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Mediterranean Action Plan
Regional Activity Centre For Specially Protected Areas

Best practice guidelines for

Aquaculture and sustainable management in Mediterranean coastal wetlands: case study of Doñana marshes (Andalucia, Spain)

Best practice guidelines for aquaculture and sustainable management in Mediterranean coastal wetlands: case study of Doñana marshes (Andalucia, Spain)

Guidelines for sustainable aquaculture in the Mediterranean region

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Cover photos: Fish farming operations in Doñana, SW Spain (courtesy of *Veta la Palma* farm).

Contents

Presentation

Aquaculture is becoming increasingly important for meeting the global demand for fishery products, as wild fish catches are on the decline. Faced with an ever-growing demand and a rapidly diminishing supply (today, most of wild fish stocks are seriously overexploited or depleted), the world's fishermen have been forced to get creative. More and more, the 'traditional' fishing industry is giving way to aquaculture, or fish farming.

With an average worldwide growth of 6.8% per year[1], the fish farming industry represents the world´s fastest growing food sector. But this spectacular growth comes with great environmental costs. Intensive aquaculture has been extremely destructive to natural ecosystems and is often seen as potentially having an effect on biodiversity through introduction of exotic species; escapes of selectively bred species that mingle with wild stocks and weaken gene pools; diseases spawned in fish-farms and spread to wild fishes; chemicals and antibiotics seep into surrounding waters and affecting marine life; or by impact on the wider environment through release of wastes resulting in harmful algal blooms that reduce water quality. Intensive aquaculture is burning up its resources almost as rapidly as the industry is growing

Conversely, carefully managed aquaculture may enable an increase in biodiversity of a particular area or ecosystem. It is, therefore, important that the aquaculture sector is provided with clear, easy-to-use and scientifically based guidelines to ensure its sustainable development. This is a declared objective of this particular Guidelines Document.

Present guidelines have been sketched by the Regional Activity Centre for Specially Protected Areas (RAC/SPA) of the UNEP Mediterranean Action Plan[2], in the context of the UNEP-MAP Strategic Action Programme for the Conservation of Biological Diversity (SAP-BIO) in the Mediterranean Region, and following the principles accounted by the Ramsar[3] Convention, the 1978 (revised in 1995) Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean(and its Protocols), the 2003 Food and Agriculture Organization (FAO) Code of Conduct of Responsible Fisheries in the Mediterranean[4], and

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[1] http://www.fao.org/fishery/topic/13540/en
[2] http://www.unepmap.org/index.php?module=content2&catid=001001002
[3] http://www.ramsar.org/cda/es/ramsar-home/main/ramsar/1_4000_2__
[4] http://www.fao.org/docrep/013/i1900e/i1900e00.htm

the 2005 common agreement signed between the World Conservation Union (IUCN) and the Federation of European Aquaculture Producers (FEAP) to cooperate in the development of sustainable aquaculture.

The document has also drawn on the results of a successful experience combining sustainable aquaculture practices and environmental conservation, developed during recent years in Doñana, a vast protected Mediterranean coastal marshland located in Southern Spain.

This guide is devoted to the interaction between aquaculture practices and the environment, particularly the conservation of threatened species and sensitive wetland habitats, and does not address other aspects of aquaculture activity such as the administrative and legal framework, economic aspects or the role of governance and private organizations on aquaculture planning.

1. Overview of "good aquaculture practices" directed towards the conservation of threatened species and sensitive wetland habitats

Good aquaculture practices, in the context of this guide, can be defined as considerations, procedures and protocols designed to foster efficient and responsible aquaculture production and to help ensure final product quality, while protecting and improving the environment.

These "good" aquaculture methodologies have been named as *aqua-environmental measures* by the Directorate-General for Fisheries and Maritime Affairs, European Commission, and figures in the European Fisheries Fund (EFF)[5].

Beneficial effects of aquaculture on wild flora and fauna can be produced as a result of different factors that are discussed separately in this guide:

- ✓ Production system design
- ✓ Feeding practices
- ✓ Cleaning and sanitation basics
- ✓ Facility biosecurity (escapes)

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[5] http://ec.europa.eu/fisheries/cfp/eff/index_en.htm

This document provides a set of guidelines for environmentally friendly aquaculture oriented to extensive or integrated multi-trophic land-based aquaculture production.

Eco-friendly aquaculture may become a valuable tool for ecological restoration and future wetland managament, since carefully managed fish ponds are true multifunctional fish farms where various services are provided for maintenance of biodiversity, generation of market goods, recreation and rural tourism.

This guide also promotes the application of a multidisciplinary and participatory ecosystem approach to integrate aquaculture management and nature conservation.

Under this outlook, site selection and management of sustainable aquaculture operations should take into consideration the relationships between the activity and its impacts on surrounding wild flora, fauna and habitat, so as to provide information on the state of the ecosystem.

Finally, principles released from these considerations can be fully implemented all along the Mediterranean coastal region, particularly in those areas where ecosystem functionality has been lost due to land misuse and ecological restoration must be prioritized.

2. Production system design

Intensive aquaculture facilities, especially fish cages, have negative impacts on fragile habitats and sensitive species. Conversely, **extensive fish farming systems** and **integrated multi-trophic aquaculture systems (IMTA)** effectively restore the flow of water into and out of the degraded wetlands, restablishing the transport of nutrients, nutrient cycling, water quality, flood storage, and many other abiotic conditions largely disturbed, and attracting local fauna.

