^2 on smooth faces of ASUs (Fig. 1). For the same day, there are more organisms on the ASU than on the natural leave, so, the epiphyte community seems to develop more rapidly on ASUs. Indeed, curves of the two faces of one ASU present density values from 7 (rough face) to 16 (smooth face) times higher than that of the natural leave (Fig. 1).

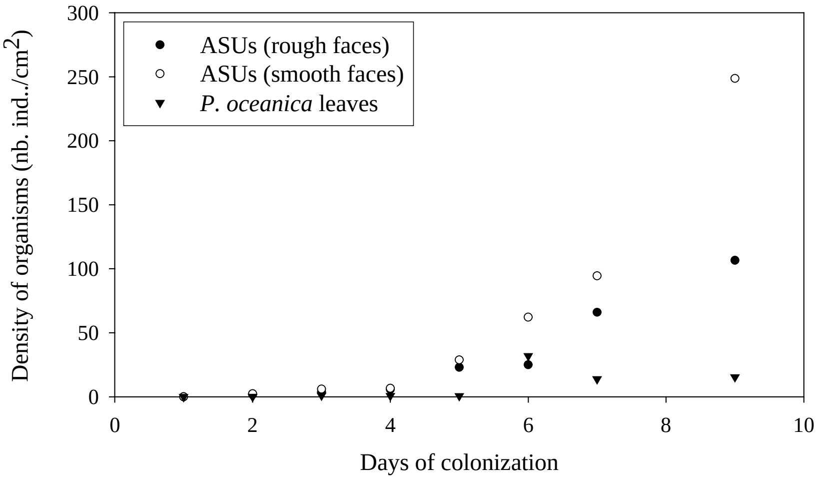

Fig. 1: Evolution of the density in number of individual by square centimetre in basal parts of ASUs rough faces (full discs), ASUs smooth faces (empty discs) and* P. oceanica *leaves (inverted triangles), with time.

Concerning the observed taxa (algae, foraminifera, bryozoans, ciliates and nematods), the most important groups found in the first days of colonization are algae and foraminifera. They represent between 82 % (natural leave) and nearly than 100 % (ASU) of the observed organisms in the end of the study. So, they are mainly responsible of the increase of density. The calculation of diversity index for those taxa shows that Shannon-Wiener diversity index (Fig. 2) is higher for natural leaves than ASUs since the fifth day of colonization, while the evolution of the evenness is more fluctuating.

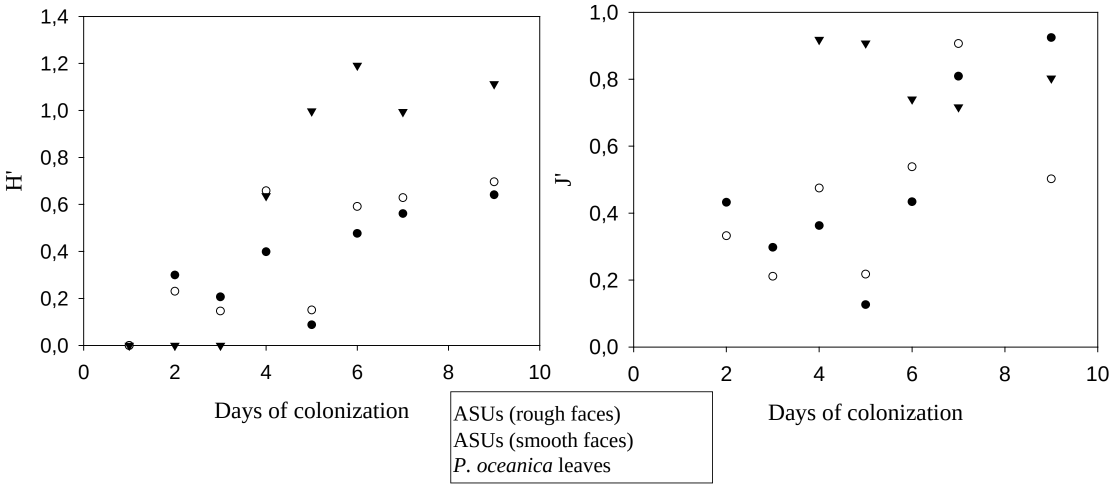

Fig. 2: Evolution of the Shannon-Wiener diversity index, H' (left) and Pielou's evenness, J' (right) according to days of colonization. The legend is the same as for Fig. 1.

Indeed, during the second and third days, evenness can only be calculated for ASUs because there are only algae on natural leaves. From the third to the sixth day, evenness is higher for natural leaves than for ASUs, what means that the epiphytic community of the bases of *P. oceanica* leaves is not really dominated by one taxon, unlike ASUs. From the seventh day, the difference in evenness between both leaves become low, what means that the distribution of taxa becomes more similar. During all the experiment, there was no clear difference between the two faces of the ASUs.

The analysis of the Bray-Curtis similarity index (Fig. 3) shows two distinct clusters, which can also be separated in two additional clusters. First clusters separate days 2, 3, 4, 5 (cluster A) and days 6, 7, 9 (cluster B) with less than 20 % similarity. In the cluster A, there is a cluster with ASUs (cluster C) and a cluster with natural leaves (cluster D) separated with more than 20 % similarity. Separation between ASUs (cluster E) and *P. oceanica* (cluster F) is also observed in cluster B, with 30 % similarity. So, there are differences in colonization according to time, but also according the type of leaves.

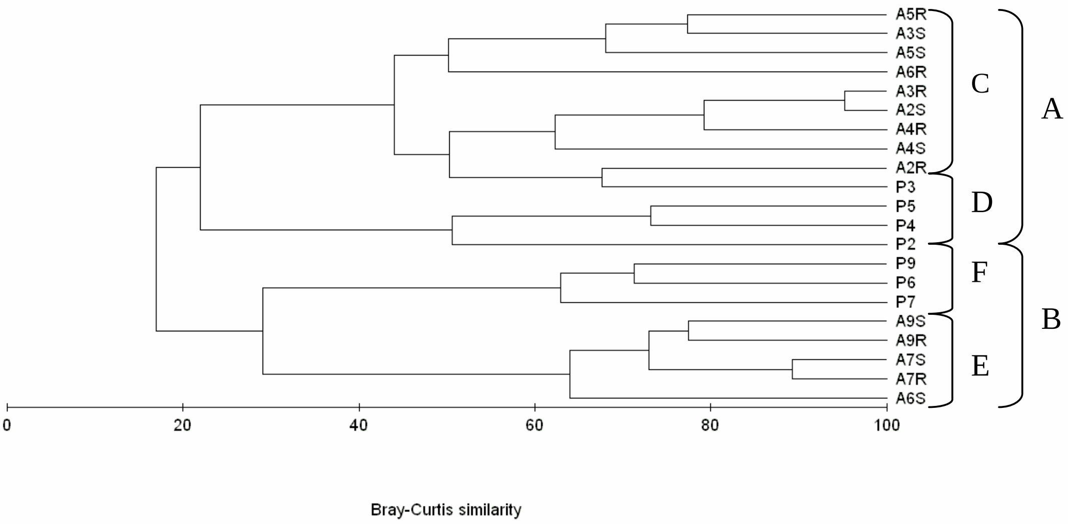

Fig. 3: Bray-Curtis similarity index analysis. In the dendrogram, A = ASU, P =* P. oceanica *leaf, number = day, S = smooth face and R = rough face.

Discussion

The colonization dynamics of *P. oceanica* leaves, concerning epiphytes biomass and according to time, is characterized by a sigmoid evolution (Cebrián *et al.*, 1999). The stabilization of the curve is reached when equilibrium between epiphytes growth and losses, due mainly to grazing pressure, exists (Alcoverro *et al.*, 1997; Cebrián *et al.*, 1999; Van Montfrans *et al.*, 1984). Curves obtained in this study (Fig. 1) don't show a sigmoid tendency because of the shortness of the envisaged period. Indeed, the study lasts only 9 days while Cebrían *et al.* (1999) had shown that epiphytes biomass reached the upper part of the sigmoid after 270 days. On artificial seaweeds, Edgar (1991) reached this part of the curve after two months, which is shorter than 270 days but still longer than our sampling period. However, the curves corresponding to ASUs show a highly increasing density of organisms towards the end of the experience, what means that colonization is in its rising phase.

The increase in epiphytes density on *P. oceanica* leaves is low in comparison with ASUs even if Shannon-Wiener diversity index and Pielou's envenness are higher. Those observations are in accordance with many authors (Bologna and Heck Jr, 1999; Cattaneo and Kalff, 1978; Edgar, 1991; Novak, 1984). This difference between both types of leaves gives the dendrogram of similarity (Fig. 3) which suggests a difference in colonization patterns.

This can be explained by a difference in bacterial communities living on the leaves or in the maturity of the biofilm, which sets up during the early stages of colonization and plays an important role in the installation of larvae and algae (Dahms *et al.*, 2004; Keough and Raimondi, 1995, 1996; Novak, 1984). This difference in the maturity of the biofilm was observed on SEM samples where a more developed biofilm on ASUs was present. That is probably one of the causes of the observed differences between both leaves.

Another cause often cited to explain the low colonization of natural leaves in comparison with artificial ones is the production of phenolic compounds by *P. oceanica* in more or less important quantity according to environmental stress (competition, sewage …). Their concentration is higher in intermediate leaves than in adult ones and presents a seasonal variation (Agostini *et al.*, 1998; Cuny *et al.*, 1995; Dumay *et al.*, 2004; Novak, 1984). Moreover, they can act on the development of the biofilm, what would increase the impact on epiphytes colonization (Harrison and Chan, 1980). As the studied zones of *P. oceanica* are those of maximal phenolic compounds production, it is possible that these compounds have influenced the coverage by epiphytes.

A third possible reason to this low colonization rate on natural leaves is linked to experimental protocol. The observed fragments of *P. oceanica* leaves correspond to younger ones. So, they are situated in a zone where leaves are tightly put side by side, what makes the access to leaf surface difficult for epiphytes, unlike ASUs which are well separated.

The differences in diversity and evenness could also be attributed to a difference in the morphology of the leaf (Schneider and Mann, 1991) or in the density of the leaves (Boström and Bonsdorff, 2000; Lee *et al.*, 2001). However, it doesn't exist a real difference in the density of both leaves types in this study because ASUs were put inside the meadow, as close as possible as *P. oceanica* shoots. So it can't explain the difference in diversity and evenness.

The difference between textures of the faces of one ASU was also observed by Bologna and Heck Jr. (1999) for the epiphytic fauna. This difference and the rapid increase in epiphytes density on ASUs is maybe due to a snowball effect. Indeed, it was proved that epiphytes colonization modifies the leaf and favours the setting up of new colonizers (Bologna and Heck Jr, 1999; Irving *et al.*, 2007; Novak, 1984).

Conclusion

Colonization by epiphytes in the early stage begins quickly and, on both types of leaves, algae and foraminifera are dominant groups. The increase in epiphytes density is higher on ASUs than on natural leaves, even if diversity and evenness are higher for *P. oceanica.* However, even if the colonization seems to be different for both leaves types, one can't exclude that, in a longer experiment, epiphytes communities would be more similar. Moreover, ASUs could be useful tools in ecology, thanks to their rapid colonization by epiphytes. That would permit a use in rapid assessment studies.

Acknowledgements

We thank Pierre Lejeune and all the staff of STARESO for their installations and their valuable assistance. We are really grateful to Renzo Biondo and Nicole Decloux for their wonderful technical support. Financial support was provided by the "Fondation de Recherches Sous-marines et Océanographiques" (University of Liège) and the "Fond National de la Recherche Scientifique" (FRFC contract : 2.4569.03).

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Actes du 3ème Symposium méditerranéen sur la végétation marine (Marseille, 27-29 mars 2007)

Javier ROMERO, Marta PÉREZ, Teresa ALCOVERRO
Departament d'Ecologia, Universitat de Barcelona, Avgda. Diagonal 645, 08028 Barcelona and Centre d'Estudis Avançats de Blanes, CSIC, Camí Accés Cala St. Francesc, 14, 17300 Blanes, Girona, SPAIN, e-mail: jromero@ub.edu

THE SEAGRASS (*POSIDONIA OCEANICA*) MEADOWS IN THE CATALAN COAST: PAST TRENDS AND PRESENT STATUS

Abstract

*Seagrass meadows are endangered and valuable ecosystems, sensitive to human impacts; many of them, to a major or minor extent, have been altered by human activities. The adequate protection and management of seagrass meadows requires information about seagrass health, status and evolution. However, this kind of information is relatively scarce, at least on an extensive basis. We compile here available data from the grey literature on the major Mediterranean seagrass (*Posidonia oceanica*) status along the Catalan coast. From those data, we conclude that significant meadows have suffered significant losses (actual surface around 75-80% of original one), but those losses have halted. More or less half of the meadows about which data exist are either showing less cover and density that expected under unaltered conditions or signals of health loss. Although this situation seems stabilized and deterioration does not appear to proceed further, the present situation is far from being satisfactory, and efforts should be done to improve seagrass quality, health and extension.*

Key-words: Seagrass, *Posidonia oceanica*, Surveillance, Monitoring, Mediterranean sea, Catalan coast.

Introduction

The importance of seagrass meadows in general, and, more specifically, that of *Posidonia oceanica*, to provide ecosystem goods and services (Costanza *et al.*, 1997) has been widely and repeatedly recognized by the scientific community. These services includes organic matter production, providing refuge and nursery grounds, acting as a buffer for point and non-point source pollution, beach protection against erosion and many others (Romero, 2004; Larkum *et al.*, 2006).

Since the 1970's, a worldwide decline of seagrass distribution and abundance has been detected and causes are mainly attributed to the negative influence of anthropogenic impacts (Short and Wyllie-Echeverria, 1996; Orth *et al.*, 2006). Indeed, *Posidonia oceanica* is very sensitive to specific impacts as bottom trawling (Sánchez and Ramos, 1996), anchoring (Francour *et al.*, 1999), coastal constructions (Ruiz and Romero, 2003), chemical wastes (Pergent-Martini and Pergent, 1995), fish farms effluents (Delgado *et al.*, 1999; Ruiz *et al.*, 2001; Pergent-Martini *et al.*, 2006), desalination plants (Gacia *et al.*, in press), geodynamic alterations (Badalamenti *et al.*, 2006), biological invasions (Villèle and Verlaque, 1995) and many others. The effect of these impacts, alone or combined, cause either a lost of vegetated areas, a reduction in seagrass abundance (cover and/or shoot density) or a deterioration of plant health.

Despite the good knowledge about the response of the seagrass to disturbances (see above), relatively little information exists concerning large-scale evaluation of its present status and of its recent evolution (Procaccini *et al.*, 2003; Peirano *et al.*, 2005), or they are confined to the grey literature (Bianchi and Peirano, 1995; Charbonnel *et al.*, 2003). To contribute to fill this gap, we present here an assessment of the recent changes and present status of the *Posidonia oceanica* meadows along the Catalan coast. To this end, we have compiled available information from diverse monitoring programmes, along with personal observations, made over the past 25 years.

Materials and methods

The Catalan coast, with a length of ca. 580 km, is situated in the north-western Mediterranean. It is a highly populated coast, with around 4 millions permanent inhabitants and ca. 20 millions of visits per year (data correspond to 2000). All this represents a relatively high pressure for the coastal marine environment. *Posidonia oceanica* is the main seagrass species which forms meadows along almost all the Catalan coast, except in the vicinities of the main rivers. In the northern rocky coast, the meadows occur from near the surface to 20-25 m, usually, but not always, in bays and coves. In the sandy coasts of the southern part, the meadows are, for the most, at some distance from the shoreline, and extends at depths from 10-12 to 18-25 m. These meadows are quite long (from a few to tens of km) and parallel to the coastline (Fig. 1).

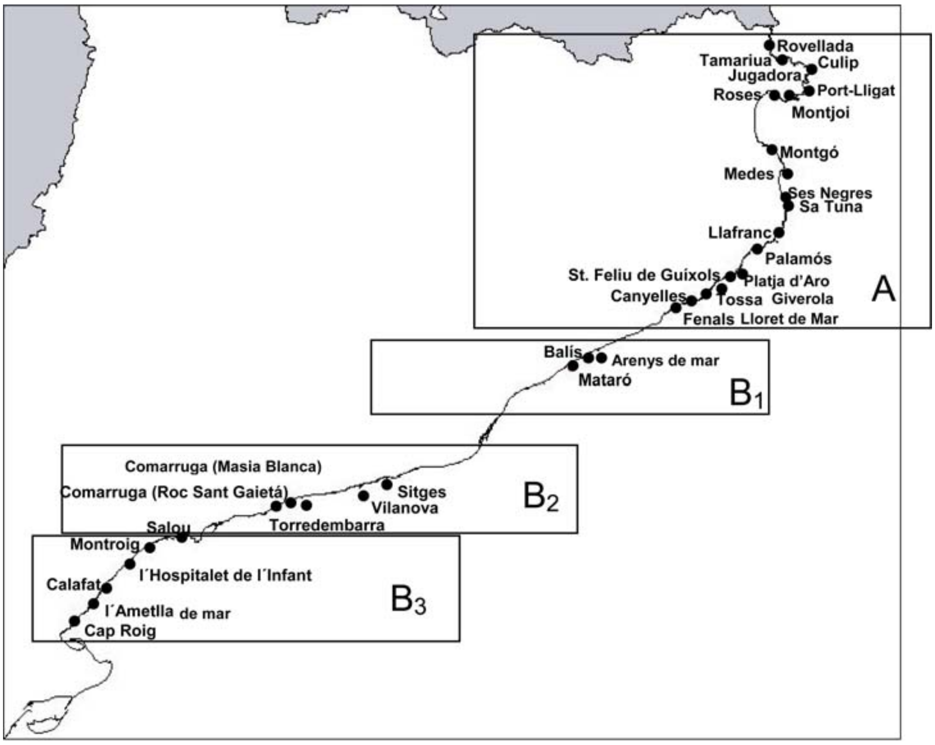

Fig. 1: Meadows in the Catalan coast belong to one of two typologies: in rocky coasts (Costa Brava, A) or in sandy coasts (B1, Maresme; B2, Garraf-Costa Daurada; B3, from Cap Salou to the Ebro Delta). The dots indicate the sampling sites of the different monitoring programmes.

The data were obtained from the following monitoring programmes (see also Table 1)

a) Monitoring of the *P. oceanica* meadow in the Illes Medes marine reserve, from 1983 to 2006
b) Surveillance network of *P. oceanica* meadows in the Catalan coast from 1998-2001 (*Xarxa de vigilància dels herbassars de fanerògames marines*, Direcció General de Pesca i Afers Marítims)
c) Monitoring of the *P. oceanica* meadow in Mataró from 1997 to 2006 (local authorities, diving club Spas, local volunteers)
d) Monitoring of *P. oceanica* meadows in the Catalan coast from 2002 to 2006, for the implementation of the Water Framework Directive (*Xarxa de Vigilància bàsica i operativa – Directiva Marc de l'Aigua*, Agència Catalana de l'Aigua).

Tab. 1: Summary of the main features of the monitoring programs.

Monitoring program	**Meadows studied**	**Number stations**	**Sampling depth (m)**	**Sampling frequency**	**Variables measured**	**Reference**
a)	1	4	5- 14	1984, 1987 and yearly from 1990 to 2006	Cover Density	Romero and Pérez, 2006
b)	21	26	5-20	yearly	Cover Density Deep limit	Renom and Romero, 2001
c)	1	2	12-20	yearly	Cover Density Limit	Muñoz-Ramos, 2005
d)	29	29	14-17	yearly	Cover Density Other parameters related to seagrass health	Romero *et al.*, 2004

Results and discussion

Three aspects should be considered, when attempting an assessment of seagrass status: seagrass meadow surface, seagrass abundance and seagrass health.

Data on seagrass surface on the Catalan coast are relatively uncertain. A cartography performed in 1991 produced an estimate of 4000 ha, later re-evaluated at ca. 6000 ha. (http://www.gencat.net/darp/c/pescamar/sigpesca/csig25.htm). In an exercise made using old aerial photographs, indications appearing in old nautical maps and available matte cartography, Romero (unpublished results) concluded that the seagrass surface at the time of the work (that is, 1995) was probably something between 75 and 80% of the original one (pre-industrial times). This contention is, however, rather speculative and should be viewed with extreme caution. What appears more consistent is the observation that the losses in seagrass surface have occurred, for the most, before 1990, and probably much earlier. In effect, since the beginning of systematic extensive seagrass observations, no significant surface losses (i.e. affecting >1% of the total) have been observed. This is largely confirmed by the monitoring of the kinetics of the deep *P. oceanica* limit. In effect, out of the 250 *balises* deployed (in 1998), only 20 (8%) indicated regression over the subsequent four-year monitoring period, with an average regression (for those 20 balises) of 0.5 m year^{-1}.

The seagrass abundance, as expressed by density (shoots per unit area) and cover (percent of substrate covered by *P. oceanica* within a relatively small spatial reference, 0.25 m^2), suffers considerable interannual fluctuations, as shown by the two longest series of available data. Although one site is in a relatively undisturbed area (Medes Islands, Fig. 2) and the other one is off of a densely populated coastline (data not shown), in none of them neither density nor cover have undergone net changes over the period studied (1984-2006 for Medes Is., 1997-2006 for Mataró). As the range of the fluctuations (expressed as 100*(maximum-minimum)/mean) have been as high as 48 % for density and 76 % for cover in Medes Is., a big caution is needed when making long term predictions using short-term data (e.g. Marbà *et al.*, 1996).

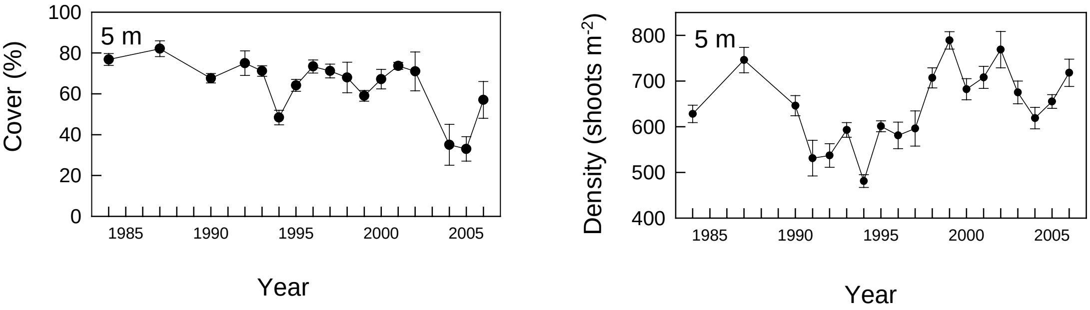

Fig. 2: Annual changes in cover and density in a permanent station situated at 5 m in the **Posidonia oceanica** ***meadow in the Medes Islands Marine reserve. Source: Romero et al., 2006.***

Despite the difficulty to establish reference values for density (but see Pergent *et al*., 1995) or cover, the analysis of a relatively large dataset (Renom and Romero, 2001) allows to reach the conclusion that a significant part of the meadows presented density and/or cover values below optimal ones (i.e. those expected in absence of human impacts). Out of 26 meadows studied during four years, 11 presented values close to the reference ones, 9 presented values moderately below (20-50 % lower than the reference) and the rest (6) largely below (> 50% lower than the reference; Fig. 3a). These figures did not change along the four-year monitoring period, indicating stability in the seagrass abundance.

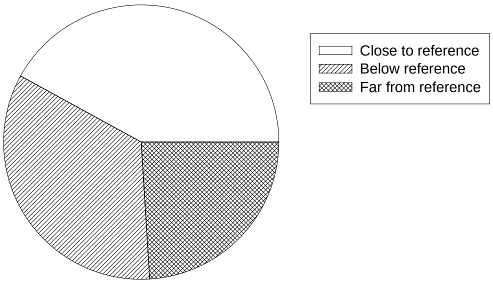

Fig. 3a: Density of meadows, compared to reference conditions, in the Catalan coast in the period 1998-2001. Source: Renom and Romero, 2001.

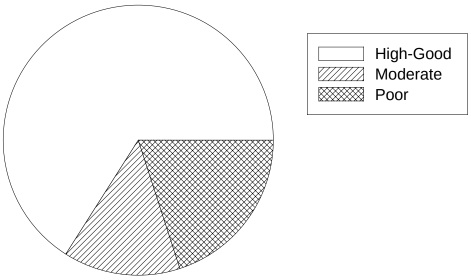

Fig. 3b: Ecological status of the meadows studied in the Catalan coast in the period 2003-2005. Source: Romero et al., 2004.

Finally, the assessment of seagrass health performed using multiple descriptors (density and cover, but also starch and nutrient concentration, isotopic composition, etc. see Romero *et al.*, 2007) indicated that, out of 29 meadows studied, about 66 % were in high or good status, 14 % in moderate status and 20 % in poor status (Fig. 3b), with reduced fluctuations for the period for which data were available.

Conclusion

Evidences presented here support the notion that seagrass meadows along the Catalan coast have significantly deteriorated, from all the three points of view considered (surface, abundance and health). However, it would seem that this deterioration is not proceeding further, at least at measurable rates. While it is true that, locally, seagrass are still suffering impacts (underwater works, moorings, etc.) such impacts are becoming less and less frequent, due to laws and other administrative considerations, both regional (seagrasses are protected species in Catalunya, *Ordre, de 31 de juliol de 1991, per a la regulació d'herbassars de fanerògames marines*), national and international (Habitat Directive, Water Framework Directive). Seagrass decline and/or regression, thus, seems to have stopped or at least slowed down dramatically. However, the situation is far from being satisfactory. To halt decline is not enough, as, roughly speaking, half of the meadows are not in good state. Efforts should be made to improve seagrass health, and to reach the environmental conditions adequate for the recovery of their abundance (density and cover) and, in the long term, also for the recovery of the surface lost. This seems especially important when seagrass meadows will have to endure, in the near future, new threats such as those derived from global climate change.

Two are probably the main difficulties for adequate seagrass conservation. The first one is the increasing importance of diffuse impacts as causes of seagrass deterioration. Such diffuse impacts arise from the intense and ever-increasing land use in coastal areas, and are the most difficult to manage. The second one is the administrative fragmentation of responsibilities on these (and other marine) ecosystems. To respond to both aspects seems a major challenge for the coming years.

Acknowledgments

Thanks are given to all the sponsors demonstrating interest in seagrasses and providing finantial support to the monitoring programmes, and specially to the Agència Catalana de l'Aigua, the Direcció General de Pesca i Afers Marítims and the Ajuntament de Mataró. Our gratitude is also for those that have enthusiastically participated in all those programmes, on a volunteer basis. Special thanks to SPAS diving club, to the Escola del Mar de Badalona and to Gregori Muñoz-Ramos, Pere Renom and Begoña Martínez-Crego.

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Marta SALES, Enric BALLESTEROS
Centre d'Estudis Avançats de Blanes. CSIC. Acc. Cala St. Francesc, 14. 17300 Blanes. Girona. SPAIN
e-mail: martas@ceab.csic.es

SHALLOW, SHELTERED WATER POPULATIONS OF *CYSTOSEIRA* SP. IN MENORCA (BALEARIC ISLANDS)

Abstract

The distribution of species of the genera Cystoseira *in shallow sheltered waters in the island of Menorca (Northwestern Mediterranean) is described after the exploration of 103 coves. Nine different taxa have been found:* C. stricta*,* C. balearica, C. compressa var. compressa, C. compressa var. pustulata *(*= C. humilis *sensu Cormaci* et al.*, 1992),* C. crinita, C. spinosa var. tenuior, C. algeriensis, C. foeniculacea var. tenuiramosa *and* C. barbata*. There is a strong assymetry between the northern and the southern coast: all the above-mentioned taxa are present in the north but only five have been found in the south. The innermost parts of the northern coves are occupied mainly by* C. crinita *and* C. spinosa var. tenuior *and the outer parts are covered by* C. balearica, C. compressa *and* C. stricta*.* C. stricta *is the only abundant species in the southern coves, where no gradation of species occur. Coves situated next to important harbour areas showed no presence of* Cystoseira *sp. populations.*

Key-words: Communities, Conservation, Marine vegetation, *Cystoseira*, Menorca..

Introduction

Brown algae of the genera *Cystoseira* dominate several rocky benthic communities in unpolluted and well iluminated areas of the Mediterranean Sea (Giaccone, 1973). These communities have a complex structure that allows the presence of a large number of vegetal and animal companion species (Bellan-Santini, 1969; Verlaque, 1987; Ballesteros, 1992). Many of these communities are currently disappearing or regressing from several localities throughout the Mediterranean Sea (Munda, 1982; Hoffmann *et al.*, 1988; Cormaci and Furnari, 1999; Thibaut *et al.*, 2005; Serio *et al.*, 2006). Eutrophication is mainly to be blamed for these disappearances, although other causes like chemical pollution, increased turbidity levels, overgrazing, or climate change have also been suggested as possible causes (Thibaut *et al.*, 2005; Serio *et al.*, 2006).

Menorca (Balearic Islands, Northwestern Mediterranean) (Fig. 1) extends about 50 km from west to east and 20 km from north to south and its coastline measures 441 km. Geologically and geographically, the island is divided into two very different parts: north and south. Materials of the northern part are more ancient and belong to different geological periods with dominance of non-carbonated materials. The coastline is very irregular with alternance of cliffs, little coves and big sheltered bays. The southern coast is totally carbonated and belongs to the Miocenic period. In consequence, the coastline is straight with rocky cliffs and narrow coves. Large coastal areas are protected, human presence is not very important, and pollution is generally low. Nevertheless, the island is not safe from touristic expansion and some focus of pollution and anthropogenic disturbances exist along the coast.

Taking into account the importance of *Cystoseira* sp. populations for biodiversity conservation, their regression observed in several Mediterranean areas, and the privileged situation of Menorca, it is worth to know the current situation of *Cystoseira* assemblages in Menorca. In this paper we describe the distribution of shallow water populations dominated by *Cystoseira* sp. in sheltered areas of the island, where the diversity of *Cystoseira* species seems to be very high.

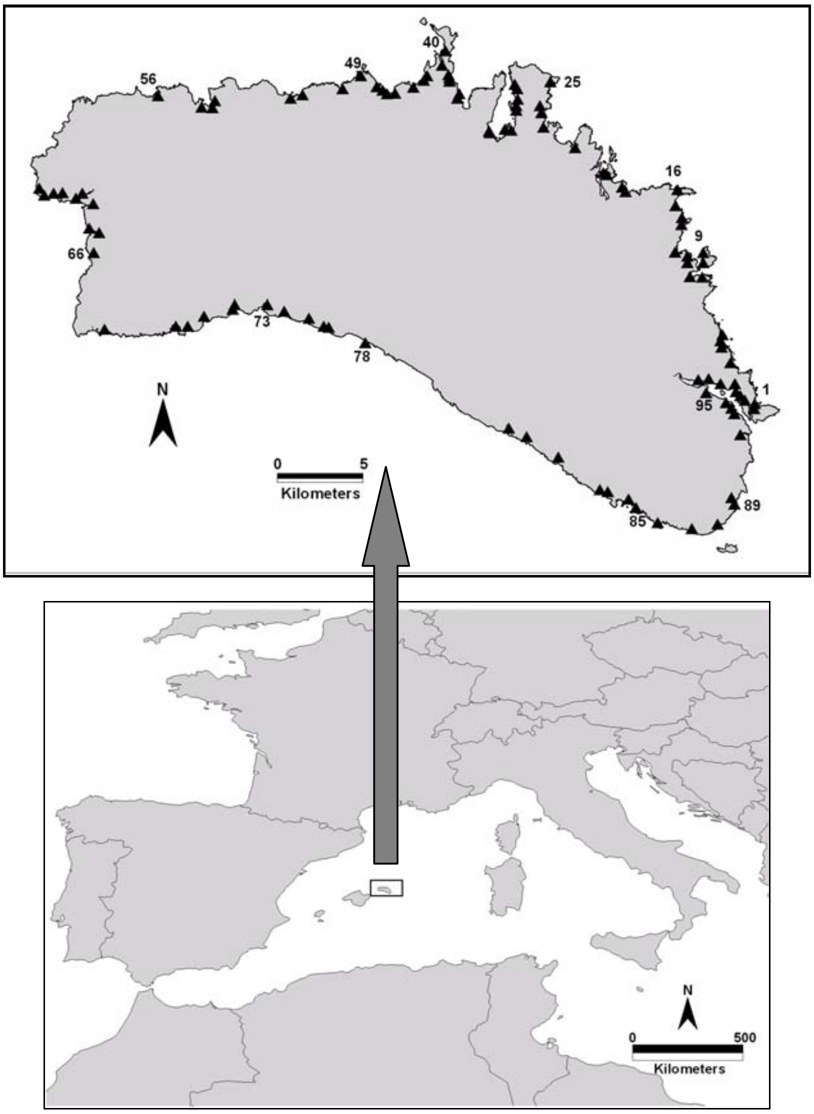

Fig. 1: Map of the study area.

Materials and methods

Field work was carried out in spring, during May and June 2005, when *Cystoseira* species are completely developed and are easy to observe and identify. A total of 103 sheltered coves were visited (Fig. 1). The coastline of each cove was surveyed by snorkeling and abundances of the different species of *Cystoseira* were recorded. These abundances were measured in a semi-quantitative scale from + (presence) to 5 (total cover) (Braun-Blanquet, 1979) for each species found at each site.

Specimens that were not identified *in situ* were collected and identified in the laboratory. Vouchers are kept in the UdG herbarium (Universitat de Girona).

Data was entered to a GIS for easy interpretation and handling in future studies. In order to make a classification of the coves according to *Cystoseira* species composition, Cluster Analysis was applied to data using *k-means* method and *Bray Curtis* distance. *Van der Maarel* transformation was performed before the analysis, since is not possible to make arithmetic operations with data expressed in Braun-Blanquet scale (Cáceres, 2003).

Results

Nine different specific and infraespecific taxa of the genera *Cystoseira* were found: *C. stricta, C. balearica, C. compressa var. compressa, C. compressa var. pustulata* (= *C. humilis* sensu Cormaci *et al.*, 1992*), C. crinita, C. spinosa var. tenuior, C. algeriensis, C. foeniculacea var. tenuiramosa* and *C. barbata*. Presence and abundance of these species at each study site are presented in Table 1.

Tab. 1: Cystoseira species abundances for each site (C.str: **Cystoseira stricta*****; C.com:*** **Cystoseira compressa *var.* compressa*****; C.pus:*** **Cystoseira compressa *var.* pustulata *(*= C. humilis *sensu Cormaci* et al.*, 1992); C. cri:*** **Cystoseira crinita*****; C.bal:*** **Cystoseira balearica*****; C.spit:*** **Cystoseira spinosa *var.* tenuior*****; C.alg:*** **Cystoseira algeriensis*****; C.foe:*** **Cystoseira foeniculacea *var.* tenuiramosa*****; C.bar:*** **Cystoseira barbata*****).***

	Site	C.str	C.com	C.pus	C.cri	C.bal	C.spit	C.alg	C.foe	C.bar
1	Es Freus	2		+		+				
2	Es Murtar		1	4	2	2		1		
3	Sa Mesquida 1	+	1	4	2	3				
4	Sa Mesquida 2	3	2	3	3					
5	Raconada M		+	3	2	3		+		
6	Cala Avellana	1	1	1	+	2	1			
7	Es Grau	2	1	+	1	2		+		
8	Pl. Tamarells			1	1 _ 2		1 _ 2			
9	Ar. d'en Moro	+	+	1	2	3	3			
10	Tamarells S		1 _2	2	3 _ 4		4	+	1	
11	Tamarells N		2	2	3		3	1	2	
12	Sa Torreta		+	2	3			3	1	
13	Cavaller		2 _ 3	1	1	+	1	2		
14	Morella Nou	+	2	+	2 _ 3	2		2		
15	Tortuga	+	2	+	2	+		1		
16	S'Escala	+	2	+	4	1 _ 2	1	+		
17	S'Enclusa		2	+	3	1	1			
18	Mongofre	+	3	+	3 _ 4	+	1	1		
19	S'Estany		+	1	+		2	+	1	
20	Cala Rotja 1			2			2		2	
21	Arenal		+		+	1				
22	Son Parc	+	+		+	1				
23	Pudent 1		1	1	2	2	2	1		
24	Pudent 2		+	1	+		+			
25	Tosqueta		1	2	2	1	1		+	
26	S'Arenalet			1	+		1	2		+
27	Cabra Salada		+	+			+		+	1
28	S'Albufereta		+	1 _ 2	+			2	+	+
29	Es Pi			1				+	+	2
30	En Pavada			+					+	+
31	S'Era			+			2		+	2
32	Cala Rotja 2						+		+	1
33	Miami 1			+					1	+
34	Miami 2			+					+	+

	Site	C.str	C.com	C.pus	C.cri	C.bal	C.spit	C.alg	C.foe	C.bar
35	Talaieta		1 _2		3 _ 4	2	4			
36	Illots Tirant	+	2	1	4	3	4		1	
37	Binidonaire	1	2		3	3	3			
38	Sa Mitjera		2		1	3	2			
39	En Saler	1	2	+	1	3	1			
40	Cala Viola	+	2	1	1	2	1	+	+	
41	Sa Nitja		2	1	2	2	2	1	2	
42	Cala Rotja 3		2	1	3	1	3			
43	Cavalleria		3	+	3	+	2			
44	Mica		1	+	2	+	3			
45	Binimel·à	+	1		3	3	+	+		
46	Morts		1	1	3	1	3	1	1	
47	Embarcador	+	+	1	4	+	2			
48	Pregonda		+	1	3	1	1		+	
49	Barril		1	+	3 _4		3	+		
50	Calderer	1 _ 2	1		3	2	+			
51	Alocs	1	2	+	2	2	1			
52	Pilar	+	1		2	1	+			
53	Vall 1	1	+		+	+				
54	Vall 2	2	1		2	+				
55	Fontanelles	1	1	2	3	2	1	1		
56	Morell	1	2			+		+		
57	Piques	1	+							
58	Forcat	3	+							
59	Brut	2	1			+				
60	Blanes	+	+							
61	Frares	+								
62	Busquets									
63	Platja Gran	+								
64	Sa Caleta	1 _2	+							
65	Santandria	+								
66	Blanca	2	+							
67	Xoriguer	3	3			4				
68	Son Saura	3	2	3		2				
69	Talaier	3	+							
70	Turqueta	2	+			1				
71	Macarelleta	2	+			2				
72	Macarella	1	1							
73	Galdana	+								
74	Mitjana	2	1							
75	Trebalúger	1	+							
76	Fustam	2	1			+				
77	Escorxada	2	1							
78	Binigaus	2	+							

Site		C.str	C.com	C.pus	C.cri	C.bal	C.spit	C.alg	C.foe	C.bar
79	Cala'n Porter									
80	Cales Coves	+				+				
81	Canutells	1	+							
82	Binidalí	2	+							
83	Biniparratx	1	+							
84	Binisafulla	3	+							
85	Sa Barca	+	2_3			3		2		
86	Binibeca	4	2							
87	Biniancolla	3	+			+				
88	Pta Prima	3	+							
89	Caló Roig	2								
90	Alcaufar	2 _ 3								
91	St Esteve	3	1			+				
92	Pedrera									
93	Fonts									
94	Corb									
95	Figuera									
96	Nou Pinya									
97	Cala Rata									
98	Apartió									
99	Llonga									
100	Cavallo									
101	Lladró									
102	St Jordi									
103	Teulera		1							

Different distribution patterns were detected in the northern and the southern coasts of the island: all the above-mentioned taxons were found in the north, but only five inhabited the southern coast. Inner parts of the northern coves were occupied mainly by *C. crinita* and *C. spinosa var. tenuior* dense populations, while *C. balearica*, *C. compressa* and *C. stricta* were common species in the outer parts. In the southern coves only *C. stricta* was very abundant and it was mainly present in the outer zones.

The results of Cluster Analysis revealed the existence of four different groups of coves (Fig. 2). A fifth group is constituted by coves where *Cystoseira* sp. are absent.

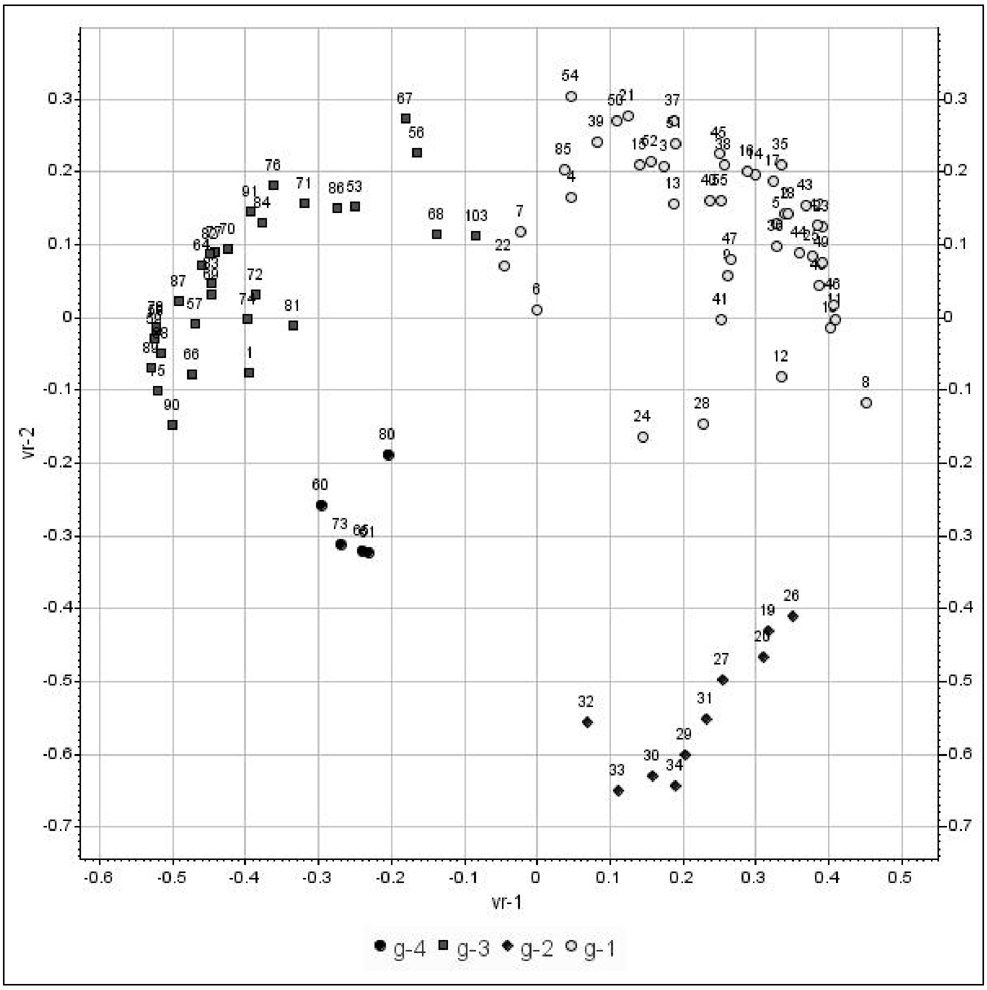

Fig. 2: Multi Dimensional Scaling representation of the study sites showing the classification made by Cluster Analysis.

Group 1

It is constituted by northern typic coves with semicircular form, low coast and horitzontal slope. Anthropogenic disturbances and river inflow is generally low. *Cystoseira* sp. populations are abundant and form dense settlements with presence of almost all the taxa found at all surveyed sites. Only *C. barbata* assemblages are absent.

Group 2

Northern coves situated at the inner part of big and extremely sheltered bays (Fornells and Addaia) are the members of this group. The bottom of these coves is soft, muddy and covered by *Cymodocea nodosa* beds. *Cystoseira* settlements are not dense in these sites, as they only grow over small stones or *C. nodosa* rhizomes. *C. barbata* is a characteristic taxa of these environments and it is normally found together with *C. foeniculacea* and *C. compressa var. pustulata* (= *C. humilis* sensu Cormaci *et al.*, 1992*)*. Other common taxa are *C. spinosa var. tenuior* and *C. algeriensis*. *C. compressa var. compressa* and *C. crinita* occasionally appear in the most exposed areas. *C. stricta* or *C. balearica* are always absent.

Group 3

Southern typic coves are assigned to this group; these are narrow coves with high coast and vertical slopes. However, some northern coves with impovered *Cystoseira* populations (e.g. Cala Morell, La Vall, Es Freus) were also assigned to this group. The coves show a clear dominance of *C. stricta*, although other species are also present.

Group 4

Southern coves with poor *Cystoseira* populations are assigned to this group (e.g. Ciutadella harbour, Cales Coves, Cala Galdana). Only three species of *Cystoseira* grow in these sites (*C. stricta, C. compressa var. compressa* and *C. balearica*) and with very low abundance.

Group 5

This group is made by all sites with absence of *Cystoseira* species, most of them situated in the harbour areas of Maó and Ciutadella.

Discussion

The number of *Cystoseira* species found in the shallow, sheltered bays and coves in Menorca is still high and similar to what it was reported for the Alberes Coast and the Catalan Coast more than seventy years ago (Sauvageau, 1912; Feldmann, 1937). This fact should be related to the relatively good environmental conservation of the island and the lack of the same environmental pressures and impacts that have degraded bays and coves in the mainland.

Some of the species are widely distributed around the island (e.g. *C. stricta, C. compressa var. compressa, C. balearica*). Other species are only or almost only present along the northern coast (e.g. *C. algeriensis, C. compressa var. pustulata, C. crinita, C. spinosa var. tenuior, C. foeniculacea*). Finally, *C. barbata* is only present in Fornells Bay (group 2). These differences are probably due to geomorphological causes more than pollution or anthropogenic disturbances. A higher geomorphological diversity in the northern coast favours a higher diversity of *Cystoseira* species; most of the taxa only present in the northern coast probably require very sheltered conditions (e.g. *C. barbata*, *C. foeniculacea*) that only some northern coves offer.

The five groups defined after applying a Clustering Analysis to the coves using as descriptors the *Cystoseira* sp. distribution, closely agree with geomorphological types. Only harbour areas have been strongly modified or are receiving strong environmental pressures that could prevent development of *Cystoseira* sp. assemblages. In fact, some species reported at these areas in the past (Rodríguez-Femenías, 1889) have currently disappeared (e.g. Maó harbour area).

Since *Cystoseira* assemblages are very good indicators of environmental quality (Bellan-Santini, 1968; Soltan *et al.*, 2001; Thibaut *et al.*, 2005; Arévalo *et al.*, 2007) and they are being used as ecological indicators in biological monitoring for water quality assessment according to the EEC Water Framework Directive (Ballesteros *et al.*, 2007; Pinedo *et al.*, 2007), the present study can be used as a baseline to check possible future changes in water quality in the surveyed coves. Moreover, this study reveals that sheltered *Cystoseira* assemblages are strongly determined by geomorphological features of the coast, not only by water quality.

Acknowledgements

This work was supported by an IP3 fellowship from CSIC and *Institut Menorquí d'Estudis* cofinanced by Social European Fund. The Natural Parc *Albufera des Grau i Cap de Favàritx* staff supported field work in the sites inside the Parc and allow us to utilize their laboratory equipments.

