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Changes in demersal wild fish aggregations beneath a sea-cage fish farm after the cessation of farming

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ABSTRACT

Demersal, non-cryptic, wild fish were counted in replicate 100 m^2 transects beneath a floating sea-cage fish farm and two nearby sandy locations at Gran Canaria (Canary Islands, eastern Atlantic) four times before and after the cessation of farming. Cessation of farming involved the removal of farmed fish and ceasing of the daily feeding, although farm structures (cages and moorings) remained. A "beyond-BACI" sampling design provided the framework to detect the effect of the cessation of farming, which produced qualitative and quantitative changes in the composition and structure of the fish assemblages beneath the sea-cage fish farm compared with two nearby controls. The aggregative effect on wild fish due to the existence of the farm decreased from approximately 50 times compared to nearby controls when the farm was in full operation to <2 times when only the farm structures remained. Abundances of POM feeders (large-sized mugilids), large benthic chondrichthyid rays and *Pagellus* spp. declined markedly at the fish farm after the cessation of farming, suggesting that the removal of daily feeding was responsible for their disappearance. In contrast, abundances of herbivores, benthic macro- and meso-carnivores were similar beneath the fish farm both before and after the cessation of farming. Benthic macro-carnivores, however, were more abundant beneath the sea-cages compared to control locations, supporting the hypothesis that the increase in the physical structure beneath farms plays a role in aggregating these species. Sparids occurred beneath the sea-cages only after the cessation of farming, while the two natural control locations did not show differences from before to after the cessation of farming. Overall, the results show that the wild fish assemblage beneath the farm partially changed after the cessation of farming to a more natural state, approaching the assemblages observed at the control sites.

Key words: wild fish; aquaculture; impact; recovery; fish farm; Canary Islands.

INTRODUCTION

Since initial development of sea-cage aquaculture in the early 1980s, the number of sea-cage fish farms has increased rapidly throughout coastal areas of the world (Ferlin & LaCroix, 2000) to produce almost 2.5 million tons of fish each year (FAO, 2003). The environmental impacts of operating sea-cage fish farms are well described and include impacts on biogeochemical processes, seagrasses and benthic communities, and transfer of antibiotics to the environment (Iwama, 1991; Rönenberg *et al*., 1992; Ruiz *et al*., 2001). Numerous studies have also described the recovery of benthic habitats after the cessation of farming (e.g. Karakassis *et al*., 1999; Brooks *et al*., 2004); however, in comparison, no study has investigated the effects of the cessation of farming on aggregations of wild fish closely associated with farms. While operating, fish farms dramatically increase the presence, abundance and biomass of wild demersal and pelagic fish in their immediate vicinity compared to control nearby areas (Carss, 1990; Dempster *et al*., 2002; Boyra *et al*., 2004; Dempster *et al*., 2004; Dempster *et al*., 2005; Tuya *et al*., 2005).

The persistent artificial input of food and possible chemical attraction due to the presence of typically 100s of tons of farmed fish may influence which species of wild fish associate with farms (Dempster *et al*., 2002). These factors, in addition to the enhanced habitat complexity or 'artificial reef' effect, have been considered as responsible for the increase in demersal wild fish abundances relative to nearby sandy bottoms (Boyra *et al*., 2004; Tuya *et al*., 2005) with an overall effect size of 1 to 2 orders of magnitude. However, no study has empirically assessed the relative importance of each of these factors involved in the attraction of different fish species around coastal aquaculture installations. In this context, we took advantage of the cessation of farming at a sea-cage fish farm at Gran Canaria (Canary Islands, eastern Atlantic Ocean) where the entire farm infrastructure was left intact. This allowed us to separate the attractive effect caused by the persistent artificial food input and the chemical attraction due to the presence of farmed fish, from the attractive effect caused by the increased structural complexity of the habitat, which has been shown to play a major role in structuring fish assemblages on shallow soft bottoms at temperate latitudes (Guidetti, 2000; Guidetti & Bussotti, 2002; Tuya *et al*., 2005). Boyra *et al*. (2004) demonstrated that this fish farm caused local aggregation of wild coastal fish through a "post-impact" sampling design (*sensu* Glasby, 1997), with differences in the abundances of some species compared to nearby sandy locations (controls).