Extensive aquaculture models are based on large fish growing ponds connected to each other and with the neighboring rivers by means of irrigation and drainage canals. Typical fishponds are earthen enclosures in which the fish live in a natural-like environment, feeding on the natural food growing in the pond itself from sunlight and nutrients available in the pond water. Fishponds are usually surrounded by reed belts and natural vegetation, thus providing important habitats for flora and fauna, and acting as huge water treatment plants where the excess of nutrients (nitrogen, phosphorus, etc.) and organic matter are removed and naturally transformed into living biomass. With the combination of extensive stabilisation ponds, fishponds and macrophyte ponds, the original nutrient removal efficiency of a disturbed wetland can be restored and enhanced. Furthermore, by the integration of valuable fish and plant species, these nutrients can be converted into marketable by-products.

In Mediterranean countries where extensive or integrated multi-trophic aquaculture (IMTA) operations are practiced, these carefully managed wetlands constitute habitats for numerous threatened species of fish, amphibians, reptiles and birds. Furthermore, the age-old maintenance of some traditional fish farming systems has decisively contributed to preserve these ecosystems. In Italy, traditional extensive *Valliculture* represents a unique ecological, landscape, and cultural heritage and contributes to the conservation of the sensitive Upper Adriatic coastal wetlands. In France, ancient salt marshes and wetlands on its Southwest coast have traditionally been devoted to the extensive culture of eel, gaining an enormous environmental and patrimonial value.

In Southern Spain, this activity plays a fundamental role for the conservation of the rich and diverse fauna of the Doñana National Park and the Guadalquivir River estuary. Extensive fish ponds in this area have become a sanctuary for more than 250 bird species, many of them listed as endangered or threatened in Annex II of the Protocol concerning Specially Protected Areas and Biological Diversity (SPA/BD) of the Barcelona Convention or in the red list of the International Union for Conservation of Nature (IUCN), and a first-rate refuge for fish species also included in Annex II and other whose exploitation is currently regulated (Annex III of the Protocol). However, this relationship between aquaculture and wildlife conservation is not equally explored in other Mediterranean countries.

Small scale fish farms are often presented as sustainable activities that require a healthy ecosystem and can only take place inside, or close to, marine (or coastal wetland) protected areas. It has been argued that if the environmental parameters become wrong, then aquaculture production will suffer as an immediate consequence[6]. However, economic activity based on sustainable aquaculture may also play an important role on the restoration of lost ecosystem functionality, increasing biodiversity and supporting a number of environmental services for the hydrology and ecology of formerly disturbed coastal wetlands and marine areas, that could gain new values for future designation as protected areas.

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[6] http://www.aquamedia.org/FileLibrary/10/IUCN_book_web.pdf

Principles:

- Sustainable land-based aquaculture and environment are interrelated. Extensive and integrated multi-trophic aquaculture systems (IMTA) create mini ecosystems and attract local fauna that may even have positive effects on fish populations and productivity.

- Areas where these types of aquaculture take place could be restored and eventually designated as marine protected areas. under IUCN categories (i.e. Category V: *Protected Landscape/Seascape: Protected area managed mainly for landscape/seascape conservation and recreation*).

Guidelines:

✓ **Environmental Impact Assessments (EIA) should be carried out for proper site and production system selection, in order to detect any possible effect on the ecosystem.** Hydrodynamic and ecological studies should be conducted as part of the selection process, as well as access to industrial infrastructure such as roads, airports, and reliable electrical power.

✓ **Environmental parameters focus on water resources** (typically surface water or groundwater) **to supply aquaculture operations as well as water discharge**. Surface water and groundwater sources for incoming water should be analyzed for water quality and for chemistry parameters appropriate for the culture species. Sampling should be conducted periodically over a year's time to evaluate seasonal fluctuations that can affect both quality and quantity. Historical data should be obtained going further back in time to determine impacts from droughts.

Table 1 shows some examples of major water-quality parameters that should periodically be analized, and their optimum values.

Table 1. Optimum values for major water-quality parameters.

Parameter	Optimum Concentration	Frequency of Monitoring
Dissolved oxygen	> 4.0 mg/l	Twice daily in ponds
pH	6.5-8.5	Twice weekly in ponds
Alkalinity	Minimum of 50 mg/l, 100-400 mg/l preferred	Several times a year in ponds
Hardness	Same as alkalinity	Same as alkalinity
Ammonia (NH_3)	< 0.15 mg/l	Twice weekly in ponds
Nitrate (NO_3)	< 50 mg/l	Once daily
Nitrite (NO_2)	< 0.5 mg/l in low-chloride water	Weekly in ponds
Hydrogen sulfide	< 0.15 mg/l	Upon initial use and periodically throughout season

- ✓ **Topography has a significant effect on surface water, directly impacting runoff and drainage patterns.** If a facility is downhill or downstream from agricultural or industrial activities, they may become an intermittent source of water contamination from fertilizers, manure, pesticides, or other chemicals.

- ✓ **Specific to pond site selection is slope, soil composition, and depth.** Ponds are designed to hold water, so unless expensive liners will be utilized, soil clay composition should be a minimum of 20 percent to ensure water retention. In addition, soil quality such as pH and organic matter concentrations are important. Ideally, soils with a pH of 6-8.5 are best, requiring minimal treatment. Soils with high organic matter should be avoided because they can create high oxygen demand and release toxic nitrogen compounds.