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Yassine-Ramzi SGHAIER, Rym ZAKHAMA-SRAIEB, Faouzia CHARFI-CHEIKHROUHA
Unité de Recherche de Biologie Animale et Systématique Evolutive, Faculté des Sciences de Tunis 2092 Manar II, TUNISIE, e-mail: yassinramzi@yahoo.com

ETUDE LEPIDOCHRONOLOGIQUE DE QUELQUES HERBIERS DE *POSIDONIA OCEANICA* DES COTES TUNISIENNES

Résumé

Six herbiers de posidonies de la côte tunisienne ont fait l'objet d'une étude lépidochronologique. La croissance de cette magnoliophyte, lors des dernières décennies, a été examinée sous la lumière des changements climatiques, du stress anthropique, ainsi que de la localisation géographique. La densité des faisceaux et l'étude lépidochronologique montrent une régression des herbiers dans les sites les plus anthropisés. La croissance des rhizomes est significativement plus élevée au niveau des stations du nord, en particulier à Tabarka (13.72±2.66 mm an^{-1}) ; ce résultat semble être lié à l'importance des apports sédimentaires des cours d'eau dans cette région.

Mots-clés : Magnoliophyte marine, *Posidonia oceanica*, Densité, Lépidochronologie, Tunisie.

Abstract

Six Posidonia *meadows were studied and compared through shoot density and lepidochronology. The growth of the seagrass was examined in the light of bioclimatic zones, anthropogenic stress and geographical location. Both shoot density and lepidochronology pointed to a regression of meadows in the most perturbed sites. The rhizome growth is more important in northern sites, particularly in Tabarka; this result seems related to an over sedimentation in this site.*

Key-words: Seagrass, *Posidonia oceanica*, Shoot density, Lepidochronology, Tunisia.

Introduction

Plusieurs études récentes ont indiqué que la variabilité du climat, associée aux pressions anthropiques croissantes sur le littoral, pourrait avoir des répercussions sur la structure et le fonctionnement des écosystèmes marins côtiers, en particulier les herbiers de *Posidonia oceanica* (Pergent *et al*., 1999; Guidetti and Fabiano, 2000; Guidetti, 2001; Gonzalez-Correa *et al*., 2005). Les limites supérieures de l'herbier, qui correspondent à la partie la plus proche de la côte en terme de bathymétrie, constituent des secteurs particulièrement sensibles à toutes les modifications du milieu (Pergent *et al*., 2005).

En Tunisie, *Posidonia oceanica* est présente sur presque tout le littoral et constitue l'écosystème marin le plus important. Les herbiers tunisiens subissent, comme partout ailleurs en Méditerranée, des agressions d'origine humaine plus ou moins importantes (Ben Maiz, 2000).

Une des caractéristiques de *Posidonia oceanica* est le fait qu'elle présente une variation cyclique de l'épaisseur de ses écailles (Crouzet *et al*., 1983). La science qui s'intéresse à ces variations est appelée lépidochronologie (Pergent, 1987). L'intérêt de cette étude est la reconstitution de l'histoire évolutive de l'environnement côtier et éventuellement l'estimation de l'importance des perturbations naturelles et/ou anthropiques sur les herbiers à *Posidonia oceanica*.

Matériels et méthodes

Six herbiers de posidonies ont fait l'objet de campagnes d'échantillonnage durant la période 2004-2006. Il s'agit des deux herbiers du bassin occidental, Tabarka et Rafraf situés respectivement au niveau de la côte Nord-Ouest et Nord-Est de la Tunisie et des quatre herbiers du bassin oriental, Hergla, El Kantaoui, Monastir et Mahdia, localisés le long de la côte Est (Fig. 1).

Le travail a été effectué par plongée sous marine ou en apnée à -2m de profondeur. Les herbiers étudiés se développent principalement sur substrat meuble à l'exception de ceux de Mahdia et Raf-Raf sur substrat rocheux. Pour chaque site, on a estimé, *in situ* et à l'aide d'un quadrat de 40 cm de côté, la densité des faisceaux ; dix répliques ont été effectuées. Une vingtaine de faisceaux orthotropes ont été prélevés au niveau de chaque site et soumis à une étude lépidochronologique au laboratoire.

Les écailles de chaque rhizome sont très soigneusement détachées en respectant l'ordre distique de leur insertion, en partant des plus anciennes vers les plus récentes. L'épaisseur des écailles est appréciée au toucher. La position des hampes florales, insérées entre les écailles, est également notée. La longueur des rhizomes entre deux écailles d'épaisseur minimale est aussi mesurée. Le nombre moyen d'écailles par cycle annuel, la vitesse de croissance des rhizomes, ainsi que les dates des anciennes floraisons (paléofloraisons) ont été estimés sur 10 ans (1993-2003).

Afin de comparer les valeurs moyennes des paramètres étudiés, le test statistique de Kruskal-Wallis et le test de Wilcoxan ont été appliqués.

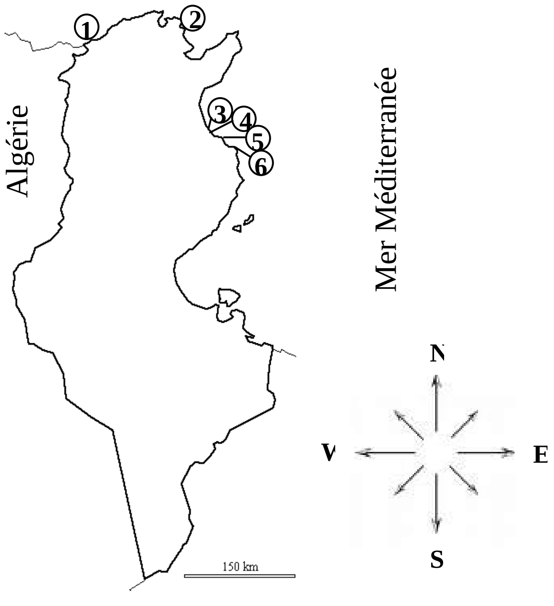

Fig. 1: Herbiers échantillonnés : 1-Tabarka ; 2-Rafraf ; 3- Hergla ; 4- El Kantaoui; 5- Monastir; 6- Mahdia.

Résultats

Densité **:** la densité des faisceaux varie de 388 faisceaux m^{-2} au niveau de l'herbier d'El Kantaoui à 894 faisceaux m^{-2} au niveau de l'herbier de Mahdia (Fig. 2). Les valeurs de la densité des herbiers étudiés diffèrent significativement (Kruskal-Wallis, P<0.01). En se référant à la classification de Giraut (1977), l'herbier de Mahdia et de Rafraf sont de type I et qualifiés de « très dense », les herbiers de Hergla, Monastir et Tabarka sont de type II et qualifiés de « dense », l'herbier d'El Kantaoui, de type III, est qualifié de « clairsemé ». Selon la classification plus récente de Pergent *et al*. (2005), les herbiers de Mahdia et de Rafraf sont considérés en « bon état », ceux de Hergla, Tabarka et Monastir en « état médiocre » et celui d'El Kantaoui en « mauvais état ».

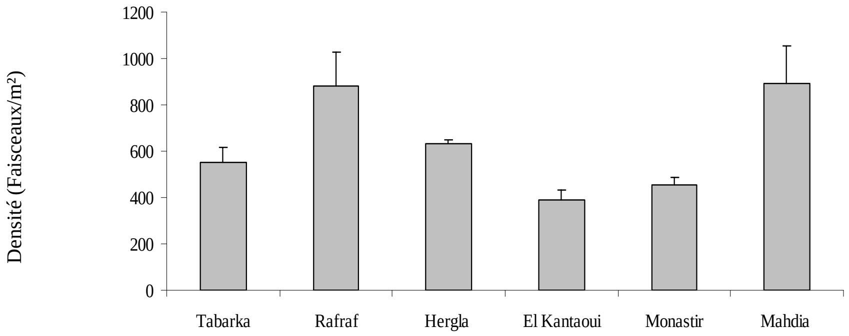

Fig. 2 : Densité moyenne des faisceaux au niveau des herbiers de Posidonies des sites étudiés (les barres représentent la déviation standard).

Etude lépidochronologique

Les résultats obtenus de l'analyse lépidochronologique sont groupés dans la table 1.

Tab. 1 : Age moyen du rhizome (± déviation standard), âge maximum, vitesse de croissance moyenne du rhizome, nombre moyen de feuilles produites par an (± déviation standard) de chaque herbier de **Posidonia oceanica** ***et des herbiers groupés selon leur localisation dans l'un des deux bassins, oriental et occidental de la Méditerranée***

Site	Moyenne d'année lépidochronologique étudiées (années)	Maximum d'année lépidochronologique étudiées (années)	Vitesse croissance moyenne du rhizome (mm an^{-1})	Feuilles (nombre an^{-1})
Tabarka	8.5 (±1.9)	18	13.7 (±2.7)	8.3 (±0.7)
Rafraf	9.7 (±1.1)	15	8.8 (±1.5)	6.3 (±0.7)
B. Occidental	9.2 (±1.1)	18	11.3 (±1.7)	7.3 (±0.5)
Hergla	9.2 (±2.4)	14	6.5 (±1.0)	8.0 (±0.7)
El Kantaoui	9.4 (±1.6)	13	6.2 (±2.0)	7.1 (±0.6)
Monastir	11.6 (±4.0)	17	7.2 (±1.4)	7.9 (±0.6)
Mahdia	9.0 (±3.3)	16	5.7 (±0.8)	7.8 (±0.5)
B. Oriental	9.8 (±0.7)	17	6.4 (±0.5)	7.7 (±0.3)

Production annuelle de feuilles **:** le nombre de feuilles produites annuellement varie de 6.3 feuilles an^{-1} au niveau de l'herbier de posidonie de Rafraf à 8.3 feuilles an^{-1} au niveau de l'herbier de Tabarka (Fig.3). Les valeurs obtenues des différents herbiers sont statistiquement significatives (Kruskal-Wallis, P<0.01).

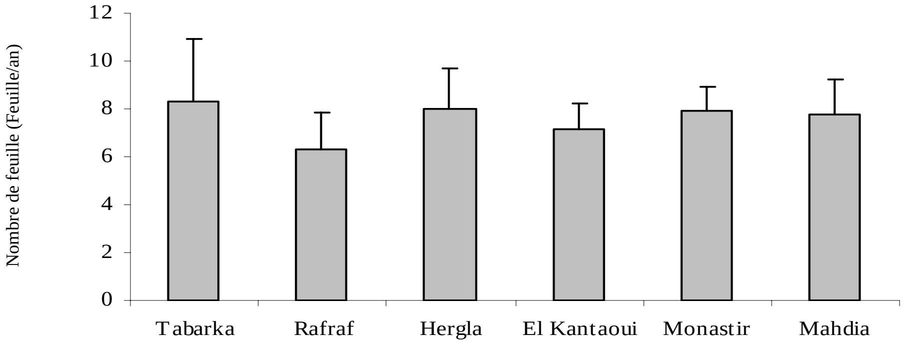

Fig. 3 : Nombre moyen de feuilles produites annuellement au niveau des herbiers de Posidonies des sites étudiés.

Vitesse de croissance moyenne des rhizomes **:** la vitesse de croissance moyenne des rhizomes (Fig. 4) est maximale au niveau des herbiers de Tabarka (13.7 mm an^{-1}) suivie par celle de Rafraf (8.8 mm an^{-1}) ; elle est minimale au niveau de l'herbier de Mahdia (5.7 mm an^{-1}). Cette vitesse varie significativement entre les différents herbiers (Kruskal-Wallis, P<0.01), ainsi qu'entre les herbiers du bassin oriental et occidental ; ce dernier montre une vitesse significativement plus importante (Wilcoxan, P<0.01).

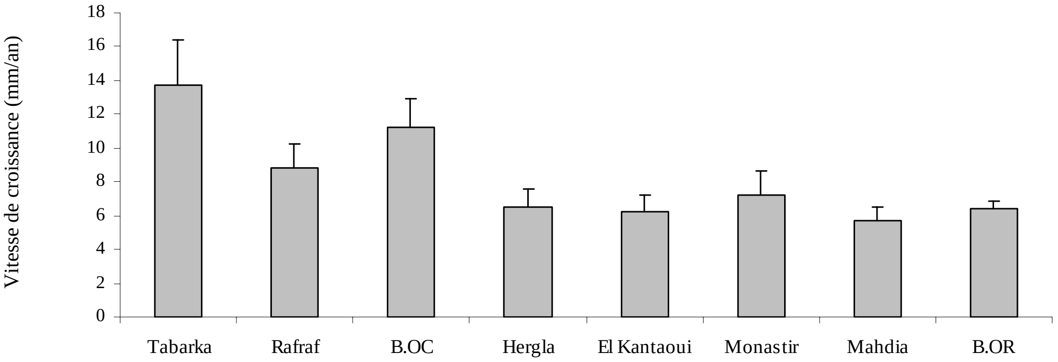

Fig. 4 : Vitesse de croissance moyenne des rhizomes au niveau des herbiers de Posidonies des sites étudiés et des deux bassins, oriental (B.OR) et occidental (B.OC).

Paléofloraison **:** les pédoncules floraux ont été trouvés durant l'année 1994 au niveau de l'herbier de Tabarka et l'année 2003 au niveau des trois herbiers, Tabarka, Hergla et Mahdia, alors qu'aucune floraison n'a été détectée au niveau des autres herbiers et à la même profondeur (Fig. 5). Le taux de floraison est important au niveau de l'herbier de Tabarka en 2003 où il atteint 40%.

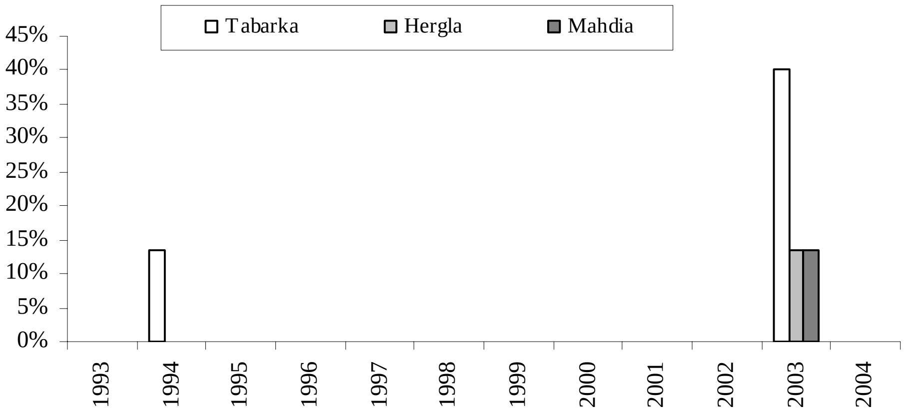

Fig. 5 : Taux de floraison de la posidonie à -2m de profondeur.

Discussion et conclusions

La variation de la densité des faisceaux, relevée dans les six herbiers, ne peut être liée à la profondeur étant donné que nos prélèvements ont été réalisés à la même faible profondeur (-2m). Cette variation s'expliquerait d'une part, par les variations des conditions du milieu, en particulier la nature substrat, meuble ou rocheux, et d'autre part, par le degré d'anthropisation. C'est le cas des deux herbiers à *Posidonia oceanica* de Mahdia et Rafraf, caractérisés par les densité les plus élevées, qui pourraient être le résultat de la nature du substrat rocheux qu'ils occupent, associé à une faible anthropisation (Zakhama and Charfi, 2005). Les travaux de Cristiani (1980) ont en effet montré des densités plus élevées pour des herbiers qui se développent sur substrats durs par rapport à ceux de substrats meubles.

La densité la plus faible, enregistrée au niveau de l'herbier d'El Kantaoui, reflète l'état de l'anthropisation de cette zone. Ceci est confirmée par la présence d'une superficie de matte au niveau de la limite supérieure de l'herbier d'El Kantaoui indiquant sa nette régression (Sghaïer *et al*., 2006a-b) qui serait due aux perturbations des conditions du milieu.

Selon Pergent-Martini *et al*. (1999), le nombre de feuilles produites annuellement est qualifié de « normal » pour tous les herbiers étudiés, à l'exception de celui de Rafraf qualifié de « subnormal ». La réduction du nombre de feuilles produites au niveau de ce dernier herbier pourrait reposer sur ces deux hypothèses : 1) elle serait due à la présence de l'espèce invasive *Caulerpa racemosa* signalée par Djelloui, (2000). En effet, nous avons observé lors de l'échantillonnage la forte prolifération de cette espèce, malgré la forte densité de l'herbier de Posidonie ; 2) elle serait la conséquence d'une stratégie adoptée par la posidonie qui investit plus d'énergie dans la croissance de ses feuilles que dans le nombre de feuilles produites ; cette hypothèse est étayée par les longueurs exceptionnelles des feuilles de *Posidonia oceanica* que nous avons enregistrées dans l'herbier de Rafraf, comparées aux feuilles des autres herbiers échantillonnés durant les mêmes périodes. Les résultats trouvés sont en contradiction avec les travaux de Dumay *et al.* (2002) portant sur la compétition entre *Caulerpa racemosa* et *Posidonia oceanica* ; ces travaux montrent que la magnoliophyte produit un plus grand nombre de feuilles de taille plus réduite lorsque l'interaction (compétition) augmente.

Au niveau des herbiers du bassin oriental, l'herbier d'El Kantaoui présente le nombre moyen le plus faible de feuilles produites annuellement reflétant la forte anthropisation du milieu (présence du port touristique, installation de complexes touristiques, …). Cette réduction du nombre de feuilles produites sous l'effet de l'anthropisation a déjà été enregistrée par plusieurs auteurs notamment Guidetti and Fabiano (2000) et Guidetti (2001).

En se référant à la classification de Pergent-Martini *et al.* (1999), la vitesse de croissance des rhizomes est qualifiée de « anormale » à Tabarka, de « subnormale » à Mahdia et de « normale » dans les autres herbiers. Par ailleurs, en se basant sur le travail de Boudouresque *et al.* (1984) qui stipule que la vitesse de croissance des rhizomes est fortement corrélée à la vitesse de sédimentation, on peut déduire que la vitesse de sédimentation du niveau des herbiers de la côte septentrionale de la Tunisie est plus importante que celle des herbiers de la côte orientale. En effet, la pluviométrie élevée (entre 1000 et 1500 mm/an) et la topographie montagneuse de la région de Tabarka favorisent l'apport sédimentaire vers la mer ; il en résulte une vitesse de croissance du rhizome élevée (13.72 ±2.66 mm).

Rafraf, recevant annuellement entre 400 et 600 mm/an, présente une vitesse de croissance de 8.79±1.48 mm, alors que dans le centre de la Tunisie, qui ne reçoit que 300 mm/an, on enregistre les faibles valeurs de la vitesse de croissance au niveau des quatre herbiers situés dans cette zone. Cette relation entre le taux de pluviométrie et la croissance du rhizome a été également mentionnée par Peirano *et al.* (2005) au niveau des herbiers italiens.

Nous avons noté une corrélation significative entre la vitesse de croissance des rhizomes et le nombre de feuilles produites annuellement au niveau des herbiers de Tabarka, Hergla, El Kantaoui et Monastir. Cette corrélation a été observée au niveau des herbiers français par Pergent-Martini (1994). Or dans notre étude, cette relation n'est pas toujours vérifiée, en particulier au niveau de l'herbier de Rafraf et de Mahdia ; ce qui laisse penser que les différences observées pour les herbiers de Rafraf et de Mahdia s'expliquent par le fait qu'ils se développent sur substrat dur (croissance différente).

Des pédoncules floraux ont été observés au niveau de trois herbiers, Tabarka, Hergla et Mahdia au cours de l'année 2003 qui semble être favorable pour la floraison aussi bien en Tunisie qu'au niveau d'autres herbiers de la Méditerranée (Balestri *et al.*, 2005). A l'exception de l'herbier de Tabarka, aucune trace de floraison n'a été relevée au niveau des herbiers superficiels (-2m) durant la période 1994-2002. Cependant, si l'on tient compte des herbiers un peu plus profonds, des floraisons biannuelles ont été observées à Hergla et El Kantaoui (Sghaïer *et al.*, 2006a) et dans le golfe de Gabès (Hamza *et al.*, 2000).

A la lumière des résultats obtenus de cette étude lépidochronologique, ainsi que des informations acquises *in situ* telles que la densité des faisceaux, la présence d'algues invasives et la superficie importante de matte morte, il apparaît clairement une différence entre les herbiers à *Posidonia oceanica* des deux côtes, septentrionale et orientale de la Tunisie, particulièrement pour la vitesse de croissance des rhizomes qui semble être une réponse et une adaptation aux conditions environnementales du milieu, particulièrement la sédimentation, elle-même liée aux précipitations et à l'impact de l'anthropisation.

Remerciements

Cette étude a été financée par MEDCORE projet (ICA3-CT2002-10003) et la DGRST (Ministère de l'Enseignement supérieur, de la Recherche Scientifique et de la Technologie.

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Abdessalem SHILI, Naceur BEN MAIZ, Charles-François BOUDOURESQUE
Institut National Agronomique de Tunisie.

DIVERSITE DES PEUPLEMENTS PHYTOBENTHIQUES DANS LES LAGUNES DU CAP BON (NORD-EST DE LA TUNISIE)

Résumé

L'étude de la diversité et de la répartition des peuplements phytobenthiques peuplant les lagunes de Korba et de Kélibia du Cap Bon nous a permis de recenser 12 espèces de macrophytes benthiques dans le premier plan d'eau et 8 dans le second. Parmi ces espèces, nous avons noté la présence de deux Magnoliophytes submergées, Ruppia maritima *et* Althenia filiformis *var.* barrandonii. *Ces deux espèces sont caractérisées par un cycle de vie relativement court aboutissant à une forte production de graines. Leur prolifération se limite à la saison printanière et au début de la saison estivale. Dans les deux milieux d'étude, ces Magnoliophytes se développent à des salinités allant de 4 à 50 psu et sont donc dotées d'une grande tolérance aux variations de la salinité. L'association Ruppia-Althenia caractérise les écosystèmes lagunaires du Cap Bon qui sont relativement confinés et exposés à des périodes de dessèchement.*

Abstract

The study of diversity and distribution of the phytobenthic communities in the lagoons of Korba and Kélibia (North-East of Tunisia) showed the presence of 12 macrophytes in the first lagoon and 8 in the second. From these species we have noted the presence of two submerged Magnoliophyta, Ruppia maritima *and* Althenia filiformis *var.* barrandonii. *These species are characterized by a relatively short life cycle which ends up with a strong seed production. Their proliferation is limited to spring and early summer. They seem to tolerate large salinity variations (from 4 to 50 psu). The Ruppia-Althenia association characterizes the lagoons in the area of Cap Bon. This community adapts well to the unstable ecosystems, relatively confined and exposed to dry periods.*

Mots-clés : Lagune, Kélibia, Korba, *Ruppia, Althenia*.

Introduction

Les lagunes de Korba et de Kélibia s'étendent au Cap Bon sur le littoral Nord-Est de la Tunisie. Il s'agit de milieux peu profonds et relativement instables en raison de leurs faibles communications avec la mer et de l'influence néfaste des zones urbaines avoisinantes.
Côtière et peu profonde (environ 0,5 m), la lagune de Korba longe la plage de la ville du même nom sur environ 8 km. Elle communique avec la mer à travers 4 petits chenaux et devient pratiquement isolée dès le début de la saison estivale. Outre les eaux marines et les eaux pluviales, ce milieu lagunaire recevait les rejets urbains et industriels de la ville de Korba.

La lagune de Kélibia est une succession de trois petites cuvettes qui communiquent faiblement entre elles et occasionnellement, en cas d'orages, avec la mer. Ce milieu reçoit essentiellement des apports d'eau par drainage des eaux pluviales. Avec ses trois bassins, cette petite lagune, s'étend sur une longueur d'environ 565 m et une largeur maximale de 122 m. La profondeur moyenne de la lagune ne dépasse pas les 30 cm. Les fonds sont plats à substrat vaseux.

De par leur position géographique, les lagunes de Korba et de Kélibia sont des sites privilégiés de transit et d'hivernage d'un grand nombre d'oiseaux d'eau. Dans ce travail, nous étudions la diversité et la répartition des peuplements phytobenthiques et particulièrement les Magnoliophytes peuplants ses écosystèmes importants du littoral tunisien.

Matériel et Méthodes

L'étude des peuplements phytobenthiques des deux milieux lagunaires du Cap Bon a été effectuée durant la période allant de 1997 à 2001. Nous avons effectué des prospections et échantillonnages dans les lagunes de Korba et de Kélibia le long de plusieurs transects perpendiculaires à la ligne des berges, selon la direction Est-Ouest pour le premier plan d'eau et Nord-Sud pour le deuxième. Parallèlement, nous avons assuré le suivi des peuplements dominants dans des stations fixes réparties dans les deux milieux lagunaires. La frange marine au voisinage de la lagune de Kélibia a été également prospectée à titre comparatif.

Résultat et discussion

Diversité du phytobenthos dans la lagune de Korba

La salinité des eaux dans la lagune de Korba varie de 20 à 75 psu. La diversité spécifique des peuplements phytobenthiques, relativement faible, montre la présence de 10 espèces de Chlorophyceae et 2 Magnoliophytes aquatiques (Tab. 1).

Tab. 1 : Liste des espèces phytobenthiques recensées dans les lagunes de Korba et Kélibia. + : espèce peu fréquente, ++ : espèce fréquente, +++ : espèce abondante.

ESPECES/LAGUNE		KORBA	KELIBIA
RHODOPHYCEAE	*Jania rubens* (Linnaeus) J.V. Lamouroux		+
CHLOROPHYCEAE/ ULVOPHYCEAE	*Cladophora* sp.	+++	+++
	Cladophora dalmatica Kützing	+	
	Cladophora prolifera (Roth) Kützing	+	
	Ulva linza (Linnaeus) J. Agardh	+	
	Ulva intestinalis Linnaeus	+	+
	Ulva compressa (Linnaeus) Greville	+	
	Ulva torta (Mertens) Trevisan	+	
	Rhizoclonium tortuosum (Dillwym)Kützing	+	+
	Chaetomorpha linum (O.F. Müller) Kützing		+
CHLOROPHYCEAE/ CHAROPHYCEAE	*Lamprothamnion papillosum* J. Groves	+	
	Chara sp.	+	+
MAGNOLIOPHYTA	*Ruppia maritima* Linnaeus	++	+++
	Althenia filiformis Petit	++	++

Le développement de la Magnoliophyte *Ruppia* se limite au secteur nord de la lagune avec une extension relativement faible et un recouvrement inférieur à 20 % (Fig. 1). Dans ce même secteur, les peuplements phytobenthiques montrent une dominance de la Chlorobionte *Cladophora* sp. et de la Magnoliophyte *Althenia filiformis*. Cette dernière constitue des herbiers très denses qui se développent au printemps et au début de l'été montrant de grandes variations saisonnières et interannuelles. Notons que les variations les plus importantes de la salinité correspondent au secteur nord, lieu de prolifération des Magnoliophytes.

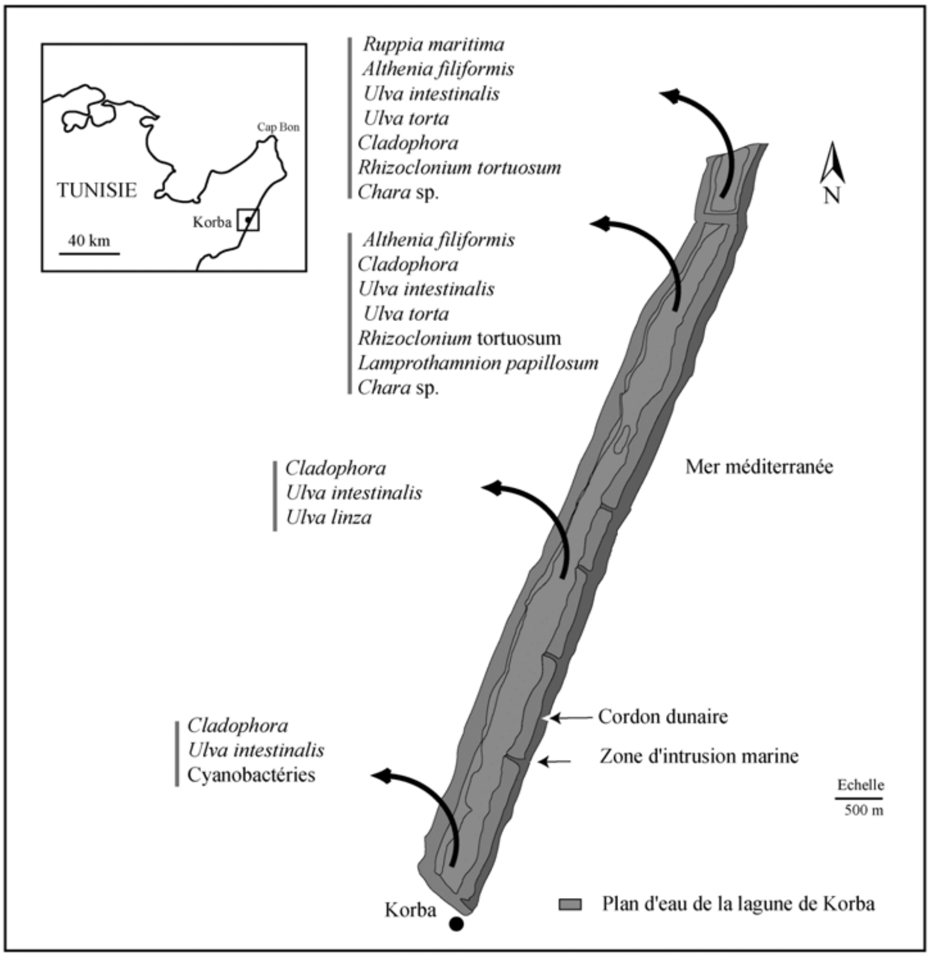

Fig. 1 : Répartition des peuplements phytobenthiques dans la lagune de Korba (saison printanière).

Diversité du phytobenthos dans la lagune de Kélibia

Dans la lagune de Kélibia nous avons observé 8 espèces de macrophytes benthiques dont 1 Rhodophyceae, 5 Chlorophyceae et 2 Magnoliophytes. Le secteur influencé par les apports directs des eaux marines est caractérisé par la dominance de *Ruppia maritima* avec des recouvrements de l'ordre de 50 à 80% (Fig. 2). Nous avons signalé également la présence des Chlorobiontes, *Cladophora* sp. et *Chaetomorpha linum* et de la Rhodobionte, *Jania rubens*. A l'ouest, dans le grand bassin de la lagune de Kélibia, *Ruppia maritima* atteint des recouvrements important de l'ordre de 80 à 100%. Dans la zone centrale se développe un herbier mixte de Ruppia-Althenia-Chara. Les espèces *Althenia filiformis* et *Chara* sp. sont plus fréquentes à proximité des berges sud de la lagune. Dans le secteur Est, le plus influencé par les apports des eaux douces, *R. maritima* présente des recouvrements relativement faibles, de l'ordre de 20%. Ce secteur est caractérisé par le développement d'amas de Cyanobactéries. Dans toute la lagune, la salinité varie de 4 psu (à l'extrême Est de la lagune) à 37 psu (après intrusion des eaux marines) avec une moyenne de l'ordre de 10 psu.

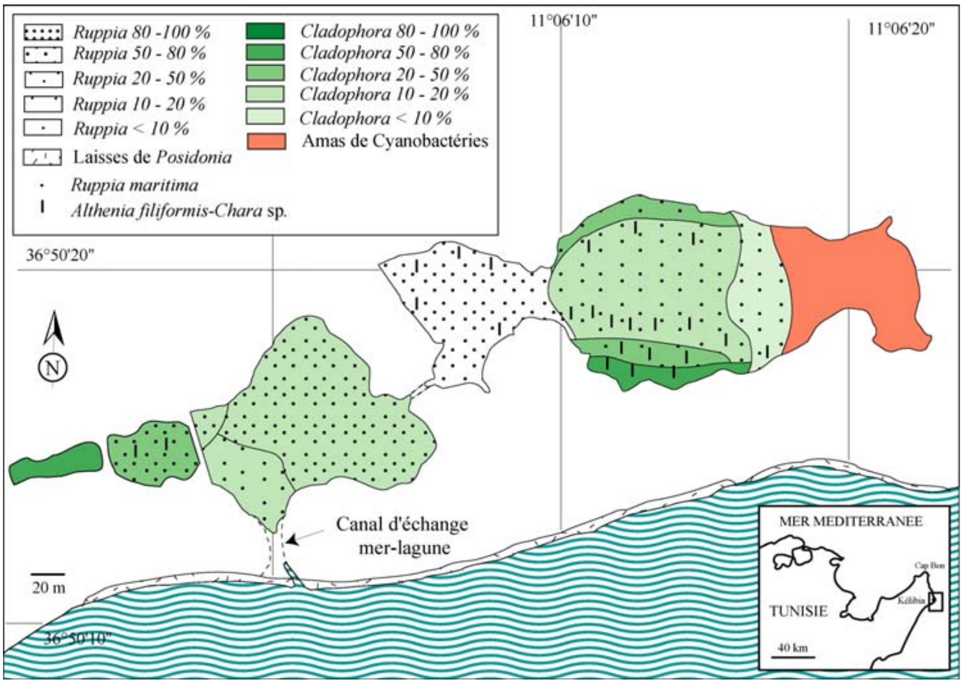

Fig. 2. Cartographie et recouvrement des peuplements phytobenthiques dominants dans la lagune de Kélibia (printemps 2001).

Dans la zone côtière marine de Kélibia nous avons noté la prolifération d'un herbier assez dense de *Posidonia oceanica* (Linnaeus) Delile et d'un herbier très clairsemé de *Cymodocea nodosa* (Ucria) Ascherson. Cette frange littorale est l'une des rares régions côtières tunisiennes permettant la prolifération des herbiers de posidonie tout près des plages. La limite supérieure de l'herbier dans le secteur d'étude est de -2 à -3 m. C'est un herbier bien portant qui se présente sous forme de plages entrecoupées par des clairières. Ces plages se serrent et deviennent de plus en plus rapprochées vers le large. Le long de la côte de Kélibia, des laisses de feuilles de posidonie sont accumulées en banquette constituant ainsi une protection naturelle contre l'érosion marine. Ces laisses sont entrecoupées par des zones d'intrusion marine.

Caractéristiques écologiques des deux Magnoliophytes **Ruppia maritima** *et* **Althenia filiformis**

Ruppia maritima

Les *Ruppia* sont des plantes cosmopolites caractéristiques des eaux côtières saumâtres et des eaux continentales salées (Verhoeven, 1979). Leur répartition et leur cycle de vie dépendent de plusieurs facteurs abiotiques. Outre la température qui est importante pour les différents stades du cycle biologique, nous décrivons ici le rôle de la salinité et la dimension de la masse d'eau.

Les *Ruppia* supportent des salinités plus élevées que celles des eaux de mer et se rencontrent rarement dans les eaux totalement douces. Ils fréquentent surtout les habitats d'eaux saumâtres et salées (Verhoeven, 1979 ; Novelo 1991). *Ruppia maritima* supporte des fluctuations de salinité entre 0,6 et 75,9 g/l (Verhoeven,1979). Cette tolérance aux variations de salinité confère à ces plantes un grand avantage compétitif (Grillas *et al*., 1993).

Dans le lac nord de Tunis l'espèce *R. cirrhosa* a bien proliféré entre 1991 et 1993 à une salinité comprise entre 31 et 43 psu (Ben Maïz, 1993 ; Shili, 1995). Il semble que ces valeurs favorisent le

développement optimum de *R. cirrhosa.* Nos observations dans la lagune de Korba montrent que *R. maritima* supporte des salinités supérieures à 50 psu.
La dimension de la masse d'eau influence généralement le type de végétation installée (Den Hartog et Van Der Velde, 1988). Verhoeven (1979) a subdivisé les habitats de *Ruppia* en trois classes :
- les petites masses d'eaux de profondeur < 1 m et de largeur < 10 m,
- les masses d'eaux intermédiaires d'une profondeur < 2 m et d'une largeur comprise entre 10 et 50 m,
- et les masses d'eaux larges de profondeur comprise entre 1 et 7 m et d'une surface > à 1 hectare.

Il indique que l'espèce *Ruppia maritima* var. *maritima* est beaucoup plus fréquente dans les petites masses d'eau et les masses d'eaux intermédiaires.

Althenia filiformis

Althenia filiformis est une Magnoliophyte aquatique peu fréquente sur les côtes tunisiennes. Les informations concernant les caractéristiques écologiques de cette espèce sont rares. C'est une plante annuelle à reproduction sexuée inféodée aux zones humides du littoral méditerranéen. Elle se trouve essentiellement dans les lagunes saumâtres en contact direct ou indirect avec la mer et dans les plans d'eau salés permanents ou temporaires. *Althenia* se développe dans les milieux de profondeur faible, généralement inférieure à 50 cm (Onnis, 1967 ; Cook and Guo, 1990).

Comme dans les milieux lagunaires de Korba et de Kélibia, les deux espèces *Ruppia maritima* et *Althenia filiformis* coexistent en peuplement mixte dans d'autres lagunes méditerranéennes (Onnis, 1967, Verhoeven 1979). Les graines *d'Althenia* germent à des salinités relativement faibles, généralement à la suite des pluies hivernales. Des expériences de laboratoire montrent qu'une salinité de 13 psu donne le maximum de germination et qu'une croissance optimale est observée à une salinité comprise entre 6 et 13 psu (Onnis, 1967). Il semble, d'après nos observations, que *Althenia filiformis* résiste peu à une augmentation brusque de la salinité.
Il est a remarqué que cette plante vasculaire qui fait partie des espèces végétales prioritaires, menacées de disparition est protégée en France.

Conclusion

Dans les écosystèmes lagunaires du Cap Bon les peuplements phytobenthiques sont adaptés aux milieux eutrophes, confinés et exposés au dessèchement. Les deux Magnoliophytes aquatiques *Ruppia maritima* et *Althenia filiformis* peuplant ces écosystèmes sont des espèces opportunistes capables d'achever leur cycle de vie durant une courte période : un à trois mois suffisent pour que le cycle soit bouclé avec une forte production de graines.
Actuellement, plusieurs projets d'assainissement et d'aménagement des zones côtières du Cap Bon sont en cours de réalisation. Les diverses actions entreprises dans le cadre des programmes de développement contribuent à rétablir l'équilibre de ces écosystèmes lagunaires. Des mesures de protection sont recommandées pour la sauvegarde de ces biotopes très importants pour la survie de certaines espèces de Magnoliophytes telle que *Althenia filiformis,* protégée dans certains pays de la rive nord de la Méditerranée.

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Thierry THIBAUT[1*], Bernat HEREU[2], Marie-Lucie SUSINI[1], Jean-Michel COTTALORDA[1], Luisa MANGIALAJO[3], Enric BALLESTEROS[4]
1- EA 3156 Gestion de la Biodiversité. Université de Nice-Sophia Antipolis, FRANCE
2- Moss Landing Marine Laboratories. Moss Landing, California, USA
3- Dipartimento per lo Studio del Territorio e delle sue Risorse (DIP.TE.RIS.). Università degli Studi di Genova, ITALY
4- Centre d'Estudis Avançats de Blanes – CSIC. Blanes, SPAIN
* Corresponding author: thierry.thibaut@unice.fr

PRELIMINARY REPORT ON THE EVOLUTION OF THE POPULATIONS OF FUCALES IN THE NATIONAL PARK OF PORT-CROS (FRANCE)

Abstract

The evolution of the populations of Cystoseira *sp. and* Sargassum *sp.(Fucales, Pheophyceae) is studied within the National Park of Port-Cros (France). In May 2005, an extensive survey recorded 17 taxa of Cystoseira and Sargassum in shallow and deep waters, added 4 new taxa to the last inventory. Contrary to other observations made in several Mediterranean locations, the populations of Fucales are highly diversified and most of them seem stable, although some regression has been observed for* C. brachycarpa *var.* balearica*. So far, no evident human impact has been identified.*

Key-Words: Cystoseira, Fucales, National Park of Port-Cros, Populations, Sargassum.

Introduction

Species of the Order Fucales, mainly those of the genus *Cystoseira* dominate several Mediterranean rocky-bottom communities (Giaccone, 1973). These species are ecosystem engineers (sensu Lawton, 1994) as their canopy provides suitable habitat for a large amount of other algae and invertebrates (Sauvageau, 1912; Funk, 1927; Serio, 1994; Rull and Gómez-Garreta, 1990; Ballesteros, 1990a,b; Ballesteros *et al.*, 1998).

Several Mediterranean Fucales are highly threatened (Boudouresque *et al.*, 1990) and recent studies evidence that their abundance and distribution has been greatly reduced in the last decades (Cormaci and Furnari, 1999; Thibaut *et al.*, 2005; Serio *et al.*, 2006). The National Park of Port-Cros (Var, France) was set up in 1963 and historical data on the populations of Fucales are numerous. Here, we analyze the evolution of these populations within the National Park with particular attention to the possible human impacts that can influence their abundance and distribution.

Material and methods

In May 2005, we surveyed all the sites which potentially could host Fucales in the upper infralittoral zone of the National Park of Port-Cros (islands of Port-Cros, Bagaud, Rascass and Gabinière). To search for deep water species, we used the map of the marine biocenosis and substrates of the National Park (Belsher *et al.*, 2005) and we surveyed on SCUBA diving 21 locations from 10 to 50 m deep.

Results

Populations of Fucales of the National Park of Port-Cros are numerous, diversified, and are found in most of the suitable locations able to host *Cystoseira* and *Sargassum*. We found 17 taxa (15 *Cystoseira* and 2 *Sargassum*) (Tab. 1). 4 new taxa are reported for the National Park of Port-Cros (*C. barbata, C. brachycarpa* var. *claudiae, C. compressa* var. *pustulata* and *C. jabukae*).

Tab. 1. Abundance of taxa of Fucales recorded within the National Park of Port-Cros in May 2005. A = Abundant; F = Frequent; R = Rare.

	Abundance
C. amentacea var. *stricta*	A
C. barbata	R
C. brachycarpa var. *balearica*	A
C. brachycarpa var. *claudiae*	F
C. compressa	A
C. compressa var. *pustulata*	A
C. crinita	A
C. elegans	R
C. foeniculacea	R
C. funkii	F
C. jabukae	R
C. sauvageauana	R
C. spinosa var. *spinosa*	R
C. spinosa var. *compressa*	F
C. zosteroides	F
S. acinarium	R
S. vulgare	F

Discussion

In general the populations of Fucales are stable since the 1970's. *Cystoseira amentacea* var. *stricta* is very abundant all around the Park and the populations remained stable for decades (see Belsher *et al.*, 1976, Meinesz *et al.*, 2000; 2001a,b; 2004; Cottalorda *et al.*, 2004). This species does not suffer from competition with mussels beds as observed for its vicariant *C. mediterranea* in the Albères coast (Gros, 1978; Thibaut *et al.*, 2005). *Cystoseira barbata* has been found in the National Park for the first time where it is localized in 3 rock pools in the South of Port-Cros and on the West cost of Bagaud. *Cystoseira brachycarpa* var. *balearica* is still abundant all around the Park but some regression has been observed in many locations where the species was previously reported forming large and dense populations down to 10 m deep (Augier and Boudouresque, 1967; 1969; 1970a; 1976b; Coppejans and Boudouresque, 1975; Belsher *et al.*, 1976; Dhondt, 1976; Coppejans; 1977). Specimens of *C. brachycarpa* var. *claudiae* have been observed for the first time in the Park in shallow water mixed with *C. brachycarpa* var. *balearica.* We have completed the distribution map of *Cystoseira compressa* made by Meinesz *et al.,* (2000; 2001a,b; 2004) and Cottalorda *et al.*, (2004). The species is very abundant all around the Park. *Cystoseira compressa* var. *pustulata* has been also first recorded during this survey; this taxa is frequent in Port-Cros, and largest populations are found on the North coast of the island. *Cystoseira crinita* was often observed and its communities mapped as *Cystoseiretum crinitae* (Augier and Boudouresque, 1967; 1970; 1975; 1976a; Belsher *et al.*, 1976; Augier, 1985): all previous records have been confirmed by our survey. *C. crinita* is more abundant in the North coast of Port-Cros while the species is mainly found inside rock pools on the South coast. *Cystoseira elegans* was never observed before in Port-Cros. The species is rare and located only on the North Coast. *Cystoseira foeniculacea* was observed once by Belsher *et al.,* (1976) in the bay of Port-Man. We did not found any specimens in this location but on 6 rock pools of the South coast. This species is rare and never dominant in the rocks pools. *Cystoseira funkii* was observed recently by Hereu *et al.,* (2003). We add new data on the distribution of this deep water species. The species is frequent, forming monospecific populations on the West coast of Bagaud and mixed populations with *C. zosteroides* on the East. *Cystoseira jabukae* is also a new species for the park. Rare, it can only be found in rock pools from the South coast. *Cystoseira* *sauvageauana* was only observed in the bay of Port-Cros behind the *Posidonia oceanica* fringing reef (Augier and Boudouresque, 1969). We did not find any specimen in this location. The reef suffered strong modifications with a decrease of its surface (Augier and Nieri, 1988). We only found few specimens of the species in rock pools on the South Coast. *Cystoseira spinosa* var. *spinosa* is rare in the park, living in mixed populations with *C. brachycarpa* var. *balearica* on the West coast. A large population was observed between 5 and 10 m deep on the Rascass islet. The species was previously rarely observed (Belsher *et al.*, 1976). *Cystoseira spinosa* var. *compressa* was observed punctually all around the Park (Pérès and Picard, 1963; Augier *et al.*, 1971; Belsher *et al.*, 1976; Augier and Boudouresque, 1978). The species is frequent especially on the North, where it is the dominant species of the deep rocky communities. *Cystoseira zosteroides* was observed punctually all around the Park (Pérès and Picard, 1963; Coppejans, 1977; Hereu *et al.*, 2003). This species is forming large communities on the West coast, while is mixed with *C. funkii* moving toward the East coast. *Sargassum acinarium* was only recorded once in the Park in 1929 in the Calanque du Sud (Feldmann Herbarium, classeur 41, Muséum National d'Histoire Naturelle, Paris). We did not find the species in this location but we observed one specimen at the South of Bagaud on deep rocks associated with *C. spinosa* var. *compressa* and *C. funkii*. *Sargassum vulgare* was previously observed in 3 locations (Augier and Boudouresque, 1967; Belsher *et al.*, 1976). The species is frequent and can form large monospecific populations with specimens more than 1 m long. *Sargassum vulgare* was also observed at 40 m deep in mixed populations with *C. funkii*, *C. spinosa* var. *compressa* and *C. zosteroides*.

Conclusion

Contrary to what it has been observed in other Mediterranean locations (Cormaci and Furnari, 1999; Thibaut *et al.*, 2005; Serio *et al.*, 2006), the populations of Fucales in the National Park are well preserved. No species previously reported has disappeared. Although Milazzo *et al.* (2002) reported an important impact of trampling on shallow *Cystoseira* populations, it is surprising that even in the locations of the island of Port-Cros suffering high summer touristic frequentation, the *Cystoseira* populations remained well preserved. Overgrazing by *Paracentrotus lividus* is very limited to few locations where *C. crinita* and *C. brachycarpa* var. *balearica* have regressed. Concerning the deep water populations of Fucales, the presence of large populations of *C. zosteroides*, *C. spinosa* var. *compressa* and *C. funkii* is a witness of clear waters and a limited human impact. The number of inhabitants of Port-Cros is reduced to around 40 people in winter and maximum 140 people in summer (more people are living on boats during this period). Sewages are treated since 1999 and waste water has no impact on the populations of Fucales. All the anchoring zones are far away from the locations hosting Fucales. Only professional fishing (tramail nets) is permitted and strictly regulated. Few fishermen (1 in winter and maximum 6 in summer) are fishing regularly within the Park. Apparently, this low fishing pressure does not impact the deep-water populations of Fucales. Diving is limited to few sites with organized mooring and divers are generally not interested in algae for collection. In conclusion, management plans established in the National Park of Port-Cros have permitted the conservation of populations of Fucales in this area, an aim that has not been achieved in other Mediterranean marine protected areas such as the one of Cerbères-Banyuls (Thibaut *et al.*, 2005).