  Good aquaculture practices in pond design provide for adequate levee height and width to accommodate required production and harvest equipment. Ponds should have adequate depth to maintain seasonal water-quality parameters and thermal stability while minimizing seasonal stratification from a minimum of about 70 cm on the shallow end to a maximum of 2 m at the deep end. Pond levee slopes of at least three to one (30 cm wide for every 10 cm in elevation) are recommended to reduce wind-induced erosion and facilitate harvesting. Ponds should have adequate levee height to absorb documented heavy rain episodes. For surface water locations, intake structures should be upstream of facility outflow. In addition, discharge waters should go through a detention (i.e. decanting) pond to precipitate settleable solids, reduce nutrient concentrations, and improve other water-quality parameters prior to leaving the farm site.

- ✓ **It should be paid attention to the attraction of local fauna by the aquaculture structures as part of the management principles.** The hydrologycal stability of fish farming ponds promotes a massive development of microalgae that efficiently assimilates excess of organic matter in the water, particularly nitrogen and phosphorous produced as waste (i.e. fecal contamination), avoiding harmful algal blooms. Microalgae, as well as sediment-linked algae and bacteria taking part in decomposition, are predated by a varied aquatic microfauna composed of worms, insects, crustaceans and small fishes that ultimately may constitute a natural component of the diet of cultivated fishes, having positive effects on enhancing local productivity.

Omnivorous fishes (i.e. mullets) and other aquatic organisms (i.e. shrimps) entering the aquaculture facilities from wild stocks, and filter-feeding birds that may favour fish ponds as feeding grounds, indirectly help nutrient recycling in the water and makes these systems much more efficient than conventional aquaculture (i.e. offshore cages).

Larval, fingerlings and juveniles of mullets enter regularly these operations from close rivers (using the irrigation / drainage canals) and grow-out in the extensive ponds. Shrimp can close its natural cycle in the water of fish ponds, with several breeding peaks along a normal year (there are some larval recruitment coming from the estuary every year in early spring) under mild Mediterranean climate conditions.

- ✓ **It should be take into consideration that a huge environmental success usually comes at an economic cost.** Extensive aquaculture activity into (or close to) protected wetland areas usually cause a formidable increase not only of relevant bird species populations, but also of those others whose overload can spoil the viability of the production system itself. Thus, the attraction of predators should be properly managed. The feeding of wild fauna on aquaculture fish stocks, or any other food, is not desirable and can lead to problems. All measures should be taken to avoid the appearance of such phenomena. This includes scaring techniques and not letting feeds or carcasses outside of closed containers.

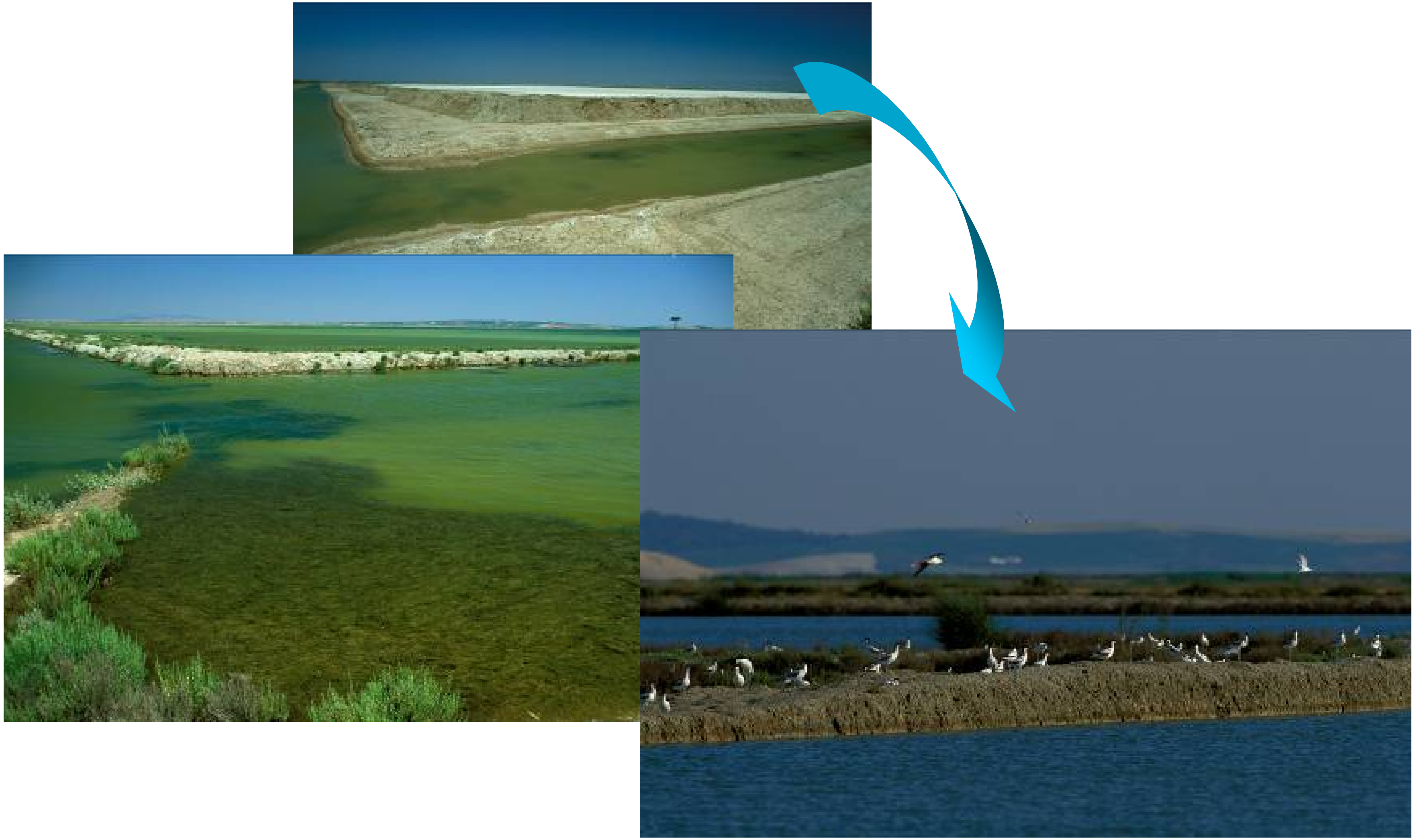
  However, local administrators can balance the above-mentioned situation with economic reparations. According to Council of Europe´s Regulation 1198/2006, every effort made to develop production methods that enhance the environment should be compensated in order to guarantee its economic feasibility.

- ✓ **The density of reared fish stocks (i.e. the number of fish per volume of water in one pond) should be optimized** in orther to avoid negative effects on the bottom communities and local flora and fauna. The concept of carrying / holding capacity is key to this issue. Extensive and integrated multi-trophic aquaculture (IMTA) systems should adjust their production (including the density of farmed fish) to the carrying capacity of the local environment. Production should be low in these operations, with culture density under 4 kg/m^3.

- ✓ **Extensive and integrated multi-trophic aquaculture (IMTA) systems frecuently become true ecological and functional mosaics,** where intervention destined to flood formerly dried up wetlands for aquaculture purposes should preserve the surrounding areas for other sustainable land uses (e.g. livestock grazing).

  Extensive areas of shallow lagoons for fish rearing should be equiped with islands and walls to serve as bird sanctuaries and nesting sites for waterfowls, and it is advisable to undergo extensive revegetation along pond shores and embankments.

  Islands and walls should be designed with irregular shapes and generally smooth slopes. Each island may presents a central area covered by marshland shrub vegetation (i.e. the *almajo Arthrocnemum macrostachyum* with seablite *Suaeda* sp.), bordered by emergent macrophytes such as common reed (*Phragmites australis*) and cattail (*Typha sp.*). Islands can be less than 1.5 m high and may be built using the sediment removed from the ponds during periodical maintenance operations. In usual conditions, a rich carpet of halophytes and marshland shrubs, offering a new and heterogeneous habitat to aquatic birds, rapidly covers new islands.



3. Feeding practices

The quantity of feed required in the conventional aquaculture systems is, in general, two or three times the volume of the output produced. For the manufacturing of these feeds, large volumes of natural raw materials are needed, and wild fish stocks are depleted in order to provide feed for carnivorous domesticates.

Hydraulic management in **Extensive fish farming systems** and **integrated multi-trophic aquaculture systems (IMTA)** is based on a continuous and controlled flow rate that allow to constantly renew the water of the ponds. This benefits farmed species, generating a large quantity of natural resources from the water of close rivers and estuaries, enhanced by the Mediterranean sun and the nutrient-rich soils of all coastal areas in the region. Fish can be fed with natural nutrients consisting of shrimps, zooplancton, microalgae, etc. At certain times of the year, it can be necessary to use an artificial feed supplement.

Principles:

- Extensive and multi-trophic fish ponds have a continuous flow of water rich in natural nutriments. Feeding management on these facilities may be based on a particular combination of natural feed (phytoplankton, zooplankton, crustaceous such as shrimps, small wild fishes, etc.) and specifically formulated feed supplement.

- A low culture density and a natural diet offering a rich source of active substances (e.g. antioxidants), minimize ecological stress along the grow-out period and increase fish resistance to diseases, ultimately reducing the risk of disease spreading to wild fishes.

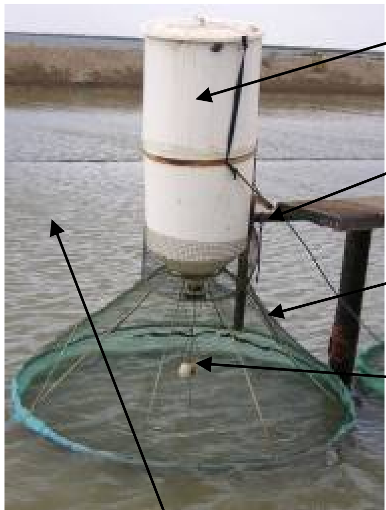
- The production of fish feed should be a sustainable activity. The sourcing of these raw materials should be environmentally accepatable, and should not have negative impacts on the ecosystems from which these ingredients are harvested.

Guidelines:

- ✓ **Extensive fish ponds and polyculture systems should have a continuous flow of water rich in natural nutriments** in which fish feed on shrimps and microorganisms naturally occuring in the water.

- ✓ **Feed management should be improved.** The way feed is delivered to the aquatic organisms is important, in order to optimise feed. Ponds can be equiped with self-demand feeders (see figure below) to provide the fish with the adequate feed supplement, always according to the requirements of the fish.