Acknowledgements

This study was funded by the National Park of Port-Cros. We thank all the people from the park for their assistance.

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Actes du 3ème Symposium méditerranéen sur la végétation marine (Marseille, 27-29 mars 2007)

Konstantinos TSIAMIS[1], Panayotis PANAYOTIDIS[2] , Barbara MONTESANTO[1]
[1] Athens University, Section of Ecology & Systematics, 15784 Panepistimiopolis, Athens, GREECE
[2] Hellenic Center of Marine Research, 19013 Anavissos, Athens, GREECE
e-mail: kostas.tsiamis@gmail.com

CONTRIBUTION TO THE STUDY OF THE MARINE VEGETATION OF RHODES ISLAND (GREECE)

Abstract

Marine benthic macroalgal flora and vegetation (Chlorophyceae, Fucophyceae, Rhodophyceae) of the upper infralittoral zone (0-1m depth) were studied, on rocky shores of Rhodes Island. On the whole, 155 taxa were identified (95 red algae, 33 green algae, 27 brown algae) from which 37 taxa are reported from Rhodes for the first time, while 5 taxa are new to the Greek coasts. Phytosociological approach showed that the phytocommunity of the brown algae Cystoseira crinita *(Fucales, Fucophyceae) dominates in the studied site, characterized by strong stability and high biodiversity. Compared to past macroalgal reaserchers in the island, Rhodes marine vegetation seems to retain its basic aspect during the last three decades. However, two lessepsian species in the studied site, the invading species* Caulerpa racemosa *var.* cylindracea *(Caulerpales, Chlorophyceae) and* Stypopodium schimperi *(Dictyoatales, Fucophyceae), exhibit special interest, indicating that potential introduction of new alien macroalgal species to the island is prospective in the next few years.*

Key-words: Macroalgae, Alien species, Rhodes, Aegean Sea, NE Mediterranean.

Introduction

Rhodes Island, located in the south-eastern part of the Aegean Sea, is part of the archipelago of Dodecanese. It is the largest and most populated Aegean island. Rhodes Island has been one of the most interesting sites of research concerning marine ecosystems since the beginning of the century (Tortonese, 1947), because of its peculiar environment: situated at the border between the Aegean and Levantine Seas and characterized by important hydrological phenomena (Theocharis *et al.*, 1999).

Subtropical water characteristics surrounding Rhodes Island (De Grissac *et al.*, 1994) seem to favour the colonization of marine alien organisms in the island (Barash and Danin, 1989), making Rhodes one of the most important stations of alien marine species migration (Pancucci-Papadopoulou *et al.*, 2006).

The first studies on macroalgal populations in Rhodes Island took place in 1898 by Reinbold. Since then, there were several important macroalgal researches during the 70'and 80' (Tsekos and Haritonidis, 1974; Diannelidis *et al.*, 1977; Diapoulis *et al*., 1986), focusing mainly to species-lists. The present study aims to contribute and supplement, as far as possible, the knowledge about marine benthic macroalgal flora and vegetation of the upper infralittoral zone on rocky shores of Rhodes Island (Chlorophyceae, Fucophyceae, Rhodophyceae) as well as to evaluate any possible differentiations that might have appeared in connection with past studies in the area. In addition, structure and composition of photophilic algal communities are studied, while special attention is given to the recovery of any alien macroalgae found in the island, and how these species affect the indigenous macroalgal communities.

Materials and methods

Six sampling locations at the upper infralittoral zone were chosen along the rocky shores of N. Rhodes (Fig. 1). These sampling sites have been also studied by past macroalgal researches in the island. Two seasonal samplings were carried out for each location, one in May 2003 and the other one in January 2006. Macroalgal samples (two replicates for each site) were collected by free diving from almost horizontal rocky surfaces, 30-50 cm below the lowest water level. Quadrats of 400 cm^2 (20cm x 20cm) were scraped off at each site ("destructive" sampling).

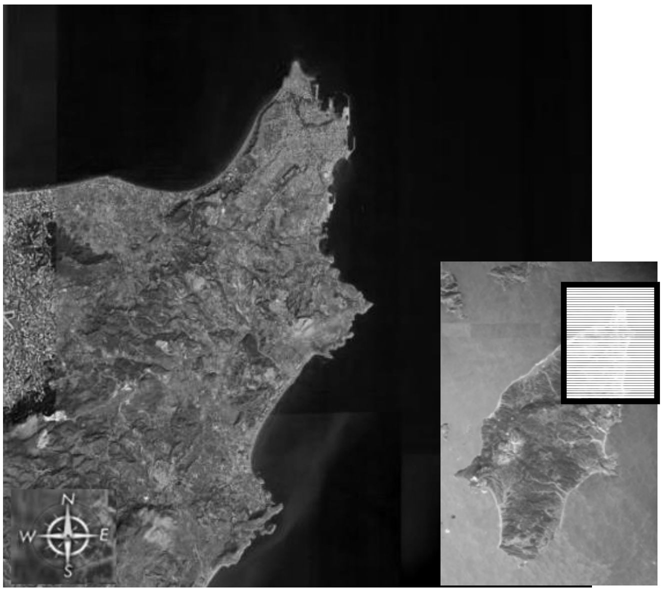

Fig. 1: Study site, located in the NE Rhodes Island, and sampling sites.

In the Phytobenthos laboratory of HCMR formalin fixed samples were carefully analyzed by identifying species presence and by estimating their vertically projected coverage. For the classification of macroalgae the following Mediterranean check-lists were used: Ribera *et al*. (1992) for Fucophyceae, Gallardo *et al.* (1993) for Chlorophyceae, and Athanasiadis (1987), Gomez-Garreta *et al.* (2001) for Rhodophyceae. Species coverage was measured based on the methodology proposed by Boudouresque (1971) and Verlaque (1987). The total coverage usually exceeded 100% due to the presence of different vegetation layers (canopy, bushy, crusts and epiphytes).

The calculation of ecological indices, Shannon & Wiener Diversity (H') and Pielou Evenness Index (J'), was based on coverage measurements, a methodology adapted to the phytobenthos by Boudouresque (1971).

Results

Macroalgal Flora and Vegetation

In the studied area a total of 155 macroalgal taxa were identified, a value which can be considered relatively high compared to past macroalgal studies of Rhodes Island, and generally of the Greek coasts (Lazaridou, 1994) and the Eastern Mediterranean (Bergin, 1984). 42 of identified taxa are reported from Rhodes for the first time, while 5 taxa are new to the Greek coasts (Tab. 1).

Tab. 1: Identified taxa reported from Rhodes for the first time. Taxa in Bold are new to the Greek coasts.

Acrochaetium microscopicum (Nageli ex Kutzing) Nageli	*Erythrocladia irregularis* Rosenvinge
Acrosorium venulosum (Zanardini) Kylin	***Erythrocladia polystromatica*** P.A. Dangeard
Aglaothamnion cordatum (Borgesen) Feldmann-Mazoyer	*Gelidiella lubrica* (Kutzing) Feldmann & G.Hamel
Aglaothamnion tenuissimum (Bonnemaison) Feldmann-Mazoyer var. *tenuissimum*	*Gelidiella pannosa* (Feldmann) Feldmann & Hamel
Aglaothamnion tripinnatum (C. Agardh) Feldmann-Mazoyer	*Griffithsia phyllamphora* J. Agardh
Amphiroa rubra (Philippi) Woelkerling	*Griffithsia schousboei* Montagne
Antithamnion antillanum Borgesen	*Hydrolithon cruciatum* (Bressan) Chamberlain
Bryopsis corymbosa J. Agardh	*Hypnea spinella* (C. Agardh) Kutzing
Bryopsis pennata Lamouroux	*Hypoglossum hypoglossoides* (Stackhouse) Collins & Hervey
Callithamnion granulatum (Ducluzeau) C. Agardh	*Jania adhaerens* Lamouroux
Chylocladia verticillata (Lightfoot) Bliding	*Laurencia microcladia* Kutzing
Cladophora crystallina (Roth) Kutzing	*Lomentaria clavellosa* (Turner) Gaillon
Cladophora flexuosa (O.F. Muller) Kutzing	*Lophosiphonia reptabunda* (Suhr) Kylin
Codium vermilara (Olivi) Delle Chiaje	*Phaeophila dendroides* (P.L. *et* H.M. Crouan) Batters
Corallophila cinnabarina (Grateloup ex Bory de Saint-Vincent) R.E. Norris	*Polysiphonia breviarticulata* (C. Agardh) Zanardini
Cottoniella filamentosa (Howe) Borgesen var. ***algeriensis*** (Schotter) Cormaci & Furnari	*Polysiphonia pulvinata* (Roth) Spreng
Cystoseira barbatula Kutzing	*Polysiphonia subulifera* (C. Agardh) Harvey
Cystoseira crinitophylla Ercegovic	*Stypopodium schimperi* (Buchinger *ex* Kutzing) Verlaque *et* Boudouresque
Ulva flexuosa Wulfen	*Taenioma nanum* (Kutzing) Papenfuss
Ulva prolifera O.F. Muller	*Taonia atomaria* (Woodward) J. Agardh
Epicladia flustrae Reinke	*Tenarea tortuosa* (Esper) M.Lemoine

The identified taxa were allotted in 3 classes, 23 orders, 37 families, 85 genera, 150 species, 4 varieties and 1 form. Red algae dominate with 95 representatives, whereas the green and brown algae participate with 33 and 27 representatives respectively.

The morphological study of the taxa revealed reduced dimensions compared to the corresponding described species of W. Mediterranean and the Atlantic, a remark that has been noticed from other authors too (Athanasiadis, 1987; Lazaridou, 1994). The reduced dimensions are probably related with the adaptation of these species to both oligotrophic conditions and high water temperatures (Athanasiadis, 1987) that characterise Rhodes Island (De Grissac *et al.*, 1994).

The value of R / P ratio in the studied area is 3.5, suggesting a warm-temperate aspect of macroalgal flora. This value corresponds to other macroalgal studies of the Greek coasts (Lazaridou, 1994; Tsirika, 2005)

When it comes to the Functional Groups of identified species based on Steneck and Dethier (1994), most of them belong to the filamentous, corticated and foliose forms. As far as the Ecological Groups are concerned (Boudouresque, 1984; Verlaque, 1987), the majority of identified taxa belong to the photophilous infralittoral thermophilous group (PhIT). Species of PhIT group also indicate warm – temperate aspect of Rhodes marine flora. Moreover, biogeographical study of identified taxa based on Cormaci *et al.* (1982) showed that the Atlantic flora element dominates, a remark that has been noticed from other authors too for the Greek coasts (Tsirika, 2005). On the other hand, only few species of the studied site are Mediterranean endemics (10%).

The vegetation of the rocky substrate in the infralittoral zone of the studied site is mainly characterized by species of the genus *Cystoseira,* which play a role of canopy algae. Considering that *Cystoseira* species are usually the dominant and most productive elements of the less anthropogenic stressed hard substratum benthic vegetation (Soltan *et al.*, 2001) in Mediterranean coasts, our results indicate that Rhodes marine vegetation seems to remain in undisturbed conditions.

In total, 5 species of the genus *Cystoseira* were identified in the present study: *Cystoseira barbatula*, *C. compressa*, *C. crinita*, *C. crinitophylla* and *C. foeniculacea*. Ecological behavior of *C. barbatula* confirms the classification of this taxon in the the photophilous infralittoral thermophilous Ecological Group (PhIT) according to Tsirika (2005). *C. compressa* was found in all sampling sites, presenting two forms: *C. compressa* f. *rosetta* and *C. compressa* f. *plana*. *C. crinita* was also collected from all sampling sites, where it forms discernible phytocommunities. The presence of *C. crinitophylla* as escorting species of the *C. crinita* phytocommunity suggests that this taxon does not form separate phytocommunity by itself (Lazaridou, 1994), at least in the studied site. *C. foeniculacea* f. *tenuiramosa* was also found together with *C. crinita*. However, the determination of *C. foeniculacea* f. *tenuiramosa* population ecology demands further research in the Mediterranean Sea (Gomez-Garreta *et al.,* 2001).

Species number, total coverage, Shannon-Wiener diversity index (H') and Pielou Evenness index (J') exhibit intermediate to high values compared to other macroalgal researches of the Aegean Sea (Tsirika, 2005). Regarding the dominance of the macroalgae classes, Rhodophyceae dominate qualitative and Fucophyceae quantitative almost in all sampling sites, whereas the participation of Chlorophyceae to the macroalgal populations is very low.

Intense seasonal variations of macroalgal populations were observed between the two sampling periods (winter and spring). The qualitative and quantitative dominance of the three macroalgal classes exhibit predictable seasonal variations for macroalgal populations of the Aegean Sea (Lazaridou, 1994).

Phenology of macroalgae reproductive structures indicated that the identified species are well adapted to their biotopes (Velaque, 1987). 36,7% of identified species were found with reproductive structures, especially tetraspores, all belonging to red and brown algae. The reproduction coefficient C(r) and reproduction density D(r) displayed higher values in spring than winther, something which is attributed to the higher coverage of brown algae belonging to Dictyotales and Fucales during spring time.

Macroalgal communities

The phytosociological study revealed the occurrence of a macroalgal community in the upper infralittoral zone of the studied site, which corresponds to the photophilous phytocommunity Cystoseiretum crinitae Molinier 1958 (Giaccone *et al.*, 1994), which is very common in the Aegean Sea (Huvé, 1972). High species number, H' and J' indices values suggest that Cystoseiretum crinitae is characterized by strong stability and high biodiversity. Moreover, seasonal variations are easily noticed in Cystoseiretum crinitae community, determined especially by the phenology of the dominant species.

Cystoseiretum crinitae community consists of different vegetation layers, analogous to layers of terrestrial vegetation, which could explain the occurrence of sciaphilous species (Lüning, 1990). The fronds of the canopy algae, especially *Cystoseira crinita* and *C. compressa*, overtop all other algae and correspond to the tree layer of terrestrial vegetation. Below canopy vegetation there are the bushy algae, analogous to shrubs and herbs in terrestrial vegetation. The most common species of bushy algae in Cystoseiretum crinitae are the calcareous red algae *Jania rubens* and *Haliptilon* *virgatum*. Community epiphytes, such as the microscopic filamentous red algae *Herposiphonia secunda*, *Ceramium flaccidum*, *Dasya corymbifera*, *Lophosiphonia cristata*, and the brown algae *Sphacelaria cirrosa,* are remarkable. Epiphytes are not specialized to certain species, but they can settle on various macroalgae (Lüning, 1990).

Alien macroalgae

Among all identified species only 4 of them have probably been introduced to the Mediterranean Sea (Tab. 2): *Asparagospis armata*, *Caulerpa racemosa* var. *cylindracea*, *Hypnea spinella* and *Stypopodium schimperi,* from which the two latter ones are reported from Rhodes for the first time.

Caulerpa racemosa var. *cylindracea* is the only one of the alien macroalgae found in the island that exhibits invading behavior until today. Indeed, this taxon was present in all selected sites, settling on several kinds of substrata, such as bare rocks, benthic fauna, encrusting algae, turf species and erect algae. This taxon has surely been introduced to Rhodes Island after 1986.

Tab. 2: Alien macroalgae reported from Rhodes Island until today.

Alien Macroalgae	Possible Origin	Introduction pathway	Found in Rhodes Island
Acanthophora nayadiformis	Red Sea	Through Suez	Tsekos & Haritonidis, 1974; Diannelidis *et al.,* 1977
Asparagopsis armata	Australia	Shipping	Diapoulis *et al.,* 1986; Salomidi *et al.,* 2003; Present study
Caulerpa racemosa var. *cylindracea*	Red Sea	Through Suez	Salomidi *et al.,* 2003; Present study
Hypnea spinella	West Indies	Shipping	Present study
Hypnea valentiae	Red Sea	Through Suez	Reinbold, 1898
Stypopodium schimperi	Red Sea	Through Suez	Present study

Discussion and conclusions

Results of this survey revealed that Rhodes Island is characterized by rich marine flora and vegetation. Phytocommunities of the brown algae *Cystoseira crinita* dominate in the upper infralittoral zone of the studied site, characterized by strong stability and high biodiversity, analogous to the corresponding communities of other Mediterranean coasts (Lazaridou, 1994)

Compared to past macroalgal researchers in the island, Rhodes marine vegetation seems to retain its basic aspect during the last three decades, with the exception perhaps of the green algae *Caulerpa racemosa* var. *cylindracea,* which exhibits an invading behavior in Rhodes, something that has been reported from other sites of the Mediterranean Sea too (Verlaque *et al.,* 2000).

Considering that many lessepsian organisms (mainly pisces and zoobenthos representatives) have been reported from Rhodes Island during the last years (Pancucci-Papadopoulou *et al.,* 2006), a significant number of lessepsian macroalgae was expected to be found in our samples. However, in general terms, only few of alien macroalgal species were found in this study compared to alien macroalgae reported from the whole Mediterranean Sea (Verlaque, 2001; Boudouresque and Verlaque, 2002). The low presence of alien macroalgae found in the present research could be ascribed to the following reasons:

A) The small number of seasonal samplings and sampling sites.

B) Most of the alien macroalgal species have been introduced into the western part of Mediterranean through aquacultures and shipping, especially in coasts of France and Italy

(Verlaque, 2001). Thus, Rhodes Island, situated in the eastern Mediterranean, seems to be out of range of for the majority of these species until today.

C) Reproductive spores of most macroalgal species (especially red algae) are capable only for short distance dispersion (Van den Hoek, 1987). On the contrary, species belonging to nekton and zoobenthos can disperse in greater distances due to their meroplanktonic juvellines. This fact could explain why a high number of lessepsian organisms have been found in Rhodes Island, such as Crustaceans, and on the other hand why there is a low presence of lessepsian macroalgae in the island. Thus, it seems that lessepsian macroalgae need more time in order to colonize Rhodes Island. However, the introduction of new alien macroalgal species to the island is prospective in the next few years, a process that seems to be accelerated by the global warming (Bianchi and Morri, 2003) and by modifications of the water thermohaline circulation of Eastern Mediterranean (Theocharis *et al.*, 1999). The finding of two new alien macroalgae in the island (*Hypnea spinella* and *Stypopodium schimperi*) seems to confirm that Rhodes marine flora is probably at the first stages of serious alterations expected in few years. Although none of those species is characterized by invading behavior until now, continuous monitoring seems to be necessary, as invading behavior has been reported at least for the brown algae *Stypopodium schimperi* in several coasts of Eastern Mediterranean (Boudouresque and Verlaque, 2002). Therefore, the study of the already introduced alien macroalgae in Rhodes Island as well as of those that will probably invade into the island in the coming years, seems to be very important, so that their impact to indigenous benthic communities could be estimated.

Acknowledgments

The authors are very thankful to Dr. M. Verlaque and Dr. I. Mpitis for the contribution to the identification of several macroalgal taxa as well as to Mr. G. Xatiris and to Mrs. M. Salomidi and N. Bellou for their aid to the samplings.

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Leonardo TUNESI, Sabrina AGNESI, Taira DI NORA, Giulia MO, Andrea MOLINARI
ICRAM, Istituto Centrale per la Ricerca scientifica e tecnologica Applicata al Mare, Via di Casalotti 300 - 00166 Roma, ITALY, e-mail: l.tunesi@icram.org

COLONIZATION OF THE GALLINARIA ISLAND (NW LIGURIAN SEA) SEAFLOORS BY *CAULERPA TAXIFOLIA* AND *C. RACEMOSA*: IMPLICATIONS FOR A NEW MARINE PROTECTED AREA

Abstract

The study for the establishment of a new marine protected area in the waters of the Gallinaria Island, allowed to evaluate the distribution of two invasive species of the genus Caulerpa (C. taxifolia and C. racemosa) in 2005. The distribution of the two algae is described in relation to the main coastal sectors of the Island, range of depth and nature of the seafloor. Considerations about the described situation are given in relation to the Island location, the original described spreading areas of the two green algae, and the need of specific management measures in the framework of the new MPA establishment.

Key-words: *Caulerpa taxifolia*, *Caulerpa racemosa*, Gallinaria Island, Marine protected area, Ligurian Sea.

Introduction

The Mediterranean Action Plan for Marine Vegetation, formulated in 1999 under the auspices of UNEP/MAP-RAC/SPA, aims to ensure the conservation of marine vegetation and plant assemblages through specific legal and management measures directed at preventing seagrass meadow and “key” vegetal assemblage habitat degradation. The plan also foresees, amongst other things, the enactment of specific research and monitoring activities in order to assess the threat of invasive species propagation on the principal Mediterranean vegetal communities of biodiversity interest.

The main invasive species hypothesized to interfere with Mediterranean phanerogams, and in particular *Posidonia oceanica*, belong to the tropical algae genus Caulerpa. The recent expansion of the species, *Caulerpa racemosa* and *Caulerpa taxifolia*, represents in fact one of the main consequences of Mediterranean coastal habitat degradation, and is considered a threat to Mediterranean coastal ecosystems (Boudouresque *et al*., 2006). The *Caulerpales* are considered strong competitors due to their capacity to proliferate in a rather extended ecological *niche* thereby outstanding other plant species and to produce toxic substances, which inhibit their grazing (Piazzi *et al.,* 2005 and relative references). In the Mediterranean, *C. racemosa* was first observed in 1926 in Tunisia (Hamel, 1931), but it was not until 1991 that Nizamuddin recorded specimens, in Libya, belonging to the invasive variety *C. racemosa* var. *cylindracea* (Sonder) Verlaque, Huisman et Boudouresque. The latter variety progressively expanded throughout the 1990s (Verlaque *et al.*, 2000; 2003) whereas, *C. taxifolia* was first observed in 1984 (Meinesz and Hesse, 1991) in the Monegasque coastal stretch and has progressively spread along the shores of various other Mediterranean countries (France, Spain, Italy, Tunisia and Croatia) (Meinesz *et al.,* 2001). Since then both species have been observed in the waters of various Italian coastal regions (*C. taxifolia* - Meinesz *et al.,* 2001; *C. racemosa* - Piazzi *et al.,* 1994; Piazzi *et al.,* 2005), including the Ligurian Sea (*C. taxifolia* - Relini and Torchia, 1992; Tunesi, 1992; *C. racemosa* – Bussotti *et al.*, 1996; Modena *et al*., 2000; Molinari and Diviacco, 2003).

The presence of *Caulerpa* sp. in the coastal waters of the Gallinaria island (Liguria) was analysed by ICRAM in 2005, within the framework of a feasibility study commissioned by the Italian Ministry of the Environment for the future establishment of the Gallinaria Island marine protected area (MPA).

The study on the occurrence of these two species in the Gallinaria Island waters provides interesting considerations for more than one reason. First of all, the area is very proximate to the site where *C. taxifolia* was first observed in the Mediterranean and, at the same time, it lies very far North from the area of first observation of *C. racemosa*. Secondly, there is good baseline data on the benthic assemblages observed in the area in the early 1990s, thus allowing the possibility of a reasonably detailed comparison on the invasive phenomenon by the two species over the course of more than a decade. Moreover, due to the vocation of the island to become a future marine protected area, information on the threat implications of the seagrass meadows and of the spreading of invasive species are particularly important in terms of future management and conservation practices that need to be applied.

Materials and Methods

The Gallinaria island is located in the North-Western Ligurian sea at approximately 1.4 km from the coast. The study area encompasses the coastal waters surrounding the island up to 30 meters depth. Field activities were conducted during the summer 2005 and were planned on the basis of the geomorphologic and oceanographic features of the island. In fact, the sub-triangular shape of the island allows to clearly identify three distinct coastal sectors: sector I, from Punta Falconara until the port, sector II, from the port until Punta Sciusciaù, sector III, from Punta Sciusciaù until Punta Falconara (Fig. 1).

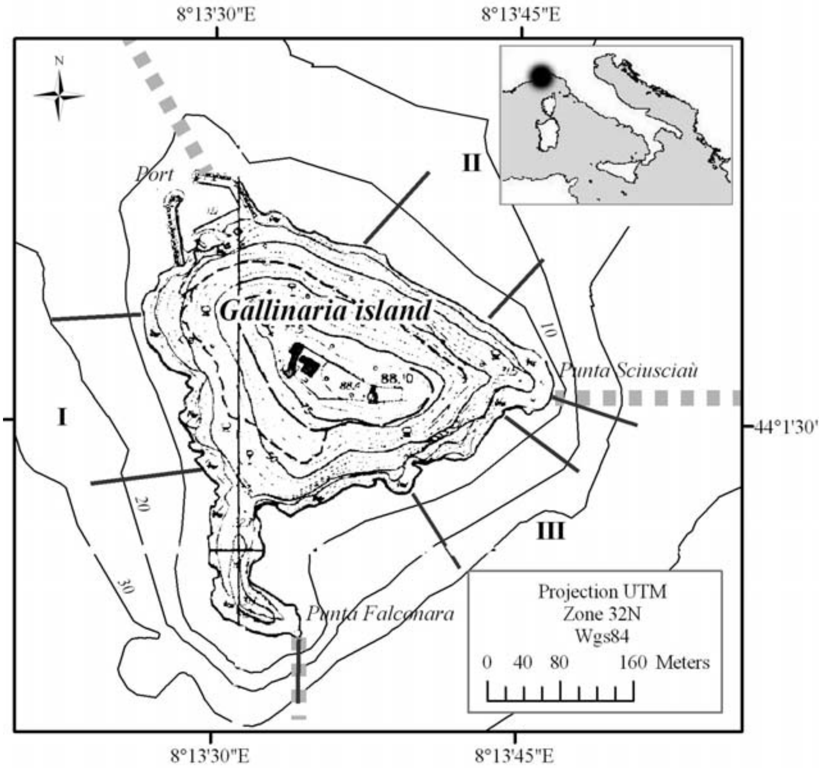

Fig. 1: The Study area, the three identified coastal sectors (dotted lines), and the location of the 8 radial dive transects (full line).

Benthic habitat assemblages, including the observations of *Caulerpa* sp. presence were recorded through scuba-diving bouts carried out along 8 radial transects, each 100 meters long, conducted in the same locations of a previous study (Balduzzi *et al*., 1994; ICRAM, 1993), and 60 free dive paths distributed randomly between the 8 transects and conducted following the natural contour of the seafloor in the 1-30 meter depth range. The positioning of each transect was obtained through a GPS.

The linear extent of coastline adjacent to each site of presence, coupled with the information achieved from the biocoenotic map, was used to measure algal distribution according to the methodology proposed by Meinesz *et al.* (2001). The coastline length was estimated applying a geographical information system (GIS), so as to evaluate the percentage of coast, per sector and in total, having seafloors colonised by *C. racemosa* var. *cylindracea* (hereafter referred to as *C.racemosa*), and *C. taxifolia*. The data was also elaborated by taking into account specific physical features such as seafloor typology and depth range on which the *Caulerpa* species were observed.

Results

Both *C. racemosa* and *C. taxifolia* were observed in the study area and throughout the island's coasts. Relevant changes in benthic assemblages were also recorded with respect to the benthic habitats observed in the early 1990s (Balduzzi *et al*., 1994), and involved in particular a large reduction and/or disappearance of the following habitats: *facies* with *Eunicella singularis*, *Cymodocea nodosa* meadows, *Posidonia oceanica* on *matte*, *Cystoseira spinosa* and *Cystoseira compressa* algal belts (Tunesi *et al.*, 2006). However, the reasons and implications to these changes require further considerations and are not the object of the present study. On the overall, *C. taxifolia* was found distributed along 15.9 % of the island's coast while *C. racemosa*, present in the area with a phenotype characterised by very short phylloids (3-4 cm of length), but very dense and interconnected rhizomes, was found distributed along 49.7% of the coast (Tab. 1). The observations concerning the species' presence, recorded within the three sectors, are reported below.

Sector I

The changes observed in the benthic habitat assemblage are minimal with respect to the past, and mostly related to the presence of the species of the *genus Caulerpa*. In fact, a *C. taxifolia* field is located within the island's port at approximately 3 meters depth, while *C. racemosa* is well extended on a wide *semi-plateau* characterised by dead *matte*, in a range of depth comprised between -6 and -20 meters, associated with the algae *Halopteris filicina*, *Padina pavonica*, *Codium bursa* and *Dasycladus vermicularis. C.taxifolia* is distributed along 33.9% of the sector's coastal stretch while *C. racemosa* is distributed along 49.7% of the coast.

Sector II

The most conspicuous changes in benthic assemblages were observed in Sector II (Tunesi *et al*., 2006). The rocky substrate of this sector stretches from the water mark to a few meters in depth and is quickly replaced by large expanses of sediment which turn into fine mud at increasing depths. *C. taxifolia* was observed, on a detritic bottom, in a rather limited and isolated spot found at 24 meters depth, while *C. racemosa* appears to have colonised this sector extensively and it is present in the 7.5-24.5 meter depth range. The latter species was found associated to *Stypocaulon scoparium*, *P. pavonica*, *C. bursa* and *Acetabularia acetabulum*. On the overall, *C. taxifolia* is distributed only along 0.2 % of the sector's coast while *C. racemosa* is distributed along 56% of the sector.

Sector III

This sector of coast also presents rather conspicuous changes in benthic habitat assemblages in that the *P. oceanica* meadow, observed by Balduzzi *et al*. (1994) and ICRAM (1993) is no longer present, except for some sparse shoots, thus leaving only dead *matte*. *C. racemosa* and other photophilous / emisciaphilous species have colonised this area of dead *matte*. Short and sparse stolons of *C. racemosa* are also present on the detritic bottoms of the sector, at depths ranging between 20-23 meters. On the overall, the species is distributed along approximately 45.1% of the sector's coast.

Tab. 1: Distribution of* C. racemosa *and* C. taxifolia *along the coasts of the Gallinaria island.

	Caulerpa racemosa			***Caulerpa taxifolia***		
	Distribution % (m of linear coast)	Depth Range	Seafloor Typology	Distribution % (m of linear coast)	Depth Range	Seafloor Typology
Sector I	49.7 (508.2 m)	6 - 20 m	Dead *matte*	33.9 (346.5 m)	1 - 4 m	Soft bottom
Sector II	56.0 (282.2 m)	7 - 25 m	Muddy detritic	0.2 (1.0 m)	24 m	Muddy detritic
Sector III	45.1 (299.2 m)	20 - 23 m	Dead *matte* and detritic	-	-	-
Island perimeter	49.7% (1089.6 m)			15.9% (347.5 m)		

Discussion and conclusions

The results of the present study indicate that the study area has been colonised by both *Caulerpa* species during the course of the last decade and provide estimates on the percentage of coastal colonisation brought about by each species.

Despite the area's proximity to the French-Monegasque border, where the initial expansion of *C. taxifolia* occurred (Meinesz and Hesse, 1991), and its long distance North from the North-African sites of the first records of *C. racemosa* (Hamel, 1931; Nizamuddin, 1991), the results of the investigation show that the presence of this latter species is instead the heaviest. The data collected in sectors I and II also indicate that, when both species are present in the same location, they tend to colonise different zones.

The prevalence of *Caulerpa* sp. on certain seafloor typologies suggests that the species most readily colonise certain substrates namely those with dead *matte* and soft bottoms, even though some rare phylloids of *C. racemosa* were also observed on rocky bottoms with photophilous and emisciaphilous algae.

The phenotype recorded in the studied area, characterised by very small phylloids, seems to be a characteristic of *C. racemosa* in the Northern part of the Western Mediterranean and specifically the Ligurian Sea (Modena *et al.*, 2000; Tunesi *pers. comm.*). In fact the *C. racemosa* phenotype, observed in the study area and consisting in poorly developed phylloids and very dense and interconnected rhizomes, suggests that its growth may be partially limited or hindered by environmental factors, despite the fact that the species manifests an extended presence throughout the coastal sector (49.7%).

The general distribution of the two algae observed on the Gallinaria Island seafloors, seems to suggest that both species avoid most exposed areas and that *C. taxifolia* shows a preference for very sheltered areas. The vertical distribution of *C. racemosa* along the three coastal sectors of the Island seems more influenced by hydrodynamism and wave exposure: the algal presence begins at 6 -7 meters depth along the more protected sectors (I and II), while along sector III, the area most exposed to the open sea, *C. racemosa* is present from the depth of 20 m onward.

The present study stresses the importance of biocoenotic maps as references in evaluating changes in coastal benthic assemblages. The collected data on the distribution of the two species of the genus *Caulerpa* should be taken into account in future research and monitoring activities in the framework of the future MPA management. In fact MPAs should be pilot sites for the definition and application of specific measures to halt invasive species colonisation, a role already indicated by the Mediterranean Action Plan for Marine Vegetation. Different approaches should be applied to reduce the impact of the spreading of these two species in the Gallinaria Island's waters. The relatively low presence and virulence of *C.taxifolia* could be counteracted with a specific eradication program, while for *C.racemosa*, given its widespread distribution in the area and the conspicuous rhizoid development in the sediment and in dead Posidonia *matte*; this approach appears more problematic. MPAs should play a strategic role in the study of this phenomenon and the new MPA could undertake a relevant regional role in the start up of a monitoring scheme, to be conducted within the framework of a Mediterranean network of MPAs, on the spreading of these invasive species and of *C. racemosa* in particular.

Acknowledgments

The authors wish to express their gratitude to Vincenzo Di Martino (CNR Taranto, Italia), Simone Bava and Luisa Mangialajo (Dip.Te.Ris. - Università di Genova, Italia) for their participation to the field activities.

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Robert TURK[1], Martina ORLANDO-BONACA[2], Žiga DOBRAJC[2], Lovrenc LIPEJ[2]
[1]Institute of the Republic of Slovenia for Nature Conservation, Piran Regional Unit, Tartinijev trg 12, 6330 Piran, SLOVENIA, e-mail: robert.turk@zrsvn.si
[2]Marine Biology Station, National Institute of Biology, Fornače 41, 6330 Piran, SLOVENIA

CYSTOSEIRA COMMUNITIES IN THE SLOVENIAN COAST AND THEIR IMPORTANCE FOR FISH FAUNA

Abstract

In the Slovenian coastal area the macroalgal belt formed by Cystoseira communities is well developed. The importance of the Cystoseira communities has been assessed by studying the fish assemblage with non destructive methods. The Cystoseira-dominated communities hosted the greater diversity of coastal fishes in comparison with other habitat types. The results showed that the structure of Cystoseira communities is an important element of the substratum complexity, thus influencing the coastal fish assemblage in their habitat choice. As such they should be taken into consideration as habitat types, deserving efficient environmental protection.

Key-words: *Cystoseira*, Fish diversity, Slovenia, Northern Adriatic.

Introduction

At the upper infralittoral zone (0-1 m depth) of the Mediterranean coast, the species of the genus *Cystoseira* are usually the dominant element of the benthic vegetation on unpolluted hard substratum and the *Cystoseira* algal community is considered as the final stage (climax) in a succession of photophilic algal communities (Pérès and Picard, 1964).

In the Slovenian coastal area, the macroalgal belt formed by *Cystoseira* communities, experienced a severe decline due to overgrazing by the sea urchin *Paracentrotus lividus* in the first seventies (Vukovič, 1976; Turk and Vukovič, 2000). Nevertheless, it is well developed at present, with four species – *Cystoseira compressa*, *C. crinita*, *C. barbata* and *C. corniculata* and with *Cystoseiretum crinitae* Molinier 1958 as the dominant association. Due to the specific geological, geomorphological and ecological conditions of the Slovenian coast and consequently to the relatively low abundance of seagrass meadows, the macroalgal communities play an important role in maintaining the coastal species and habitat diversity. The evaluation of the distribution of the *Cystoseira* communities in the Slovenian coast and the definition of their importance as far as the diversity of coastal fish species is concerned, could be used as an additional important argument for securing a more wise and sustainable use of the coastal ecosystem.

Materials and methods

Study Area

The Gulf of Trieste is the northernmost part of both the Adriatic and the Mediterranean Seas. The area is characterized by the biggest tidal differences (semidiurnal amplitudes approach 30 cm) and the lowest winter temperatures (below 10°C) in the Mediterranean Sea (Boicourt *et al.*, 1999). The Slovenian coastal area covers only a small portion of the Adriatic Sea, *i.e.* the southern part of the Gulf of Trieste. Its coastline is approximately 46 km long. It is a shallow semi-enclosed gulf with a maximum depth of ca. 33 m in waters off Piran. In recent decades the Slovenian coastal area has suffered from many anthropogenic impacts such as intensive farming, mariculture, overfishing, and sewage outfalls. At the same time many activities on the coast such urbanisation, intensive farming, and "massive" tourism and others destroyed or changed the natural shoreline. Nowadays only 18% of the coastline is still in natural state (Turk, 1999).

The present study was conducted in the coastal zone of Slovenia, in shallow waters (from 0.5 to 5 m depth), where benthic communities are high primary production areas with relevant secondary production, and they are able to maintain the richest ichthyofauna (García-Rubies and Zabala, 1990; Bouchereau and Lam Hoaï, 1997; Methven *et al.*, 2001).

Field sampling

The fieldwork was carried out using SCUBA diving and snorkeling from May to October of the years 2001-2006, during the reproductive period of most faunal and algal species.

Data were collected for different projects. For the aim of the European Water Framework Directive, in the year 2006, benthic macroalgae were sampled along the Slovenian coast. The sampling of benthic macroalgae was destructive, on a quadrat 20 cm x 20 cm (400 cm^2), which is considered to be the minimal sampling area for the infralittoral communities of the Mediterranean (Montesanto and Panayotidis, 2001). At 51 sampling stations samples were collected in a depth range from 2 to 5 m. All the algae were scraped from the sampling area and collected in plastic bags. At each sampling station three (rarely two) samples were randomly collected. The identification of the marine algae was carried out at the Marine Biology Station of the National Institute of Biology, following the classification proposed by Ercegović (1952), Feldmann-Mazoyer (1940), Giaccone (1973), Van Den Hoek (1963), Hauck (1885) and Oltmanns (1922).

From 2001 to 2006 data were also collected in order to record species richness and abundance of fish assemblages occurring over different shallow inshore macrohabitats, including *Cystoseira* communities. The sampling occurred by using the transect technique (Harmelin, 1987), a non-destructive diving visual census methodology. Horizontal transects (Macpherson, 1994) from 60 to 90 m in length were laid out at different depths, from 1 to 5 m. In each range, two fixed transects were established on the bottom with meter-marks. The fish were counted mostly within 2 m^2, 1m^2 to the left and 1m^2 to the right of the line. In total 70 horizontal transects were surveyed in Slovenian coastal waters. Once the visual counts of fish had been done, a number of environmental variables were measured, adapted from Larsonneur, 1977 (in UNEP, 1998): bottom substrate composition and the abundance of physical structures like macrophytes. Four main benthic macrohabitats were therefore examined: *Cymodocea nodosa* meadows, *Cystoseiretum crinitae* subass. *Halopithetosum incurvae, Cystoseiretum barbatae* and boulders covered with algal turf.

Results

The macroalgal belt formed by *Cystoseira* communities is well developed in Slovenian coastal waters (Vukovič, 1980). The dominant association is *Cystoseiretum crinitae* Molinier 1958, but *Cystoseira crinita* was almost never found to be the dominant element. Instead, two main subassociations were identified: *Cystoseiretum crinitae* subass. *Halopithetosum incurvae* Boudouresque 1971 and *Cystoseiretum crinitae* subass. *Cystoseiretosum compressae* Molinier 1958.

In the lower mediolittoral zone of the Piran area (from Pacug to Fornače), compact communities of *C. compressa* var. *rosetta* were found, while *Cystoseiretum barbatae* Pignatti 1962 was dominant in the upper infralittoral belt. Species from the genus *Cladophora, Valonia utricularis, Sphacelaria cirrhosa, Dictyota dichotoma, Haliptilon virgatum, Wrangelia penicillata* and *Anadyomene stellata* were found as epiphytes on *C. barbata*. Other abundant species of this community are: *Padina pavonica, Ulva rigida, Halimeda tuna, Halopteris scoparia, Dictyota linearis, Flabellia petiolata, Peyssonnelia squamaria, Alsidium corallinum, Acetabularia acetabulum* and *Chondrophycus papillosus.*

Cystoseiretum crinitae subass. *Halopithetosum incurvae* was found to inhabit hard bottoms near the *Posidonia oceanica* seagrass meadow in the Koper Bay, at Cape Ronek and at the locality of Bele Skale.

In the habitat type constituted by *Cystoseiretum barbatae* the highest number of fish species (31) was found (Tab. 1). The number of fish species was much lower in other habitat types, like boulders covered with a low stratum of algal turf (26 species) or *Cymodocea nodosa* meadows (25 species). At surveyed sites where *Cystoseiretum crinitae* subass. *Halopithetosum incurvae* grows, 24 fish species were counted.

On the other hand, in *Cystoseiretum crinitae* subass. *Halopithetosum incurvae* the highest average density of fish individuals was evaluated (65.16 ± 61.49). The boulders covered with algal turf had the second highest value (34.02 ± 41.05), while *Cystoseiretum barbatae* which had the highest number of species, had just the third position in terms of average density (33.35 ± 44.43). This sequence does not change even if we substract the numerical contribution of the gregarious species *Atherina hepsetus* (Tab. 2). Excluding the values for gregarious species such as *Atherina hepsetus*, the members of the family Labridae also dominated the assemblage in terms of average density of individuals in each habitat type.

The Shannon-Wiener diversity index (Tab. 2), which considers both the number of species and the abundance of individuals per site, showed the lowest diversity of the fish assemblage for the *Cymodocea nodosa* meadow. The *Cystoseiretum barbatae* had the highest diversity, which means that this habitat type had not only a greater number of species present, but the individuals in the assemblage were distributed more equally among these species. Boulders covered with algal turf and *Cystoseiretum crinitae* subass. *Halopithetosum incurvae* had approximately the same diversity of the fish community (Tab 2).

Discussion and conclusions

In the years 1972/73 the vegetation of the rocky bottom in Slovenian coastal sea suffered a disaster caused by the explosion of the population of the sea urchin *Paracentrotus lividus*, which consumed virtually the whole infralittoral vegetation, except a few hundred metres along Cape Ronek and on some islets off the coast between Izola and Koper (Vukovič, 1976). Now, different communities associated with species of the genus *Cystoseria* are present at different depths.

The arborescent and big-sized brown algae increase the spatial heterogeneity and thus offer a plethora of suitable ecological niches for many other benthic algal epibionts and invertebrates. The structure of algal communities is an important element of the substratum complexity, thus influencing the coastal fish assemblage in their habitat choice, as well. *Cystoseira* communities are known to host a variety of fish species, as shown also in our study. Certain species of temperate wrasse species are building nests in algal belt dominated by *Cystoseira.* Algal communities and fish assemblage seem to be linked at two levels: spatial (habitat selection) and trophic (acess to prey) (Ruitton *et al.*, 2000).

Certain fish families such as wrasses (Labridae) and sea breams (Sparidae) are more correlated with the dense algal belt, provided in *Cystoseiretum* communities, whereas others such as blennioids (Blenniidae) and gobies (Gobiidae) rather select more bare habitat types (Orlando-Bonaca and Lipej, 2005).

The highest number of fish species has been recorded in the habitat type constituted by *Cystoseiretum barbatae*, whereas the highest average density of fish individuals was counted in *Cystoseiretum crinitae* subass. *Halopithetosum incurvae* evaluated (65.16 in./100m^2). It seems that the height of the vegetation belt is also important, since in boulders covered with a low stratum of algal turf a lower number of species were recorded.

Tab. 1: Frequency of occurrence of the recorded fish species in different habitat types.

	Cymodocea nodosa	*Cystoseiretum barbatae*	*Cystoseiretum crinitae*	Boulders with turf
Aidablennius sphynx		2,56		27,27
Atherina hepsetus	30,00	7,69	20,00	9,09
Chromis chromis		43,59	70,00	18,18
Dicentrarchus labrax		2,56		
Diplodus annularis	100,00	71,79	70,00	36,36
Diplodus puntazzo		7,69	20,00	
Diplodus sargus		25,64	10,00	
Diplodus vulgaris	100,00	66,67	100,00	18,18
Gobius cobitis	10,00	51,28	40,00	45,45
Gobius cruentatus	90,00	71,79	80,00	45,45
Gobius fallax	70,00	30,77	80,00	36,36
Gobius niger				9,09
Hippocampus guttulatus	10,00			
Labrus merula	10,00	38,46	60,00	27,27
Lipophrys dalmatinus	50,00	64,10	60,00	63,64
Mugil cephalus	10,00			
Mullus surmuletus	10,00	7,69		36,36
Oblada melanura	10,00	15,38	50,00	
Pagellus erythrinus	10,00			
Parablennius gattorugine	10,00	33,33	50,00	18,18
Parablennius incognitus		23,08	20,00	45,45
Parablennius rouxi		12,82		
Parablennius sanguinolentus	20,00	35,90	40,00	72,73
Parablennius tentacularis	40,00	2,56		9,09
Pomatoschistus bathi	50,00	38,46	40,00	45,45
Salaria pavo				9,09
Sarpa salpa	30,00	35,90	40,00	18,18
Sciaena umbra		2,56		
Serranus hepatus		12,82		9,09
Serranus scriba	80,00	92,31	90,00	90,91
Sparus auratus	10,00			
Symphodus cinereus	100,00	97,44	100,00	100,00
Symphodus ocellatus	90,00	89,74	90,00	54,55
Symphodus roissali	80,00	100,00	100,00	100,00
Symphodus rostratus		7,69	40,00	
Symphodus tinca	80,00	94,87	100,00	81,82
Tripterygion tripteronotus	50,00	46,15	60,00	63,64
Total number of species S	25	31	24	26

Tab. 2: Average density (per 100 m²) and standard deviation (in parenthesis) of the recorded fish species in different habitat types and values of Shannon-Wiener diversity index.