  Feeding multiple times per day, according to fish needs, enhances fish growth and allows for the nutrient wastes to be released more evenly throughout the day and be processed by the benefitial bacteria, rather than having pulses or spikes of nutrients from single or infrequent feedings



Feed should be utilized no more than three months of receipt to maintain feed quality and safety. Onsite, feed should be stored in a cool and dry environment, preferably in a building or enclosure that can also be kept clean and free of rodents and other pests. If moisture, mold, or rancidity are detected, the feed should be inmediately removed from the site and dispossed off properly.

- ✓ **Using good quality feed of the proper size and nutritional value (protein, vitamins, and minerals) for the size of fish being cultured is essential** to maximize growth, maintain a healthy immune system, and reduce feed waste and associate negative impacts on water quality.

- ✓ **Fish-feeding behavior should be carefully observed.** Good record keeping of feeding amounts will provide valuable information in order to reduce feed waste and provide insights on fish health.

- ✓ **Feed should always come from reputable feed suppliers.** Feed production technologies and feed quality and safety (e.g. free of GMOs –) should be improved. New fabrication technologies should be promoted to improve the quality of the feeds, and therefore their efficiency. Certificates of compliance of feed manufacturer should be provided, informing on the good origin of raw material (free of genetically modified organisms - GMOs -, antibiotics, etc.). In addition, local analyses plans for the monitoring and control of animal feed to guarantee the absence of forbidden or undesirable substances (for example, dioxins), should be performed on an annual basis, in the framework of European, regional and local prevailing regulations.

- ✓ The use of low-trophic level species (e.g. from the trophic web promoted in the fish ponds by careful hydraulic management, or from raw materials cultured for this purpose sucha as algae, worms, or molluscs) should be promoted as a **source of alternative ingredients** in order to reduce the percentage of fish meal and fish oil (main source of animal protein for fish feed elaboration), and increase ecological efficiency.

4. Cleaning and sanitation basics

Extensive fish ponds and polyculture systems behave like huge water treatment plants, where the excess of nutrients (nitrogen, phosphorus, etc.) and organic matter of biological origin, is removed from the water and transformed into living biomass by means of natural processes. This biomass is finally extracted from the system via commercial fishing and predation by birds.

In water, inorganic nitrogen is present in several forms: ammonia, nitrite and nitrate. All these forms are biochemically convertible, according to the oxidation and reduction state of the water and the activity of organisms - mainly bacteria and cyanobacteria - that are capable of fixing nitrogen from the air into a form available to the remainder of the biota. Ionized ammonium (NH_4^+) and ammonia (NH_3) are usually found in equilibrium in water. The equilibrium is governed by pH; above pH 9.5, ammonia may be predominant and, in concentration among 0.1 – 0.2 mg/l it may be toxic for aquatic organisms. When an aquatic plant or animal dies, or an animal excretes, the initial form of nitrogen is organic. Then bacteria (or in some cases, fungi) convert the organic nitrogen into ammonia (ammonification).

In extensive and polyculture fish ponds, where pH is usually under 9.5, ammonium is present mainly in the ionized form and in concentration rarely above 0.1 mg/l. In this extensive and shallow water sheet, ammonia is chemical and biologically converted to nitrate. The primary stage of nitrification is the oxidation of ammonia to nitrite (NO_2^-), an intermediate form of nitrogen which accumulation (continuous values above 0.5 mg/l) is toxic for life. The second stage is the oxidation of the nitrites into nitrate (NO_3^-), an essential nutrient for photosynthesis that is assimilated by the aquatic plants and algae. Recorded nitrite values in the ponds are always under 0.2 mg/l, explaining to a large extent that water flow management in the fish farm allows a total performance of nitrification process.

Phosphorus is the primary nutrient limiting biological productivity in any aquatic system. The cycling of phosphorus is complex in the aquaculture ponds, with the majority being bound up in the particulate phase as living biota (i.e. algae and bacteria). Labile compounds are excreted by the algae and bacteria. The compounds, algae, and bacteria combine with each other to form a snot-like (colloidal) material. Most of this colloidal material is lost from the productive zone by sedimentation in the bottom of the ponds, leaving a minimum portion in the form of soluble orthophosphate (PO_4^{3-}). Orthophosphate is quickly assimilated by algae and macrophytes living in the water and covering pond banks and channels, so final concentration of this phosphorous form usually remain in almost untraceable levels (0.01 - 0.34 mg/l). In addition, the huge ecological productivity of fishing ponds and particularly the high renovation rate of phytoplankton, help to maintain soluble orthophosphate concentration at a very low level.

Principles:

- The hydrologic system operating in extensive and multi-trophic fish farms contributes to maintain oxygenation and water quality, and to avoid eutrophization caused by the increase in the amount of nitrogen and phosphorous compounds. In addition, the strength of nitrogen and phosphorus cycles in this aquatic systems allows to effectively control the amounts of nutrients in water, particularly phosphorous, that are applied to surrounding agricultural lands as fertilizers and are finally carried into estuary water with run off.
- It can be considered that these sustainable aquaculture systems run a natural lagoon technology for water purification that assures the improvement of intake water quality. Water taken daily from close rivers or estuaries returns to them with an improved microbiological, physical and chemical quality.
- These managed wetland behaves as a sanitary shelter, with an optimum environmental quality, against possible epidemic outbreaks.

Guidelines:

- ✓ **After finishing a culture cycle, each fish pond should be totally dried up (see image below) and the sediment in excess removed from the vessel.** This operation should usually be undertaken at the beginning of summer, once every 4 or 5 years, rotating over all existing ponds of the facility, so that the organic content of soil including bacterial spores mineralize via photoxidation.