	Cymodocea nodosa	*Cystoseiretum barbatae*	*Cystoseiretum crinitae*	Boulders with turf
Aidablennius sphynx		0.02 (0.13)		0.06 (0.12)
Atherina hepsetus	6.86 (11.63)	1.79 (6.57)	5.60 (11.81)	1.40 (4.43)
Chromis chromis		1.97 (3.51)	0.77 (0.66)	2.00 (4.29)
Dicentrarchus labrax		0.01 (0.05)		
Diplodus annularis	2.32 (1.79)	1.40 (1.75)	0.82 (0.68)	0.35 (0.56)
Diplodus puntazzo		0.03 (0.09)	0.10 (0.21)	
Diplodus sargus		0.17 (0.38)	0.03 (0.09)	
Diplodus vulgaris	1.07 (0.67)	1.18 (1.20)	3.12 (1.44)	0.07 (0.15)
Gobius cobitis	0.04 (0.13)	0.40 (0.63)	0.22 (0.31)	0.18 (0.28)
Gobius cruentatus	1.32 (1.61)	0.72 (0.86)	0.77 (0.70)	0.93 (1.82)
Gobius fallax	0.68 (0.78)	0.92 (2.02)	3.18 (2.61)	0.46 (0.77)
Gobius niger				0.03 (0.09)
Hippocampus guttulatus	0.03 (0.09)			
Labrus merula	0.04 (0.13)	0.20 (0.30)	0.36 (0.34)	0.11 (0.18)
Lipophrys dalmatinus	0.53 (0.76)	0.71 (0.86)	0.47 (0.56)	2.52 (3.27)
Mugil cephalus	0.08 (0.26)			
Mullus surmuletus	0.03 (0.09)	0.04 (0.15)		0.20 (0.30)
Oblada melanura	0.03 (0.09)	0.86 (3.17)	7.37 (10.56)	
Pagellus erythrinus	0.06 (0.18)			
Parablennius gattorugine	0.04 (0.13)	0.25 (0.53)	0.20 (0.22)	0.06 (0.12)
Parablennius incognitus		0.10 (0.22)	0.06 (0.12)	0.22 (0.43)
Parablennius rouxi		0.21 (0.55)		
Parablennius sanguinolentus	0.11 (0.27)	0.28 (0.52)	0.42 (0.59)	2.91 (3.73)
Parablennius tentacularis	0.15 (0.21)	0.01 (0.04)		0.03 (0.09)
Pomatoschistus bathi	0.46 (0.52)	0.97 (1.46)	0.66 (1.05)	0.42 (0.57)
Salaria pavo				0.03 (0.09)
Sarpa salpa	0.48 (0.81)	1.82 (3.91)	1.75 (2.51)	0.54 (1.44)
Sciaena umbra		0.01 (0.05)		
Serranus hepatus		0.10 (0.26)		0.03 (0.09)
Serranus scriba	0.91 (0.76)	1.64 (1.06)	2.70 (1.99)	1.59 (1.20)
Sparus auratus	0.03 (0.09)			
Symphodus cinereus	5.31 (2.47)	3.39 (2.19)	3.47 (2.34)	4.99 (2.37)
Symphodus ocellatus	3.34 (3.20)	2.97 (3.58)	9.31 (6.94)	3.08 (6.09)
Symphodus roissali	2.14(2.20)	7.68 (4.51)	19.83 (11.49)	10.19 (6.44)
Symphodus rostratus		0.03 (0.10)	0.14 (0.19)	
Symphodus tinca	0.51 (0.41)	3.17 (3.28)	2.97 (2.96)	1.07 (1.50)
Tripterygion tripteronotus	0.15 (0.17)	0.30 (0.50)	0.85 (1.13)	0.59 (0.72)
Total Density: average (SD)	26.72 (29.47)	33.35 (44.43)	65.16 (61.49)	34.02 (41.05)
TD without Atherina	19.86 (17.84)	31.55 (37.86)	59.56 (49.68)	32. 62 (36.62)
Diversity index	**2,30**	**2,68**	**2,35**	**2,37**

Our results show that the *Cystoseira* communities are an important element of the habitat complexity of the Slovenian infralittoral and that they indeed play a crucial role in the conservation of species and habitat diversity. According to that, greater effort would be needed to carry out a complete and accurate cartography of the macroalgal communities distribution and to monitor their evolution in space and time in order to be able to foresee the causes of their possible decline. Last but not least, the conservation of good environmental status is an obligation also according to the proposed EU Marine Strategy Directive.

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Christophe VIALA[1], Claire NOEL[1], Michel COQUET[1], Benoît ZERR[2], Patrick LELONG[3], Jean-Luc BONNEFONT[3]
[1]SEMANTIC-TS, 39 Ch Buge, 83110 Sanary, FRANCE, e-mail : contact@semantic-ts.fr
[2] DGA/GESMA, Groupe d'Etudes Sous Marines de l'Atlantique BP 42 – 29240 BREST Naval, FRANCE
[3] IOPR, Institut Océanographique Paul Ricard, Ile des Embiez, 83140 Six-Fours, FRANCE

PERTINENCE DE LA METHODE DIVA POUR L'INTERPRETATION DES MOSAÏQUES SONAR LATERAL

Extrait

Cet article présente les travaux de recherche réalisés par la société SEMANTIC-TS en collaboration avec le GESMA et l'IOPR dans le cadre de la détection acoustique des herbiers de posidonies. La méthode de reconnaissance acoustique des fonds marins DIVA (Détection & Inspection Verticale Acoustique) mise au point par la société SEMANTIC TS est brièvement exposée. Cette méthode exploite la forme du signal acoustique de sondeur mono faisceau pour en déduire des informations sur la couverture du fond. On présente ensuite les résultats de l'application de cette méthode sur une zone pilote pour laquelle la vérité terrain est précisément investiguée. Dans le même temps un levé au sonar latéral de haute résolution est effectué sur la zone. L'analyse de la mosaïque sonal met en évidence des zones géographiques pour lesquelles l'interprétation est ambiguë. Les informations complémentaires apportées par la méthode DIVA sont qualifiées et on montre comment elles permettent de lever les ambiguïtés d'interprétation.

Mots-clés: Cartographie, Acoustique sous-marine, Classification, Sonar latéral, Echosondeur.

Introduction

Les travaux présentés ici s'inscrivent dans le cadre d'un projet d'étude plus global (Noel *et al.*, 2006) concernant la mise au point d'une méthode opérationnelle de cartographie de la couverture des petits fonds marins, et tout particulièrement des champs de végétations sous-marines de type herbier de posidonies en Méditerranée, ou de crépidules ou laminaires en Atlantique, par fusion multi-capteurs. Ce projet est issu du constat, par SEMANTIC TS et le GESMA d'un besoin commun de cartographie de la couverture du fond marin, aussi bien dans des applications civiles que militaires car l'herbier dissimule la présence des mines. Après la mise au point d'une méthode monofaisceau ayant pour but de déterminer la nature de la couverture en incidence normale, des données de sonar latéral sont exploitées pour cerner les zones de couverture homogène. Enfin, la fusion de ces données doit permettre de générer les cartographies de façon plus précise et plus aisée c'est-à-dire en diminuant les besoins en vérité terrain (plongeur, caméra).

Cet article présente, sur une zone connue et proposée par l'Institut Océanographique Paul Ricard (IOPR), les premiers résultats de la fusion de données sonal et méthode monofaisceau DIVA.

Matériels et méthodes

Les méthodes et moyens suivants sont mis en œuvre à partir du navire instrumenté « Semantic » dédié à la reconnaissance des fonds marins :

- Sonar Klein 5000 du GESMA: sonar latéral multivoies haute résolution, de fréquence 455 kHz, de résolution 20 cm à 75 mètres et de portée max 150 mètres.
- Sondeur monofaisceau Simrad ES6 grande précision (sondeur scientifique)
- D-GPS différentiel RTK LEICA GX1230 centimétrique: Une base et un récepteur
- Station d'acquisition et de traitement des données. Centrale de navigation

- Plongeurs professionnels. Caméra vidéo fixée sous la coque et/ou tractée par le navire
- Méthode DIVA de reconnaissance acoustique des fonds marins (Détection & Inspection Verticale Acoustique).

Le principe de la méthode de reconnaissance acoustique des fonds marins DIVA développée par SEMANTIC TS est le suivant. Le navire instrumenté se déplace sur la zone à lever. Un PC installé à bord, récupère les informations en provenance des divers instruments de mesure, c'est-à-dire :

- la position (latitude, longitude et élévation de la mer) indiquée par un GPS différentiel,
- la réponse impulsionnelle du signal sonore réverbéré par le fond fournie par le sondeur.

Le système analyse et traite la réponse impulsionnelle et en déduit les caractéristiques de la végétation fixée sur le fond sous-marin. Le PC traite les informations et, à une latitude et une longitude, il associe les informations caractéristiques de la végétation. La première étape consiste à extraire du signal reçu par le sondeur le premier écho du fond. Une méthode d'analyse discriminante permet ensuite d'affecter à cet écho une classe de biocénose préexistante (par exemple : sable, posidonie, …). Cette affectation se fait par l'intermédiaire de fonctions discriminantes calculées à partir de fichiers d'apprentissage pour chacune des classes définies (phase d'apprentissage). Enfin, le résultat de la classification de l'écho est associé à la latitude et la longitude fournies par le GPS, ce qui en assure le géo-référencement (Noel *et al.*, 2005).

Semantic TS dispose sur son navire instrumenté d'un sondeur acoustique monofaisceau qui permet ce type de fonctionnement. Ce sondeur est un sondeur scientifique haut de gamme qui a déjà été utilisé par des équipes de l'INRA pour la caractérisation d'espèces de poissons (travaux similaires) à partir du signal acoustique réverbéré par les bancs de poissons (Lurton, 2002). Seule la fréquence d'émission à 200 kHz de ce sondeur a été exploitée. Sur le sondeur utilisé, la réponse acoustique est différente selon que le son se réfléchit sur une zone couverte de végétation ou non.

La méthode DIVA exploite ce phénomène pour localiser les herbiers de posidonies. La méthode permet actuellement de bien distinguer les fonds de sable et de posidonies. Elle est à l'étude sur les mattes mortes et les roches.

La précision du GPS est centimétrique en longitude et en latitude. La précision de la caractérisation de la couverture du fond dépend directement de la profondeur et correspond à la surface insonifiée par le sondeur. Dans le cas du Simrad ES60, l'angle d'ouverture du transducteur étant de 7°, les surfaces insonifiées en fonction de la profondeur sont les suivantes (Tab. 1) :

Tab.1 : et caractérisation du fond en fonction de la profondeur avec le suivi ES60.

Profondeur (m)	Diamètre de la pastille (m)	Surface insonifiée (m²)
5	0,6	0,3
10	1,2	1,2
15	1,8	2,6
20	2,4	4,7
25	3,1	7,3

Résultats

La zone d'étude sur laquelle sont réalisés les essais est une zone située à l'ouest du port de la Coudoulière à Six Fours (Var, France). Cette zone a été désignée par l'IOPR et choisie en raison de la diversité de ses particularités : vaste prairie d'herbier, avec présence d'une coulée de sable en son milieu et îlots de posidonies.

La zone représente un carré d'environ 1km de côté et sa profondeur moyenne est de 10 m. Semantic a mis en œuvre des plongeurs et une caméra sous-marine fixée sous la coque de son navire. Des photos géo-référencées ont été prises sur l'ensemble de la zone.

Le sonar latéral du GESMA est opéré sur la zone, et la mosaïque sonal obtenue après dépouillement et traitement des données est représentée sur la figure 1 ci-après :

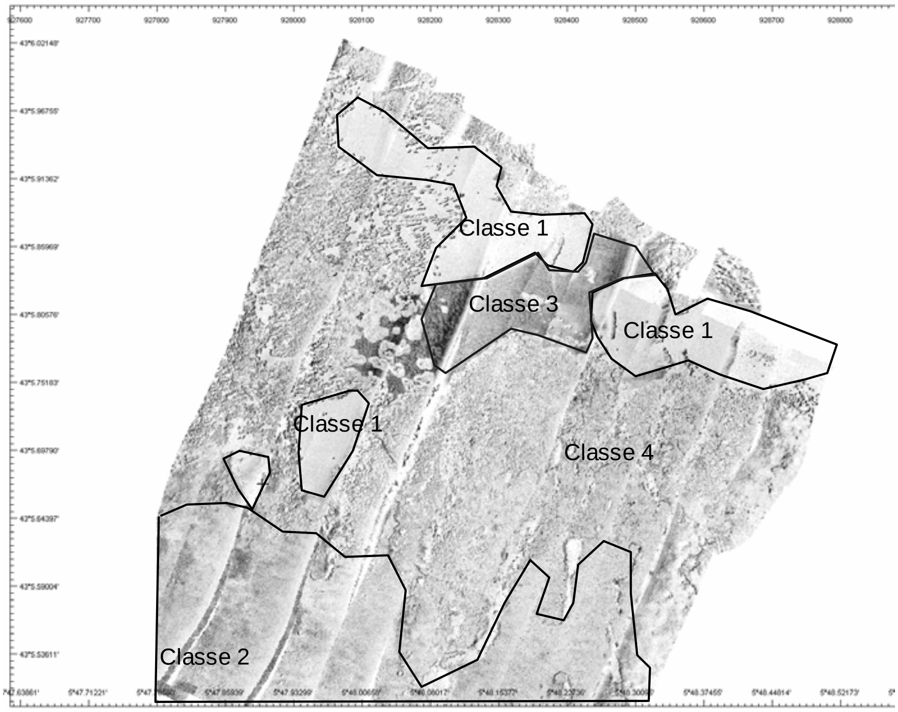

Fig. 1: Mosaïque Sonar latéral Klein 5000 - 455 kHz Octobre.

Ce sonar est actuellement un des sonars latéraux les plus résolvants du marché. Tracté à 3 m de profondeur et par mer calme, il permet d'obtenir une mosaïque de grande précision. L'intérêt d'avoir mis en œuvre ce sonal, dans des conditions où ni lui, ni la plate-forme de mesure, n'impriment de larges mouvements, est de pouvoir caractériser sur une zone pilote les performances maximales que peut atteindre ce type de système.

Cette mosaïque sonal met en évidence quatre zones géographiques différentes de réponse acoustique homogène. Sans information a priori sur la vérité terrain, l'interprétation qui peut raisonnablement être faite de cette image est la suivante :

- Classe 1 sédiment superficiel de type 1, sable probablement
- Classe 2 sédiment superficiel de type 2, sable mais de grain différent, car le pouvoir réfléchissant est un peu plus fort que pour la classe 1
- Classe 3 sédiment superficiel très réfléchissant acoustiquement, à déterminer
- Classe 4 végétation

La méthode acoustique DIVA étant mise en œuvre en même temps que le levé sonal, on dispose de données acoustiques au nadir du navire, sur chaque radiale de mesure sonal. Les informations prélevées avec cette méthode acoustique sont représentées ci-après sur la figure 2 en superposition de la mosaïque sonal :

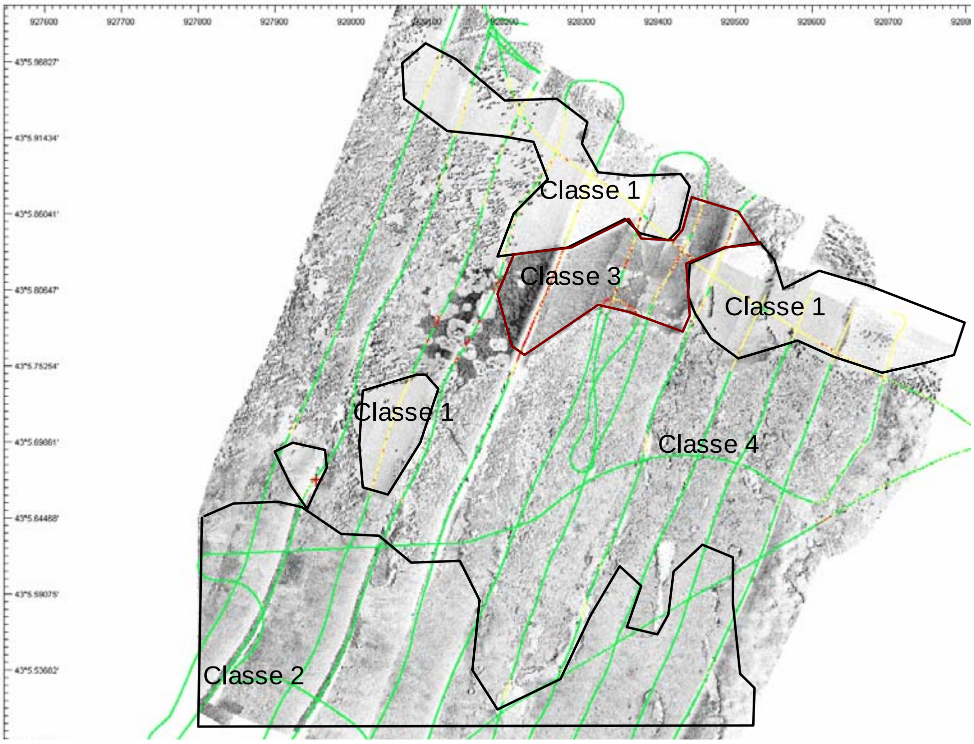

Fig. 2: Fusion des données multicapteurs DIVA & Sonar latéral. (Légende DIVA : Point Vert : Posidonie – Point jaune : Sable – Point Rouge : Sable grossier)

La figure 3 présente quatre "échos" (niveau sonore en fonction de la profondeur) représentatifs des différentes classes de la figure 2.

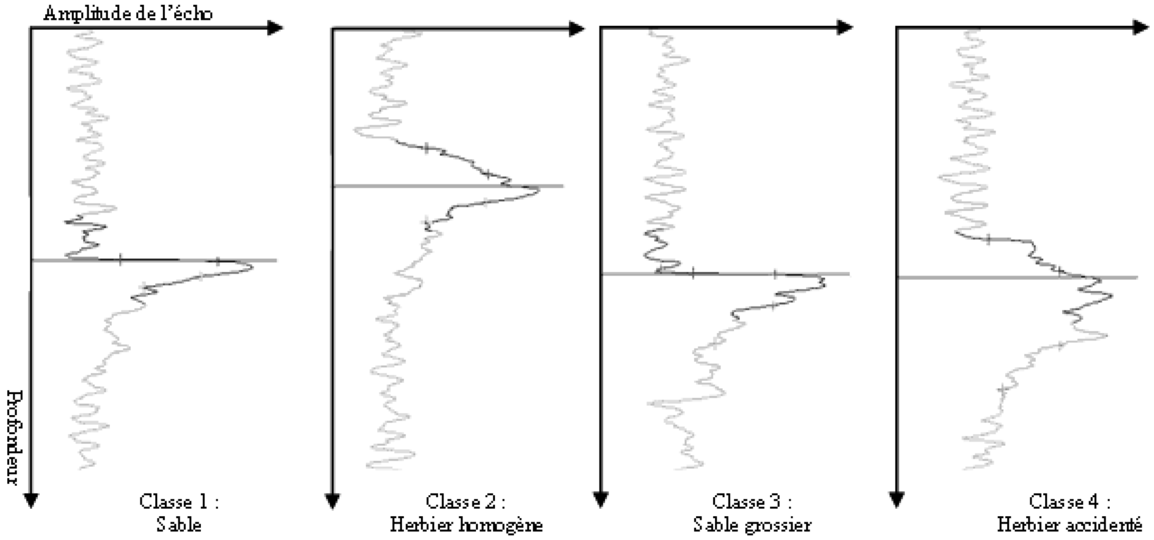

Fig. 3: Echos (niveau sonore en fonction de la profondeur) représentatifs des différentes classes.

La méthode DIVA indique du sable pour la classe 1, et de la posidonie pour la classe 4, ce qui est en accord avec l'interprétation a priori de la mosaïque sonal. Par contre, elle est en contradiction avec une interprétation classique de la mosaïque sonal en concluant que la classe 2 est de la posidonie.
La vérité terrain prouve que la méthode DIVA a raison. Les observations sur le terrain montrent que l'herbier de la zone de la Vaille n'admet pas la même dynamique au nord et au sud de la zone, et ce en raison des activités humaines, plus précisément des rejets liés à l'existence d'une ancienne briqueterie à terre. L'herbier présente dans la partie nord de la zone un relief accidenté avec une bathymétrie fluctuant de +/- 1 m autour du profil moyen du fond. Dans la partie sud de la zone l'herbier est plus homogène et la surface de la canopée est bien plane.
Les changements de la dynamique de l'herbier et de son microrelief associé, engendrent une modification de la rugosité de la canopée et permettent d'expliquer pourquoi, dans la partie nord de la zone, la réponse acoustique au sonal est plus forte que dans la partie sud, bien qu'il s'agisse d'herbier de posidonie dans les deux cas. Ce phénomène introduit une ambiguïté lors de l'interprétation des mosaïques sonals. Le seul moyen actuel de lever l'ambiguïté étant de disposer de la vérité terrain, la méthode DIVA offre un complément innovant en apportant des informations supplémentaires, nombreuses, précises et bien géo-référencées.

La zone de sable grossier a une texture très différente au sonar latéral et ne signe pas trop à l'échosondeur. Notons de plus qu'après une calibration spécifique, la méthode DIVA est capable de mettre en évidence du sable grossier pour la classe 3 (points rouges), apportant aussi un moyen de classification de la nature superficielle des sédiments. Par contre la reproductibilité de cette reconnaissance n'est pas assurée et un étalonnage est nécessaire sur ce type de fond afin de déterminer les paramètres du signal rétrodiffusé par le fond qui permette de l'identifier (Lurton et Pouliquen, 1994).

La figure 4 présente les résultats de l'interprétation de la mosaïque sonal grâce à la méthode DIVA.

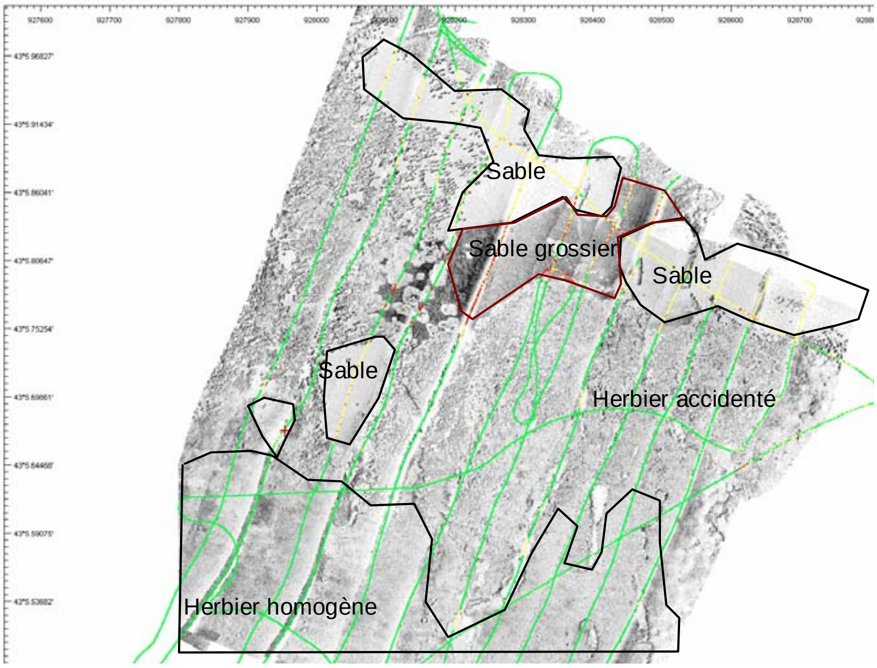

Fig. 4: Interprétation de la mosaïque grâce à la méthode DIVA. (Légende DIVA : Point Vert : Posidonie – Point jaune : Sable – Point Rouge : Sable grossier)

Discussion et conclusions

L’exploration de la zone pilote au sonar latéral très haute résolution montre que les zones d’herbier accidenté et homogène ont une texture très différente au sonar latéral. Sur la mosaïque l’herbier homogène aurait pu facilement être interprété comme un fond sablo-vaseux. La méthode DIVA (Détection & Interprétation Acoustique Verticale) avec échosondeur lève cette ambiguïté facilement.

Ces travaux mettent en évidence que la fusion des données multicapteurs, sonar latéral et méthode échosondeur, apporte une aide précieuse et innovante à l’interprétation, d’autant plus précieuse que la méthode DIVA est opérée simultanément au sonal et ne nécessite pas de sortie en mer supplémentaire.

Remerciements

Les auteurs remercient :
- la D4S/MRIS de la DGA qui soutient actuellement ces travaux au travers du contrat de recherche N° 05.34.011.00.470.75.65
- l’Agence de l’Eau Rhône Méditerranée et Corse ainsi que La Région PACA qui ont soutenu financièrement l’étude de faisabilité de développement de la méthode DIVA, et plus spécifiquement la Région PACA pour son aide à l’amélioration du navire de support et de levés en mer.
- ainsi que l’équipe dynamique d’acquisition des données en mer, Sylvain LE GOANVIC, Christophe GENTY, Gilles KERAMPRAN, Bruno LE BRETON du GESMA et Eric BAUER de SEMANTIC TS.

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Skerdilaid XHULAJ[1], **Aleko MIHO**[2]
[1]Museum of Natural Sciences, Faculty of Natural Sciences, University of Tirana, ALBANIA, e-mail: xhulaj@yahoo.com
[2]Department of Biology, Faculty of Natural Sciences, University of Tirana, ALBANIA, e-mail: amiho@icc-al.org

SEASONAL DATA ON PHYTOPLANKTON OF SOME ALBANIAN LAGOONS

Abstract

Interesting lagoons and other wetlands with a total surface of 150 km^2 extend along the Albanian coast, distinguished for the richness of breeding and refuge habitats for flora and fauna. Considered potentially of high economic importance the coastal wetlands are under the continuous pressure of tourism, aquaculture and fishing, and pollution from agriculture, towns and industry.

The periodic data on phytoplankton of Narta, Karavasta and Patoku are presented here, focused also in harmful algae and trophy state. Relatively, low values of phytoplankton were observed mainly in Patoku and Karavasta. Diatoms predominate often, but relative high amount of dinoflagellates were found in Karavasta and Narta (November 04) and almost all lagoons in April 06. The increase of dinoflagellates, some of them belonging to toxic species, can be for the scarce water circulation in the lagoons with the sea. The data reported will help to increase the awareness of local representatives and other interested people to protect the wetlands, use them properly, and to develop new strategies for the future development. It would also help Albanian government to fulfill the international standards in environmental protection, as a party of international conventions. Presenting the data in this symposium aims to make the situation better known to the most relevant international community, especially in Mediterranean area to join efforts in common cooperation in the future.

Key-words: Albanian coastal lagoons, Phytoplankton, Toxic algae.

Introduction

Despite wide reclamation for agricultural purposes ca. 30-40 years ago, important lagoons and other wetlands extend along the Albanian coast, with a total surface of 150 km^2 (NEA/AKM, 1999) and a water volume of 350 million m^3 (Pano *et al.*, 2006). Karavasta, Narta, Patoku, Viluni, Merxhani, Ceka, Orikumi are situated along Adriatic coast, formed by the activity of rivers Drini, Buna, Mati, Shkumbini, Erzeni, Semani and Vjosa. Only Butrinti is situated in the Southern part, in Ionian Sea. The lagoons represent crypto-depressions started to form since Pliocene (ca. 4-5 millions years ago), continued during Quaternary up to now days. Kabo (1990–91) gives the main hydrological characteristics, and Pano *et al.* (2006) give an overview about the development dynamics of Albanian Adriatic coastline.

The wetlands are distinguished about the richness of breeding and refuge habitats for flora and fauna, especially for wintering of migratory of globally threatened birds, i.e. Dalmatian pelican. Due to that, Karavasta and Divjaka National Park has been designated Ramsar site (http://www.ramsar.org/ profiles_albania.htm) (NEA/AKM, 1999). The ecology, focused mainly in the fisheries has been reviewed by Peja *et al.* (1996); according that, during periods of high productivity in lagoons up to 6,000 kg of fish has been annually harvested. Moreover, coastal wetlands were characterized by a high diversity of microscopic algae, reviewed recently by Miho and Witkowski (2005), where ca. 440 taxa of diatoms were reported.

Actually, the coastal zone and especially wetlands are considered of high economic values, which make the zone to be under the continuous pressure of tourism, aquaculture and fishing; especially

Adriatic coast in the other side is affected by the intense activities of agriculture and industry, urban pollution, sand extraction from the rivers, etc (Cullaj *et al.*, 2005; Miho *et al.*, 2005).

In the present paper, periodic data on phytoplankton of Narta, Karavasta and Patoku, the most representative lagoons of Adriatic coast, are presented for the first time. It aims also to evidence better the values and the general importance of Albanian coast and the coastal wetlands to increase the awareness of the most relevant international community, especially in Mediterranean area to join efforts in common cooperation in the future.

Material and methods

Since November 2004, a study of hydrochemistry and biology of coastal Adriatic lagoons of Narta, Karavasta and Patoku have started, within the framework of the program INTERREG III B CADSES '*Management and Sustainable Development of Protected Transitional Waters*'. To represent better the habitats in lagoons, four stations were selected in Narta, close to pumping station (N1), in the middle (N2), close to the main channel that links with the sea (N3), and close to Zverneci Island (N4); two stations were selected in Karavasta, middle of the lagoon, Southern (K1) and Northern (K2) part of the central channel, and two stations in Patoku, external lagoon (P1), and southern internal lagoon (P2). Phytoplankton data on four seasonal tours are presented here: November 04, April 05, November 05 and April 06. Four series of about 500 ml water were sampled in each mentioned station, at the surface (25-150 cm). During the first tour some physic-chemical data (T, °C; C, µS/cm^2; TDS g/l; S, ‰; DO%; O_2 mg/l; pH) were taken in common with the Italian group from Lecce University, Italy. Moreover, net samples (mesh size of 25 µm) were taken to evidence the floristic composition. Samples were stored in plastic bottles in formaldehyde up to 4%, taken in dark place, and elaborated as soon as possible.

Counting were done with sedimentation chambers of 25 ml, using the inverted microscope XDS-1R, objective 40x and ocular 10x, after the method Utermoehl (1958), described also in Guillard (1973) in EU Standard prEN 1524 (2005). After Lund *et al.* (1958) about statistics applicable to algal populations, more than 400 cells were counted, with an accuracy of roughly +/-10% at the 95% confidence, considered adequate in this kind of studies.

Additonal observations were done with an optical microscope Leica DML (objective 63x PL APO), objective 40x and ocular 10x. Cleaning of diatom frustules was performed using the acid method, as described by Krammer and Lange-Bertalot (1991). The material, first was boiled with HClcc and then, after washing, again boiled with H_2SO_4cc, adding during the procedure some crystals of KNO_3. Microscopic slides were prepared using Naphrax (index 1.69). Some observations and photos were taken by using Nikon Eclipse 600 light microscope with an integrated digital camera Nikon, beside Prof. A. Witkowski, University of Szczecin, Poland. Determinations were made using Krammer and Lange-Bertalot (1986-2001), Rampi and Bernhard (1978; 1980), Ricard (1986), Sournia (1978), Witkowski *et al.*, (2000), etc. Former samples, permanent slides and photos were deposited in Section of Botany, Tirana University.

Results

To give a rough estimation of the studied habitats, some physic-chemical features on the stations were given in Table 1, measured during the first sampling tour, November 04. In the Table 2, values of taxonomic groups of phytoplankton (cells/liter) in lagoons of Patoku, Karavasta and Narta are reported, taken during four sampling tours (autumn 04-spring 06).

Tab. 1: Physic-chemical data on the stations of Patoku (P1, P2), Karavasta (K1, K2) and Narta (N1, N2, N3, N4), November 2004. C, conductivity, µS/cm2, TDS, total dissolved solids, TDS g/l, S, salinity, ‰; DO, dissolved oxygen, DO%: O2, oxygen, O2 mg/l

Stations	**T, °C**	**C, µS/cm^2**	**TDS, g/l**	**S, ‰**	**DO%**	**O$_2$, mg/l**	**pH**
P1	7.57	47,752	31.21	30.9	127	12.33	8
P2	9.3	53,030	34.83	35	105	9.57	8
K1	8.69	68,970	44.82	46.5	116	10.03	7.7
K2	8.95	71,595	46.53	48.6	116	9.82	7.1
N1	6.86	57,339	37.27	37.6	118	11.23	7.9
N2	7.01	60,842	39.55	40.2	126	11.79	8.1
N3	6.32	63,516	41.29	42.2	132	12.31	7.9
N4	7.5	79,135	51.43	54.2	121	10.16	8

Tab. 2: Values of different taxonomic groups of phytoplankton (cells/liter) in various stations of Albanian Adriatic lagoons: Patoku (P1 & P2), Karavasta (K1 & K2) and Narta (N1, N2, N3, & N4), during four sampling tours: November 04, April 05, November 05, April 06.

Groups	**P1**	**P2**	**K1**	**K2**	**N1**	**N2**	**N3**	**N4**
Diatoms-Centricae	3,954	1,810	14,599	31,583	3,035	2,622	93,918	30,570
Diatoms-Pennatae	127,422	88,061	80,197	81,735	367,755	172,732	396,310	626,355
Dinophyceae	116	1,013	104,608	140,879	246,361	326,000	485,847	61,857
Cryptophyceae	60,595	46,691	52,983	71,501	107,498	98,006	164,556	369,065
Phytoflagellate	35,989	13,957	12,198	19,819	25,435	23,318	16,257	73,262
Chrysophyceae	0	0	0	189	0	0	0	0
Haptophyceae	0	0	1,618	0	0	0	0	0
Cyanophyceae	0	0	0	0	0	551	21,909	0
Prasinophyceae	0	0	0	0	0	0	3,684	0
Other Algae	0	0	0	0	16,900	15,165	16,317	0
Total-Nov.-04	**228,076**	**151,531**	**266,203**	**345,707**	**766,984**	**638,393**	**1,198,799**	**1,161,110**
Diatoms-Centricae	5,701	7,288	790	18,736	134,568	507,546	153,053	2,244,535
Diatoms-Pennatae	290,408	198,180	94,211	51,886	255,627	81,207	149,857	329,855
Dinophyceae	14,362	37,977	33,801	44,619	573,188	257,156	84,422	305,484
Cryptophyceae	224,743	420,303	306,191	213,484	2,667,684	2,551,262	832,581	13,535
Phytoflagellate	17,024	21,863	59,214	38,030	28,423	13,535	77,936	0
Haptophyceae	0	0	0	0	14,036	0	790	0
Cyanophyceae	0	0	0	0	0	0	6,316	46,000
Euglenophyceae	0	25,507	0	0	0	0	9,173	0
Other Algae	0	0	0	0	0	0	0	399,269
Total-April-05	**552,238**	**711,119**	**494,206**	**366,755**	**3,673,527**	**3,410,706**	**1,314,129**	**3,338,677**
Diatoms-Centricae	22,541	6,029	52,075	91,471	13,422	69,962	6,247	
Diatoms-Pennatae	286,949	215,322	146,587	195,370	226,986	92,014	109,942	
Dinophyceae	19,659	21,532	97,900	133,941	307,265	67,339	68,818	
Cryptophyceae	172,312	98,187	114,348	75,835	263,949	161,066	229,463	
Haptophyceae	592	0	0	0	861	0	677	
Cyanophyceae	6,316	64,597	0	0	0	5,598	0	
Euglenophyceae	0	0	0	0	0	544	0	
Prasinophyceae	0	0	0	0	2,584	544	0	
Other Algae	27,633	25,839	0	0	13,781	21,161	9,526	
Total-Nov.-05	**536,002**	**431,506**	**410,910**	**496,617**	**828,847**	**418,230**	**424,672**	
Diatoms-Centricae	197,249	271,222	187,761	142,113	625,296	781,620	429,722	2,333,018
Diatoms-Pennatae	254,716	271,222	225,658	225,012	776,883	941,497	439,873	923,733
Dinophyceae	121,145	120,749	129,193	159,877	1,335,860	586,215	399,269	615,822
Cryptophyceae	77,657	117,034	146,419	76,978	170,535	159,877	101,509	296,068
Haptophyceae	0	0	0	0	18,948	0	0	0
Cyanophyceae	0	0	0	0	966,367	0	54,138	592,136
Euglenophyceae	6,213	3,715	0	0	0	17,764	10,151	0
Other Algae	0	26,008	0	11,843	0	0	27,069	0
Total-April-06	**656,980**	**809,950**	**689,031**	**615,822**	**3,893,889**	**2,486,973**	**1,461,731**	**4,760,777**

November 04

The lowest values of phytoplankton were observed in Patoku (up to 228,000 cells/l in P1), moderate values in Karavasta (up to 345,700 cell/l in K3), and very high values in Narta, especially in N3 and N4 (up to 1,198,800 cell/l in N3). Diatoms dominated mainly in Patoku; while *Dinophyceae* were the most abundant in Karavasta, followed by diatoms. High values of pennatae were observed in Narta, followed by high values of dinoflagellates and cryptophyeceae. It is worth to mention the presence in high quantity of species from genus *Prorocentrum* (*Dinophyceae*) in Narta, especially *P. micans* and *P. minimum* (up to 406,600 cells/l) in N3; the last one considered toxic (Hallegraeff *et al*., 2003). Abundant and widespread species of diatoms were *Cocconeis scutellum, Licmophora* sp., *Navicula* sp., etc.

April 05

High values were observed in all lagoons, where the highest was in Narta, up to 3.673.500 cell/l in N1. Relatively, lowest values were observed in Karavasta, up to 366.700 cells/l in K2. The most abundant were *Cryptophyceae* in almost all the lagoons (up to 420.300 cells/l in P2; up to 306,200 in K1; up to 2,667,700 in N1). Diatoms were also important in all the lagoons, mainly penatae in Patoku, Karavasta and Narta1; centricae were also present in all lagoons, but they dominate in N2 and N4 (up to 2,244,500 cell/l in N4). There were present mainly species from genera *Chaetoceros* and *Thalassiosira* among the centricae, and species from *Navicula* and *Nitzschia* among the penatae (i.e. *Navicula transitans*, *Cylindrotheca closterium*). *Dinophyceae* were relatively low in Patoku and Karavasta, but with high abundance in Narta (up to 573,200 cells/l in N1). Genus *Prorocentrum* was again presented in all the lagoons: *P. micans* up to 249,600 cells/l in N1 and *P. minimum*, up to 253,800 in N4.

November 05

The data in Patoku and Narta were comparable with the previous season (up to 536,000 cells/l in P1), but the values in Narta were relatively lower than in April 05, up to 828,800 cell/l in N1. Diatoms, cryptophyceae and dinoflagellates were the most important. Mainly pennatae diatoms dominated in Patoku (up to 286,900 in P1) and Karavasta (up to 195,300 in K2); diatoms were, also, abundant in Narta (up to 240,000 cells/l in N1) but lower than dinoflagellates (up to 307,200 in N1) and cryptophyceae (up to 263,900 cell/l in N1). *Chaetoceros* sp. *diverse* may be considered abundant among the centric diatoms, and *Cylindrotheca closterium* among the penatae. *Prorocentrum* was mainly abundant only in Narta, i.e. *P. minimum* up to 103,700 cells/l in N1.

April 06

The phytoplankton was the most abundant of all the previous seasons in all three lagoons. The maximum was observed in Narta stations, up to 4,760,700 cells/l in N4, and the minimum in K2 (ca. 615,800 cells/l). Diatoms dominated in Patoku and Karavasta, followed by dinoflagellates and lesser the cryptophyceae. Beside N1, where dinoflagellates were the most abundant (ca. 1,335,800 cells/l), in the other Narta sations the diatoms dominated, too. During this period, the centric diatoms increased, mainly due to *Chaetoceros* sp. *diverse* (in Narta), or *Cyclotella* sp. *diverse* (in almost all the lagoons) or *Thalassiosira weissflogii* in Karavasta and Narta. *Cylindrotheca closterium* was relatively abundant in all stations, *Asterionellopsis glacialis* in N2 and N3. Dinoflagellates represented with many species, but the most abundant in Narta were species of *Prorocentrum* (*P. micans* up to 720,000 cells/l in N1). In Narta 1 there were also abundant filamentous cyanopheceae, *Oscillatoria* sp., up to 966,300 cells/l.

Discussion

Albanian wetlands hide interesting biotopes, moreover, important especially for wintering of migratory birds (known more than 70 species; NEA, 1999). Karavasta lagoon (surface area 43.3 km^2, maximum depth of 1.5 m, situated between Semani and Shkumbini deltas; Pano *et al.*, 2006) is the largest and the most important. Presence of globally threatened water birds, i.e. the Dalmatian pelican (*Pelecanus crispus*), supported the declaration recently as Ramsar site. The lagoon is connected with the sea through three short channels. Divjaka National Park spreads out close to the lagoon in the northwest, a typically dune forest (12 km^2), bordered by brackish or freshwater; pines (*Pinus halepensis* and *P. pinea*) grow up in old dunes, mixed with shrubs, grasses or reeds near lagoon shores (Cullaj *et al.,* 2005).

As in the other Albanian lagoons, microscopic algae and trophy state of Karavasta is scarcely known. About 65 diatom species were reported by Miho and Witkowski (2005) and Dedej (2006) represented mainly by the genera *Fragilaria* and *Cocconeis*. Miho and Xhulaj (2005) report data on diatoms of water complex Karavasta–Divjaka, mainly marine and brackish waters; ca. 170 species of diatoms, mainly pennatae were listed. In the present publication a larger view of microscopic algae is given. Compared to the other lagoons, phytoplankton in Karavasta was less abundant in all the studied seasons. The dinoflagellates were an important part of the phytoplankton; there were also relatively abundant several toxic species, as *Dinophysis sacculus, D. rotundata, Prorocentrum lima, P. minimum, etc.*

Narta lagoon, situated in the southern part of Vjosa delta, about 3 km far from Vlora city, has a surface of 41.8 km^2, the maximum depth of 1.5 m and an average of 0.7 m. The lagoon communicates with the sea via two channels. Protic (1907) provided the first data on some brackish habitats from the Albanian coast (in Orikumi and Narta: Vlora region), with 196 species, 107 of which were diatoms. Our data show an intense growth of phytoplankton in the lagoon, represented not only by high amount of diatoms, but often by dinoflagellates, *Cryptophyceae* and even filamentous blue green algae.

Pennate diatoms were most abundant in Karavasta. Unlike in other lagoons (Butrinti or Ceka), blooms or intensive growth of dinoflagellates were not observed there. In agreement with Guelorget and Lefebvre (1993), zones 4 and 5 seem to prevail within the lagoon, characterized by a high productivity, mostly attributable to phytoplankton. Therefore, it may be used mainly in an extensive way for farming detritivorous fish species (e.g., mullet) or peneid shrimps (Dutrieux and Guelorget, 1988).

Actual lagoon of Patoku (5 km^2) is the youngest, started to form at the beginning of XXth century; the lagoon is situated between Ishmi and Mati deltas (Laçi district), and it is connected with the sea through two channels (the northern artificial). The lagoon has a tendency to be transformed in a marshland, and in front of it a new lagoon is forming (MSHN-MASH, 2006). About 50 species of diatoms were reported by Miho and Witkowski (2005) and Dedej (2006). In MSHN-MASH (2006), a checklist of 117 species of diatoms is given for the zone Lalzi-Rodoni bays, including Patoku. In our data, the phytoplankton is relatively not abundant. Above mentioned toxic species were not abundant as in Narta and Karavasta.

As it is shown in the Figure 1, the low values of phytoplankton were observed mainly in Patoku and Karavasta. Diatoms predominate often, but relative high amount of dinoflagellates were found in Karavasta and Narta (November 04) and almost all lagoons in April 06. The increase of dinoflagellates can be considered as a stressing indicator, due to scarce water circulation in the lagoons, through the connecting channels with the sea. The scarce communication and the eventual high content of nutrients from the surrounding villages and cultivated fields were probably the consequence of the high presence of filamentous cyanobacteria (*Oscillatoria* sp.) in Narta. It is worth to stress the high presence of dinoflagellates of the genus *Prorocentrum* and *Dinophysis* (Hallegraeff *et al.*, 2003).

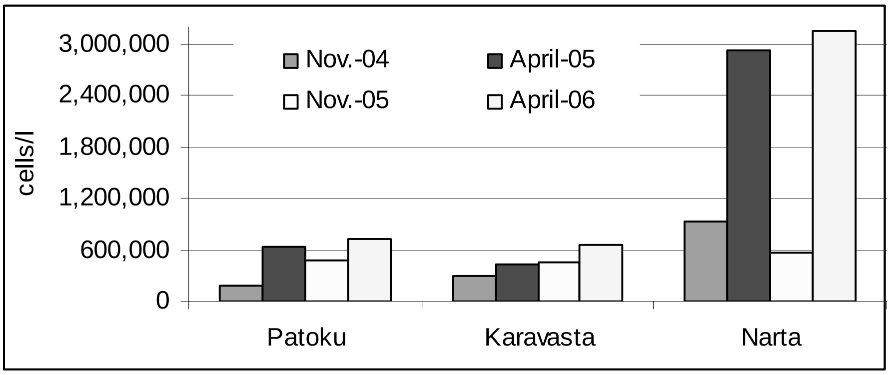

Fig. 1: Average values of phytoplankton (cells/liter) in Albanian Adriatic lagoons of Patoku, Karavasta and Narta, in four sampling tours: November 2004, April 2005, November 2005 and April 2006.

Considering the biological indicators in paralic ecosystems given by Guelorget and Perthuisot (1984), the high content of phytoplankton in almost all stations shows that Narta lagoon belong mainly to zone V. After Dutrieux and Guelorget (1988), similar habitats, characterized by a high content of phytoplankton, are suitable to an extensive fishing (i.e. mullets) or shrimps (*Peneidae*). Karavasta and Patoku may belong to the zones IV and V, too, as confirmed even by Guelorget and Lefebre (1993) during their campaign in April 1993 in the lagoons of Butrinti, Karavasta and Patoku.

Albanian coastal wetlands are, however, very sensitive ecosystems that were under strong impact in the past due to the extensive agricultural reclamation and unsustainable industry (Cullaj *et al.,* 2005; Miho *et al.*, 2005; UNEP, 2000). At present, they support the impact from the densely populated industrial centres, intensive agriculture and tourism along the whole coastal zone (INSTAT, 2004). The studied lagoons are under the direct influence of the rivers: Ishmi, Tirana, Lana, Gjanica, etc., heavily loaded with urban and industrial sewage waters. Moreover, high levels of heavy metals have been found in Vlora and Durresi bays, Mati delta, etc. Petroleum industry in Fieri and Vlora also result in an adverse ecological impact on the Semani and Vjosa deltas and their related lagoons. Coastal dune forests are under pressure of tourist development, too. Also, the high rate of erosion caused by excessive woodcutting, overgrazing or firing in relative shallow water basins, further increases the amount of suspended matter transported to the sea by the rivers.

As conclusion, Albanian coastal wetlands still possess important values for the whole Mediterranean region. Therefore, the responsibility to protect them properly would be a continuous task for Albanian Government, to fulfill also the international standards in environmental protection, as a part of international conventions. We wish that the information given here would help to make the situation better known to the most relevant international community, especially in Mediterranean area to join efforts in common cooperation in the future.

Acknowledgements

Sampling was started under the support of the program INTERREG IIIB CADSES ‘Management and Sustainable Development of Protected Trasitional Waters’, and first microscopic observations and countings were done beside Prof. A. Basset, Department of Ecology, University of Lecce, Italy. Additional, assistance in determinations (especially diatoms) were given by Prof. A. Witkowski, Department of Paleooceanology, Institute of Marine Sciences, Szczecin, Poland, during a research visit of S. Xhulaj, supported by the project TEMPUS CD_JEP-17099-2002. To all of them, the authors are glad to express the highest sense of gratitude.