In the Mediterranean region, marked seasonal variations in water level and the effect of severe droughts that periodically occur in the area, combined with high summer temperatures and increase of salt content in the water during that season, frequently produce strong oxygen depletions in stagnant waters that can trigger epidemic outbreaks of *Clostridium* or *Salmonella*, eventually leading to wild fauna (e.g. bird) death. For example, occurrence of avian botulism outbreaks has been reported in Doñana in different occasions along recent past, causing die-off of some 30,000 birds in 1986.

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- ✓ **If possible, the whole fish farm extension including ponds and irrigation / drainage canals, should be flooded or dried up in a maximum of 48 hours**, maintaining the system in optimal sanitary conditions. This is essential for fish farming operations and for achieving a complete ecological integration with the surroundings landscape.

- ✓ **It should be encouraged to perform regular monitoring of water quality at the fish farm, both at request of the fish farm** (se below) **or by order of local Administrations through authorized agencies**.

- ✓ Apart from the parameters considewred in Table 1, **it should be paid attention to the concentration of photosynthetic pigments** as an indicator of biological activity: Chlorophyll A (mg/m^3) and A_{446}/A_{660} ratio (relation carotenes / chlorophyll).

- ✓ **It is important (particularly during nights) to monitor dissolved oxygen concentration in the water** (for example, using portable oxygen analyzers). During late spring and early summer in most of the Mediterranean region, the sudden rise of temperature in the water and the exponencial increase of phytoplankton, usually promote oxygen depletion along the night with a minimum value just before the daybreak. Oxygen depletions can be extremely harmful not only for cultured fish, but also for the wild fish fauna that is attracted to fish ponds.

- ✓ Finally, **good aquaculture sanitary procedures include animal and pest control involving exclusion, control, and eradication measures where appropriate.** In extensive ponds and integrated multi-trophic aquaculture (IMTA), the most significant animal vectors are some species of birds (e.g. Greater cormorant *Phalacrocorax carbo*) and rats.

  For bird control, a combination of scare tactics and other non-lethal techniques are often the most effective. As regards terrestrial animals, particularly rat control, usually perimeter traps close to habitat.may be effective.

In case of fish or water contaminated:

A Food Emergengy Response Plan should be implemented. if any member of the farm´s staff is informed by the Government (or its approved laboratories) about the existence of a contamination problem that may affect the health or commercial quality of a product, the Quality Manager should collect the necessary information to identify what has happened. This information should include:

- Name of product (species).
- Affected pond/es number and its/their size.
- History of the culture cycle of such species (traceability, survival rate at the end of grow-out period, pathological conditions, other incidents along the cycle, etc.).
- Amount, date, and customers to whom the product has been distributed.
- Analyses performed on fish or feed of affected pond, and on water.

Once the incident has been identified, a Crisis Committee should be activated for its complete management, that would include the analysis of nature incident, eventual isolation of the affected culture unit, application of corrective measures (water treatment, etc.), and reporting to external partners (customers, distributors, etc.).

5. Facility biosecurity (escapes)

Sustainable aquaculture systems should be designed to effectively contain organisms and minimise the possibility of escape[7]. The design of aquaculture facilities should consider the need to prevent escapes, not only because of the economic loss that these mean for the producers, but also for environmental reasons.

Principles:

- Although it has been claimed that domestication of species for aquaculture is necessary, because the interaction of these organisms with their wild counterparts should not have negative effects, it should be encouraged to work with native species naturally living in the neighbouring rivers.
- Mediterranean coastal wetlands suffer strong fluctuations in salt content, temperatures, etc. Since the conditions at the extensive and polyculture fish farms located in the nearby are quite similar to those existing in the wild wetland area, farming native species will ensure that the fish will be genetically well adapted to such fluctuations. Consequently, working with such species will ensure the success of the culture. Additionally, the aim of these aquaculture systems should be to achieve an absolute respect with conservation objectives, excluding any aquaculture model based on alien species.

[7] http://www.aquamedia.org/FileLibrary/10/IUCN_book_web.pdf

Guidelines:

- ✓ **Extensive ponds and, particularly, integrated multi-trophic aquaculture systems (IMTA) should rely on domesticated species or wild species native from the area surrounding the facility**. Thus, the potential impact on the wild ecosystem of fish escapes could be minimised.

- ✓ In these aquaculture operations where water is continuously renewed in order to maintain it in excellent physical, chemical and biological conditions, **the different compartments of the facility should be equipped with physical barriers** to reduce the possibility of accidental escapes.

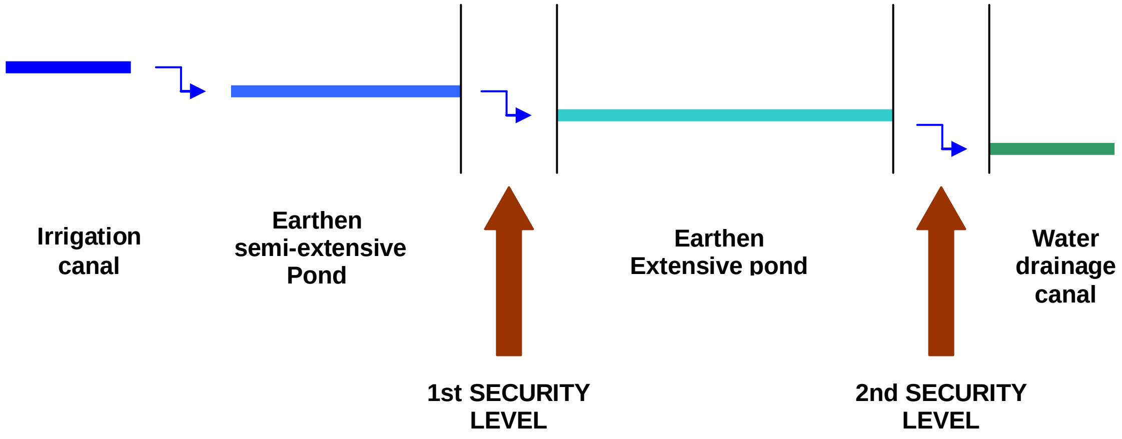
  The valves placed at the exit of semi-extensive ponds should be provided with curved filtering grids, wich mesh size varies depending on the size of the fish that growith within the unit. Such grids prevent fish escape from the semi-extensive culture system into the extensive ponds. Additionally, the floodgates placed at the entrance to the extensive ponds should be equipped with filtering / collecting devices that act as a second security mechanism to avoid any accidental arrival of escaped fishes into the ponds (see images below).

  Similarly, the valves placed at the exit of the extensive ponds and at the entrance to the water-drainage channels are provided with filtering grids and filtering / collecting devices.

Exit flow valve

Exit flow valve

The combination of filtering grids and filtering / collecting devices placed between the irrigation channels, semi-extensive earthern units and extensive earthern ponds, constitute two main security levels in the active prevention of fish escape from extensive and polyculture aquaculture operations.



A third security level consisting of a filtering grid should also be placed in the communication between main water-drainage canal and the river, further minimizing the possibility of any accidental escape from the facility into the river.

- ✓ **Contingency plans should be set up for the eventuality of escapes**. Domesticated organisms do not tend to disperse quickly after escaping. For this reason, there is a period of time in which the recapture of the organisms is feasible, and after which this task becomes almost impossible. In order to take action as soon as an escape takes place, detailed contingency plans must exist and personnel must be properly trained. Research on surveillance of escaped organisms should be encouraged.

- ✓ **More knowledge is needed concerning the quantitative and qualitative effects of escapes on local populations**[8]. Also, because the escape of cultured organisms has an important cumulative effect, producers should report to the competent authorities the occurrence of such escapes in order to better understand their effects.

[8] http://www.aquamedia.org/FileLibrary/10/IUCN_book_web.pdf

Conclusions

Extensive fish farming systems and **integrated multi-trophic aquaculture systems (IMTA)** managed as it was described in this guide, may effectively become much more than fish farm. This fish production operations may be managed to restore the damage produced in original wetland areas by former land-uses, minimizing its own ecological footprint and combining the economic benefits of aquaculture with objectives in conservation.

However, the benefits that sustainable practices on extensive aquaculture and polyculture systems provide to wetlands, and the role of these activities on ecosystem rerstoration, are only known at a local scale and are not conveniently widespread all over the Mediterranean area.

The case study of Doñana in SW Spain, studied by RAC/SPA with the help of external consultation, constitutes an excellent example of the guiding principles that could be applied to other coastal wetlands in the Mediterranean region, where aquaculture could effectively support a number of environmental services for the hydrology and ecology of many disturbed coastal areas, restoring the damage produced in the original landscape by land misuses, minimizing its own ecological footprint and combining the economic benefits of aquaculture with objectives in conservation.

This kind of management has become an integral part of Doñana ecosystem and plays a fundamental role as buffer for the whole area, providing food and water for thousands of birds during moulting time, breeding season and post-breeding annual migration, as well as during particularly dry interannual periods[9]. Wintering ground for visiting northern birds (e.g. 70,000 greylag geese) and nesting sanctuary for spring-migrating species from Africa (e.g. 500 purple herons), Doñana aquaculture area has become the lungs, larder and hospital for European aquatic birds. From some 30,000 birds recorded in 1984[10], population has exponentially