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POSTERS

Maha Ahmed Mohamed ABDALLAH
Department of Marine Environment, Marine Pollution Lab. National Institute of Oceanography and Fisheries, Alexandria, EGYPT, e-mail: mahaahmed72007@Yahoo.com

CHEMICAL COMPOSITION AND TRACE ELEMENT CONCENTRATION OF MARINE ALGAE *ENTEROMORPHA COMPRESSA* AS A POTENTIAL FOOD SOURCE

Abstract

Enteromorpha compressa *is a marine seaweed present almost year round. The seaweed was collected during autumn and winter of 2005 and 2006 along Alexandria beach. This work determines chemical composition, mineral content and trace elements of* E. compressa**,** *and recommends its use in human diets. Atomic absorption spectrophotometry of the dry algae indicated that this alga contained higher amounts of both macrominerals (2689 and 4840 mg/100g; Na,K,Ca,Mg) and trace elements (118 and 199 mg/100g; Fe,Zn,Mn,Cu), than those reported for edible land plants. Chemical analysis indicated that* E. compressa *has 11.3 and 6.6% protein, 4.1 and 4.2% total lipids and 8.7 and 8.16% carbohydrate.* E. compressa *is recommended for human consumption because it has several beneficial components.*

Key-words: Marine algae, *Enteromorpha compressa*, Chemical composition, Trace elements, Nutritional value.

Introduction

Commercially available varieties of marine macroalgae are commonly referred to as ‘‘seaweeds”. Seaweed is suitable for human and animal feed, as well as for fertilizer, fungicides, herbicides, and phycocolloids (algin, carrageenan and agar)(Chapman and Chapman, 1980). Seaweeds contain high amounts of carbohydrates, protein and minerals (Rupe´rez and Saura-Calixto, 2001). Because of there low fat contents and their proteins and carbohydrates, which cannot be entirely digested by human intestinal enzymes, they contribute few calories to the diet (Lahaye and Kae Aer, 1997). The protein content of seaweed varieties varies greatly and demonstrates a dependence on such factors as season and environmental growth conditions. Thus edible marine seaweeds may be an important source of minerals (Nisizawa *et al.*, 1987), since some of these trace elements are lacking or very minor in land vegetables.

The green algae genus *Enteromorpha* has great potential for commercial exploitation because of its abundant and varied chemical composition, quality and concentration of basic nutriments for other living organism. Only a few studies deal with the chemical composition of this genus (Naidu *et al.*, 1993). In view of the current increasing demand for seaweed products, and the few reports on minerals of edible seaweeds, the aim of this work was to determine the mineral content and trace metals of edible marine green seaweeds.

Materials and Methods

Sample collection and preparation

Sampling was carried out from the beaches along Mediterranean Sea coast in the city of Alexandria, Egypt (31° 11′-31° 22 ′N and 29° 49′-30° 7 ′E) in autumn 2005 and winter 2006. Samples of *E. compressa* were collected manually at depth between 20 and 50 cm, it were rinsed with fresh water to eliminate foreign materials. Then they were air-dried for three days. The total sample collected each year was about 15 kg. Whole plants were ground in agate mortar and sieving using a 1 mm mesh, avoiding over heating that could lead to oxidation. They were stored in plastic bags in dark at room temperature.

Mineral and trace element analysis

Samples for mineral analysis were subjected to acid digestion and analyzed through atomic absorption spectrophotometer following the procedures described by AOAC (1990).

Protein, Total lipids and Carbohydrates

These substances were determined according the method described by (Folch *et al*., 1957; Bradford, 1976; Carroll *et al*., 1956). All samples were analyzed in triplicate.

Statistical analysis

t-test used for comparing samples from the two years.

Results and discussion

Minerals content

Atomic Absorption spectrophotometry determination of algae (Tab. 1) showed that *E. compressa* contained high amounts of macrominerals (2807 and 5038 mg/100g) and trace elements (118 and 199 mg/100g) needed in human nutrition. Macrominerals contents of typical land vegetables (USDA, 2001), expressed for direct comparison as Na+K+Ca+Mg in mg/100g dry weight, are carrots 3276; sweet corn 1347; green peas 1452 and tomato 3429. Actually, *E. compressa* had high macrominerals contents that measured in the previous land vegetables. Sodium content in *E. compressa* was lower than the value reported for land vegetable USDA (2001). Consequently, Na/K ratios were below 1.0 in the studied algae collected in the two years (0.1 and 0.3 respectively), which is interesting from the point of view of nutrition, since the intake of NaCl and diets with high Na/K ratio have been related to the incidence of hypertension. With respect to P, these algae contain more than 60 times the quantity of any of the common vegetables.

Levels of essential trace elements (Tab. 1) detected in *E. compressa* during the two years (Fe+Zn+Mn+Cu, 118 and 199 mg/100g) were extremely higher than that in previous reports on seaweeds (Ortega-Calvo *et al*., 1993).

Tab. 1: Macrominerals and trace elements (mg/100g dry weight) in* E. Compressa *(Mean values of triplicate determination ± standard deviation).

Mineral	2005	2006
Na	74.2±0.55	74.62±0.91
K	785±5.8	2115±8.3
Ca	1450±9.1	2330±12.0
Mg	380±2.0	320±1.9
Fe	101.28±3.7	177.83±4.0
Zn	3.94±0.58	4.05±0.77
Mn	11.43±6.9	15.51±4.4
Cu	1.03±0.59	1.58±0.76
Total contents	2807	5039

Also higher than that measured land plants as sweet corn (4.9 mg/100g) and spinach (50.7 mg/100g). Zinc content (3.94 and 4.05 mg/100g) in *E. compressa* was below the maximum amount allowed in macroalgae for human consumption in Japan and France (1.5-10 mg/100g (Indegaard and Minsaas, 1991). This standard was used because a specific standard for edible algae dose not exist in Egypt. Most of trace elements present in the algal biomass are heavy metals (Cd, Cu, Hg, Pb, Zn, Cr) but their content is generally below the toxic limits allowed in several countries (Aguilera-Morales *et al*., 2005).

Chemical composition

Many researches finding that the nutritional contents of macroalgae depend not only on season and geography, but also on the nutrient content of environment. A significant difference ($p<0.05$) was found in protein levels of *E. compressa* between the two years (Tab. 2). Protein in samples collected in 2005 was similar to that of *Enteromorpha prolifera* (12% to 15%) reported by (Tewari, 1972) and to that of oats (13.3%) and other cereals (Morales de León *et al*., 2000). The high protein digestibility shows that the proteins of this algae is easily hydrolyzed for the enzymes trypsin, chymotrypsin and peptidase (NRC, 1994).

***Tab. 2: Chemical composition (mg/100g dry weight) of marine algae* E. Compressa.**

	2005	2006
Protein	11.3±0.5	6.6±0.42
Carbohydrate	8.7±0.14	8.16±0.27
Total lipids	4.11±1.6	4.21±0.43

Lipids are within the range mentioned for seaweed (1-4%) (Haroon *et al*., 2000), and relatively higher than that measured for *E. intestinalis* (1.85%) and *Ulva rotundata* (1.95%). High concentrations of carbohydrates were recorded in *Enteromorpha* sp. (8.7 and 8.16 mg/100g Tab. 2). Although the components of the cell wall do not contribute to nutrition, they form an important component in diets. During transit in intestinal tract, this material absorbs water, metals and organic substances that are eliminated in feces. In addition, hemicellulose besides favoring increase in volume and weight of feces increases bile production, which participates in the digestion of fatty acids.

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Yelda AKTAN
Fisheries Faculty, Istanbul University, Ordu St., No: 200, 34470, Laleli, Istanbul, TURKEY, e-mail: yaktan@istanbul.edu.tr

A PRELIMINARY STUDY ON SELECTED BENTHIC ALGAE AND THEIR EPIPHYTIC FLORA IN IZMIT BAY (MARMARA SEA, TURKEY)

Abstract

In marine coastal ecosystems, benthic algae are important contributors to primary production. The aim of this preliminary study, from March 1999 to September 2000, is to investigate of the seasonal distribution on selected marine benthic algae and their microflora in an eutrophic bay. During the research period, a total of 13 macroalgae were collected on the littoral zone of Izmit Bay. A total of 60 epiphytic algal taxa from five classes, Bacillariophyceae, Rhodophyceae, Cyanophyceae, Dinophyceae, and Chlorophyceae were determined. Species composition of epiphytic algal flora was characterized by the presence of Bacillariophyceae. Most common taxa from Bacillariophyceae were Achnanthes *sp. and* Synedra tabulata *(Ag.) Kütz. and they did not show host preference while some species were more abundant on some hosts. Together with prevailing physical and chemical factors, structure, density and seasonal occurrence of the host plants and epiphytic attachment modes had affected epiphytic developments in general.*

Key-words: Macroalgae, Epiphytes, Izmit Bay.

Introduction

In marine coastal ecosystems, benthic algae are important contributors to primary production and are a limiting resource for sessile plants and animals. Benthic macroalgae are important as balance of littoral sediments and as protected and reproduction area. Besides we must know which season and frequency we could encounter to some species to be economic. Epiphytic (species growing on macroalgae or macrophytes) algae play an important role in marine communities, contributing to the primary productivity of ecosystems (Bellegratis *et al*.,1999), supplying main food source for fauna living on and amongst the macro algae such as molluscs and amphipod crustaceans (Scipione and Mazzella, 1992; Mazzella and Spinochia, 1992; Mazzella *et al*., 1994; Snoeijs, 1994) and comprise a major portion of the biota present in a given area (Scipione and Mazzella, 1992; Mazzella and Spinochia, 1992). Izmit Bay, located in the north-eastern part of the Marmara Sea is one of the most polluted areas in the Marmara Sea. The area is inserted in a rather complex hydrological system, in a zone of transition between dense and a warmer cold waters originating in the Mediterranean Sea, and cold, lower-salinity water coming from the Black Sea. The aim of this preliminary study is to investigate of the seasonal distribution on selected marine benthic algae and their microflora in an eutrophic bay.

Study Area

Izmit Bay, a semi-enclosed sea, was located on the north-eastern part of the Marmara Sea. Several industries have been developing rather rapidly around the Bay. In addition to untreated or partly treated domestic wastes originating from the increasing population, the substantial industrial development, the heavy maritime traffic and the agricultural activities in the surrounding areas have caused considerable pollution load. In terms of its oceanographic characteristics, Izmit Bay may be separated into three distinct regions western, central and eastern, which are connected to each other through narrow openings. Main morphometric characteristics of Izmit Bay are given in Table 1 (Okay, 2001).

Tab. 1: Main morphometric characteristics of Izmit Bay.

	Eastern	Central	Western
Length (km)	16	20	17
Width (km)	2-5	3-10	3-5.5
Max depth (m)	35	180	200
Surface area (km^2)	44	166	100

Material and methods

Field studies were conducted between March 1999-September 2000 and macro algae were sampled from 8 stations on the littoral sediments of the Izmit Bay. In this research, growth of host plants and epiphytic trends were examined every four weeks. Macro algae sampling was carried out by SCUBA-diving snorkelling and by the hand. Epiphytic algae on host plants were separated to be apply washing-tearing methods in laboratory, temporary slides were prepared for counting. Counting was made by means of a light microscope at a magnification of 400.

Results and discussion

There are various environmental factors which affect the increase and decrease in the biomass of benthic algae. While nutrients, light and temperature conditions influence biomass increase, the mobility or instability of the environment, strong waves, large amounts of precipitation of the suspended material and consumption by animals reduce it (Aktan and Aykulu, 2005). In measurements taken from the surface waters of the littoral zone in Izmit Bay, changes in temperature were recorded at different sites and in various seasons, related to wind and wave movements. Salinity measurements showed changes parallel to evaporation and rainfall. While these changes were very small in open waters, they were more evident in the shore region of Izmit Bay. The results of the physical and chemical parameters (maximum, minimum and average values of surface water in Izmit Bay) were summarized in Table 2.

Tab. 2: Results of some physical and chemical parameters.

	Min	Max	Average
Temperature (^{0}C)	3.5	30	18.4
pH	7.2	9.5	8.3
Salinity (‰S)	13	28	21.3
NO_3-N (µg l^{-1})	2 (Dec 99)	40.9 (Mar 99)	13
PO_4-P (µg l^{-1})	2 (Dec 99,Mar 00)	38 (May 99)	8.2
SiO_2 (µg l^{-1})	7 (Dec 99)	430 (Mar 00)	5.5
Suspended solids (mg l^{-1})	17.8 (Sep 99)	32.4 (May 99)	22.6

During the research period, a total of 13 macroalgae were collected on the littoral zone of Izmit Bay as host plants (Tab. 3). Some genera were represented two or three species, like *Cladophora hutchinsiae* (Dillwyn) Kützing, *Cladophora* sp., *Enteromorpha compressa* (Linnaeus) Nees. var. *compressa, Enteromorpha linza* (Linnaeus) J. Ag., *Enteromorpha intestinalis* (Linnaeus) Link, *Ulva lactuca* Linnaeus, *Ulva rigida* C. Agardh, *Ceramium diaphanum* (Lightfoot) Roth var. *diaphanum, Ceramium rubrum* (Hudson) C. Agardh var. *rubrum, Gracilaria verrucosa* (Hudson) Parpenfuss., *Gracilaria* sp., *Punctaria hiemalis* Kylin, recorded as epiphytic on *Cystoseira,* and *Polysiphonia* sp. were recorded as small epiphytic forms on the other hosts, and they were not evaluated as host plants. Occurrence and relative frequencies of host plants at stations are given in Table 3. Species of *Enteromorpha, Ulva* and *Ceramium* were recorded at all stations. Specimens were not taken continual because of no regular seasonal growth of macro algae.

Tab. 3: Distribution and abundance of macro algae in Izmit Bay (% 100-80 constantly present, % 80-60 largely present, % 60-40 generally present, % 40-20 Sometimes present, % 20-1 rarely present).

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8
BRYOPSIDOPHYCEAE								
Bryopsis hypnoides Lamour	28	17	61	44	61	11	-	33
Cladophora sp.	28	22	17	17	-	-	-	-
Codium fragile (Sur) Hariot	6	17	17	61	11	-	-	6
CHLOROPHYCEAE								
Enteromorpha sp.	56	67	39	28	72	28	17	61
Ulva sp.	61	67	56	28	22	6	6	17
FUCOPHYCEAE								
Cystoseira barbata C. Agardh	22	-	83	89	-	-	-	-
Ectocarpus siliculosus (Dillw.) Lyngb.	-	-	-	-	-	-	6	-
Syctosiphon lomentaria (Lyngb.) Link	17	17	-	11	17	-	-	-
RHODOPHYCEAE								
Calithamnion corymbosum (Sm.) Lyngb	6	-	6	-	6	-	-	-
Ceramium sp.	56	67	44	28	89	22	6	39
Gracilaria verrucosa (Hust.) Papenf.	11	28	-	28	28	-	-	-
Gymnogongrus griffithsiae (Turn) *Martius*	-	-	-	-	6	-	-	-
Porphyra sp.	6	-	-	-	6	-	-	-

In terms of epiphytic algae, 60 species of five different classis, Bacillariophyceae (67 %), Cyanophyceae (15 %), Dinophyceae (12 %), Rhodophyceae (3 %), and Chlorophyceae (3 %) were identified. Diatoms were most important groups in terms of composition and distribution of epiphytic algae than the other taxonomic groups. The dinophytes (*Dinophysis caudata, Protoperidinium* sp., *Prorocentrum compressum, P. lima, P.micans, P. minutum, P. scutellum* and cyanophytes (*Aphanocapsa* sp., *Lyngbya* sp., *Merismopedia glauca, M. tenuissima, Oscillatoria* sp., *O. limosa, O. tenuis, Pseudanabaena* sp., *Spirulina* sp.) recorded subdominant, were represented with seven and nine species respectively. However, they did not recorded as common and not reached high numbers in density. In terms of distribution of epiphytic diatoms on host, the highest species number was recorded on *Cystoseira barbata* var. *barbata*. Dominant taxa recorded on host plants from Izmit Bay were given in Table 4.

A lot of studies indicated that morphologic structure and age of host was important for the development of epiphytic diatoms (Round, 1981; Snoeijs, 1994). *Cystoseira* is a perennial plant, found year around and long-lived host plant. The bushy, perennial thallus constitutes a suitable settlement for epiphytes. The specimen of *Cystoseira* in the Izmit Bay supports considerable epiphytic assemblages on the thalli. *Achnanthes* sp. and *Navicula ramosissima* var. *mucosa* were dominant in these assemblages. No significant differences in the composition of epiphytic algae were recorded on the host plants however their abundance changes considerably. In spring and autumn period, an extensive epiphytic diatom growth was observed on the host plants-particularly *Cystoseira, Bryopsis, Codium,* and *Scytosiphon.* In this reason, there is also affect of to be cover with intensive epiphytic algae (mainly diatoms) of small forms of filamentous algae (*Ectocarpus, Callithamnion, Polysiphonia, Cladophora,* and *Ceramium*), living on these hosts.

Tab. 4: Dominant taxa on host plants (Lic abb*= Licmophora abreviata*, Syn tab*= Synedra tabulata*, Coc sp.*= Cocconeis *sp., Str uni*= Striatella unipunctata*, Ach sp.*= Achnanthes *sp., Coc ped*= Cocconeis pediculus*, Nav ram*= Navicula ramosissima*, Syn sp.*= Synedra *sp., Mel num*= Melosira nummuloides*, Eri car*= Erithrotrichia carnea*, Aud sp.*= Audoniella *sp.).

Macro algae (Host plants)	Dominant epiphytic taxa
Bryopsis hypnoides	Lic abr, Syn tab
Cladophora sp.	Coc sp., Lic abr, Str uni, Syn tab
Codium fragile	Ach sp., Coc ped, Lic abb, Syn tab, Eri car, Aud sp.
Enteromorpha sp.	Ach sp., Lic abb, Syn tab
Ulva sp.	Ach sp., Lic abb, Nav ram, Eri car
Cystoseira barbata var. *barbata*	Ach sp., Nav ram
Ectocarpus confervoides var. *confervoides*	Nav ram
Scytosiphon lomentaria	Lic sp., Nav ram, Syn sp.
Callithamnion corymbosum	Lic sp.,
Ceramium sp.	Ach sp., Coc sp., Mel num, Nav ram, Syn tab, Eri car, Aud sp.
Gracilaria verrucosa	Nav ram, Lic abb, Syn tab
Gymnogongrus griffithsiae	Ach sp.
Porphyra sp.	Mel num, Lic abr, Syn tab

Acknowledgements

I am grateful to Süheyla Karataş and Armağan Düğenci for help sampling by SCUBA diving in the field. This study was supported by the Research Fund of Istanbul University, Project Number: T-670/190299.

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Martese AZZOPARDI, Patrick J. SCHEMBRI
Department of Biology, University of Malta, Msida MSD06, MALTA, e-mail: marthese.azzopardi@um.edu.mt

EXPLORING THE USE OF ROCKY SHORE MACROALGAE AS INDICATORS OF ENVIRONMENTAL CONDITION

Abstract

We attempted to use macroalgae to discriminate between seven sites around the Maltese Islands displaying different water quality. The study focused on the macroalgal communities from the mediolittoral to upper infralittoral zones, since these assemblages can be easily accessed from the shore. The results obtained showed that distinct macroalgal assemblages inhabit the selected sites and that the assemblage at the reference site was the most dissimilar. Interannual variation in macroalgal assemblage structure at each site was minimal. All taxonomic levels considered (genus, order, family, class and phylum) were able to distinguish between sites. Chlorophyll a content, water turbidity and dissolved phosphates were the physico-chemical parameters that discriminated between sites.

Key-words: Rocky shores, Macroalgal assemblages, Malta, Water quality, Multivariate analysis.

Introduction

Currently, the most widely used approach in pollution impact studies is the analysis of the whole assemblage of species in an area (Clarke and Warwick, 2001). In this study we attempted to use macroalgae inhabiting the uppermost infralittoral and the mediolittoral zones in the Maltese Islands to discriminate between sites chosen *a priori* and displaying different water quality. Another aim was to examine how the level of taxonomic identification affects the analyses.

Materials and methods

Seven locations around the Maltese coast (Fig. 1) were selected. All had the same substratum type and comparable slopes but were affected by different degrees of anthropic impact. Selection was based on the results of a long-term monitoring of levels of nutrients, chlorophyll and water transparency as indicators of environmental quality (Axiak, 2004). Five replicate 0.5 m × 0.05 m quadrats were placed at random in the upper infralittoral/mediolittoral zones at each site and the percentage cover of each species of macroalgae was recorded on three separate occasions each year in 2003 and 2004. Annual percentage cover values are presented here. The results were analysed using multivariate methods: group average linkage hierarchical cluster analysis, Non-metric Multidimensional Scaling ordination (MDS) and Principal Component Analysis (PCA). Computations were made using the PRIMER 6 suite of programs (Clarke and Gorley, 2006).

Results

PCA ordination based on environmental variables (mean values of salinity, temperature, dissolved nitrates, dissolved phosphates, Beam Attenuation Coefficient (BAC) and chlorophyll a content recorded between 1998 and 2003; data from Axiak, 2004) clearly distinguished the sites, with PC1 and PC2 collectively explaining 77.3% of the variation; PC1 appeared related to chlorophyll a content and BAC, and PC2 to dissolved phosphate. The sites could therefore be arranged in a series with Qbajjar as the reference site and, in order of deteriorating water quality, St. Paul’s Bay, Marsascala-J, St. Angelo, Manoel Island, Birzebbuga and Marsascala-W. Distinct macroalgal assemblages inhabited the seven sites as indicated by hierarchical cluster analysis and MDS ordination (Fig. 2). The assemblage at the reference site (Qbajjar) was the most dissimilar. Interannual variation in macroalgal assemblage structure at each site was minimal. MDS plots distinguished between sites at all taxonomic levels with acceptable stress values that ranged from 0.09 (genus level) to 0.133 (family level) (Fig. 3).

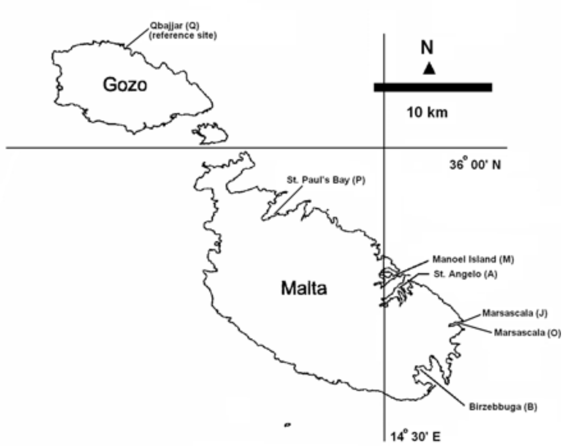

Fig.1: Map of the Maltese Islands showing the location of the sites studied.

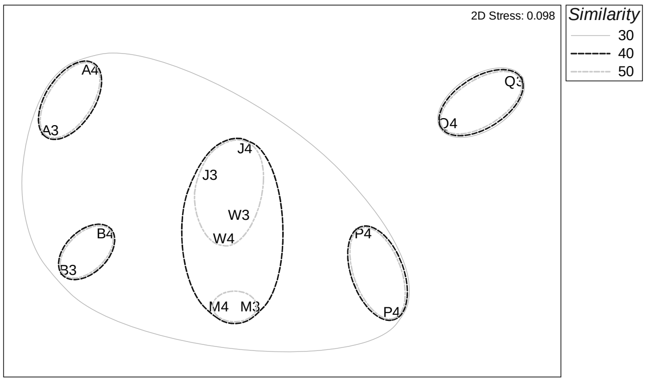

Fig.2: Overlay (at 30, 40 and 50% similarity) of the results of hierarchical cluster analysis on a non-Metric Multidimensional Scaling Ordination plot of the annual mean values of the percentage cover of macroalgal species at all sites recorded in 2003 (labels ending in '3') and 2004 (labels ending in '4'). (Site codes are as given in Fig. 1).

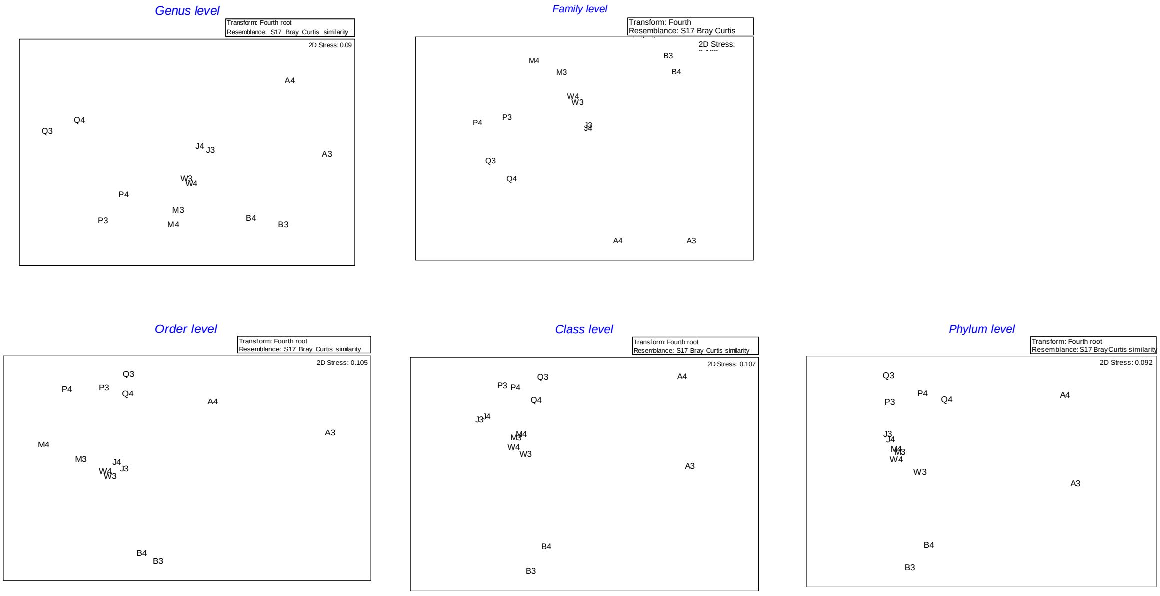

Fig. 3: The results of non-Metric Multidimensional Scaling Ordination of the annual mean values of the percentage cover of macroalgae at all sites recorded in 2003 (labels ending in '3') and 2004 (labels ending in '4') for the genus, order, family, class and phylum taxonomic levels. (Site codes are as given in Fig. 1).

Conclusion

The use of macroalgae to assess water quality seems to be justified. Since no specialised equipment is necessary and there is no need for identification to species level, this technique may provide a relatively rapid and low cost method of assessing water quality in rocky coastal areas.

Acknowledgments

We are grateful to Prof Victor Axiak (University of Malta) for making available his unpublished results on water quality in Maltese coastal waters, and to the University of Malta for financial support.

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Said BELBACHA, Rachid SEMROUD, Renaud DUPUY DE LA GRANDRIVE, Mathieu FOULQUIE, Hesham SERIDI
Département des Sciences de la Mer, Université d'Annaba, BP 12, Annaba 23000, ALGERIE
e-mail : said_belbacha@yahoo.fr

DONNEES PRELIMINAIRES SUR LA BIODIVERSITE PHYTOBENTHIQUE DU LITTORAL D'EL KALA (EST ALGERIEN)

Résumé

Dans le cadre du projet régional pour le développement d'Aires Marines Protégées dans la région méditerranéenne (Projet Med MPA) une étude a été réalisée dans le but d'élaborer un plan de gestion de la partie marine du Parc National d'El Kala (PNEK). Dans cette perspective, une évaluation du patrimoine biologique du littoral s'étendant entre le Ras Rosa à l'ouest et le Ras Segleb à l'est, a été entreprise. Deux campagnes ont été réalisées entre les mois de juillet et d'août 2004 durant lesquelles l'ensemble du linéaire côtier a été exploré. L'inventaire floristique nous a permis l'identification préliminaire de 50 macrophytes. Par ailleurs, nous avons pu mettre en évidence des formations remarquables telles que les forêts de Cystoseira *de mode battu, un récif-barrière de l'herbier à* Posidonia oceanica, *les encorbeillements à* Corallina elongata *et la forêt à* Dictyopteris polypodioides. *La biodiversité estivale identifiée dans cette unité marine ainsi que la mise en évidence d'espèces dites remarquables traduit l'importance de cet espace marin qu'il faut impérativement protéger.*

Mots-clés : Macrophytes, Biodiversité, Protection, Sud-Est méditerranéen.

Introduction

La zone côtière marine d'El Kala au nord-est du pays, classée Réserve de la biosphère par l'UNESCO comprend de nombreux sites d'intérêt stratégique au point de vue écologique et se place au premier rang national concernant les pôles de diversité biologiques. Peu de travaux ont été entrepris dans le région d'El Kala et ont soit concernés des études partielles ou préliminaires (Vaissière et Fredj, 1963 ; Pergent *et al.*, 1990) soit n'ont pas aboutit aux résultats escomptés (ECOVALOR-AIC, 1996,1997). Dans le cadre du Projet régional pour le développement d'Aires Marines Protégées dans la région méditerranéenne (Projet MedMPA), une étude est entreprise dans le but d'élaborer un plan de gestion de la partie marine du Parc National d'El Kala (PNEK).

Matériel et méthodes

Milieu d'étude

La région d'El Kala est située à la frontière algéro-tunisienne (Fig. 1). La partie marine du PNEK, objet de la présente étude est délimitée à l'ouest par le Cap Rosa et à l'est par le Cap Segleb. La zone côtière majoritairement constituée de substrat dur est caractérisée par une côte découpée, prolongée en récifs, îlots, falaises, traduisant un milieu physiquement diversifié.

Méthodes

Deux campagnes ont été réalisées entre les mois de juillet et d'août 2004. L'exploration de l'ensemble du linéaire côtier (40 km) du parc national a été réalisée en plongée sous-marine entre la surface et 64 m de profondeur, totalisant ainsi 44 plongées.

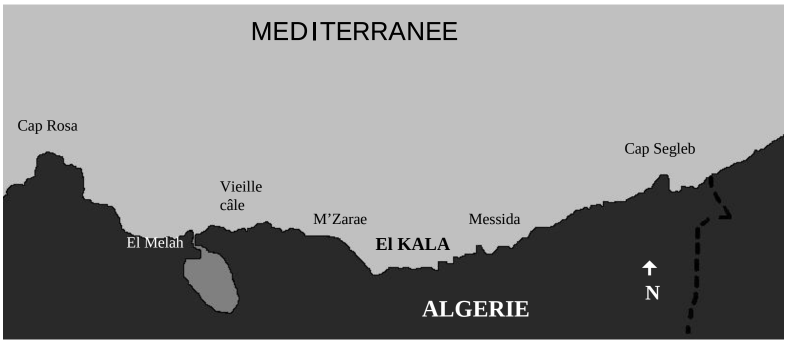

Fig. 1 : Carte de la région d'El Kala.

Chaque secteur a fait l'objet d'un transect partant du large vers le rivage et positionné systématiquement par GPS en début et fin de chaque plongée. L'identification des espèces a été réalisée in situ ou après récolte sauvage.

Résultats

L'exploration de la côte d'El Kala nous a permis l'identification de 50 taxa de macrophytes (Tab. 1).

Tab. 1 : Liste des espèces de macrophytes benthiques observées entre juillet et août 2004 à El Kala.

Rhodophytes
Amphiroa rubra (Philippi) Woelkerling
Asparagopsis armata Harvey
Chondracanthus acicularis (Roth) Fredericq
Chondrophycus thuyoides (Kützing) G. Furnari
Chondria sp.
Corallina elongata Ellis & Solander
Fauchea repens (C. Agardh) Montagne et Bory
Gelidium crinale (Turner) Gaillon
Gelidium spatulatum (Kützing) Bornet
Gracilaria bursa-pastoris (S.G.Gmelin) P.C.Silva
Gracilariopsis longissima (S:g:Gmelin) Steentoff. L.M. Irvine et Farrnham
Hypnea musciformis (Wuffen) J.V. Lamouroux
Jania rubens (Linnaeus) J.V. Lamouroux
Lithophyllum strictaeformae (Areschoug) Hauck
Lithophyllum incrustans Philippi
Lithophyllum byssoides (Lamarck) Soslie
Mesophyllum lichenoides (J. Ellis) Me. Lemoine
Nemalion helminthoides (Velley) Batters
Peyssonelia squamaria (S.G. Gemlin) Decaisne
Phyllophora crispa (Hudson) P.S. Dixon
Plocamium cartilagineum (Linnaeus) P.S. Dixon
Polysiphonia sp.
Rhodymenia pseudopalmata (J.V. Lamouroux) Silva
Sphaerococcus coronopifolius Stackhouse
Ochrophytes
Colpomenia sinuosa (Merteus ex. Roth) Derbes & Solier
Cladostephus spongiosum (Hudson) C. Agardh f. verticillatum (Lightfoot) Prod'Homme van Reine
Cystoseira compressa (Esper) Gerloff & Nizamuddin
Cystoseira sedoides (Desfontaines) C. Agardh
Cystoseira spinosa Sauvageau
Cystoseira amentacea (*C. Agardh) Bory v. stricta* Montagne
Cystoseira zosteroides C. Agardh
Dictyopteris polypodioides (A.P. De Candolle) J.V. Lamouroux
Dyctiota dichotoma (Hudson) J.V. Lamouroux
Dyctiota fasciola (Roth) J.V. Lamouroux
Dyctiota spiralis Montagne
Halopteris filicina (Grateloup) Kützing
Padina pavonica (Linnaeus) J.V. Lamouroux
Ralfsia verrucosa (Areschoug) Areschoug
Sargassum vulgare C. Agardh
Stipocaulon scoparium (Linnaeus) Kützing
Zanardinia typus (Nardo) P.C. Silva
Zonaria tournefortii (J.V. Lamouroux) Montagne
Chlorophytes
Acetabularia acetabulum (Linnaeus) P.C. Silva
Codium bursa (Linnaeus) C. Agardh
Codium effusium (Rafinesque) Delle Chiaje
Codium fragile (Suringar) Hariot ssp. Tomentosoides (Goor) P.C. Silva
Dasycladus vermicularis (Scopoli) Krasser
Halimeda tuna (J. Ellis & Solander) J.V. Lamouroux
Flabellia petiolata (Turra) Nizamuddin
Ulva laetevirens Areschoug
Phanerogame
Posidonia oceanica (L.) Dellile

L’excellente qualité des eaux, la diversité des substrats et l’absence relative de perturbation, notamment dans les secteurs prospectés, permet le développement de communautés vivantes riches et équilibrés, qui témoignent de la diversité biologique du milieu.

La principale communauté benthique de la zone étudiée est sans nul doute l’herbier à *Posidonia oceanica* avec son récif barrière. Il se développe depuis la surface de l’eau jusqu’à -35 m de profondeur ; à l’exception de quelques zones telles que la Messida et la plage Verges. L’herbier est principalement installé sur substrat rocheux. Son extension bathymétrique est limitée par un important hydrodynamisme comme en témoigne les nombreux ripple-marks. Au niveau de la limite inférieure il se présente sous forme de touffes plaquées sur le coralligène associé à d’autres macrophytes. Par ailleurs, les fonds rocheux de l’infralittoral, abritent une autre formation végétale remarquable, bien représenté sur le littoral du PNEK sur un type de substrat constitué de nombreuses roches orientées Sud-Nord, au pendage presque vertical ou de roches plates, orientées face à la surface : les forêts de Cystoseires. Quatre espèces principales de Cystoseires sont présentes dans la zone étudiée selon deux types de milieu : les peuplements de mode battu (*Cystoseira amentacea v. stricta, C. sedoides*), et ceux de profondeur (*C. spinosa, C. zosteroides*). D’autre part, les encorbeillements à *Corallina elongata* ont été observés dans de nombreuses stations sur la frange côtière du PNEK. Les formations les plus remarquables sont situées au niveau de M’zara, la Messida et Boutreboucha. Enfin, nous avons également rencontré des forêts bien développées de *Dictyopteris polypodioides* dans les stations du cap Segleb.

Conclusions

Cette étude nous a permis d’identifier une biodiversité importante et de mettre en évidence des formations remarquables considérées comme menacées en Méditerranée (PNUE/UICN/GIS Posidonie, 1990) : - l’herbier à *Posidonia oceanica*, les forêts à *Cystoseira*, les encorbeillements à *Corallina elongata* et les forêts à *Dictyopteris polypodioides*. Ces éléments traduisent l’importance de cette zone marine qu’il faut impérativement protéger et préserver.

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Walid BELGACEM, Hafedh GHRAIRI, Oum Kalthoum BEN HASSINE
Unité de Recherche de Biologie, Ecologie et Parasitologie des Organismes Aquatiques, Faculté des Sciences de Tunis, Campus universitaires El Manar I, TUNISIE, e-mail : walidbelgacem@yahoo.fr

ETUDE PRELIMINAIRE D'UN HERBIER DE POSIDONIE A RAS JEBEL (NORD-EST DE LA TUNISIE) : PHENOLOGIE ET DIVERSITE DES MACRO INVERTEBRES

Résumé

Dans le présent travail, nous avons procédé à l'étude de la phénologie et des macro invertébrés de l´herbier de posidonies, Posidonia oceanica, dans la région de Ras Jebel (Nord Est de la Tunisie) en vue d'apprécier l´état de ce dernier et de ses habitants. Pour cela, un échantillonnage saisonnier a été réalisé durant la période allant de Septembre 2004 à Août 2005. L'herbier étudié est caractérisé par une densité normale à 1,5 m alors qu'elle est sub-normale supérieure 3 et 5 m (Pergent-Martini, 1994). Le recouvrement est estimé à 80%.

Pour l'étude biocénotique, nous avons inventorié 152 espèces appartenant à 10 phylums. L'analyse de divers indices écologiques nous a permis de conclure que les différentes populations recensées aux différentes profondeurs sont en équilibres durant toute la période de l'échantillonnage.

Mots-clés : *Posidonia oceanica,* Phénologie, Macroinvertébrés, Ras Jebel.

Introduction

La posidonie, espèce endémique de la Méditerranée, est considérée comme étant le terme ultime d'une succession de peuplements et sa présence est la condition sine qua none de l'équilibre écologique des fonds littoraux méditerranéens (Boudouresque et Meinez, 1982). Cette importance écologique nous a amené à effectuer des prospections dans le Nord Est de la Tunisie afin de mieux connaître l'état de l'herbier sur ces côtes. Pour cela, nous nous sommes intéressés à l'étude de la phénologie ainsi qu'aux macroinvertébrés associés à cette phanérogame.

Matériel et méthodes

Les paramètres phénologiques ont été étudiés sur 15 faisceaux orthotropes prélevés au hasard. Les faisceaux sont disséqués en respectant l'ordre distique des feuilles en allant des plus âgées vers les plus jeunes. Par la suite, ces feuilles sont dénombrées selon leur type (adulte et intermédiaire). Pour chaque type de feuille, nous avons mesuré la longueur totale du limbe ainsi que sa largeur. Ces paramètres nous ont permis de calculer l'indice foliaire.

Pour établir un inventaire des macro-invertébrés de l'herbier de posidonie de Ras Jebel et apprécier la diversité spécifique de cette macrofaune, nous avons effectué des prospections préliminaires du site afin d'identifier les stations de prélèvement. Ces prospections nous ont permis de définir 9 stations localisées à trois niveaux de profondeur à savoir 1,5 ; 3 et 5 m. Les prélèvements ont été réalisés à l'aide d'un quadrat de 20 cm de côté selon la méthode de Somaschini décrite en 1994 (*in* M.C. Buia., 2004).

Résultats

La densité foliaire varie en fonction de la profondeur. En effet, elle est égale à 789 faisceaux par m² à 1,5 m ce qui correspond à une densité normale (Pergent-Martini, 1994). Pour les stations situées à -3 m et -5 m, la densité foliaire prend les valeurs moyennes respectives de 985 et 890 faisceaux par m² ce qui la caractérise de sub-normale supérieure. Le nombre moyen de feuilles par faisceau oscille entre un maximum hivernal de 5,15 feuilles/faisceau et un minimum automnal de 4,17 feuilles/faisceau. De même le nombre moyen global de feuilles (Adultes +Intermédiaires) par unité de surface présente une valeur moyenne maximale de 4578 feuilles / m² pendant la saison hivernale. Le suivi de la longueur moyenne des feuilles a permis de révéler des fluctuations en fonction des saisons. Pour les feuilles adultes, la longueur moyenne varie de 17,49 ± 3,13 cm en automne à 48,23 ± 12,06 cm en été. Quant aux feuilles intermédiaires, la longueur moyenne fluctue de 7,56 ± 0,80 cm en automne à 36,87 ± 16,12 cm au printemps. Concernant la largeur moyenne des feuilles, elle fluctue entre 0,84 ± 0,04 cm et 0,89 ± 0,01 cm. Le calcul de l'indice foliaire (Leaf Area Index) a révélé une valeur maximale moyenne de l'ordre de 14,92 m²/m², enregistrée pendant le printemps.

Quant à l'étude de la macrofaune benthique de l'herbier de posidonie, elle nous a permis d'identifier 152 espèces appartenant à 10 phylums et réparties comme suit : 1 Spongiaire, 2 Cnidaires, 62 Mollusques, 1 Bryozoaire, 1 Némertien, 3 Tuniciers, 9 Echinodermes, 4 Sipunculidés, 21 annélides et 48 Crustacés.

Durant toute la période d'échantillonnage, nous avons remarqué des fluctuations de la richesse spécifique entre un maximum hivernal (81 espèces) et un minimum automnal (45 espèces). En revanche, la valeur de la richesse spécifique ne varie pas beaucoup durant le printemps et l'été (66 et 71 respectivement). Cette faible variation peut être expliquée par les conditions hydro climatiques clémentes qui règnent au cours de ces deux saisons et qui ne diffèrent pas beaucoup. La valeur moyenne minimale de l'indice de Shannon – Weaver (H'), enregistrée durant toute la période d'échantillonnage, est égale à 4,92 bits. Cette valeur classe le site de Ras Jebel comme étant un secteur à peuplement normal. Le suivi saisonnier de l'indice de Simpson (Is) a montré une variation de sa valeur entre un minimum de 23,54 bits, enregistré en été et un maximum de 27,51 bits observé en hiver. Ces résultats indiquent que 24 à 28 espèces ont les mêmes abondances durant toutes les saisons. L'importante valeur de l'indice de Simpson durant l'hiver peut être expliquée par le fait que les espèces sont représentées par un nombre élevé d'individus.

En outre, nous avons remarqué que la valeur de l'indice d'Equitabilité est toujours supérieur à 0,8 au niveau des différentes stations prospectées, ce qui indique que les différentes populations sont bien équilibrées à toutes les profondeurs prospectées et durant toute la période d'échantillonnage.

Conclusion

Cette étude a permis d'apprécier l'état de l'herbier de posidonie dans la région de Ras Jebel. En effet, d'après la classification de Pergent-Martini (1994), la densité foliaire varie de normale à sub-normale supérieure en fonction de la profondeur.

Quant aux différents indices écologiques calculés, ils étaient caractéristiques de populations bien équilibrées aux différentes profondeurs prospectées et durant toute la période d'échantillonnage. Cette zone mériterait de faire objet d'un programme de protection contre toutes activités anthropiques pouvant entraîner sa dégradation.

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Mounir BEN BRAHIM[1], Terashima HIROAKI[2], Asma HAMZA[1]
[1]Institut National des Sciences et Technologies de la Mer - Centre de Sfax -BP.1035-3018 Sfax –TUNISIE
[2]Japan International Cooperation Agency

OBSERVATIONS SUR LA PHENOLOGIE DES DIFFERENTS TYPES D'HERBIERS DE POSIDONIE DANS LE GOLFE DE GABES (TUNISIE)

Résumé

La densité foliaire de la phanérogame marine Posidonia oceanica *ne peut traduire à elle seule l'état de vitalité d'un herbier. Cinq stations du golfe de Gabès (Tunisie) sont prospectées en été 2006. Les paramètres phénologiques relevés dans cette étude nous ont permis de remarquer que ces mensurations varient avec la qualité de l'herbier. Par contre, la forme et le type d'herbier n'ont aucune influence sur la densité et sur les autres paramètres phénologiques de la plante.*

Mots-clés : Phénologie, Faisceaux foliaires, Golfe de Gabès.

Introduction

Les critères phénologiques de la phanérogame *Posidonia oceanica* rendent certainement compte de la vitalité de cette espèce mais peuvent en outre traduire la qualité du milieu où ces structures se développent (Pergent et Pergent-Martini, 1995; 1999). La présente étude se propose via une analyse des paramètres phénologiques de définir l'état des différents types d'herbiers de *Posidonia oceanica* dans le golfe de Gabès et de relever les différences entre les stations de prélèvement.

Matériel et méthodes

Les échantillons ont été collectés en été 2006 dans 5 stations du golfe de Gabès (Tab. 1; Fig. 1)

Tab. 1 : Nombre de faisceaux collectés, profondeur dans les différentes stations prospectées.

Station	**Kraten**	**Attaya**				**Mahrès**			**Zarrat**	**Ajim**
Prof	-5m	-5m	-10m	-15m	-20m	-5m	-10m	-15m	-5m	-5m
Nbre faisceaux	10	20	23	18	24	10	10	11	15	26

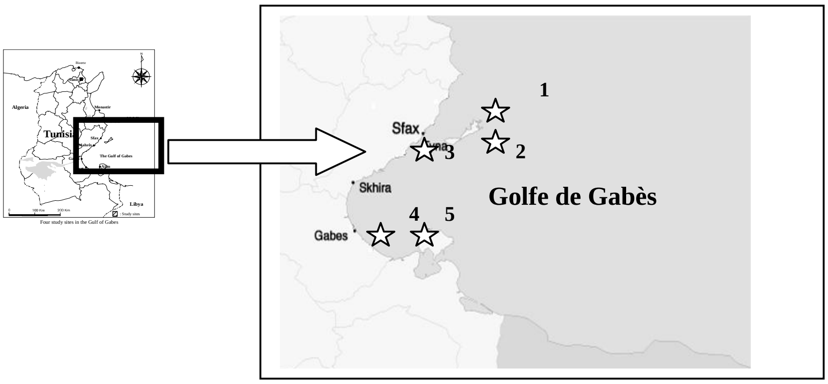

Fig. 1: Carte des différents sites d'échantillonnage du golfe de Gabès

(1 : Kratten ; 2 : Attaya; 3 : Mahres ; 4 : Zarrat ; 5 : Ajim)

L'identification du type d'herbier s'est faite en se basant sur la classification de Giraud (1979). Les paramètres phénologiques traités concernent la biométrie des faisceaux foliaires (longueur totale des feuilles et du pétiole et nombre de feuilles par faisceaux).

La densité est mesurée dans des quadrats à toutes les stations et à toutes les profondeurs. 12 quadrats, espacés de 10m, sont ainsi effectués tout le long d'une radiale pour chaque station et seulement un prélèvement pour les mensurations phénologiques y est établi.

Pour les comparaisons statistiques moyennant le test Kruskal-wallis, le test de Dunn et le test "Khi^2", nous avons choisi les feuilles adultes entières de rang 2 (Ad2).

Résultat et discussion

Dans cette région, plusieurs formes d'herbiers sont identifiées. Selon la classification de Pergent *et al* (1995), la densité est anormale pour la profondeur de -5m dans presque la totalité des stations sauf à Ajim où elle est normale. Aux autres profondeurs elle est définie comme subnormale. On remarque que les formes de l'herbier ne présentent aucune influence sur la densité foliaire. Dans notre cas ce sont souvent les structures en touffe qui présentent le plus grand nombre de faisceaux.

Tab. 2 : Densité et forme des herbiers dans les différentes stations prospectées.

Station	**Profondeur**	**Forme herbier**	**Long moy (cm)**	**Nbre moy f/faisc**	**Densité**	
Attaya	- 5 m	Plaine	53 ± 5,42	9,57 ± 0,27	244,25 ± 6,38	Anormale
	- 10 m		58,96 ± 3,48	7,90 ± 0,47	219,75 ± 3,01	Anormale
	- 15 m		54,27 ± 7,83	9,58 ± 0,51	240,75 ± 4,48	Subnormale
	- 20 m		61,50 ± 2,04	10 ± 0,71	202 ± 2,87	Normale
Kraten	- 5 m	Tigré	38,11 ± 4,36	8,60 ± 0,66	597,32 ± 13,82	Anormale
Mahrès	- 5 m	Plaine	74,26 ± 19,02	8,50 ± 0,67	437,5 ± 7,77	Anormale
	- 10 m		47,30 ± 6,61	9,63 ± 0,43	267,25 ± 5,20	Subnormale
	- 15 m		40,89 ± 8,41	9,28 ± 0,52	277,5 ± 2,91	Normale
Zarrat	- 5 m	Touffe	43,99 ± 8,39	7,33 ± 0,36	519,25 ± 9,03	Anormale
Ajim	- 5 m	Touffe	42,50 ± 6,15	8,80 ± 0,58	978,75 ± 5,39	Normale

L'analyse comparative de la longueur moyenne de la feuille adulte de rang 2 (Ad2) met en évidence une variation significative de 5 % entre les stations et qui apparaît entre Attaya et Mahrès. L'analyse statistique suggère aussi une différence entre les deux herbiers. Cette variabilité de taille se situe essentiellement au niveau de -10 m (Fig. 2).

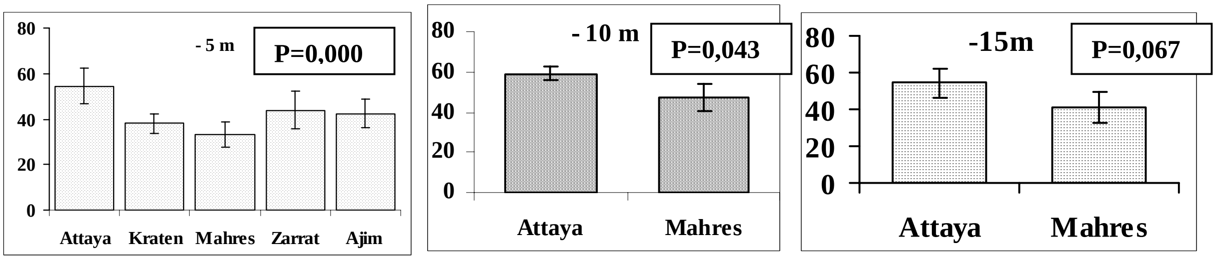

Fig. 2: Résultats de test Khi2 entre les stations prospectées.

Conclusion

L'évolution de la densité à elle seule ne traduit pas l'état de santé et la vitalité d'un herbier de posidonie. La longueur de la feuille, le nombre de feuilles/faisceau sont deux paramètres qui traduisent la santé de l'herbier. La forme de l'herbier n'a aucune influence sur la densité et sur les autres paramètres phénologiques de la plante.

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Imen BEN CHIKH ALMI, Aslam Sami DJELLOULI, Yosr MEZGUI
Département de Biologie, Faculté des Sciences de Tunis, Campus Universitaire-El Mannar II 2092 Tunis, TUNISIE
e-mail : posidonie_imen@ yahoo.com

CARTOGRAPHIE ET CARACTERISATION D'UN HERBIER A *POSIDONIA OCEANICA* DE LA BAIE DE SIDI-SELEM (BIZERTE, TUNISIE)

Résumé

Les fonds de la Baie de Sidi Selem (Bizerte, Tunisie) sont occupés par un vaste herbier à Posidonia oceanica*. La présente étude a permis de relever les limites d'une portion de cet herbier, localisée à proximité du littoral, au voisinage d'une zone urbaine ainsi que d'une zone touristique. Cette cartographie est complétée par une étude des paramètres biométriques.*

Mots-clés : *Posidonia oceanica,* Herbier, Cartographie, Phénologie.

Introduction

Les herbiers à *Posidonia oceanica* (Linné) Dellile constituent des formations extrêmement fréquentes le long du littoral tunisien (Molinier et Picard, 1952 ; El Asmi-Djellouli, 2004). Compte tenu de l'importance du rôle de ces écosystèmes, à la fois sur les plans écologique et économique, il apparaît aujourd'hui nécessaire d'en connaître l'exacte étendue, d'en apprécier l'état et d'en prévoir l'évolution. D'autre part, nous ne disposons à l'heure actuelle que de peu d'informations sur les herbiers du littoral nord tunisien et d'aucune cartographie de ce secteur (I.N.S.T.M/APAL, 2003). Ce travail constitue une première étape dans la caractérisation d'un herbier situé dans la région de Bizerte, à proximité d'une zone fortement anthropisée.

Matériels et méthodes

Les limites de l'herbier, observées depuis la surface, ont été relevées au moyen d'un GPS, à raison d'un point tous les 5 m. Les résultats obtenus sont reportés sur une carte topographique au 1/25 000 et l'ensemble est traité sur un logiciel SIG. Les erreurs de positionnement sur le terrain sont corrigées par rapport à des repères visibles à la côte. Les paramètres biométriques de l'herbier sont étudiés selon la méthode décrite par Pergent (1993) et portent sur un échantillonnage constitué par 20 rhizomes orthotropes prélevés selon un cycle saisonnier. La densité moyenne de l'herbier (nb de faisceaux/m²) est calculée à partir de vingt comptages réalisés à l'intérieur d'un cadre métallique de 400 cm².

Résultats

La portion d'herbier étudiée (Fig.1) occupe une superficie d'environ 14 hectares. Elle s'insère entre le littoral et un herbier plus profond non cartographié. Elle montre une limite supérieure frangeante et présente une répartition homogène, probablement liée à l'uniformité des reliefs et du substrat. Quelques structures érosives (marmites, chenaux,..) sont observées dans la matte. On observe également un important déchaussement des rhizomes et il faut également remarquer une importante zone de matte morte à la limite supérieure de l'herbier, indiquant une régression. La vitesse moyenne de croissance des rhizomes, au sein de l'herbier, est estimée à 8,86±0,96 mm/an ; cette vitesse s'accompagne d'une production variable de feuilles au cour de l'année lépidochronologique où le nombre moyen d'écailles par cycle varie entre un minimum de 7.05±0.45 écailles par cycle et un maximum de 8.30±0.52 écailles par cycle, soit en moyenne 7.86±0.13 écailles par cycle.

Le nombre global moyen de feuilles (A+I) varie entre un maximum hivernal de 5.9±0.75 et un minimum estival égal à 5.5±1.18. L'existence de ces variations est conforme à la littérature (Pergent et Pergent-Martini, 1988), les valeurs observées restent relativement faibles par rapport à celles relevées par les auteurs en d'autres sites et rassemblées par El Asmi-Djellouli (2004). On note par ailleurs que le nombre global moyen de feuilles (A+I) ne varie pas entre les stations étudiées et reste constant en fonction de la profondeur, cette observation est conforme à celle réalisée à Sidi Rais (El Asmi, 2003). La mesure de la densité des faisceaux donne une valeur de 375 Faisceaux/m^2 ; comparée à l'échelle de Giraud (1977), elle indique un herbier de type III clairsemé ; l'échelle de Pergent-Martini (1994) indique un herbier à densité anormale pour cette profondeur.

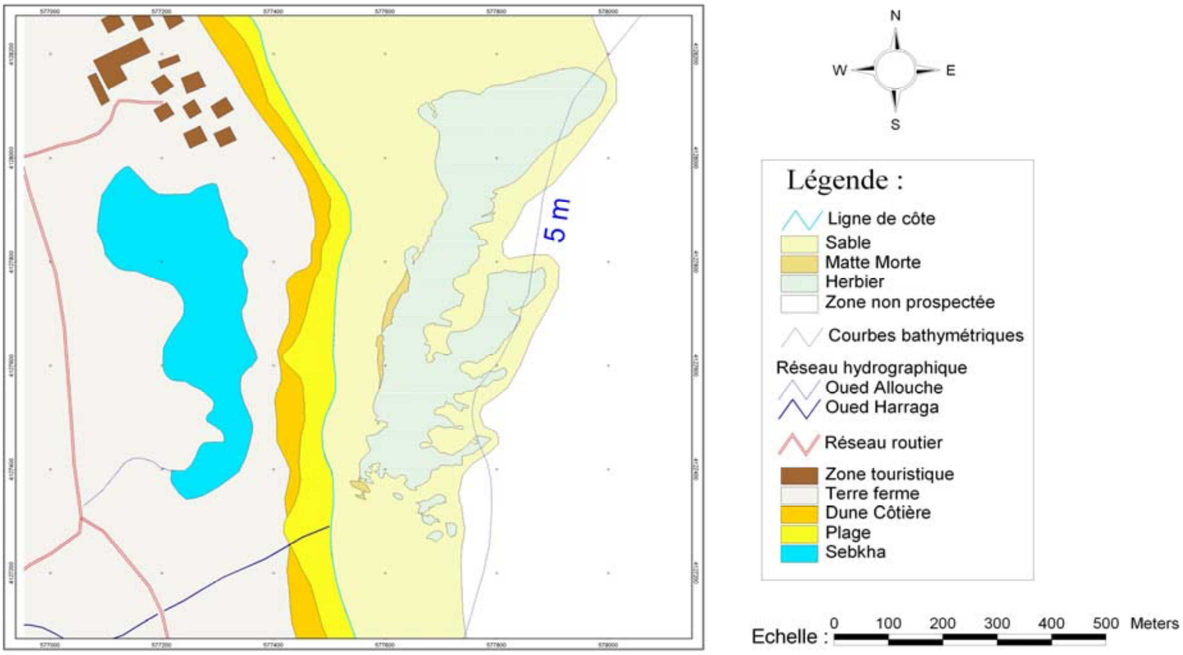

Fig. 1 : Carte de répartition de l'herbier de P. oceanica dans la baie de Sidi Selem.

Conclusion

La comparaison des valeurs biométriques ainsi que la régression de la limite supérieure de l'herbier dénote un état de dégradation de ce dernier. Cet état est certainement lié à la forte pression anthropique dans la région. Un suivi de l'état de l'herbier est donc préconisé, de même qu'il serait utile d'étudier l'herbier situé plus en profondeur.

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Naceur BEN MAIZ[1], Abdessalem SHILI
[1]Société de Promotion du Lac de Tunis, BP 36, 1080 Tunis Cedex, TUNISIE, e-mail : del@splt.com.tn

LES PEUPLEMENTS PHYTOBENTHIQUES DU LAC NORD DE TUNIS DE 1926 A 2006

Mots-clés : Lac nord de Tunis, Restauration lagunaire, *Chaetomorpha linum, Ruppia cirrhosa, Nanozostera noltii.*

Le nouveau système de circulation des eaux mis en place dans le cadre de la restauration et l'assainissement du lac nord de Tunis, a entraîné une amélioration sensible de la qualité des eaux et de la diversité biologique dans la lagune par rapport aux situations antérieures, avec une nette atténuation des facteurs d'eutrophisation (Ben Maïz, 1994, 1997 ; Pergent and Kempf, 1993).
Les observations effectuées au niveau du phytobenthos après l'achèvement des travaux de restauration ont permis d'identifier 38 espèces de macrophytes, alors qu'on comptait seulement une dizaine d'espèces avant l'assainissement du lac (Ben Maïz, 1993, 1997 ; Shili, 1995 ; Trabelsi, 1995 ; SPLT, 1997 ; Ben Romdhane et Zarrouk, 2003 ; Meddeb, 2006). La transformation était surtout rapide et spectaculaire en ce qui concerne les peuplements phytobenthiques dominants dans le lac, ce qui traduit parfaitement l'évolution du milieu naturel lagunaire (Ben Maïz, 1993, 1997).
Par comparaison aux résultats des observations effectuées auparavant, on distingue deux phases d'évolution des peuplements phytobentiques du lac nord de Tunis.

Une phase de dégradation progressive depuis le début du 20ème siècle jusqu'à 1986 :

- 1929 (Heldt) : Le lac Nord ne communique avec la mer que par l'intermédiaire du canal de navigation. *Ulva rigida* était dominante dans la partie Ouest du lac mais les parties centrales et orientales sont colonisées par des phanérogames (*Nanozostera noltii* et *Ruppia cirrhosa*) où l'on retrouve également de nombreux *Acetabularia acetabulum*.
- 1952-1954 (Molinier et Picard, 1954) : Creusement du canal Khéireddine entre la lagune et la mer, mais l'enrichissement en matières organiques du milieu se poursuit. Les peuplements d'*Ulva* se développent vers la partie centrale de la lagune aux dépens des phanérogames. L'algue *Caulerpa prolifera* pénètre dans la partie Est mais les *Acetabularia* disparaissent.
- 1973-1976 (Zaouali, 1974 ; Belkhir, 1980 ; Belkhir and Hadj Ali Salem, 1981, 1984) : L'augmentation des rejets d'eaux usées entraîne une augmentation de la turbidité et un déséquilibre écologique marqué (crises dystrophiques). Les espèces nitrophiles sont dominantes avec apparition d'*Enteromorpha sp. plur.* dans la partie Ouest de la lagune, à proximité des arrivées d'eaux usées. Des touffes de *Chaetomorpha* se développent dans la partie centrale alors que les *Caulerpa* sont remplacées par des *Gracilaria*. Quelques bandes de *Nanozostera noltii* persistent à proximité du canal Khéireddine.
- 1985-1986 (Belkhir et Hadj Ali Salem, 1984 ; Ben Maïz, 1993; Fig. 1) : La dégradation du milieu est à son maximum à cause de la multiplication des rejets urbains à la fin des années 70 et au début des années 80. Les peuplements d'*Ulva* couvrent plus des deux tiers de la lagune; les *Chaetomorpha* ne sont plus représentées que par quelques touffes, dans la zone orientale et les *Gracilaria* ne subsistent qu'à proximité du canal Khéireddine. Les phanérogames ont presque totalement disparues.

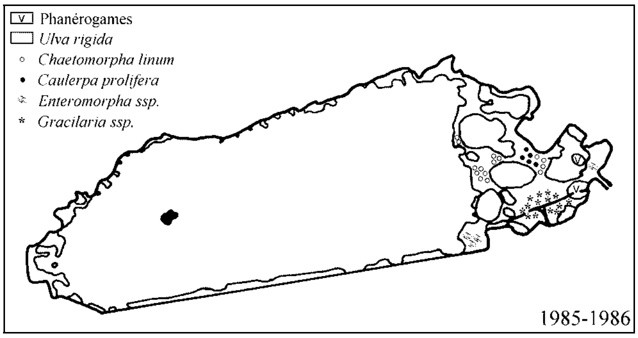

Fig. 1: Peuplements phytobenthiques du Lac Nord de Tunis en 1985-1986

Une phase de restauration relativement rapide, depuis la fin de 1988 :

- 1988-1989 : Les phanérogames (*Ruppia* et *Nanozostera*) s'installent à nouveau dans la partie nord de la lagune dès la fin des travaux d'assainissement du lac. Les peuplements d'*Ulva* ont fortement régressé et ne forment que quelques peuplements dans la partie sud. En revanche, on note la prolifération de *Chaetomorpha linum*, ainsi que l'apparition de *Gracilaria sp. plur.* qui occupent des surfaces considérables en fonction des saisons.
- 1990 : Les phanérogames (*Ruppia*, *Nanozostera* et *Cymodocea*) couvrent plus des trois quarts de la partie nord, l'*Ulva* continue à régresser aux dépens du *Chaetomorpha*; apparition de *Caulerpa* à l'est du lac.
- 1991-1992 : Les phanérogames, notamment le *Ruppia*, se sont bien développés et continuent leur progression vers la partie Sud du lac, avec apparition saisonnière des *Gracilaria* ; les *Ulva* ont pratiquement disparu du lac.
- 1994-1995 : Les *Ruppia* se retrouvent partout dans le lac, avec des couvertures dépassant souvent les 50%, tandis que les *Nanozostera* et *Cymodocea*, ainsi que les algues *Caulerpa* et *Gracilaria* n'ont pas connu de progressions sensibles. Le *Chaetomorpha* est observé un peu partout mais prolifère surtout dans la partie sud du lac, où la profondeur est faible et les fonds sont très riches en matière organique.

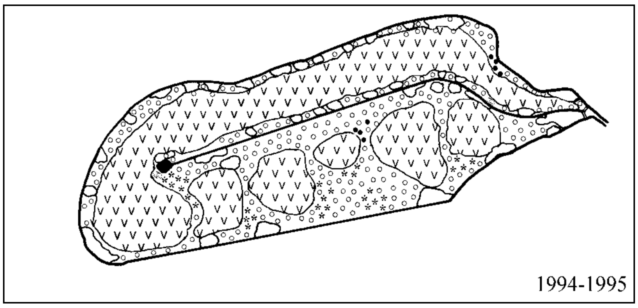

Fig. 2: Peuplements phytobenthiques du Lac Nord de Tunis en 1994-1995

Cette espèce forme de grandes masses flottantes grâce aux installations de filets de pêche fixe qui en se colmatant entravent la libre circulation des eaux et bloquent l'évacuation de ces algues. A côté de ces espèces dominantes, il y a apparition de plusieurs espèces saisonnières appartenant aux genres *Hypnea*, *Polysiphonia*, *Ceramium* etc…

- Les situations observées entre 1997 et 2000 ne montrent pas de modifications significatives par rapport à celle observée en 1994-1995, sauf durant les années pluvieuses où on enregistre une biomasse plus importante en *Chaetomorpha* qui est collectée saisonnièrement dans le cadre de l'entretien du plan d'eau du lac nord.
- 2003 : Les *Ruppia* se retrouvent plus fréquents dans la partie sud du lac et les *Chaetomorpha* occupent les parties sud et ouest du lac où on les observe souvent libres, surmontant les tiges des *Ruppia*. On note aussi plusieurs étendues de *Cymodocea* au nord-est et quelques touffes à l'ouest et, avec une moindre importance des *Nanozostera* plus près des rivages. D'importantes plages de *Caulerpa prolifera* apparaissent au sud-est. A noter aussi la présence de plusieurs espèces saisonnières appartenant aux genres *Dasya*, *Cladophora*, *Gelidium*, *Hypnea*, *Cystoseira* etc…

- 2006 : Les *Ruppia* se retrouvent presque dans les mêmes secteurs signalés en 2003, avec une couverture de près de 78%, mais on observe des *Nanozostera* beaucoup plus étendus dans plusieurs endroits du lac (dans 46% de la surface du lac). Les *Chaetomorpha* occupent presque tous les secteurs du lac (88% de couverture), avec souvent des touffes importantes qui surmontent les herbiers à *Ruppia* ; cette prolifération est vraisemblablement liée au déversement des eaux pluviales chargées. Le *Cymodocea* présente des touffes éparses notamment du côté nord est du lac. A noter également la présence un peu partout et notamment dans la moitié est de la lagune de plusieurs espèces saisonnières appartenant aux genres *Gracilaria*, *Cystoseira, Caulerpa, Ulva, Cladophora, Corallina, Jania*, des Ectocarpaceae etc…

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Rafik BEN SAID[1], Mohamed Salah ROMDHANE[2], Amor EL ABED[1], Ridha M'RABET[1]
[1] Institut National des Sciences et Technologies de la Mer (INSTM).
[2] Institut National Agronomique de Tunisie (INAT).
e- mail :Rafik.Bensaid@instm.rnrt.tn

L'ALGUE ROUGE *GELIDIUM SPINOSUM* (S.G. GMELIN) *P.C. SILVA* DES COTES DE MONASTIR (TUNISIE) :

QUELQUES ASPECTS BIOLOGIQUES

Résumé

La rhodophycée Gelidium spinosum (S.G. Gmelin) P.C. Silva *(Rhodophycées ;Gélidiales), a été étudiée pendant une année, depuis septembre 2000 jusqu'au mois d'Août 2001, sur la côte de Monastir (Tunisie) . Les résultats globaux obtenus montrent que le poids moyen maximum (environ 37 g) a été atteint en Mai. Il en est de même pour la longueur (environ 11 cm). La biomasse maximale a été obtenue également pendant la même période (environ 7000g. m*^{2}*). La fertilité a varié entre 0 et 100%.*

Mots-clés : *Gelidium spinosum*, Poids, Longueur, Biomasse, Fertilité.

Introduction

L'intérêt pour les végétaux marins et en particulier les algues est en progression continue de par le monde, et ce pour différentes raisons, notamment pour leurs richesses en protéines, glucides, lipides et sels minéraux (Pérez, 1997). Par ailleurs, l'extraction des phycocolloides (alginates , agar-agar , carraghénnanes) constitue un important créneau pour l'exploitation des algues marines. Parmi les agarophytes les plus recherchées figurent *Gracilaria, Gracilariopsis, Gelidiella, Pterocladiella* et *Gelidium*. Le présent travail sur *Gelidium spinosum* (S.G. Gmelin) P.C. Silva constitue une contribution à la connaissance des algues marines tunisiennes d'un point de vue biologique, afin de les exploiter rationnellement et les cultiver ultérieurement afin d'en extraire, en particulier l'agar-agar.

Matériel et méthodes

Les thalles de *Gelidium spinosum* (S.G. Gmelin) P.C. Silva ont été récoltés mensuellement depuis Septembre 2000 jusqu'au mois d'Août 2001 sur la côte rocheuse de Monastir, dans deux grands bassins naturels, ayant une profondeur allant de 0 à -5m. 40 individus sont prélevés et conservés dans de petits sachets en plastique jusqu'à leur traitement au laboratoire. La biomasse a été estimée en utilisant un cadrat de 50 cm de côté et la fertilité des thalles a été suivie sous la loupe binoculaire.

Résultats

Poids et Longueur

Le poids moyen des thalles varie entre un minimum (5.05g) en Janvier et un maximum (36.7g) en Mai (Fig.1). Le poids moyen saisonnier est minimal en hiver (6.85g) et maximal au printemps (21g). Entre ces deux saisons, le poids moyen saisonnier s'accroît rapidement d'un facteur supérieur à 3.

La longueur de *Gelidium* varie irrégulièrement depuis Septembre jusqu'au mois d'Août (Fig.1). Ainsi, la longueur est minimale en Novembre (7.2 cm) et maximale (10.25 cm) en Janvier. La variation saisonnière de la longueur n'est pas très prononcée. Elle est minimale en automne (7.18cm) et maximale en été (9.73cm) .

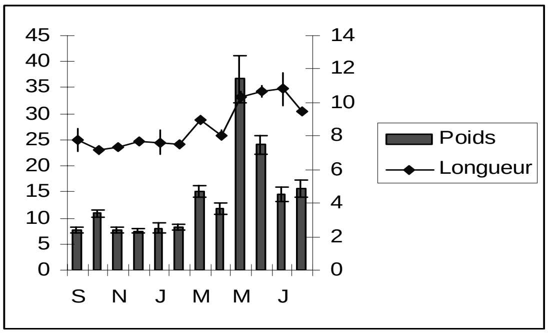

***Fig.1 : Variation mensuelle du poids et de la longueur de* G.spinosum.**

Biomasse

La biomasse humide varie entre un minimum (453.37 g.m^{-2}) obtenu en Novembre et un maximum (6925 g.m^{-2}) en Mai (Fig.2).Depuis Juin, la biomasse chute progressivement jusqu'à la fin d'Août. Il en est de même pour la biomasse sèche qui fluctue entre 130.46 g.m^{-2} (Novembre) et 1562.76 g.m^{-2} (Juin) .La variation saisonnière est très claire notamment entre l'hiver et le printemps.

Fertilité

Les résultats obtenus sur la fertilité (Fig.3) montrent que celle-ci varie entre 0% (Mai) et 100% (Septembre, Juin, Juillet et Août). Les thalles fertiles sont tous composés de tétrasporophytes. Les tétrasporocystes sont plus ou moins remplis de tétraspores selon le degré de maturité.

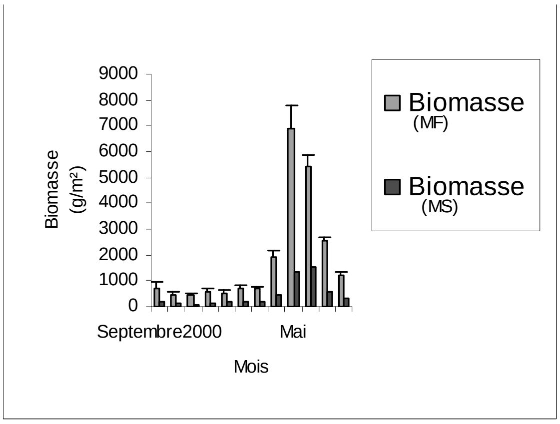

Fig. 2 : Variation de la biomasse.

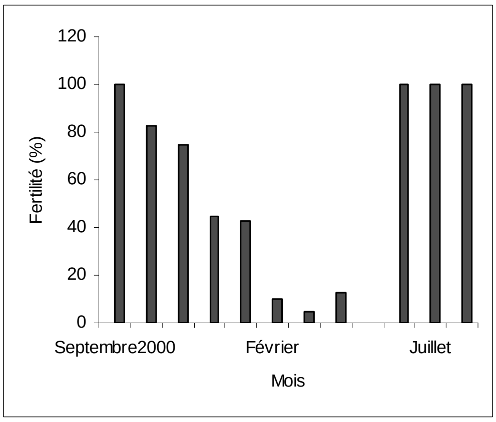

Fig. 3 : Variation de la fertilité.

Discussion et conclusion

Au terme de cette étude sur *Gelidium spinosum* (S.G. Gmelin) P.C. Silva des côtes de Monastir (Tunisie), nous pouvons dire que le poids, la longueur des thalles, la biomasse et la fertilité varient mensuellement et saisonnièrement. Nos résultats sont en parfait accord avec les résultats de Mouradi-Givernaud (1992). *Gelidium sesquipedale,* vivant sur les côtes marocaines, montre également une croissance très active au printemps (Mouradi-Givernaud *et al,* 1999). Hernanez-Guerroro *et al* (2000) ont montré que l'abondance de *Gelidium robustum* vivant sur les côtes de Mexico, est maximale après un up-welling supérieur à la moyenne.

En conclusion, nous pouvons dire que *Gelidium spinosum* (S.G. Gmelin) P.C. Silva des côtes de Monastir (Tunisie) prolifère pendant la saison printanière, lorsque la température de l'eau devient clémente. La fertilité est maximale en plein été.

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Maria Cristina BUIA, Lucia PORZIO, Francesco PAOLO PATTI
Laboratorio di Ecologia del Benthos, Stazione Zoologica 'A. Dohrn', P.ta S. Pietro, 80077 Ischia (Naples), ITALY
e-mail: mcbuia@szn.it

THE APPLICATION OF THE "CARLIT METHOD" TO ASSESS THE ECOLOGICAL STATUS OF COASTAL WATERS IN THE GULF OF NAPLES

Abstract

In order to monitor and assess the ecological status of coastal waters in the Gulf of Naples (Italy) according to the WFD, a first attempt of classification based on the cartography of littoral communities dominated by macroalgae (CARLIT) was adopted to evaluate all the coasts of the Vivara Island, that with those of Ischia and Procida, will be part of the Marine Protected Area named 'Regno di Nettuno'. According to the results, two ecological status of Vivara' water bodies were identified: a poor ecological status in the East area (where the anchoring pressure is higher) and a moderate one in the rest of the island. This evaluation testifies the high deterioration of the coastal water since 1976, when the first monitoring, based on macroalgae, was performed.

Key-words: Monitoring, Macroalgae, Bioindicators, Classification system, Water Framework Directive.

Introduction

According to the Water Framework Directive 2000/60/CE (WFD), macrophytes such as seagrasses and macroalgae are defined as basic quality elements to be used for the evaluation of the ecological status of marine surface waters (Casazza *et al.*, 2004). Up to now, two classification systems based on macroalgae have been proposed. One of them, the CARLIT index (Ballesteros *et al.*, 2007), is based on the cartography of littoral communities dominated by macroalgae, such as several species of *Cystoseira*, *Corallinales* and green algae, used as quality elements. The aim of the present study was to use this index to assess the ecological status of water bodies in the Marine Protected Area "Regno di Nettuno" located in the Gulf of Naples starting from Vivara, the only island without urban areas.

Materials and Methods

The little island of Vivara (34 ha) is located in the Gulf of Naples (Italy), between Ischia and Procida Islands, to which is connected by a 100 meters long bridge (Fig. 1).

Fig. 1: Map of the Gulf of Naples with the location of the Vivara Island.

Vivara will be part of the next marine protected area “Regno di Nettuno”; in particular the West side of the island will be an integral reserve named Zone A (as required by the Italian low L. 394/91) and the East side will be Zone C, where some human activities are allowed. The study was carried out in September 2006 along the totality of the rocky shores of the island, which represented the 100% of the entire coasts. Littoral and upper-sublittoral communities were identified by snorkelling observations in 115 sectors, each of 25m (scale of 1:5000) and the ecological status of the coasts was evaluated by using the CARLIT method according to Ballesteros *et al.* (2007).

Results and discussion

The ecological status of water bodies around the island of Vivara is represented in Fig. 2: a poor ecological status (orange line) in the East area and a moderate one (yellow line) in the rest of the coast were defined.

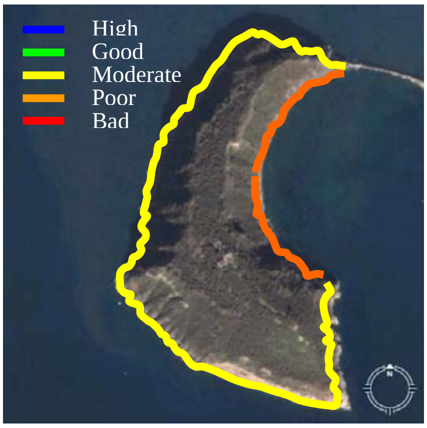

Fig. 2: Representation of the ecological status of the coastal waters around the island of Vivara.

This evaluation is the first attempt of ecological evaluation for the Italian coasts according the WFD by using macroalgae as bioindicators. The results testify the high deterioration of the coastal water along the Vivara Island since 1976, when the first monitoring, based on macroalgae, was performed (Cinelli *et al.*, 1976). During that survey, in fact, the brown algae *Cystoseira mediterranea* and *C. crinita* were widespread while at the present, due to their sensitivity to environmental changes (Thibaut *et al.*, 2005), they are completely absent; the only *Cystoseira* species, *C. compressa*, has a very spotted distribution. The qualitative and quantitative changes in Cystoseira richness may be related to the increase in the pleasure boats’ pressure, mainly in the more sheltered West side.

Acknowledgments

The authors are grateful to Vincenzo Rando and Bruno Iacono for their support during the fieldwork.

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Maria Cristina BUIA, Filippo SILVESTRE, Stefania FLAGELLA
Laboratorio di Ecologia del Benthos, Stazione Zoologica 'A. Dohrn', P.ta S. Pietro, 80077 Ischia (Naples), ITALY
e- mail: mcbuia@szn.it

POSIDONIA OCEANICA: A QUALITY ELEMENT FOR ECOLOGICAL STATUS ASSESSMENT

Abstract

The Posidonia oceanica *meadows sorrounding the Island of Ischia, in the northern part of the Gulf of Naples (Italy), cover about 17 Km^2 of the seafloor, forming a continuous belt. Long-term studies carried out since 1979 demonstrate a substantial stability of its distribution but a reduction in shoot density in some beds. According to the POSWARE Classification that we have elaborated on a limited number of structural and functional parameters of* Posidonia oceanica, *the ecological status of Ischia water bodies 'sensu WFD' have been evaluated. Results demonstrated that the quality of the meadows is worst in the north-west side of the island, where the anthropogenic pressure is higher, and that the regression risk is higher in the shallowest stands. In these areas all human activities should be strictly controlled in order to protect the Posidonia system.*

Key-words: Monitoring, Seagrass, Bioindicators, Classification system, Water Framework Directive.

Introduction

The *Posidonia oceanica* (L.) Delile meadows sorrounding the Island of Ischia, in the northern part of the Gulf of Naples (Italy), cover about 17 Km^2 of the seafloor, forming a continuous belt mapped in detail in 1979 (Colantoni *et al*., 1982)(Fig. 1). The different exposure of the coasts of the island, coupled with different environment conditions and bottom type, give rise to meadows extremely diversified in terms of physiognomy (continuous and patchy beds), depth range (from 0 to down to 38m in depth), shoot density, associated communities and genetic variability (Procaccini *et al*., 2003). The 2000's monitoring of beds around the island demonstrated a substantial stability of distribution but a reduction in shoot density in some beds (Buia *et al.,* 2003). According to the WFD 2000/60/CE, an Italian classification system (POSWARE) based on a limited number of structural and functional *Posidonia* parameters, has been proposed (Silvestre *et al.,* 2006). The aim of the present study was to use this Index to assess the ecological status of water bodies around the island of Ischia.

Fig. 1: Map of* Posidonia oceanica *distribution around the island of Ischia (Buia* et al.*, 2003 modified).

Materials and Methods

By using the POSWARE method (Silvestre *et al.*, 2006), the ecological status of water bodies around the island of Ischia (Gulf of Naples, Italy)(Fig. 1) were derived from the most studied *Posidonia* meadows, according to the WFD (Casazza *et al.*, 2006).

Results and discussions

Three different ecological status around the coasts of Ischia were defined (Fig. 2). A good-moderate status is evident in the south-west sector of the Island, where the anthropogenic pressure is low; on the opposite island sector, the conditions of the meadows are poor, mainly in the shallowest stands that seem to be more vulnerable to decline in comparison with deepest ones. In order to more strictly control all human activities along the coastal area, the ecological status of water bodies could be related to the vulnerability of these systems to realize environment risk assessment maps.

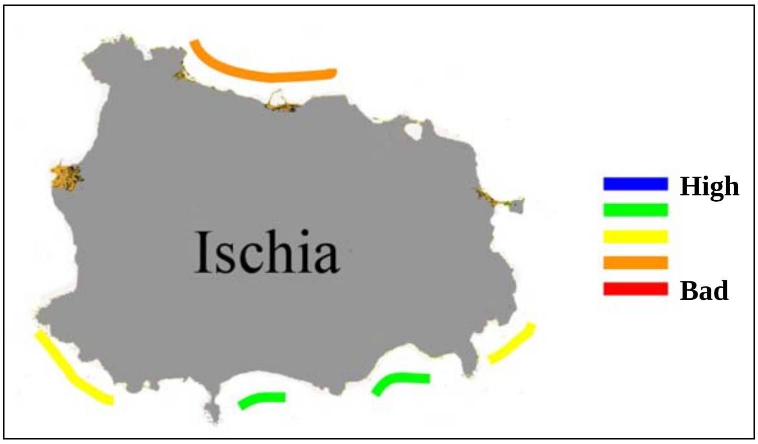

Fig. 2: Map of the ecological status of water bodies around the Island of Ischia.

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Francesco Luigi CINELLI[1], Federico BOCCALARO[2], Francesca CINELLI[1], Marina BURGASSI[1], Luigi PIAZZI[1], Francesco RENDE[3], Matteo ZANELLA[4]
1 Università di Pisa, Dipartimento di Biologia; Via A. Volta 6, 56121 Pisa, ITALIA. e-mail: f.cinelli@biologia.unipi.it.
2 AIPIN (Associazione Italiana per l'Ingegneria Naturalistica), ITALIA
3 Università della Calabria; Dipartimento di Ecologia, ITALIA
4 Coastal Protection Systems (groupe Maccaferri); Bologna, ITALIA

TECHNIQUE DE FIXATION DES BOUTURES DE *POSIDONIA OCEANICA* (L.) DELILE EN MEDITERRANEE : ADAPTATION EN MILIEU MARIN D'UN SYSTEME DEJA UTILISE SUR TERRE

Résumé

A partir du mois d'Octobre 2006, à l'Ile d'Elbe, près de la localité de Cavo, dans la municipalité de Rio Marina, a été mise en place une expérimentation d'un système de fixation des boutures de Posidonia oceanica *(L.) Delile en adaptant une méthode deja utilisée pour la végétation terrestre en Génie Biologique. Les matériaux sont distribués par la Société Coastal Protection Systems de Bologna, Italie. Nous avons utilisé : 3 matelas "Reno", 3 Macmat RM (Renfort Métallique) nattes tridimensionnelles pérennes, renforcées par insertion à la fabrication d'un grillage double torsion à maille hexagonale, 4 bionattes en fibre d'agave dont 2 avec un grillage double torsion et 2 sans aucun renfort. Les résultats, vraiment préliminaires de l'expérimentation, ont donné des résultats positifs.*

Mots-clés : *Posidonia oceanica*, Boutures, Fixation, Génie Biologique, Île d'Elbe.

Introduction

Une limite à la réimplantation de *Posidonia oceanica* est non seulement la difficulté à fixer les boutures de la plante sur le fond marin mais aussi la nécessité d'utiliser des structures qui doivent être très résistantes à l'action des vagues (s'il s'agit d'une zone près de la surface ou en mode battu) ou à l'action des courants de fond (Fonseca *et al.*, 1998; Paling *et al.*, 2001; Gobert *et al.*, 2005). Dans ce travail, nous présentons les résultats vraiment très préliminaires d'une expérimentation d'un système de fixation des boutures déjà utilisé sur terre en Génie Biologique. (Boccalaro et Cantasano, 2001).

Matériel d'étude

L'expérimentation a été conduite près de la localité de Cavo (une zone qui se trouve au NE de l'Ile d'Elbe), sur un fond de 7 m de profondeur. Les matériaux choisis ont été : trois matelas "Reno", trois quadrats Macmat RM et quatre bionattes.

Fig. 1, 2, 3 : Structures utilisées pour la fixation.

Les trois matelas "Reno" ont une dimension de 1m x 1m x 0,23m. Il sont recouverts de géotissus avec une «geostuoia» à trois dimensions Macmat RM (Renfort Métallique), natte tridimensionnelle pérenne renforcée par insertion à la fabrication d'un grillage double torsion à maille hexagonale de 1m x 1m comme couvercle (Fig. 1, 2, 3). Les trois quadrats de 1m x 1m sont des structures en Macmat RM. Deux de ces quadrats ont été fixés sur le sable sur un fond horizontal, le troisième a été fixé sur une matte morte présentant une pente relativement forte. Enfin, les bionattes sont des structures en fibre d'agave, dont 2 ont été fortifiées avec grillage double torsion et 2 sans aucun renfort. Les matelas ont été mis en place sur le fond et comblés de sable ; les quadrats en "Macmat RM"et les bionattes en fibre d'agave ont été fixées sur le fond avec des balises en acier.

Résultats

Deux mois après leur mise en place, nous avons observé que les matelas Reno et les quadrats Macmat RM étaient restés intacts. Le quadrat mis en place sur la matte morte a été intégré à l'habitat benthique du fait de la rapide colonisation de l'algue *Caulerpa prolifera* (Forsskaal) Lamouroux. Les bionattes en fibre d'agave, sans grillage, double torsion, montrent des signes de soulèvement due à la présence de feuilles mortes au dessus.

Discussion et conclusion

Ces résultats préliminaires soulignent que les matériaux choisis peuvent être utilisés dans la réimplantation de *P. oceanica* pour leur stabilité élevée et leur résistance à l'hydrodynamisme (entre Novembre et Décembre il y a eu deux orages de forte intensité), pour la simplicité d'assemblage et de mise en place et pour le coût acceptable de réalisation. Ces résultats soulignent également que les boutures utilisées et prélevées dans la prairie à coté (surtout des boutures qui étaient en train de se détacher naturellement de la matte) sont restées bien vivantes. Le temps d'expérimentation est néanmoins trop court pour permettre une quantification précise de la survie des boutures.

Remerciements

Nous remercions la Coastal Protection Systems qui nous a gracieusement fourni les matériaux.

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Stefano COPPO, Giovanni DIVIACCO
Regione Liguria, Via D'Annunzio, 113, 16121 Genova, ITALY
e-mail: stefano.coppo@regione.liguria.it

MARINE HABITATS ATLAS OF LIGURIA REGION (ITALY)

Abstract

The importance of the Posidonia oceanica *meadows and of the other marine habitats is basic in the coastal ecosystems economy. For this purpose information on main Ligurian coastal habitats have been revised and an integration of bibliographical data with field investigation has enabled to produce a map, by means of GIS technology. The habitats was included in 24 different typologies and 83 colour maps in 1:10000 scale, were realised. Maps include also other information, as topography, water-waste pipelines, fish-farms, artificial reefs, marine protected areas. A synthetic description of the habitats, for each coastal segment, has also been provided in the text. In the last part information and considerations on management aspects of coastal marine habitats of Liguria have been given.*

There is a confirmation that P. oceanica *meadows in Liguria have been damaged by human activity, particularly in the last fifty years, even if sometimes a recent slight trend to restoration has been observed, and, at present, in some meadows there is a substantial stability.*

Key-words: Cartography, Coastal management, Liguria, Marine habitats.

Introduction

The importance of the *Posidonia oceanica* meadows and of the other marine habitats is basic in the coastal ecosystems economy. Therefore these habitats must be known and protected by means of concrete actions, in the framework of an integrated management, to avoid their deterioration, due to the impact of human activities on the coast (Boudouresque *et al*., 2006).

Previous mapping and description of Ligurian sea-grasses meadows was made at the beginning of Nineties (Bianchi and Peirano, 1995) and we needed more recent and detailed data, for coastal management actions. For this purpose information on main Ligurian coastal habitats has been revised and an integration of bibliographical data with field investigation has permitted to produce a map, by means of GIS technology.

Materials and methods

An integration of different methods was carried out, according to recent methodology used during the last decades (Bianchi *et al*., 2003):

- Bibliography analysis;
- Standardisation of symbology;
- Georeferencing of bibliographic data;
- Selection, scanning and georeferencing of regional aerial photographies of Ligurian coast;
- Interpretation of aerial photographies and digital orthophoto;
- Field surveys by means of Side Scan Sonar, submersible videocamera and diving transects;
- Integration of all data by means of GIS technology;
- Elaboration of final maps.

Results

The integration of the different kinds of information permitted to realise the cartography of the Ligurian coastal bottoms included among surface and 50 m depth, for a lenght of nearly 300 km. The habitats was included in 24 different typologies (Tab. 1). Mapping was produced by means of GIS technology, that allow all the functions of analysis and implementation of the rich data-base associated. The Ligurian coast is represented in 83 colour maps in 1:10000 scale, that include also other information, as topography, water-waste pipelines, fish-farms, artificial reefs, marine protected areas. A synthetic description of the habitats, for each coastal segment, was also provided. In the last part information and considerations on management aspects of coastal marine habitats of Liguria have been given.

Tab. 1. Tipologies identified for the Ligurian marine habitats atlas.

SOFT BOTTOMS	SEA-GRASSES	HARD BOTTOMS
Littoral sands	*Posidonia oceanica* Meadows	Infralittoral photophilic algae on rocky bottom
Coarse sediments	Mosaic formations of *Posidonia oceanica* alive and dead	Infralittoral photophilic algae on beach-rock
Harbour assemblages	Dead “Matte” of *Posidonia oceanica*	Popolamenti delle alghe sciafile infralitorali
Caulerpa taxifolia	*Posidonia oceanica* on rocky bottom	Popolamenti delle alghe sciafile circalitorali
Caulerpa racemosa	*Cymodocea nodosa* Meadows	Coralligenous assemblages
Coastal detritic bottoms	High density *Cymodocea nodosa* Meadows	Dark and semi-dark marine caves assemblages
Muddy detritic bottoms	*Cymodocea nodosa* Meadows with *Posidonia oceanica*	
Coastal mud bottoms	*Cymodocea nodosa* Meadows on dead “matte” and possible presence of *P. Oceanica*	
	Mixed meadow of *P. oceanica* and *Caulerpa taxifolia*	
	Mixed meadow of *C. nodosa* and *Caulerpa taxifolia*	

Conclusions

As regards *Posidonia oceanica* there is generally a good corrispondence between the total area of 4844 hectares, and the 4800 hectares indicated by the ENEA Atlas of seagrass beds of Liguria in 1995 (Bianchi and Peirano, 1995). The area of Ligurian *P. oceanica* beds is small, compared with other Mediterranean Regions, for natural and human reasons. The Imperia Province contributes to total area with more than 50%, while La Spezia Province contributes less than the other Provinces, due more to morphological, hydrological and sedimentological conditions, than to human activity. There is a confirmation that *P. oceanica* meadows in Liguria have been damaged by human activity, particularly in the last fifty years, even if sometimes a recent slight trend to restoration has been observed, and, at present, in some meadows there is a substantial stability. *Cymodocea nodosa* meadows of Liguria present on the contrary a total area higher than that recorded by Bianchi and Peirano (1995). As regards the other main coastal habitats the biodiversity richness of Ligurian coast is confirmed, not only for submersed walls and for the bottom of small islands, but also for the presence of many rocky outcrops and shoals along the Ligurian coast.

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Guiseppe DI CARLO, Maria Cristina BUIA, Sylvie GOBERT, Gilles LEPOINT, Begona MARTINEZ-CREGO, Gérard PERGENT, Christine PERGENT-MARTINI, Gabrielle PROCACCINI, Pere RENOM, Fiona TOMAS, Branko VELIMIROV, A. VERGES
Center for Coastal Habitat and Fisheries Research, NCCOS/NOS/NOAA, 101 Pivers Island Road, Beaufort, NC 28516, U.S.A., e-mail: Giuseppe.DiCarlo@noaa.gov

DEVELOPING A CONCEPTUAL OVERVIEW OF MEDITERRANEAN SEAGRASS MEADOWS

Abstract

This paper classifies Mediterranean seagrass diversity into three habitat types and proposes the main limiting factor for each habitat. The major processes that categorise each habitat are described and significant threats or gaps in understanding are identified.

Key-words: Seagrass, Habitat diversity, Mediterranean Sea, Environmental threats, Conceptual diagrams.

Seagrasses, in particular *Posidonia oceanica*, form dense extensive meadows, which represent key ecosystems in the Mediterranean marine environment. These meadows play a functional and structural role by attenuating wave energy and limiting coastal erosion, providing nursery habitats and spawning grounds for several fish and invertebrate species (Hemminga and Duarte, 2000). Several other seagrass species are found in the Mediterranean Sea: *Cymodocea nodosa*, *Zostera noltii*, *Halophila stipulacea* and *Ruppia maritima*. In this paper, we identified three seagrass habitats – estuarine, rocky shore and sandy shore – and we described the physical features for their natural state. In the estuarine seagrass meadows, *Z. noltii*, *C. nodosa* and *R. maritima* dominate. These species can tolerate fluctuations in salinity and turbidity that occur seasonally. Such ecosystems are subjected to nutrient inputs associated with runoff and seagrasses are restricted to shallow water depths, due to light attenuating processes. In rocky shore seagrass habitats, water motion regimes from wave exposure scour sediments and restrict seagrass growth to small pockets of sediments trapped between rocks. In the sandy sediment habitats, *C. nodosa* is found from the shallow subtidal to the beginning of dense and extensive *P. oceanica* beds. *P. oceanica* meadows can form extensive mattes and *récif barrière* on both rocky and sandy bottoms, with roots and rhizomes forming an organic peat layer which allow vertical growth of the meadow.