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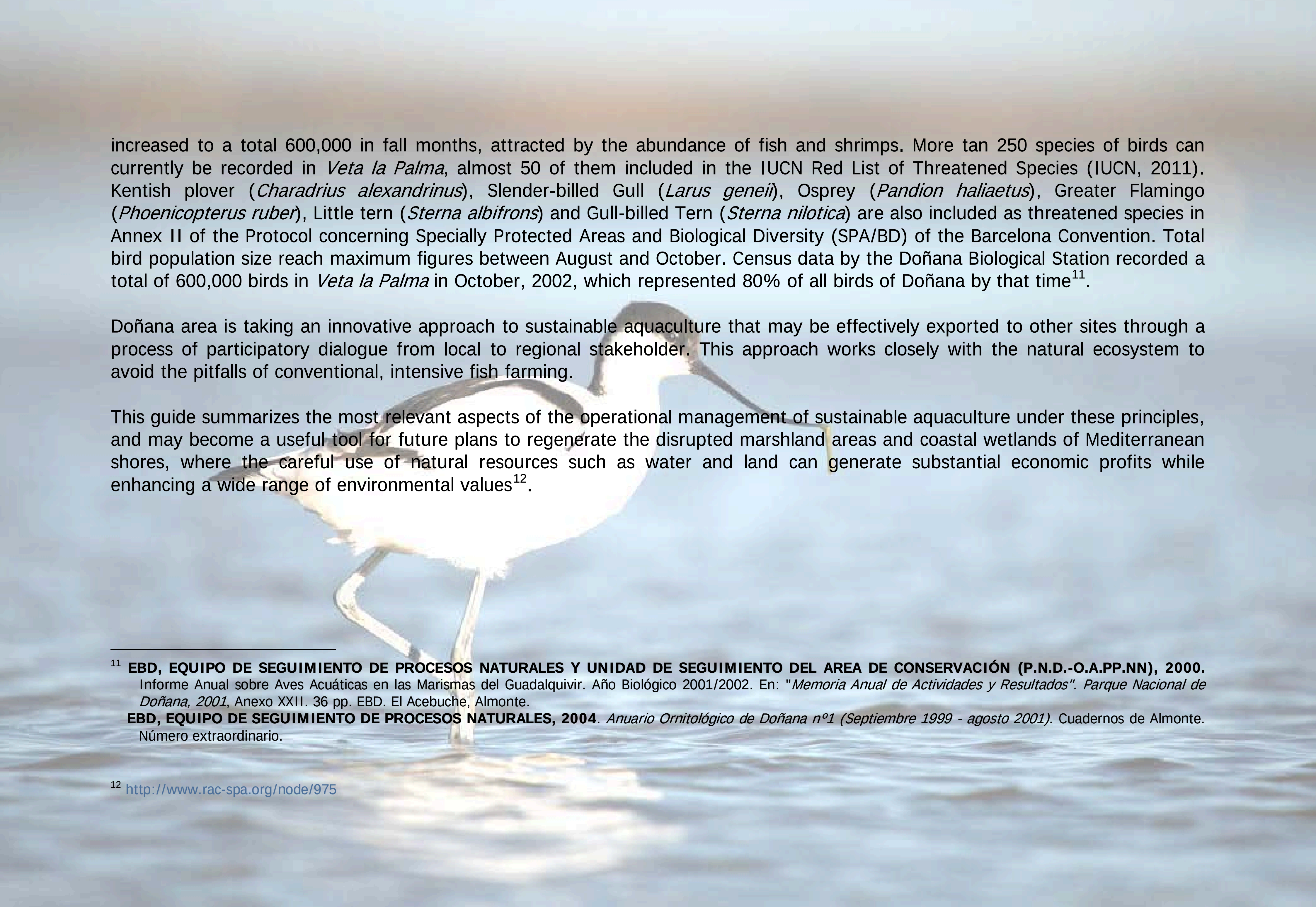
[9] **Quirós Herruzo, F. and Maneiro Márquez, M.A. 1996.** *Estudio Ornitológico de la finca Veta la Palma, T.M. de Puebla del Río (Sevilla).* Monografía encargada por el Parque Natural del Entorno de Doñana.

[10] **Fernández-Cruz, M.; Martín-Novella, C.; Fernández, G.; González, E. and París, M. 1989.** Informe sobre la evolución e importancia de las poblaciones de aves de los antiguos lucios reinundados del sur de Isla Mayor (Sevilla). En *Modificaciones y Actividades Complementarias al Proyecto de Acuicultura Extensiva en la finca Veta la Palma, Pesquerías Isla Mayor, S.A.*



increased to a total 600,000 in fall months, attracted by the abundance of fish and shrimps. More tan 250 species of birds can currently be recorded in *Veta la Palma*, almost 50 of them included in the IUCN Red List of Threatened Species (IUCN, 2011). Kentish plover (*Charadrius alexandrinus*), Slender-billed Gull (*Larus geneii*), Osprey (*Pandion haliaetus*), Greater Flamingo (*Phoenicopterus ruber*), Little tern (*Sterna albifrons*) and Gull-billed Tern (*Sterna nilotica*) are also included as threatened species in Annex II of the Protocol concerning Specially Protected Areas and Biological Diversity (SPA/BD) of the Barcelona Convention. Total bird population size reach maximum figures between August and October. Census data by the Doñana Biological Station recorded a total of 600,000 birds in *Veta la Palma* in October, 2002, which represented 80% of all birds of Doñana by that time[11].

Doñana area is taking an innovative approach to sustainable aquaculture that may be effectively exported to other sites through a process of participatory dialogue from local to regional stakeholder. This approach works closely with the natural ecosystem to avoid the pitfalls of conventional, intensive fish farming.

This guide summarizes the most relevant aspects of the operational management of sustainable aquaculture under these principles, and may become a useful tool for future plans to regenerate the disrupted marshland areas and coastal wetlands of Mediterranean shores, where the careful use of natural resources such as water and land can generate substantial economic profits while enhancing a wide range of environmental values[12].

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[11] **EBD, EQUIPO DE SEGUIMIENTO DE PROCESOS NATURALES Y UNIDAD DE SEGUIMIENTO DEL AREA DE CONSERVACIÓN (P.N.D.-O.A.PP.NN), 2000.** Informe Anual sobre Aves Acuáticas en las Marismas del Guadalquivir. Año Biológico 2001/2002. En: "*Memoria Anual de Actividades y Resultados". Parque Nacional de Doñana, 2001*, Anexo XXII. 36 pp. EBD. El Acebuche, Almonte.
EBD, EQUIPO DE SEGUIMIENTO DE PROCESOS NATURALES, 2004. *Anuario Ornitológico de Doñana nº1 (Septiembre 1999 - agosto 2001)*. Cuadernos de Almonte. Número extraordinario.

[12] http://www.rac-spa.org/node/975