We provided a counter part for each habitat to present the most significant environmental threats to seagrasses in the Mediterranean region. Increased awareness of human impacts on seagrass meadows has generated renewed interest in understanding the dynamic nature of seagrass communities. Seagrass meadows are experiencing a widespread decline throughout the Mediterranean Sea due to the heavy exploitation of coastal waters (Duarte, 2002). There are various threats that can lead to negative effects on the different seagrass habitats here described. In the estuarine habitats, increased nutrient runoff can lead to seagrass overgrowth by epiphytes. In sandy sediment habitats, overfishing, industrial and sewage outfalls and fish farms lead to a slow but constant seagrass decline. In rocky seagrasses habitats trawl fishing, boat anchoring and eutrophication can be detrimental to seagrasses. Overall, the reduction in water clarity as well as mechanical disturbance, resulting from coastal development, can affect seagrass beds irreversibly (Duarte, 2002). The presence of such a high diversity of seagrass habitats in the Mediterranean Sea makes generalizations difficult. Different habitat types have different ecological processes, different threats and therefore different management requirements. This paper defines three broad habitat types and their key features, identifying research needs and major threats with the aim of increasing our understanding of the diversity and dynamics of seagrass habitats for a rapidly changing Mediterranean coastal environment.

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Aristeidis DIAPOULIS*, Konstantinos TSIAMIS
Hellenic Center of Marine Research, 19013 Anavissos, Athens, GREECE, e-mail: adiapo@ath.hcmr.gr

MARINE FLORA AND VEGETATION OF SOUTH AEGEAN SEA (GREECE)

Abstract

Marine benthic macroalgal flora and vegetation (Chlorophyceae, Fucophyceae, Rhodophyceae) of the upper infralittoral zone (0-1m depth) were studied, on pristine rocky shores of several islands in the S. Aegean Sea. On the whole, 88 taxa were identified (60 red algae, 19 brown algae, 9 green algae). Benthic vegetation is mainly characterized by species of the genus Cystoseira, *especially* C. crinita *(Fucophyceae, Fucales, Cystoseiraceae), which forms specific phytocommunities. The present paper describes the composition, abundance and community structure of the S. Aegaen macroalgal populations, which could be considered as one of the most pristine areas of the Eastern Mediterranean.*

Key-words: Macroalgae, Phytobenthos, Aegean Sea, E Mediterranean.

The south part of the Aegean Sea has always been one of the most interesting sites of marine research due to its peculiar environment: situated at the border between the Aegean and Levantine Seas and characterized by important hydrological phenomena (Theocharis *et al.,* 1999).
Eleven sampling locations at the upper infralittoral zone were chosen along pristine rocky shores of several islands of the S. Aegean Sea: Kithnos, Tinos, Amorgos, Rhodes and Kastellorizo Islands (Fig. 1). Macroalgal samples were collected during 2000 by free diving from almost horizontal rocky surfaces, 30-50 cm below the lowest water level. Quadrats of 400 cm^2 (20cm x 20cm) were scraped off at each site (“destructive” sampling).

Fig. 1: Studied sites, located in the S. Aegean Sea. 1=Kithnos, 2=Tinos, 3=Amorgos, 4=Rhodes, 5=Kastellorizo Islands.

In the laboratory formalin fixed samples were carefully analyzed by identifying species presence and by estimating their vertically projected coverage. For the classification of macroalgae the following Mediterranean check-lists were used: Ribera *et al.* (1992) for Fucophyceae, Gallardo *et al.*

(1993) for Chlorophyceae, and Gomez-Garreta *et al.* (2001) for Rhodophyceae. The calculation of ecological indices, Shannon & Wiener Diversity (H') and Pielou Evenness Index (J'), was based on coverage measurements, a methodology adapted to the phytobenthos by Boudouresque (1971).

In total 88 macroalgal taxa were identified through the samples. Red algae dominate with 60 representatives, whereas the brown and green algae participate with 19 and 9 representatives respectively. The value of R / P ratio in the studied area is 3.2, suggesting a warm-temperate aspect of macroalgal flora. Among all identified taxa, the red algae *Falkenbergia rufolanosa* (tetrasporiophyte of *Asparagopsis armata*) is considered to be exotic taxon for the Aegean Sea.

Species number (21-27), total coverage (60-138%), Shannon-Wiener diversity index (H'=2.48-3.15) and Pielou Evenness index (J'=0.53-0.71) exhibit similar values compared to other macroalgal researches of the Aegean Sea (Chryssovergis, 1995). Regarding the dominance of the macroalgae classes, Rhodophyceae dominate qualitative and Fucophyceae quantitative in all sampling sites, whereas the participation of Chlorophyceae to the macroalgal populations is very low.

The vegetation of the studied site is mainly characterized by species of the genus *Cystoseira*, especially *C. crinita*, which forms specific phytocommunities, similar to those of the whole Aegean Sea (Tsiamis *et al.*, 2006). Community's structure consists of different vegetation layers, analogous to layers of terrestrial vegetation. The fronds of the canopy algae, especially *Cystoseira crinita* and *C. compressa*, overtop all other algae. Below canopy vegetation there are the bushy algae, such as the brown algae *Padina pavonica* and *Dictyota fasciola*, and the calcareous red algae *Jania rubens* and *Haliptilon virgatum.* Encrusting red algae are also present, such as *Lithophyllum cystoseirae* and *Hydrolithon farinosum*. Community epiphytes, such as the microscopic filamentous red algae *Herposiphonia tenella* and the brown algae *Sphacelaria cirrosa,* are remarkable.

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Marta DIAZ-VALDES, Eleuterio ABELLAN, Andres IZQUIERDO, Alfonso RAMOS-ESPLA
Dept. CC. del Mar y B.A., University of Alicante P.O. Box 99, 03080, Alicante, SPAIN
E-mail: marta.diaz@ua.es

EVALUATION OF THE MACROALGAE COMMUNITIES IN THE VALENCIAN ROCKY COASTS (SE SPAIN) FOR THE EUROPEAN WATER FRAMEWORK DIRECTIVE (WFD)

Introduction

In accordance with the European Water Framework Directive (WFD 200/60/EC) the ecological quality of Valencia's water bodies had been evaluated on the basis of the status of macroalgae species as biological indicators.

Littoral macroalgae communities are documented bioindicators of the environmental quality due to (i) fixed and superficial location allow the exhibition to many agents along the coast, (ii) reflect the conditions that have been previously exposed, (iii) the different species have different sensibility to the anthropogenic disturbances.

Material and methods

The study was carried out along Valencian Community's coast (West Mediterranean). 22 stations were sampled in August 2005 (high tourist pressure) and May 2006 (high development communities). On every station there have been taken measurements of physical parameters and impacts. Two replicates samples were scraped off in the upper infralittoral zone, from a 15×15 cm surface. In laboratory algae and colonial invertebrates were identified and quantified in term of coverage, and solitaries invertebrates were quantified by number found. Environmental categories were made on basis of bibliography (i.e. Golubic, 1970; Borowitzka, 1972; Littler and Murray, 1975; Belsher, 1977; Ballesteros, 1984; Levine, 1984; Benedetti-Cecchi *et al.*, 2001; Pinedo *et al.*, 2007) and observations in field. Multivariate analysis (Cluster, MDS and Simper) were carried out with Primer statistic package.

Results and discussion

A total of 71 indicator taxa were identified, 65 macroalgae and 5 invertebrate species. The results from the multivariate analysis are represented in Figure 1. Samples were separated in four groups depending on total community of macroalgae.

Locality type I: Ecological quality Moderate. *Corallina elongata* is the dominated specie together with *Mytilaster minimus;* grouping two industrialized stations (summer and spring).

Locality type II: Ecological quality Good. The three more important species are *Hypnea musciformis*, *Cystoseira compressa* and *Corallina elongata* (summer and spring).

Locality type III and IV: Ecological quality Very Good. Type III group the summer samples dominated by *Jania rubens*, *Laurencia* sp. and *Cystoseira* rhizoids, whereas type IV group the spring samples dominated by *Cystoseira* species.

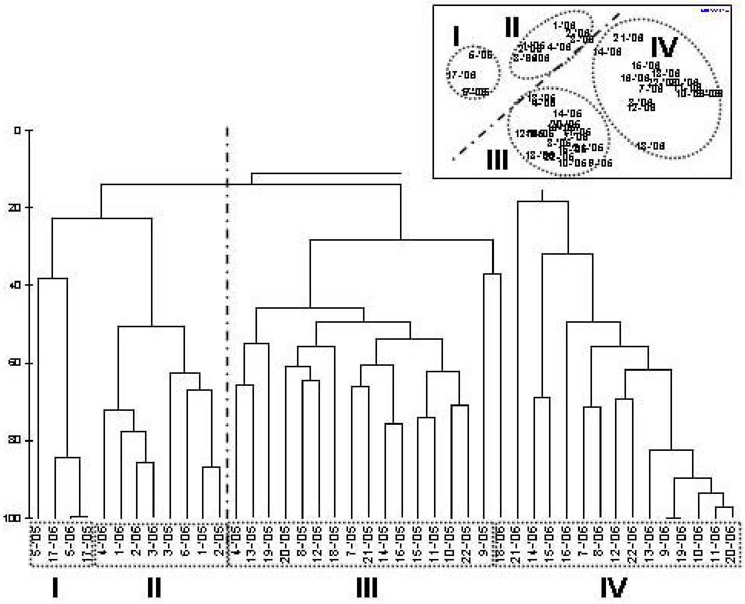

Fig. 1: Multivariate results based on the found algal community in the sampling stations.

For ecological status Moderate (type I) and Good (type II) are not important the period of time for sampling, because the effect of pollution on macroalgae community is higher than natural seasonal changes. In the other hand for the ecological status Very Good the samples had been separated in two different groups, the spring one dominated by *Cystoseira* species (high developed communities) and summer group where communities are in regression mainly due to the tourist pressure on the Valencia's coast.

Acknowledgements

This study has been financed by Conselleria de Territori i Habitatge of the Generalitat Valenciana.

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Christelle DYC*, Sylvie GOBERT, Gilles LEPOINT, Jean-Marie BOUQUEGNEAU, Aurélia CHERY*[1], Alexandre VOLPON*[1], Pierre LEJEUNE*[1]
Oceanology, University of Liège, B6, Sart Tilman B-4000 Liège, BELGIUM, e-mail: Christelle.Dyc@ulg.ac.be.
*[1] Scientific staff of STARESO (STAtion de Recherches Sous-marines et Océanographiques (Calvi, Corsica)

USE OF *POSIDONIA OCEANICA* (L.) DELILE AS A POLLUTION INDICATOR STUDY OF A ZONE SITUATED IN REVELLATA BAY (CALVI BAY, CORSICA)

Abstract

In September 2005, in Revellata Bay (Calvi, Corsica), a meadow of Posidonia oceanica *presenting damaged bunches and scattered with dead matte was discovered between 20 and 40 m of depth. This zone, called Cocauré (Site 1), doesn't seem to have ever been pointed out before and air photographs (from 1975 to 2001) do not allow the distinction of the substrate beyond 20 m of depth. In June 2006, for the first time and thanks to different parameters (length and width of sheets, length of foliar sheath, coefficient A, surface and foliar biomass, lepidochronology, granulometry, content of organic matter and concentration in nutrients), we tried to characterize this zone (position, extent, type of substrate) and to compare it with a well-known meadow situated opposite STARESO (Site 2). The results show that the growth of* P. oceanica *in Site 1 have less vitality than in Site 2. Furthermore, we observed dead matte zone between 16 and 25 m of depth in Site 1. Nevertheless, in absence of former data, parameters we measured do not allow to determine whether the situation observed in Site 1 is caused by natural dynamics of the zone (zone of downstream from a return river) or by anthropic activity).*

Introduction

The small Bay situated opposite Alga's beach (Calvi Bay, Corsica), between Punta Vaccaja and Punta di l'Oscellucia, represents a coveted substrate for damping of pleasure boats. This Bay is characterized by the presence of a return river which corresponds to a perpendicular channel to the coast borrowed by surface waters. These surface waters are pushed by the wind towards the coast and go back to the open sea at the level of the seabed by digging in the *P. oceanica* meadow (Boudouresque, 2006). Their bed can extend until 10 – 15 m of depth, to be wide from 100 to 300 m and is often surrounded by *dead matte* (Blanc and Jeudy de Grissac, 1984 ; Boudouresque and Meinesz, 1982). Currents of return can be important and mainly during wintry storms (Boudouresque, 2006). In September 2005 a dive was realised opposite Alga's beach by scientific staff of STARESO. They discovered an extent of the seagrass *P. oceanica* presenting damaged bunches and scattered with *dead matte* between 20 and 40 m of depth. The meadow expanse, called *Cocauré*, is scattered with *dead matte* and is unknown by scientific. In June 2006, for the first time, we characterized this zone and compared it with a known area of meadow situated opposite STARESO.

Materials and methods

Our samplings have been carried out in Revellata Bay (Calvi Bay, Corsica) on two different sites. The first one is situated opposite STARESO (42°35'N, 8°43'E) and the second one opposite Alga's beach (42°33 ' 43 " N, 8°43 ' 38 " E). We used (1) transects method to determine the type of substrate we met ; (2) the shoots density (shoot.m^{-2} of substrate) was been estimated, and (3) orthotropic rhizomes and bunches of *P. oceanica* were been taken *in situ*.

Results

(1) The analysis of transects show that both sites are characterized by different profiles. In Site 2, the sediment is continuously colonized by *P. oceanica* except an expanse of natural origin sand (= *Banane*) broad of 3 m and situated between 15 and 17 m of depth. In Site 1, *dead matte* zones are observed between 15 and 30 m of depth and testify of previous presence of *P. oceanica* meadow. These expanses are maximal between 16 - 20 m of depth and between 21 - 25 m of depth where they represent, respectively, 58 % and 56 % of the substrate. The meadow colonizes only 20 % and 16 % of the substrate respectively. (2) In Revellata Bay, variations recorded since 1975 (Bay, 1984) were classified as natural temporal variations. We used the meadow's classification, according to their density, established by Pergent (2005). The both sites present similar density except at 15 m of depth. The meadow presents in Site 2 show the same density throughout the bathymetric gradient compared to the meadow presents in Site 1. (3) The Biomass and foliar surface are significantly weaker in Site 1 compared to Site 2. However, this difference is not caused by a weaker density in Site 1 but it translates the fact that the sheets of bundles taken in this site are narrower and shorter than these taken in Site 2.

Discussion and conclusion

The situation revealed in Site 1 is not alarming and we can suppose an imbalance of environmental conditions which would be more marked in deep zones. The presence of *dead matte* can be natural or the consequence of the disappearance of foliar bundles of *P. oceanica* further to a chemical, mechanical, physical pollution and so on (Gobert, 2006, comm.pers. ; Boudouresque, 2006 ; Boudouresque *et al.*, 1985; 1986). Furthermore, we observe differences between biometric parameters measured in both sites but, at the moment and due to the absence of former data, we cannot guarantee the origin of these observations. We cannot exclude the existence of a natural spatial variation of the meadow present in Site 1 or assert influence of anthropic factors such as *P. oceanica* survival is threatened. To continue the study of Site 1 and to try to determine the existence of some anthropic activities (boats and\or modification of the sedimentary contributions) or the impact of natural factors (return river), it will be necessary : (a) to mark out the *Cocauré*'s zone to define its exact expanse and evolution ; (b) to esteem the exact surface of different types of substrate by using cadrats ; (c) to put permanent cadrats to establish if, in some places, the meadow re-colonizes the *dead matte* ; (d) to take daily photographs to estimate the exact boats number (the size and the anchoring time) which anchor in the zone ; (e) to make physico-chemical measures on one (or some) annual cycle (light, turbidity, temperature, currents, nutriment content of free and interstitial water) to characterize the site ; (f) to make biometric measures on one (or some) annual cycle ; (g) to make analyses at the level of the sediment, the shoots (carbon, nitrogen, phosphor, isotopes, organic matter and so on).

Acknowledgements

We thank FNRS (convention FRFC : 2.4569.03F) and French Community (convention ARC : 05/10-333).

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Yolanda FERNÁNDEZ-TORQUEMADA, Marta DÍAZ-VALDÉS, Francisco COLILLA, José Luís SÁNCHEZ-LIZASO, Alfonso RAMOS-ESPLÁ
Department of Marine Sciences and Applied Biology, University of Alicante, P.O. Box 99; E-03080. Alicante, SPAIN, e-mail: Yolanda.Fernandez@ua.es

EVALUATION OF THE STATUS OF *POSIDONIA OCEANICA* MEADOWS IN THE VALENCIAN COAST (SE SPAIN) FOR THE EUROPEAN WATER FRAMEWORK DIRECTIVE (WFD)

Abstract

The Water Framework Directive (2000/60/EC) determines that the ecological status of waters inside the European Union should be defined on the basis of different Biological Quality Elements, such as the endemic seagrass Posidonia oceanica, *that is employed for Mediterranean coastal waters. In this study we present a preliminary evaluation of the status of* P. oceanica *meadows in the Valencian coast for the implementation of the WFD in this region of SE Spain.*

Key-words: Water Framework Directive, Biological Quality Element, *Posidonia oceanica*.

Introduction

The Water Framework Directive (WFD) 2000/60/EC establishes a comprehensive approach to water policy oriented on the protection of surface waters and groundwaters inside the European Union. The main objective of this Directive is to reach at least a "good ecological status" for all the surface water bodies, including marine coastal waters, by 2015. The WFD also determines that the ecological status of a water body should be defined on the basis of Biological Quality Elements (BQEs), organisms or groups of organisms that are considered sensitive to disturbances, such as phytoplankton, macrophytes, benthic invertebrate fauna and fish. In the Mediterranean Sea, *Posidonia oceanica* is an endemic seagrass that constitutes one of the most important and productive ecosystems, but this species is also very vulnerable to several anthropogenic impacts (Ruiz, 2000). Therefore, *P. oceanica* seems to be an adequate bioindicator (Romero *et al.*, 2007) and has been proposed as one of the BQEs for Mediterranean coastal waters.

The main objective of this study is to present a preliminary evaluation of the status of *Posidonia oceanica* meadows in the Valencian Community region (SE Spain) for the application of the EU water framework directive.

Materials and methods

The study was conducted along the Valencian coast (SE Spain, NW Mediterranean) during October 2006. Sampling was performed at 15 locations between -14 and -16 m of depth. At each locality we sampled three sites in which *P. oceanica* rhizome baring, shoot density, percent of plagiotropic rhizomes and meadow cover were measured. In addition, in each site ten *Posidonia* shoots were haphazardly harvested and transported to the laboratory, where the morphology, biomass, load of epiphytes, herbivore pressure and production (estimated by the lepidochronology technique) of plants were determined.

With all the obtained data univariate analysis (ANOVAs) were made in order to know the variability and importance of each descriptor, selecting those with a known behaviour to several anthropogenic disturbances that contributed with higher information about the quality of the meadows.

These descriptors were: shoot density, shoot foliar surface, dead matte cover, meadow cover, herbivore pressure, rhizome baring/burial, percent of necrotic tissues, percent of plagiotropic rhizomes and leaf epiphyte biomass. In our region there is not a pristine area to be used as a reference condition, so we composed one virtual site with the best values of our metrics, at the same time that we considered a "worst site" as the opposite of the reference condition. Then we used the selected metrics of these two virtual sites, together with our 15 real meadows, to carry out a principal components analysis (PCA). The results of this analysis were translated into the values of the ecological quality ratio (EQR) defined by the WFD. Finally, we employed this EQR values to classify the current ecological status of the studied *Posidonia oceanica* meadows into one of the five classes established by the Directive (high, good, moderate, poor and bad).

Results

According to this work there is a clear trend in the ecological quality of *Posidonia* meadows along the Valencian Community. We only find one locality (Oropesa) with a good ecological status in the northern coast, followed by stations classified with a moderate (Benicassim) and poor (Castellón) quality. While the central coast (Almassora and La Pobla de Farnals) is characterized by the disappearance of its meadows. In the southern coast, excepting the meadow situated closest to the main city (Alicante) with a moderate quality, the rest of the stations can be classified with a good or high ecological status.

Discussion and conclusions

The evaluation obtained in the present work seems to agree with the principal anthropogenic impacts that affect our region. In fact, most of the meadows of the southern Valencian coast (Alicante province) have "good" or "high" ecological status, compared with those with a "moderate" or "poor" status in the central coast (Valencia province), where urban, industrial and agricultural discharges have significantly degraded the quality of seawaters and its main biological communities.

Anyway, the methodology and results presented in this work are a first step for the application of the WFD in our coasts. During next years we will continue with an exhaustive monitoring of *Posidonia oceanica* meadows in the Valencian Community in order to improve this evaluation and classification technique and it will be compared with the classification obtained using other biological indicators.

Acknowledgments

This work has been financed by the Conselleria de Territori i Habitatge of the Generalitat Valenciana. We also would like to thank the participants in the MED-GIG meetings for their ideas and contributions.

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Lefter KASHTA, Murat XHULAJ, Xhemal MATO, Sajmir BEQIRAJ, Arian GAÇE
Institute of Biological Research, Academy of Sciences of Albania, e-mail: Ikbiol@albmail.com; lefterkashta@yahoo.com

THE STATE OF POSIDONIA MEADOWS ALONG THE ALBANIAN COAST: GENERAL EVALUATION

Abstract

Different observations (aerial visual recording, scuba diving), measurements (density, bed cover) and lepidochronological analysis has been carried out along the Albanian coastline. The aim of the study was the evaluation of the presence and the state of Posidonia oceanica meadows in both Adriatic and Ionian coast. Although Posidonia meadows present in general a normal state, in some locations regressions phenomenon until "matte morte" are identified.

Introduction

The present study has been carried out in 2005, in the framework of a project financed by the Albanian Ministry of Environment. The entire coastline of Albania was object of different observations (aerial visual recording, scuba diving), measurements (density, bed cover) and lepidochronological analysis.

Materials and methods

Sampling and measurements have been conducted according to known methods (Pergent, 1990; Pergent *et al*., 1995; Pergent-Martini *et al*., 1999) in several localities along the Albanian coastline (Fig. 1). Some localities are at the same site. The numbering starts from north.

Results

Based on our observations, *Posidonia oceanica* beds in the Adriatic coast of Albania are rare and isolated mainly in Cape Rodon, Porto Romano and Vlora bay (localities 1-5). The state of the *Posidonia oceanica* beds along the Ionian coast from Vlora bay to southern border (localities 6-21) is considered as normal according to their density, leaves production and rhizome growth rate. The lower depth limit of seagrasses beds is observed at 15-20 m in Adriatic localities and at 25-30 m in Ionian localities. The bottom cover varies from isolated shoots (5%) or 30% in lover depth limit to 90% in shallow waters, whereas the density from 30-70 shoots/m^2 to 1200 shoots/m^2. Based on our measurements and seagrass bed density classification (Pergent-Martini *et al.*, 1999) we evaluated the state of Posidonia oceanica beds in study sites as below: 58 % of localities have subnormal high density; 5 % have normal density; 5 % have subnormal low density and 32 % have extremely low density. Along with the regression phenomenon of the *Posidonia oceanica* beds observed, it has been identified a mass growth of the invasive *Caulerpa racemosa*, which developed mainly on "matte morte", from 2 m to 21 m depth (localities 3, 4, 5, 8, 13, 14, 15, 18, 19).

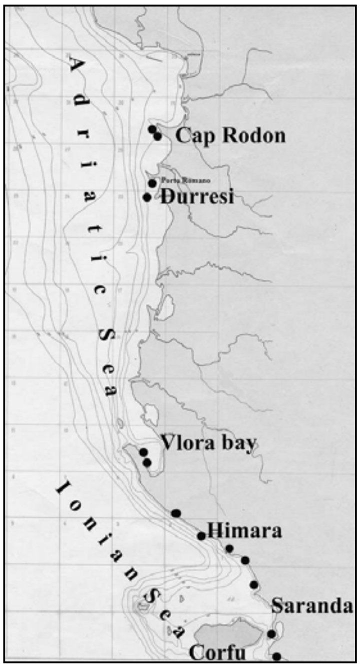

Fig. 1: Study sites along the Albanian coast.

The results from lepidochronological analysis have shown that, in general, the values of leaves production and growth rate of rhizomes are normal (Fig.3). The number of leaves produced annually varies from 5.4 (loc. 2, at 16 m depth) to 7.4 (loc. 9, at 5m depth). The annual growth rate of rhizome, in diving localities, varies from a minimal value of 0.33 cm/year to a maximal value of 1.17 cm/year.

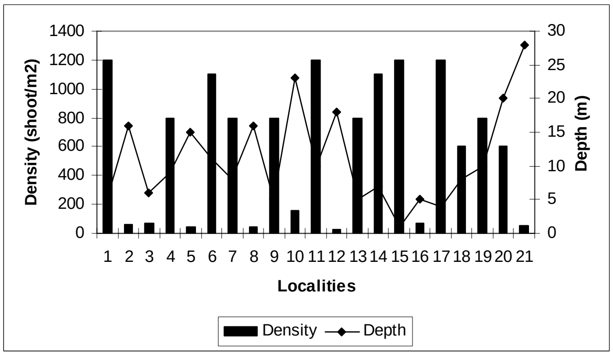

***Fig. 2:** The density of* **Posidonia oceanica** *beds in different localities along the Albanian coast.*

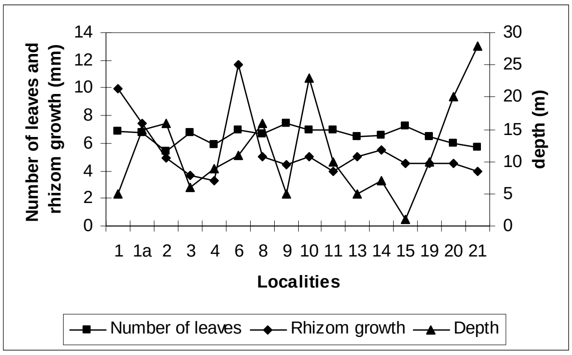

***Fig. 3:** Lepidochronological data from different sites along the Albanian coast during of summer 2005.*

Total length of adult leaves from all measurements is comprised between 21.8 cm (loc. 3) and 89.5 cm (loc. 6), whereas the wideness between 0.61 cm (loc. 4) and 0.95 cm (loc. 15).

The maximal length of adult leaves (125 cm) was measured at locality 6. The shorter leaves are observed in the Vlora bay (loc. 3, 4).

The leaf surface area calculated is between 74 cm^2/shoot (loc. 3) and 327 cm^2/shoot (loc. 6).

The level of herbivore pressure is high; coefficient A varies from14% (loc. 14) to 88% (loc. 20).

Discussion and conclusions

Posidonia oceanica beds occupy wide surface mainly along the southern coastline of Albania. The scarce distribution along Adriatic coast seems to be linked to the effect of freshwater flows and high values of suspended materials coming from the rivers.

Based on our observations and measurements, the studied *Posidonia oceanica* beds in general are in normal or healthy state. Some localities, with subnormal low density values, must have been subjected to human activity impacts (sand excavation, fishing activity and explosive substances) creating regressions phenomenon until “matte morte”.

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Mohamed KSONTINI, Aslam Sami DJELLOULI, Habib LANGAR, Saâdi ABDELJAOUED
Faculté des Sciences de Tunis : 2092 El Manar II-Tunis ; TUNISIE, e-mail : kos_tn@yahoo.fr

L'HERBIER A *POSIDONIA OCEANICA* DE PORT-PRINCES (CAP BON, TUNISIE): ETUDE ET PRESENTATION D'UN PATRIMOINE NATUREL

Résumé

La région de Port-Princes (Cap-Bon, Tunisie), présente un herbier à Posidonia oceanica *apparenté à un « récif barrière ». L'étude de photos aériennes et des observations de terrain a permis de dresser une carte au 1/20 000. Cette étude, complétée par celle des paramètres biométriques (phénologie et lépidochronologie) ainsi que celle des sédiments de la matte, ont permis de faire ressortir l'état de bonne santé de l'herbier et suggèrent la mise en place de mesures de conservation.*

Mots-clés : *Posidonia oceanica*, Récif barrière, Cartographie, Lépidochronologie, Phénologie, Port-Princes.

Introduction

La mise en œuvre des protocoles visant à la protection des herbiers à *P. oceanica* nécessite une connaissance préalable de leur répartition. Malgré la présence d'herbiers à *P. oceanica* tout le long des côtes tunisiennes, ceux-ci n'y ont été que peu étudiés et les travaux se limitent pour la plupart à de simples signalisations (INSTM/APAL, 2003). Pour ces raisons, la présence d'un herbier à Port-Princes (Golf de Tunis, Cap-Bon, Tunisie) a suscité notre intérêt. Cet intérêt se trouve renforcé par le fait que les herbiers à *P. oceanica* sont rares dans le Golf de Tunis (INSTM/APAL, 2003), à l'exception de quelques localités où l'on observe quelques structures remarquables, comme le récif barrière de Sidi Rais, dans la région du Cap-Bon (El Asmi *et al.*, 2003).

Matériels et méthodes

La cartographie de la zone étudiée a été réalisée d'après les photographies aériennes 63, 64 et 65 au 1/10 000 dont les observations ont été validées par des études menées le long de transects. L'ensemble des données recueillies a été ensuite traité par un Système d'Information Géographique (SIG). L'étude des paramètres biométriques est réalisée sur un échantillon de 23 faisceaux orthotropes récoltés en septembre 2005. L'étude des paramètres foliaires et l'étude lépidochronologique ont été effectuées selon la méthode décrite par Pergent (1987). Les sédiments piégés au sein de la matte ont été prélevés par carottage. Une fois la carotte libérée, les différents faciès sont identifiés à l'œil nu et la granulométrie de chaque faciès a été obtenue par tamisage par voie humide. Les poids secs des différentes fractions sont reportés sur des courbes cumulatives, interprétées selon la méthode graphique (revue *in* Rivière, 1977).

Résultats

L'herbier est situé dans la crique Ben Romdhane, localisée à 1,5 Km à l'Est de Port-Princes (Fig.1) et limitée par deux caps rocheux de nature gréseuse.

La cartographie du site étudié a permis de subdiviser la zone en plusieurs secteurs (Fig.1) :

- Un secteur sud-ouest, constitué par une large auréole sableuse, alimentée par les alluvions de l'Oued Ben Romdhane (Fig.1). Elle constitue une zone dépourvue de végétation fixée.

- L’herbier à *P. oceanica* occupe le secteur nord. Frangeant dans sa limite supérieure, il atteint l’isobathe -6,5 m à sa limite inférieure. Il se développe généralement sur une matte continue, pouvant atteindre 3 m d’épaisseur. L’herbier est parsemé, par endroits, de matte morte et de marmites érosives, particulièrement dans sa partie est.
- Le secteur sud est occupé par un pseudo-lagon, siège d’un herbier à *Cymodocea nodosa* colonisant les zones sableuses et les plates-formes rocheuses ensablées. *C. nodosa* est également présente sur la matte morte et le fond des marmites érosives.

La présence d’une partie frangeante, ainsi que d’un pseudo lagon, apparente l’herbier à un « récif barrière » tel que décrit par Boudouresque et Meinesz (1982). Il s’en distingue cependant par le fait qu’il s’établit sur des infractuosités présentes au sein de la roche.

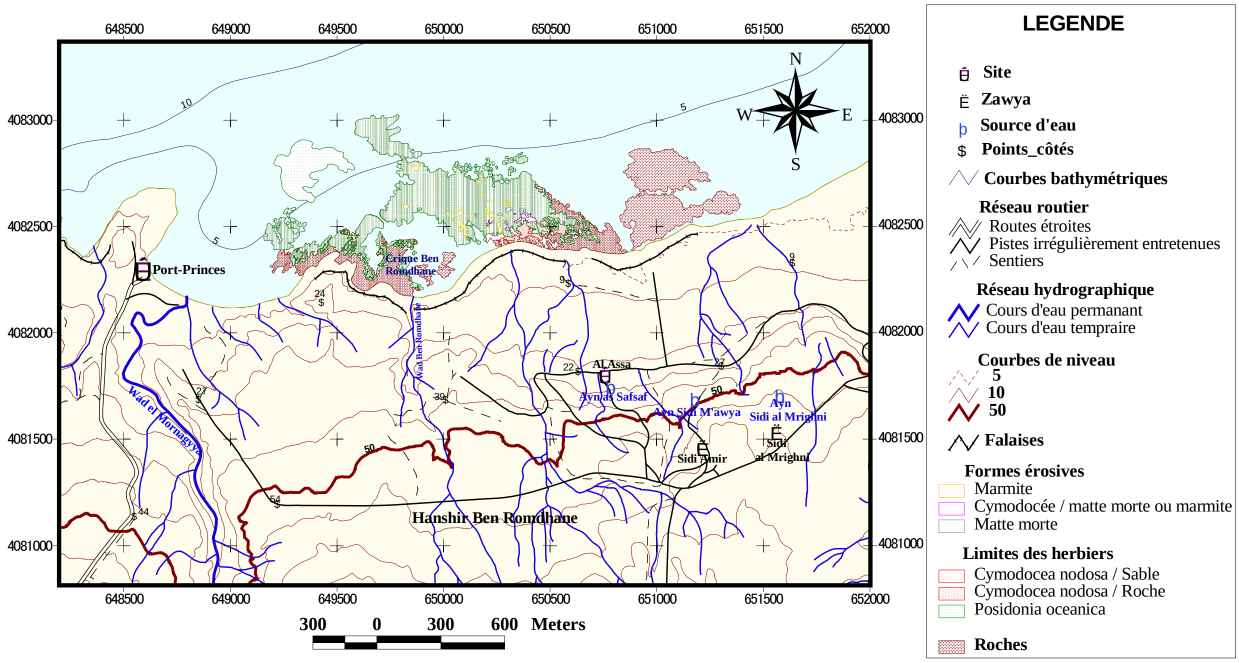

Fig. 8 : Carte de localisation des principales biocénoses marines dans la région de Port-Princes.

L’étude phénologique, nos résultats comparés au moyennes méditerranéennes, revues *in* El-Asmi, Djellouli (2004), montrent que le nombre global moyen de feuille par faisceau (G = 4,35) est similaire aux moyennes, par contre la surface foliaire moyenne (127,98 cm²) y est inférieure. D’autre part, le nombre moyen d’écailles par cycle, égal à 7,86, reste conforme aux moyennes alors que l’allongement moyen des rhizomes (6,6 mm/an) y est légèrement inférieur. La croissance pondérale moyenne (0,07 g/an) est elle, légèrement supérieure à la moyenne méditerranéenne.

Du point de vue sédimentaire, les trois horizons identifiés sur la carotte ont une texture sableuse coquillée. Cependant, les deux horizons supérieurs, de couleur beige-gris sont différents par la nature des organes de *P. oceanica* qui les occupent. La base de la carotte est de couleur noire. Selon le diagramme de Shepard (1954) les proportions sableuses supérieures à 95 %, dans les trois horizons, permettent de classer les sédiments de la matte comme franchement sableux. Les coefficients d’uniformités relatifs aux trois horizons indiquent une granulométrie variée et assez serrée. D’autre part, les indices granulomètriques permettent d’identifier des sables fins (Médiane et Moyenne) mal classés à modérément classés. Les courbes représentatives sont curtiques (Kurtosis) et très asymétriques vers les grossiers (Skewness). Finalement, le diagramme de Passega révèle que les sédiments proviennent du roulement sur le fond avec un peu de suspensions gradées.

Conclusion

La cartographie a permis de mettre en évidence la présence dans la région de Port-Princes (Tunisie, Cap-Bon), d'une structure d'herbier remarquable, s'apparentant à un récif barrière. Ce dernier présente des paramètres indiquant un bon état de conservation et semble peu influencé par l'activité anthropique. Cependant la présence de tâches de matte morte et de marmites érosives, révèle un état d'équilibre fragile qui peut être facilement rompu sous l'effet d'un accroissement, dans la région, de l'activité balnéaire ou de la pêche. Dans le but de préserver cette conservation, un suivi des paramètres de vitalité de l'herbier apparaît donc impératif ; il devrait être accompagné par un contrôle de son extension qui s'appuiera sur la présente cartographie et sur un balisage des limites de l'herbier.

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Céline LABBE*, Céline LAFABRIE, Roger KANTIN, Christine PERGENT-MARTINI, Gérard PERGENT
* EqEL, Université de Corse, 20250 Corte, FRANCE, e-mail: labbe@univ-corse.fr

HUMAN INDUCED CONTAMINATION (ORGANIC AND INORGANIC) OF *POSIDONIA OCEANICA* MEADOWS

Abstract

The aim of this study is to evaluate the contamination of two Posidonia oceanica *meadows. The results show that this contamination is higher in the meadows of Toulon than in those of Calvi and thus seems to indicate that they are more threatened.*

Key-words: *Posidonia oceanica*, Phenology, Trace metals, Polycyclic Aromatic Hydrocarbons.

Introduction

The major sources of pollution of surface waters include effluent discharges by industries, atmospheric depositions of pollutants and occasional accidental spills of toxic chemicals (Ikem and Egiebor, 2005). Trace metals and polycyclic aromatic hydrocarbons (PAH) are regarded as serious pollutants because of their toxicity, their persistence and their tendency to accumulate in organisms (Schüürmann and Market, 1998; Al-Yakoob *et al.*, 1994). The aim of this study is to evaluate the contamination of 2 *Posidonia oceanica* (L.) Delile meadows.

Materials and methods

Shoots of *Posidonia oceanica* were collected in July (2004 for metal analyses and 2006 for PAH analyses) in Calvi (Corsica, France) and in Toulon (France). The analyses were carried out on the blades by spectrometry (trace metals) and by HPLC-fluorescence (PAH). The metals analysed are Ag (silver), As (arsenic), Cd (cadmium), Hg (mercury) and Pb (lead) as they are considered toxic for organisms and as they are related to human induced impacts. The PAH analysed are BaA (benzo a anthracene), Chry (chrysene), Fluot (fluoranthene), Phen (phenanthrene), Pyr (pyrene) as they are part of the PAH recommended by US-Environmental Protection Agency.

Comparison of the inorganic contamination of the sites

The highest concentrations are recorded in Toulon for all the metals except for cadmium (Fig. 1).

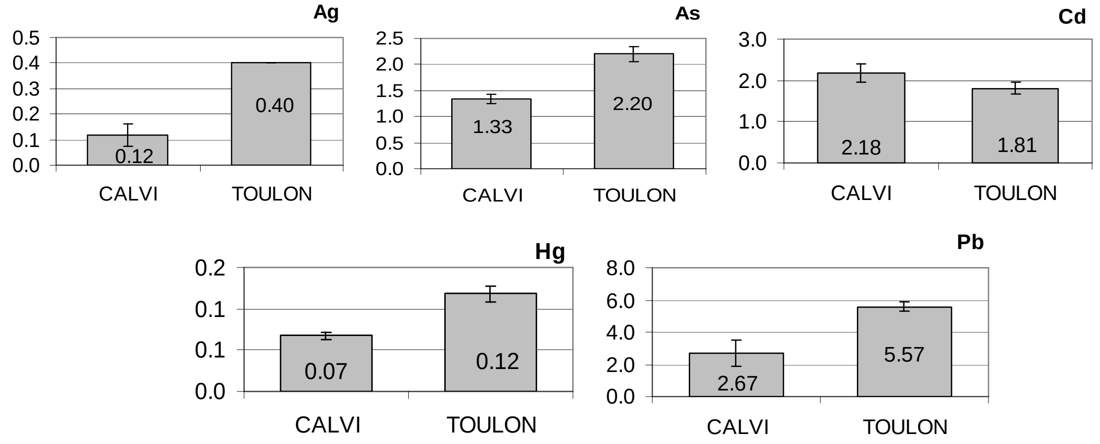

Fig. 1: Trace metal concentrations (µg.g-1 ±S.E.).

This highest [Cd] found in Calvi can be related to a geomorphological particularity of the west coast of Corsica. Indeed, Lafabrie *et al.* (in press) have already reported high levels of Cd in this part of the Corsica. In general terms, the meadows of Calvi are less contaminated by trace metals than those of Toulon.

Comparison of the organic contamination of the sites

The highest concentrations in PAH are recorded in Toulon for the major part of the PAH considered (Fig. 2). The use of the ratio of lower molecular weight against high molecular weight seem to indicate pyrolytic orign of PAH in Toulon and an petrogenic origin in Calvi (Soclo *et al.*, 2000). Globally, the meadows of Calvi are less contaminated by PAH than those of Toulon.

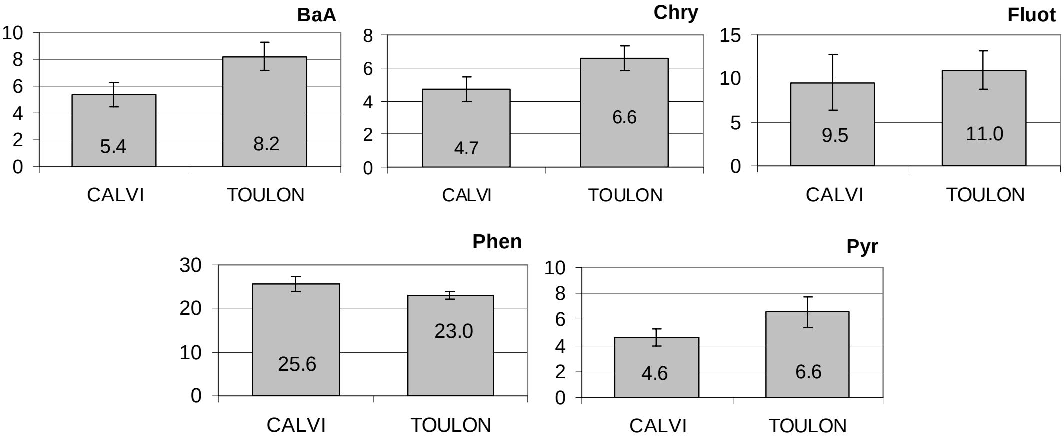

Fig. 2: Polycyclic Aromatic Hydrocarbons concentrations (µg.kg-1 ±S.E.).

Conclusion

The metal and PAH contaminations are higher in the meadows of Toulon than in those of Calvi and thus seems to indicate that they are more threatened.

Aknowledgments

This work was led with the financial support of Territorial Collectivity of Corsica, of the GdR and of INTERREG programs.

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Julien LASSAUQUE*, Alexandre MEINESZ, Thierry THIBAUT
E.A. 3156 Gestion de la Biodiversité, Université de Nice Sophia-Antipolis, UFR Sciences, 06108 Nice cedex 2, France
*Corresponding author: julien.lassauque@unice.fr

WHAT REMAINS OF THE *POSIDONIUM* 18 YEARS AFTER?

Abstract

Long-term success of transplantation experiments conduced on Posidonia oceanica *was assessed 18 years after. If the technique by itself gave good results in term of survival rates, the very slow growth of this seagrass prevents from massively using this procedure to restore damaged meadows.*

Key-words : Long-term success, *Posidonia oceanica,* Transplantation.

Introduction

Since year 1988, cuttings of *Posidonia oceanica* (L.) Delile coming from various parts of the Mediterranean were transplanted in the Port-Cros National Park (France), in order to constitute a kind of underwater arboretum, called *Posidonium.* This collection was implemented through years, and constitutes today a unique example for long-term monitoring of transplantation experiments. Eighteen years later, what remains of the *Posidonium*?

Material and methods

Cuttings of *Posidonia oceanica* with various characteristics (Tab. 1) were transplanted in the Port-Cros National Park (Meinesz *et al.*, 1993).

Tab. 1: characteristics of the transplanted cuttings of* Posidonia oceanica *in Port-Cros National Park.

Origin symbol	Country	Site	Year	Number of cuttings	Depth of origin	Type of rhizoms	Growth in aquaria (days)
POC	France	Port-Cros	1988	52	11	Orthotropic	0
GOJ	France	Golfe-Juan	1988	56	3	Orthotropic	2
LAS	France	Lavezzi - San Bainzu	1988	7	5	Orthotropic	861
ATH	Greece	Athens	1988	3	5	Plagiotropic	114
IZM	Turkey	Izmir	1988	5	11	Orthotropic	296
CAR	Spain	Carthagena	1989	3	3	Plagiotropic	49
BAN	France	Banyuls	1989	60	5	Orthotropic	84
LAP	France	Lavezzi - Piantarella	1989	37	5	Orthotropic	84
ALG	Algeria	Algiers	1989	8	8	Orthotropic	111
TAR	Italy	Taranto	1990	16	5	Plagiotropic	48
MAJ	Spain	Palma de Mallorca	1991	2	6	n.d.	1758
ISL	Italy	Ischia - Lacco Ameno	1993	40	10	Plagiotropic	563
ISC	Italy	Ischia - Castello	1993	11	10	Plagiotropic	563
MAL	Malta	Malta	1995	4	5	Plagiotropic	203

Annual surveys were carried out from 1989 to 1995, and lastly in 2006. All the information collected during this monitoring phase was gathered together into a database (Access, Microsoft, USA), in order to facilitate exploitation and analysis of the data.

Results

Survival of transplanted cuttings. Success of transplantation after several years widely varies from 0% (CAR) to 100% (ISC, MAJ). From the 14 initial patches, only one did not survive (CAR). Moreover, differences can be noticed between short-term and long-term survival, as in particular for cuttings from LAS, IZM, ATH and CAR (Tab.2).

Dynamics of vegetative multiplication. Vegetative multiplication of the transplanted cuttings has been assessed by counting the number of shoots per patch. For each patch, a reference number of shoots was determined as the minimum number of shoots counted only on the cuttings that were still living in 1995. This operation was possible because until 1995, the cuttings could be individually identified, so that the evolution of every single cutting could be followed. Rates of mean annual vegetative multiplication are determined in respect to this reference number (Tab. 2), and vary from 15% - 17% (ISC, TAR) to 28% (LAP, ISC).

Tab. 2: survival rates of transplanted cuttings of* Posidonia oceanica*; number of shoots for each patch: at transplantation date, reference value (see text), at present day; mean annual vegetative multiplication rate from reference to present; n.d.: missing data.

Origine	Survival rate		Number of shoots per patch					Mean annual multiplication rate
	After one year	Overall	Transplantation		Reference		Present	
			Year	Nb	Year	Nb	Nb	
POC	81%	62%	1988	52	1988	32	1397	23%
GOJ	25%	20%	1988	56	1988	11	329	21%
LAS	100%	43%	1988	28	1990	6	211	25%
IZM	100%	40%	1988	7	1988	4	241	26%
ATH	100%	67%	1988	10	1988	7	320	24%
BAN	87%	75%	1989	65	1989	49	1027	20%
LAP	62%	22%	1989	38	1989	9	568	28%
ALG	63%	63%	1989	10	1989	9	453	26%
CAR	100%	0%	1990	6	1990	0	0	0%
TAR	75%	50%	1990	80	1991	28	284	17%
MAJ	100%	100%	1991	6	1991	6	184	26%
ISL	n.d.	98%	1993	162	1997	257	896	15%
ISC	n.d.	100%	1993	57	1997	56	523	28%
MAL	n.d.	n.d.	1995	n.d.	1997	5	37	25%

Discussion

The survival rates observed one year after transplantation (25% to 100%) are similar to those reported in others works, *e.g.* from 31% to 100% (Molenaar *et al.*, 1993). However, long-term success of transplantation can be rather different than one year survival. This phenomenon has been linked to the existence of storage processes that occur within *P. oceanica*, which allow survival for some years, even with negative nitrogen balances (Lepoint, 2004).

The number of shoots counted during the last survey in 2006 seems to indicate that the patches are in active extension, even if this vegetative multiplication is quite slow: after 18 years, the largest patch (POC) covers an area of only 5 m². Nevertheless, the *Posidonium* is still alive…

Acknowledgments

We are grateful to the National Park of Port-Cros which kindly supported this work from the beginning. We also want to thank all the divers that contributed through years to the realization and the monitoring of this long-term project.

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Luisa MANGIALAJO
Dip.Te.Ris., University of Genova, C.^{so} Europa 26, 16132, GENOVA, ITALY, e-mail: luisama@dipteris.unige.it

A PROSPECTION OF FUCALES POPULATIONS IN THE LIGURIAN SEA ROCKPOOLS

Abstract

Several species of Cystoseira and Sargassum are preferably found in rockpools: the aim of this study is to assess their abundance in Liguria. Three species of Cystoseira and one of Sargassum were found in the 24 rockpools surveyed. This low diversity is probably due to the past regression of Fucales, a phenomenon observed in several areas. Possible causes of disappearance of Ligurian Fucales are discussed.

Key-words: Fucales, Cystoseira, Sargassum, Herbivory, Water quality.

Introduction

Canopy-forming brown algae, and in particular Fucales, are known to play, worldwide, the role of habitat formers on understorey assemblages, modifying physical and biological factors (Bulleri *et al*., 2002 and references therein). In the Mediterranean Sea Cystoseira and Sargassum genus are the commonest structuring brown algae. In particular the genus Cystoseira dominates in several communities (Giaccone and Bruni, 1973) and some species are preferably found in low shores rockpools. The aim of this study was to assess the abundance of Fucales in Ligurian rockpools, in the naturalistically valuable sites.

Materials and methods

Only the naturalistically valuable Ligurian sites were considered: Portofino and Cinque Terre (Marine Protected Areas instituted), Bergeggi and Gallinara Island (Marine Protected Areas in institution process), La Mortola (Regional Protected Area) and Palmaria Island (Unesco's World Heritage site, together with Tino and Tinetto Islands, not considered in this study). Coastline was covered in a pneumatic boat and rockpools were visually censed in spring 2006. In La Mortola, Gallinara, Bergeggi and Cinque Terre, 2 km of coast were surveyed; in Palmaria 4 km and in Portofino 10 km. Only rockpools considered favourable to host Fucales assemblages were considered: depth > 50 cm, surface > 1 m^2, good communication with open sea (all sites were in zones subjected to medium-high hydrodynamic conditions) and absence of close freshwater sources. In each rockpool algal assemblagles were visually quantified giving to most common species a cover percentage (according to the Braun-Blanquet classes).

Results

In total 24 rockpools were surveyed in 5 sites (none in Cinque Terre). Four species of Fucales were found: *Cystoseira amentacea* var. *stricta*, *C. compressa*, *C. elegans* and *Sargassum vulgare*. Abundances of algae (and invertebrates) are reported in Table 1. *C. amentacea* was found in 6 rockpools (25 % of total), generally in the outer portion of the rockpool, in exposed conditions. *C. compressa* is largely the commonest species of Fucales, being present in 18 rockpools (75 % of total). Nevertheless only in 4 rockpools its cover is higher than 50 %. *Cystoseira elegans* is found only in one rockpool in the southern front of Gallinara Island. A dozen of individuals was found in this large rockpool (approximately 20 m^2) in two small patches. In the same rockpool a high density of adult sea urchins in patches is reported. *Sargassum vulgare* is also a common species in Ligurian rockpools, being present in 8 rockpools (33 % of total), but never covering more than 50 % of the surface. Other abundant algal taxa are Dictyotales, Ulvales and Corallinales (Tab. 1).

Tab. 1: Composition and abundance (percentage cover classes) of Fucales and other algal and invertebrate taxa in Ligurian rockpools (classes: 1: < 5 %; 2: 5.1 – 25 %; 3: 25.1 – 50 %; 4: 50.1 – 75 %; 5: 75.1 – 100 %).

Rockpools	**Ca**	**Cc**	**Ce**	**Sv**	**Di**	**Pa**	**Ul**	**Cl**	**Co**	**EC**	**As**	**Co**	**La**	**Bm**	**Mu**	**Su***
Mortola01		4			3		2									
Mortola02	1	4			2	1	2		1				1			
Gallinara01	1	2	1	2						4						HD
Gallinara02		3		3	2				2				1			
Bergeggi01	1	4		1	3											
Bergeggi02		3					3									
Bergeggi03		2			3		2	3								
Bergeggi04	2				4		2		2							
Bergeggi05		3		2	3		2							2		
Bergeggi06					4		2				2					
Bergeggi07		2			4		3									
Bergeggi08**				2			2		2			3				
Bergeggi09**	2					2	2					3				
Bergeggi10**		3		1						3						ID
Portofino01	2	3		2			2									
Portofino02		1					2			5						HD
Portofino03		3			2		2			2						ID
Portofino04		5					1		1							
Portofino05		3			3	2	1									
Portofino06		2		3	2	1	1			2						LD
Palmaria01					3					3						HD
Palmaria02					3				3						2	
Palmaria03		2			2		4								2	
Palmaria04		2			1		3			3					1	HD

Ca = *Cystoseira amentacea* var. *stricta*
Cc = *C. compressa*
Ce = *C. elegans*
Sv = *Sargassum vulgare*
Di = *Dictyota dichotoma* and *Dictyopteris polypodioides*
Pa = *Padina pavonica*
Ul = Ulvales
Cl = *Cladophora* sp.
Co = *Colpomenia sinuosa*
EC = Encrusting Corallinales
As = *Asperococcus bullosus*
Co = *Corallina elongata*
La = *Laurencia* complex
Bm = Benthic mucillages aggregates (*Nematochrysopsis marina*)
Mu = Mussels
Su = Sea urchins

* Sea urchins: LD = low density (< 1 m^2); ID = intermediate density (< 4 m^2); HD = high density (> 4 m^2). **Rockpools located on the small island.

Discussion and conclusions

Several Fucales are considered highly threatened in the Mediterranean Sea and recent studies record their regression in different Mediterranean areas (Thibaut *et al.*, 2005 and references therein). Unfortunately, historical data on Fucales distribution are absent in Liguria and therefore it's impossible to assess their regression. Nevertheless, we expected to find a higher diversity in species (e.g. Port Cros, Thibaut *et al.*, same issue); furthermore all the species found in this survey are considered common or tolerant, except for *Cystoseira elegans.* This latter species represent the only new report for the Ligurian list of algae in Marine Protected Areas (Mangialajo *et al.*, 2004) but the species was found only in one rockpool in Gallinara Island. The very low number of individuals and the evident herbivory pressure in this rockpool highlight that this population, probably unique in Liguria, is highly threatened. High densities of sea urchins were recorded in other rockpools, in concomitance with high cover of encrusting Corallinales and low Fucales. One of the major causes of regression of Fucales in rockpools in Liguria seem to be herbivory. Contrarily, in Bergeggi, the abundance of Ulvales stresses the enrichment in nutrients, probably due to the high density of seagulls, living numerous in the inhabited island and feeding in the close Savona garbage dump. The case of Palmaria is different: as showed in a previous study, the whole eastern Ligurian coast seem to be affected by basin-dynamic disturbances (Mangialajo *et al.*, 2007). Furthermore, in this zone, the mussel aquaculture represents a source of this competitive-for-space bivalve: in 3 out of the 4 rockpools censed on Palmaria island low covers of *Mytilus galloprovincialis* were recorded. This study highlight a sounding situation for the Fucales populations in Ligurian rockpools, where probably several species are definitely lost. Conservative interventions are therefore expected in order to preserve the present populations.

Acknowledgments

I thank V. Asnaghi for her help in the field and T. Thibaut for the critical reading.

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Carmen MIFSUD[1], Edwin LANFRANCO
[1]Malta Environment and Planning Authority, Carmen.mifsud@mepa.org.mt

CAULERPA RACEMOSA (CHLOROPHYTA, CAULERPALES) IN THE MALTESE ISLANDS (CENTRAL MEDITERRANEAN)

Abstract
The green alga Caulerpa racemosa*, Chlorophyta, was recorded for the first time in the Maltese Islands from the island of Gozo, in February 1997 and from the island of Malta in February and August of the same year. Ad-hoc surveys from 1997 to 2003 showed that this algae was spreading rapidly all over many sites in the Maltese islands. This paper discussed such records, the form, densities, depth and % cover this alga was found in. It speard so profusely, that this algae was also found in maerl grounds at great depths, and also in the lower mediolittoral in just a few mm of water.*

Key-Words: *Caulerpa racemosa,* Maltese Islands, Mediterranean Sea, Algae, Alien species.

Introduction

The green alga *Caulerpa racemosa* (Forsskål) J. Agardh has spread rapidly in the Mediterranean basin, and this rate of expansion has caused great concern with regards to its possible impact on Mediterranean benthic communities. It was recorded first in Tunisia (Hamel, 1926), with subsequent records from all over the Mediterranean, including East coast of Sicily, Lampedusa (Alonghi *et al.*, 1993), Cyprus (Hadjichristophorou *et al.*, 1997; Argyrou *et al.*, 1999) and Sardinia, just to name a few. Thus its eventual presence in Malta was predictable.

C. racemosa was first observed in the Maltese Islands in February and August 1997 from four different sites. In February it was reported from Dwejra and ta' Slima (Gozo) (Borg *et al.*, 1997) and Hurds Bank (Malta) (Fig. 1). The records for February indicated that *Caulerpa racemosa* occurred patchily in deep waters, while its 'invasive' presence in shallow water was established in August of the same year by the first author, where it was found growing profusely in M'Scala [SSW].

Material examined

The Material from the Maltese Islands was collected through surveys using SCUBA diving or snorkelling, during the period 1997 till 2003. Dives were carried out to check for the presence of *Caulerpa racemosa* and, when encountered, estimates of the area of bottom covered, extent of population and identification of accompanying algal species were made. Samples were collected and preserved either in 5% solution formaldehyde in seawater or as exsiccata.

Results

Table 1 shows a summary of the information collected during the survey and figure 2 shows the sites where *Caulerpa racemosa* was found. The following algae were found as accompanying species at the Delimara site: *Dictyopteris membranacea*, *Halopteris filicina*, *Derbesia* sp., *Osmundaria volubilis, Padina pavonica, Dasycladus vermicularis* , *Halopithys pinastroides, Pterocladia capillacea, Jania adhaerens, Haliptilon squamatum, Symploca* sp. and *Cystoseira* sp.

***Tab. 1: Occurrence of* Caulerpa racemosa.**

No (see fig 1)	Date	Location	Depth(m)	% cover
1	February '97	Dwejra (Gozo)	-30	5-10
2	February '97	Ta' Slima (Gozo)	40	5-10
3	February '97	Hurd's Bank	35	20-30
4	August '97	M'Scala (near the waterpolo pitch)	-0.1-10	70
5	June '98	M'Xlokk	-15-25	30-40
6	July '98	Kalanka it-Tawwalija-Dellimara	-6-8	20-25
7	October '98	Wied Iz-zurrieq[2]		few fronds
8	June '99	Munxar Point	-4-6	20-30
9	August '99	Off Qawra /Ghallis	--36-50	20-30
10	October '99	Xatt l-Ahmar (Gozo)	-30	5-10
11	March 00	Kalanka t-Tawwalija	-6-8	5
12	June 00	Spinola Headland	-10	1-2
13	July 00	St.Thomas Bay	-2	5-10
14	October 01	Tigné (Sliema)	-0.1	5
15	August 02	Off il-Hofriet	-22 m	-
16	March 03	Birzebbuġa	-0.4	-
17	June 03	Ħondoq ir-Rummien	-5-15	15
18	June 03	Ghar Lapsi	-1-13	10
19	June 03	St. George's Bay-Paceville	-0.1-1	15
20	October 03	Blata l-Bajda	+0.05 – 0.3	50

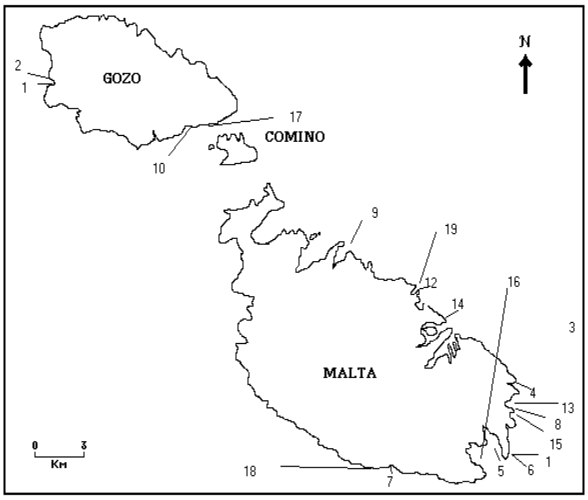

Fig.1: Distribution of* Caulerpa racemosa *as detailed in Table 1 (according to chronological order when found).

Discussion

In contrast to what had been stated back in 1999, when this alga was reported from three sites (Stevens, 1999), with sparse growth, it was subsequently found to be undergoing prolific expansion in several habitats and sites around Malta.. In places like Marsascala, with intense anthropogenic disturbance, the alga was found in very dense 'meadows'; hence it seems that degraded localities appeared to favour expansion and enhanced growth of this species. This has been also stated by Riggio (1995) and Di Martino and Giaccone (1995), and Buia *et al*.(1998) stated that one could even suggest the use of this species as an indicator of an active environmental disturbance. Although certain sites in Malta, where it grew, can still be considered as quite pristine (e.g. Ħondoq ir-Rummien NE Gozo). On level ground (at Delimara,) when interspersed among the *Posidonia* meadows, it had a smaller form, whilst on the vertical sides of the *Posidonia* matte, it was considerably larger and darker. These observations support those made in culture by Ohba and

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[2] Only a few strands were found on this date but later in winter it was not found again, however toward the end of 2002 it was found again abundantly in this place.

Enomoto (1987), whereby the type of branches produced were influenced greatly by the ambient conditions, particularly by temperature and light intensity. Also Alongi *et al* (1993) stated that type of branches were influenced by lack of light penetration, caused by deeper waters. According to Giaccone (Giaccone *et al*., 1995) this species normally grows in sheltered areas, which may thus explain its sporadic development at Wied iz-Zurrieq, and its subsequent disappearance; however *C. racemosa* was also found in other exposed sites around the Maltese Islands. Further investigations need to be carried out to establish the expansion mechanism by which it spreads, and to find if there are any natural predators of this alga It still needs to be established whether the introduction of this species is having an adverse impact on the marine benthic assemblages and habitats of the Maltese Islands.

Acknowledgements

We would like to acknowledge all our diving buddies who supported our work and accompanied us on the survey dives throughout this investigation. Joseph A. Borg, Marthese Azzopardi, Carmelo Camilleri, Anthony Aquilina, Marlene Vella, Miraine Rizzo and Patrick J. Schembri also gave us valuable information on the spread of this alga.

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Silvia OLIVA, Oriol MASCARÓ, Javier ROMERO, Marta PÉREZ
Department of Ecology, Faculty of Biology, University of Barcelona, Diagonal 645, 08028, Barcelona, SPAIN
e-mail: silviaoliva@ub.edu.

ROOT MORPHOLOGY OF *CYMODOCEA NODOSA* REFLECTS EUTROPHICATION GRADIENTS

Abstract

With the aim to gain knowledge about the relationship between root features (morphology and biomass allocation) and the degree of eutrophication in the seagrass Cymodocea nodosa *(Ucria) Ascherson, we examine here both, root branching as the root branching index (IR), and the root biomass as the Root Weight Ratio (RWR) under contrasting situations of nutrient and organic matter availability. We took benefit from the existence of a strong eutrophication gradient within an estuarine bay (Alfacs Bay; Northeast of Spain), sampling along such gradient. Data obtained demonstrates that, on the one hand, roots are much less branched in nutrient-rich than in nutrient-poor environments and, on the other hand, that root biomass is higher in nutrient-poor than in nutrient-rich zones. These results seems to indicate a substantial plasticity of this plant. Moreover, the IR and RWR indexes seem to reflect nutrient status, and can be used as indicators for the assessment of the eutrophication degree in coastal systems.*

Key-words: Roots, *Cymodocea nodosa*, Eutrophication, Root branching index (IR), Root weight ratio (RWR).

Introduction

Intraspecific changes in biomass allocation between leaves and roots, and in root morphology have been attributed to differences in soil fertility in terrestrial plants (Reynolds and D'Antonio, 1996). The seagrass *Cymodocea nodosa* (Ucria) Ascherson has been shown able to demonstrate some degree of morphological plasticity, depending on nutrient supply and sediment redox conditions (Perez *et al*., 1994). The objective of this study is to find descriptors related to *C. nodosa* root morphology reflecting environmental quality. To do this, we examined root features along a gradient of nutrients and organic matter availability in a coastal embayment.

Materials and methods

The study was performed in an estuarine embayment (Alfacs Bay, NE Spanish coast). The bay receives freshwater nutrient and organic-rich inputs from rice paddy fields from April to October along its northern shore. This generates a contrasting gradient of nutrient availability and organic matter richness (Perez *et al*., 1994) to which the seagrass plants, occupying most of the shallow bottoms of the bay, are submitted. To examine the variability in root morphology, we selected three contrasting *Cymodocea nodosa* stands representing the most eutrophic, the less eutrophic (conditions close to those of normal Mediterranean seawater) and intermediate conditions. To test seasonal variability, we sampled in April and June 2006. At each station we sampled three replicate quadrats (40 x 40 cm) for the estimate of leaves and rhizome biomass, and three replicate corer samples (15 cm diameter) for root biomass and morphological observations. The plant material was transported to the laboratory, sorted into leaves, rhizomes (not used) and roots, and dry-weighed. The Root Weight Ratio (RWR) was calculated as root biomass divided by the root plus leaf biomass (RWR= Broots /(Broots + Bleaves); Reynolds and D'Antonio, 1996).

To calculate the Radicular Index (I_R) we separated and placed carefully over a drier filter paper five roots of each replicate core. The I_R was computed as the total number of ramifications divided by the total length of the main root (I_R= nº ramifications / total length). The significance of the variability among zones and the seasonality was assessed using two-way ANOVA.

Results and Discussion

The root weight ratio (RWR) did not present significant differences between sites in April (Fig. 1), but did so in June, with values ca. 3-fold higher in the eutrophic zone than in the oligotrophic one. The root branching index (IR) presented significant differences among zones, being sharper in April (8-fold higher in the nutrient-poor than in the nutrient rich) than in June (only 2-fold. Fig. 1).
Changes in root morphology and biomass (higher biomass and higher frequency of branching in the poor zone) can be interpreted as an accommodation of the plant to the nutrient regime. When nutrient concentration in the water is high (northern shore, nutrient-rich zone), nutrient uptake occurs through leaves, and no much resources are allocated to the development of a high root biomass. In contrast, when nutrient shortage in the water takes place (southern shore, nutrient-poor zone; see Pérez *et al.*, 1991), leaf nutrient uptake is not enough to meet plant demands, and more resources are allocated to develop a large and branched root biomass (Romero *et al.*, 2006).
An alternative explanation based on root mortality due to sediment anoxia cannot be excluded. However, both descriptors used seem to reflect well the degree of eutrophication and, provided enough attention to seasonality, can be used as bioindicators.

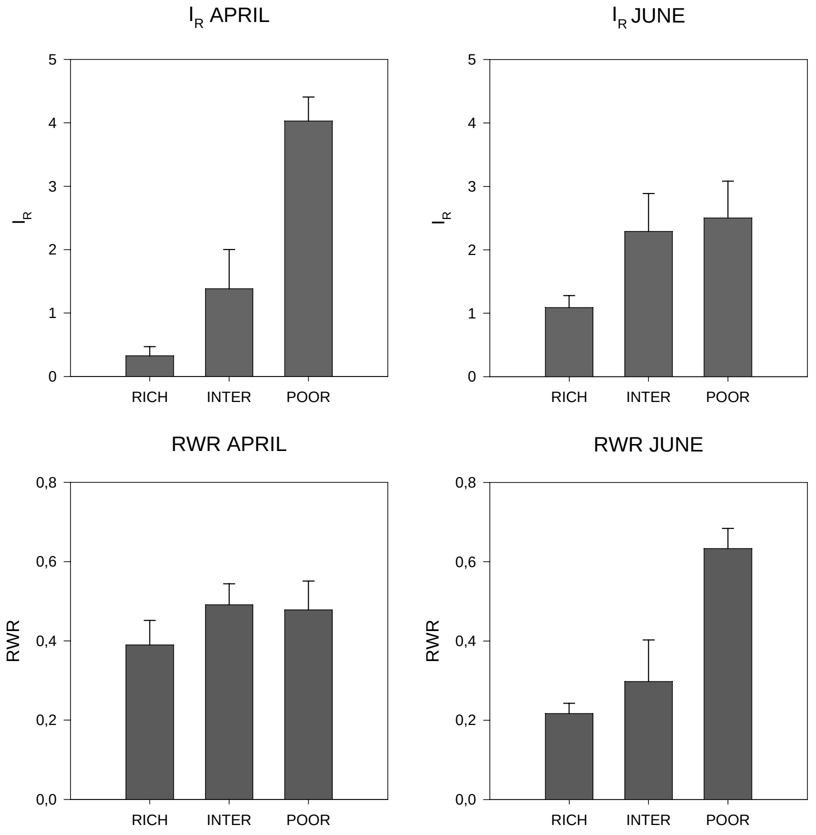

Fig. 1: Variability in IR and RWR in* C. nodosa *stands across a gradient of nutrient supply.

Acknowledgements

This work was funded by the Agència Catalana de l’Aigua (Generalitat de Catalunya) as a part of their Water Framework Directive implementation strategy. We thank Jordi Camp, Tania García, Izaskun Llagostera and Neus Sanmartí for assistance in the field and laboratory.

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Andrea PEIRANO*, **A. BALDI, A. BRUSCHI, G. DI NALLO, Andrea SCHIRONE**
ENEA - Marine Environment Research Centre, C.P. 224, 19100 La Spezia, ITALY, e-mail: peirano@santateresa.enea.it

SEAGRASS MONITORING: THE IMPORTANCE OF INFORMATIVE SYSTEMS FOR A LARGER PUBLIC APPROACH

Abstract

The structure of the Interreg3B-Posidonia Informative System is presented. The data-based visualisation system was created with the aim of answering not only scientists requests but also to sensitise a wider public, from coastal managers to sea lovers, to the problem of the monitoring of seagrasses, giving special attention to the Mediterranean Posidonia oceanica *(L.) Delile (Magnolyophyta, Posidoniaceae). The query sections are easy to access and a limited number of operations allow visualising data and graphs. Multimedia presentations as photos, videos and Internet connections are emphasised to favour the approach to the scientific problem to a larger public.*

Key-words: Monitoring, Environmental data base, Informative system, *Posidonia oceanica*, Seagrasses.

Introduction

The use of Internet has favoured the cooperation between scientific laboratories and the creation of Informative Systems, i.e. software that allow the interrogation and visualisation of environmental data following a logic and scientific approach.

One example at the regional level is the European EUROGOOS project where 35 countries provide standardised, validated oceanographic data that are processed for ocean forecasting (Manzella *et al.*, 2001). The data are accessible and easy to read also for non specialists through a dedicated informative system (*http://vosdata.santateresa.enea.it:54321/mfs/).*

At the national level the informative system SIDIMAR, developed by the Italian Ministry of the Environment, has a public access and aggregates marine data collected during a three-year monitoring program on the coastal water quality (*http://www.sidimar.ipzs.it*). Here is presented the informative system developed during the Interreg3B MEDOCC - POSIDONIA project founded by the European Community. The aim of the project was to design a WEB system with the following prerequisites: a) to give an easy access to a data bank comprehensive both of oceanographic and biologic data; b) to create a tool that could attract and sensitize a larger part of the public to the problems of coastal management, c) to promote the monitoring of the seagrass *Posidonia oceanica*.

Material and Methods

The Interreg3B-Posidonia Informative System is formed by two main parts: one data base designed in 1988 which includes thousands of hydrographic stations made in the Mediterranean Sea from 1910 (Bruschi and Sgorbini, 1988) and one informative system created for the Interreg project. Since its creation the data base has been updated and the system is now based on Unix (Linux) with a Rdbms Oracle 9i, working on a Http Server: Apache 2.0.52. The user interface was developed with Php 5.1.4 and graphic library GD 2.0.28 (with Gif, Jpg ,Png support), Java applet and Mysql 4.1.7. Through a data-entry procedure all the data collected are validated and uploaded in the data bank (Oracle Rdmbs) where they are organised in “data” and ‘metadata’. The metadata gather all the information that is associated to a station (project name, coordinates, data owner, sampling method, laboratory measurements, bibliography etc.). The Interreg3B-Posidonia interface of the informative system uses free Applet: LiveMap 3.0 and Rosa Applet 1.2.0. It was designed to support a larger utilisation of the data collected during *Posidonia oceanica* monitoring cruises, allowing the simple access, interrogation and utilisation of the data bank and the visualisation of data, graphs and introducing the use of multimedia tools in the metadata sections.

Results and Conclusions

Today the data base collects a total of 27,909 stations so divided: Sedimentology (293 stations from 1984 to 1997), Physical Oceanography (27,223 stations from 1910 to 1997), Biology (393 stations from 1981 to 2006). Stations regarding seagrasses are 33, from 1991 to 2006. The Interreg3B-POSIDONIA Informative System was activated in December 2006 through the address *http://www.santateresa.enea.it/wwwste/posidonia/siamn/home.htm* that gives access to the page of the data base of the project (Fig. 1). On the left of the page the user may select the area or the information of interest divided into four main topics (discipline, parameter, data typology, cruises), on the right the results of the query are presented in tables and maps where active labels or points give the possibility to view data, graph and metadata windows. The windows were designed to give an easy access to all the options. For instance, the graph options allow visualising simplified bar graph of each *P. oceanica* parameter, allowing the user to change the number of samples. In the case of data concerning the cartography of the *P. oceanica*, the user can zoom, measure, and see the depth of the meadow and the coordinates with simple buttons or click-and-drag options. The metadata window was specially designed for a wide public approach, from manager to sea lovers; it contains all the information of the selected stations (geographical position, cruise name etc.) together with a series of multimedia tools that allow the user to visualise the documentation (articles, papers, posters), to have links to other web-sites and to see photographs, drawings and videos. In conclusion, the Interreg3B-Posidonia Informative System offers even to the non-specialist the possibility of approaching the ‘scientific world’ of the *P. oceanica* monitoring, seeing the methods, the data and their use, both from a superficial or from a more specialised point of view. This approach contributes both to a larger utilisation of data and to sensitising a larger public to seagrass management.

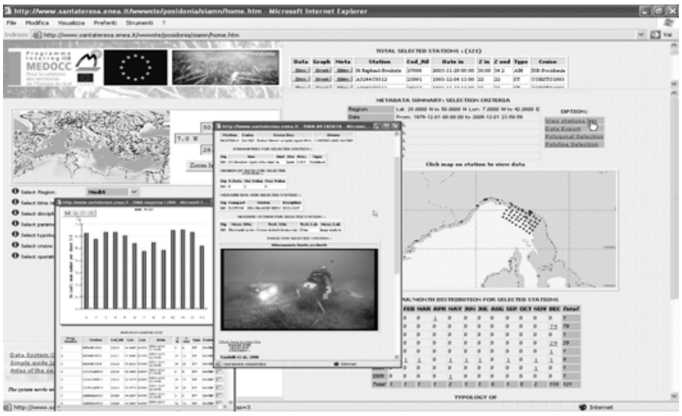

Fig. 1: The home page of the Interreg3B-Posidonia Informative System and two examples of the windows of visualisation of graph (left) and metadata (middle).

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Andrea PEIRANO[*], **Sergio SGORBINI, Silvia COCITO, Massimo MORGIGNI**
ENEA - Marine Environment Research Centre, C.P. 224, 19100 La Spezia, ITALY, e-mail: peirano@santateresa.enea.it

MONITORING THE LIMITS OF *POSIDONIA OCEANICA* MEADOWS USING THE MDM (MICROCARTOGRAPHY DIVING METHOD)

Abstract

A new method to map the limit of the Posidonia oceanica *(L.) Delile (Magnolyophyta, Posidoniaceae) beds is proposed. The MDM method consists of an array of four buoys that detect every second the position of an underwater acoustic device (pinger). The pinger is fixed to one underwater scooter and is conducted by a diver along the limit of the* P. oceanica *meadow. Data on position and depth of the pinger are sent to one onboard receiving unit that memorises them and shows in real-time on a computer screen the limit of the meadow with the accuracy of 3-50 cm. The method is suitable in all the operations (impact assessments, Marine Protected Areas cartography, etc.) where a rapid and accurate monitoring of seagrass meadows is required.*

Key-words: Monitoring, *Posidonia oceanica*, Cartography, SCUBA methods.

Introduction

Both in monitoring systems and in coastal impact assessment the need of fast and precise methods to map seagrass meadows at suitable scale is well known. These requirements are stressed during emergency (e.g. oil pollution, tsunami, etc.) when having subsequent, short-term maps of the impacted meadows is crucial to control and quantify the damage.

Remote sensing, towed video camera and SSS (Side Scan Sonar) are the most effective mapping methods, in terms of surface covered per day, however these methods may be limited by turbidity, in little bays or when steep bottoms, shallow rocks or obstacles (buoys, anchorages, shoals, etc.) are present (McKenzie *et al.*, 2001). In these constraints the contours of seagrass meadows are usually mapped with interpolation of limits detected by divers, but one of the main problem in diving operations is the difficulty to obtain a good accuracy in underwater positioning.

One solution adopted in the Mediterranean Sea to study the seagrass *Posidonia oceanica* that colonises coastal bottoms down to 40 m depth, is to fix a limited number of permanent markers on the bottom or use acoustic telemetry (for a review see Boudouresque *et al.*, 2006). Here, we present a method that allows a fast and accurate 'microcartography' of seagrass meadows from shallow to deep bottoms without the use of bottom markers.

Material and methods

The Microcartography Diving Method (MDM) was developed using the commercial underwater tracking system GIB (GPS Intelligent Buoys) by ACSA (France) that consists of one underwater pinger that communicates with four buoys. The buoys transmit their position and the pinger position to a portable deck-unit every second. One PC connected to the deck-unit computes in real time the DGPS coordinates, the metric distance and the depth of the pinger. Usually used to track AUV (Autonomuos Underwater Vehicles) and ROV (Remotely Operated Vehicles) course and to localise 'black boxes' in flight disaster, we adapted the system to map the limit of the meadows of the Mediterranean seagrass *Posidonia oceanica.* We mounted the pinger on a 2 m long pole fixed to one underwater scooter driven by a SCUBA diver. The pinger was inserted into a hydrodynamic modelled foam to neutralise its weight (5 kg out of water) and to reduce the water friction.

A pvc tablet was fixed to the scooter to note the characteristics of the meadow and the recording time. The system was tested during the Interreg3B-Posidonia project found by the European Community in two sites of the Ligurian Sea (NW Mediterranean): Imperia (Italy) and Saint Raphael (France). At Imperia the accuracy of the method was tested performing a comparison between the positioning data collected by two divers along a fixed path 50 m long and marked by nine fixed poles. At St. Raphael the method was used to track the deep limit of a *P. oceanica* meadow at 32 m of depth in a protected area.

Results

The time required to deploy the system (the four buoys) was 20 minutes. A difference of 3 to 48 cm for the X coordinate (latitude) and 1.5 to 46 cm for the Y coordinate (longitude) of the two divers' position on fixed stops (the poles) was found. The two tracks run by the divers along a course from the first to the last pole were for the majority of the way overlaid (Fig. 1). The maximum difference recorded was around 50 cm. At St. Raphael the method was used to track the deep limit of a *P. oceanica* meadow at 32 m of depth. The method allowed mapping nearly 600 m of limit in 42 minutes of bottom diving time. The analysis of the records showed that the maximum accuracy in positioning was achieved during a continuous course. During stops, errors in positioning were due to the light oscillations of the pinger made by divers.

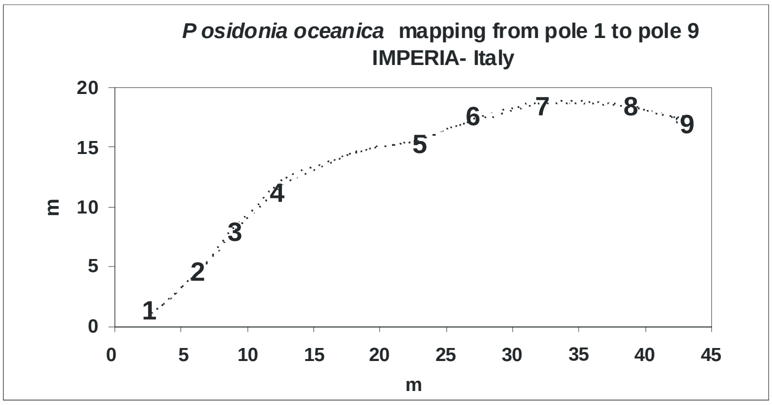

Fig. 1: Comparison of the courses followed by two different divers from pole 1 to pole 9.

Discussion and conclusions

Despite the accuracy in positioning is less than expected (nominally ± 15 cm), both the two divers comparison tests and the recording speed (nearly 1 km of seagrass limit per hour) indicated that the method might be successfully used when detailed seagrasses maps (<1: 500) are needed. The method doesn't require to fix underwater acoustic devices on the bottom and to follow an underwater procedure of calibration as in telemetry approach (Descamp *et al.*, 2005). Future implementation of the system may include a video recording camera fixed on the pole-scooter system.

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Dorothée PETE, Jean-Marie BOUQUEGNEAU, Sylvie GOBERT
Laboratoire d'Océanologie, MARE Centre, Université de Liège (ULg), Institut de Chimie, B6c, Allée de la Chimie 3, Sart-Tilman, 4000 Liège, BELGIUM, e-mail : Dorothee.Pete@ulg.ac.be

USE OF EXERGY TO DETECT AND MEASURE PERTURBATIONS AFFECTING *POSIDONIA OCEANICA* (L.) DELILE MEADOWS: CHARACTERIZATION IN THE SEDIMENTARY COMPARTMENT

Abstract

Within the scope of the European Water Framework Directive, it seems important to characterize state and evolution of marine ecosystems in a global way. So, it is proposed to use both thermodynamic indicators called exergy (Ex) and specific exergy (Ex_{sp}) in Posidonia oceanica *meadows. Aims of this project are to detect and measure perturbations owed to nutrients loading and mechanical spoiling in the Mediterranean coastal zone. It will be led in the Bay of Calvi, on the microbenthic loop (organic matter, bacteria, microphytobenthos and meiofauna) and will be divided in two parts: sampling in different zone of the meadow and* in situ *experiments. In the end of this study, it will be possible to give a diagnostic on the health of* P. oceanica *meadow and to determine how this health will evolve, thanks to the introduction of the exergy in a model.*

Key-words: Exergy, Microbenthic loop, Nutrients, *Posidonia oceanica*, Mediterranean Sea.

Introduction

Within the scope of the European Water Framework Directive, it is important to characterize state and evolution of marine ecosystems in a global way. To estimate the integrity of the Mediterranean coastal zone, it is proposed to use exergy (Ex) and specific exergy (Ex_{sp}) in *Posidonia oceanica* meadows. Those concepts come from thermodynamics and give an estimation of the distance between an ecosystem at a given state and thermodynamic equilibrium, which correspond to an inorganic soup (Jørgensen *et al.*, 2005a). Thus, the more an ecosystem is organised and close to climax state, the farer from this equilibrium it will be and the higher exergy it will present.
The exergy index (Ex) is a good measure of the capacity of an ecosystem to move closer or away form climax state. It is formulated by: $Ex = \sum_{i}^{n} \beta_i . C_i$, where β_i is a weighting factor which gives a specific weight to each *i*th group of organisms of the ecosystem, and where C_i is the biomass of each *i*th group. The factor β is an estimation of the quantity of information present in the biomass and corresponds to a measure of the complexity of this biomass (De Wit, 2006; Jørgensen *et al.*, 2005b). Specific exergy (Ex_{sp}) takes into account the way of an ecosystem uses available resources, independently of their quantity, *i.e.* exergy divided by the total biomass of the ecosystem (Marques *et al.*, 2003).

In this project, those indicators will be calculated for the microbenthic loop (organic matter, microphytobenthos, meiofauna and bacteria) of *P. oceanica* meadows because it is one of the most important sub-system in the marine environment and because it reacts quickly to perturbations.
Aims of this project are to elaborate and validate a new method, based on exergy, to detect and measure effects of perturbations owed to nutrients loading and mechanical spoiling in the Mediterranean coastal zone.

Material and methods

This project takes place in the Bay of Calvi, Corsica, France. Samples will be taken in different zone of the Bay: the oceanographic station STARESO (10 m), STARESO (20 m), Alga Beach (10 m), Calvi fish farm (20 m), Calvi sewage (20 m) and *in situ* experiments (nutrients enrichment, transplantation, pulling out of shoots) will also be led in STARESO, at 10 m depth.

At each site, sediment cores will be taken in March, June and November to determine biomasses of every parts of the microbenthic loop (Gambi and Dappiano, 2004) and to calculate different diversity index (Jørgensen *et al.*, 2005a). Other cores will be taken to determine sediment granulometry and redox potential. Nutrients content of interstitial water will be quantify (Gobert, 2002) and the density of the meadow will be estimated too (Soullard *et al.*, 1994).

Ex and Ex_{sp} will be calculated using β factors coming from Jørgensen (2005b) and results will be compared with diversity index. Correlations will also be established with all the environmental parameters in order to qualify their influence on Ex and Ex_{sp}.

Expectations

At the end of this study, it will be possible to give a diagnostic on the health of a *P. oceanica* meadow and to determine how this health will probably evolve, thanks to the introduction of exergy in a model.

Acknowledgements

This study is financially supported by a grant from the “Fond National de la Recherche Scientifique”, Belgium.

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Marie-Lucie SUSINI[1], F. ROUSSEAU[2], Alexandre MEINESZ[1], Thierry THIBAUT[1]
[1] EA 3156 Gestion de la Biodiversité, Université de Nice-Sophia Antipolis, 06108 Nice cedex 2, France.
[2] Laboratoire de Cryptogamie, MNHN, Paris.
e-mail: susini@unice.fr

PRELIMINARY PHYLOGENY OF THE *CYSTOSEIRA* GENUS (PHAEOPHYCEAE)

Abstract

Sequences of LSU rDNA, rbcL gene and RUBISCO Spacer were determined for representatives of the Sargassaceae (Fucales, Phaeophyceae) in order to assess their molecular phylogeny. More than forty taxa from both hemispheres were included in the study. Sampling focused on the ubiquist genus Cystoseira. *Phylogenetic analyses were performed on separate and combined data sets. Results confirm that the* Cystoseira *genus is polyphyletic. Taxonomy and sister taxa among the genus are discussed with the help of combined morphological analysis. Ancestral and derived lineages are highlighted.*

Key-words: *Cystoseira*, Phylogeny, *rbc*L, RUBISCO Spacer, LSU rDNA.

Introduction

Taxonomy among the *Cystoseira* genus is complex and is still a matter of discussion. This work aimed to confirm the polyphyly of this genus and to compare the molecular groups with the morphological (Giaccone and Bruni, 1973) and chemical groups (Amico *et al.*, 1985) commonly used for systematics.

Materials and methods

45 specimens representative of the Sargassaceae were collected. 25 samples belonging to the *Cystoseira* genus were used. Three molecular markers were selected for amplification: the LSU rDNA (C'1-D2), the *rbc*L gene and the RUBISCO Spacer. Sequence alignments and phylogenetic analysis were performed using BioEdit Sequence Alignment Editor and PAUP* version 4.0 b10 (Parsimony).

Results and discussion

Data confirm the polyphyly of the *Cystoseira* genus. The strict consensus tree combining the three molecular markers shows a strong correspondence between molecular groups and morphological and chemical groups of the *Cystoseira* genus (Giaccone and Bruni, 1973; Amico *et al.*, 1985) (Fig. 1). This tree is supported by high bootstrap values (MP).

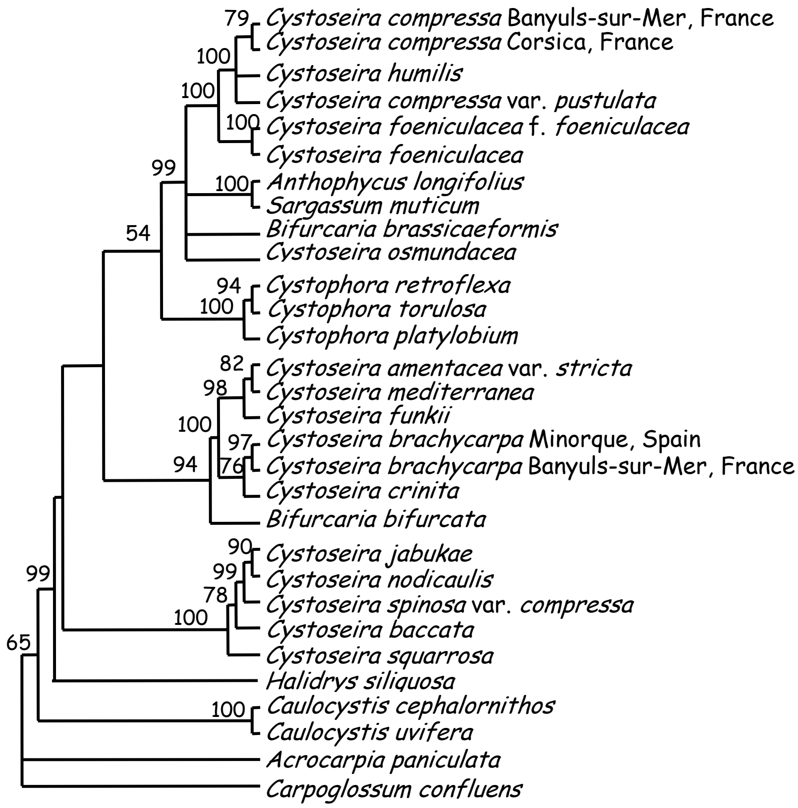

***Fig. 1: Strict consensus tree of the 9 most parsimonious trees inferred from the 3 molecular markers (2128 bp). Numbers above branches indicate bootstrap proportions (% of 1000 replicates). Outgroup =* Acrocarpia paniculata.**

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Murat XHULAJ, Lefter KASHTA
Department of Biology, Faculty of Natural Sciences, University of Tirana, ALBANIA.

HALOPHILA STIPULACEA (FORSSKÅL) ASCHERSON AND *CAULERPA RACEMOSA* (FORSSKÅL) J. AGARDH IN ALBANIA

Abstract
The distribution, some biometric measurements and ecological data about two introduced species, Caulerpa racemosa *var.* cylindracea *and* Halophila stipulacea *along Albanian coast are presented.*

Key-words: *Halophila, Caulerpa,* Mediterranean Sea, Albania.

Introduction
Halophila stipulacea, a seagrass introduced into the Mediterranean Sea as a Lessepsian immigrant is nowadays common in the eastern Mediterranean. In the Albanian coast it is recorded in Ksamili, Saranda and Vlora bay (Kashta and Pizutto, 1995).

The invasive variety of *C. racemosa*, which has been spreading at a rapid rate throughout most of the Mediterranean Sea and the Atlantic, belongs to *C. racemosa var. cylindracea* (Sonder) Verlaque, Huisman et Boudouresque, an endemic taxon from the southwest coast of western Australia (Verlaque *et al.*, 2004; Ruitton *et al.*, 2005). Following the first record in Vlora bay in 2002, it seems to be common along the Albanian coast.

Materials and methods
Underwater observations and collections of plant material have been carried out during summer 2005 in several localities along Albanian coastline (Kashta *et al.*, 2005). Some results of biometric measurements from preserved material are presented here.

Results
Halophila stipulacea in the Albanian coastline creates small meadows near the *Posidonia oceanica* bed or associated to *Cymodocea nodosa*, *Zostera noltii* and *Caulerpa prolifera*. In Albania it has been found in several localities, in depth from 2 m to 15 m (Fig.4), which represents the northern limit of its distribution. The population found in 4 m depth in the southern locality (Ftelea, July 2005) is relatively small, but of a considerable density. In Himara (Porto Palermo, -3 m) it has been found with reproductive organs (Fig. 1). Mean length of leaves measured from this population is 53 mm, and mean width 7 mm. It is, most probably, the earliest population introduced in our coast.

Fig. 1: **Halophila stipulacea** ***with reproduction organs (photo: L. Kashta)***

It seems that *Halophila stipulacea* prefers protected sites in enclosed areas in the Albanian coastline, as in the majority of the other Mediterranean locations**.**

C. racemosa is found in a wide range of substrata (sand, mud, rocks, and especially dead matte of Posidonia) from 1 to 25 m depth in several localities along Ionian Sea and in Vlora bay, Adriatic Sea (Fig. 4).

In Vlora Bay, near to the harbor, it creates a small population situated in 5 m depth, in a mixed substrate of sand and mud, in the edges of a dead bed of *Posidonia oceanica*, and of rare individuals of *Cymodocea nodosa*. Vertical axis 4-7 cm high sprang out from horizontal stolons, spread out on the substrate (Fig. 2). The morphology show a stolon 1.5 – 2 mm in diameter, with erect axis 2-7 cm high that bears clavate branchlets 2.5 - 4 mm long and 1-1.5 mm in diameter. Branchlets are radially or distichously arranged on a cylindrical rachis. Ramified fronds have rarely been found (Fig. 3).

Fig. 2: First record of **Caulerpa racemosa** *in Albania (Vlora bay, photo: Xh. Mato, 2002).*

Fig. 3: Ramified frond (or vertical axis) from Vlora bay at 5 m depth, august 2002 (photo from herbaria: L. Kashta).

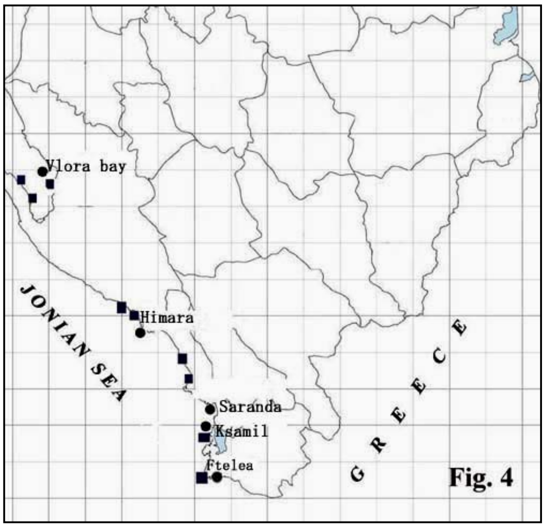

Fig. 4: The map of distribution of **Halophila stipulacea** *(●) and* **Caulerpa racemosa** *var.* **cylindracea** *(■) along Albanian coast.*

Discussion and conclusions

Caulerpa racemosa which has been spreading at a rapid rate throughout most of the Mediterranean Sea, last years is found also in Albania. Following the first record in Vlora bay in 2002, it seems to be common in wide range of depth and substrata along the Albanian coast.

Halophila stipulacea, in Albanian coastline creates small meadows in enclosed areas near the *Posidonia oceanica* beds or associated to *Cymodocea nodosa*, *Zostera noltii* and *Caulerpa prolifera*. Albanian localities until now represent the northern limit of its distribution.

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