We aimed to detect changes in the composition and abundance of sub-adult and adult demersal wild fish assemblages associated with a sea-cage fish farm 'before' and 'after' the cessation of farming, by establishing the temporal and spatial persistence of the differences between the 'impacted' location (the fish farm) and two nearby sandy locations as controls, following the appropriate criteria of a "beyond-BACI" design (*sensu* Underwood, 1992, 1993, 1994). More specifically, we hypothesized that (1) fish assemblages beneath the sea-cage fish farm would differ significantly before and after farming ended compared with control locations; whereas (2) assemblages at control locations before and after farming ended would be relatively consistent through time.

MATERIALS AND METHODS

AREA OF STUDY AND EXPERIMENTAL DESIGN

The study was conducted around the 'Arguineguín' farm located 300 m off the southern coast of Gran Canaria (Canary Islands, 28ºN, eastern Atlantic, Fig. 1) in 9 to 11 m of water (Boyra *et al*., 2004). The farm cultured both gilthead sea bream (*Sparus aurata* Linnaeus, 1758) and European seabass (*Dicentrarchus labrax* Linnaeus, 1758) and operated from June 1993 to June 2003, when the aquaculture company went bankrupt. The farm complex comprised 12 cages and produced an average of more than 180 t yr^{-1}. The entire farm infrastructure, including the majority of sea-cages and all mooring devices, was left untouched after farming ceased. The cages were situated above a sandy bottom covered by sparse patches of the seagrass *Cymodocea nodosa* Ucria (Ascherson) and the green algae *Caulerpa* spp. The cessation of farming in June 2003 was considered as the 'impact', which consisted of the removal of all farmed fish and termination of the daily input of food pellets. As a result, the term 'impact' used in this paper differs to the classical 'disturbance' concept, as it describes a reduction of a human-induced perturbation of the marine environment.

Selection of impact and control locations and sites within locations followed an asymmetrical "beyond BACI" sampling design. The mechanisms and the logical structure of these analyses, as well as the potential to detect both temporal and spatial disturbances, have been widely discussed and demonstrated (Underwood, 1991, 1992, 1993, 1994; Kingsford & Battershill, 1998). Lack of nearby sea-cage fish farms prevented the use of a more 'formal' set of controls, where farming should have been monitored through time. We therefore were able to solely select nearby soft bottoms as control locations; two controls (nearby sandy locations located between 600-1000 m away from the sea-cage fish farm) and one impact location (the sea-cage farm) were thus established. To increase the spatial replication, we randomly sampled two sites within each of these locations approximately 40 to 80 m apart. Temporal replication was included before and after the impact by randomly selecting 4 sampling times 2 years before (from May 2000 until June 2001), and 4 times 2 years after (from April 2005 to May 2005) the impact. As a result, our asymmetrical design involved sampling two control and one perturbed location before and after the cessation of farming at several nested temporal and spatial scales.

ESTIMATION OF FISH ASSEMBLAGES AND ECOLOGICAL FISH CATEGORIES

Sub-adult and adult demersal, non-cryptic, fish populations (> 5 cm total length) were sampled by visual counts (Boyra *et al*., 2004; Tuya *et al*., 2005). At each sampling time, four replicate 100 m^2 transects were randomly censused during daylight hours at each site within each location. Consequently, a total of 192 transects were made throughout the study. The abundance of fish species was recorded by a SCUBA diver using a modification of the method of Harmelin-Vivien *et al*. (1985). Therefore, when fishes were grouped in schools larger than 20 individuals, their numbers were estimated according to six abundance classes (20-40, 40-70, 70-150, 150-300, 300-700, >700).

Groups of fishes with similar ecological requirements were aggregated into six categories (*sensu* Guidetti *et al*., 2003), defined on the basis of their feeding behaviour and spatial organization around the farm: (1) POM feeders: particulate organic matter feeders (large-sized fish within the family Mugilidae); (2) SPA: meso- and macrocarnivorous sparids (the genera *Diplodus* and *Pagrus*, *Lithognathus mormyrus*, *Spondyliosoma cantharus* Linnaeus, 1758, and *Oblada melanura* Linnaeus, 1758) – this group did not include *Sparus aurata*; (3) HERB: herbivorous fish (*Sarpa salpa* Linnaeus, 1758, and *Sparisoma cretense* Linnaeus, 1758); (4) BENMESO: bentho-demersal meso-carnivores usually found as solitary individuals (*Bothus podas*

Delaroche, 1809, *Canthigaster rostrata* Bloch, 1786, *Chelidonichthys lastoviza* Bonnaterre, 1788, *Mullus surmuletus* Linnaeus, 1758, *Sphoeroides marmoratus* Lowe, 1838, *Xyrichthys novacula* Linnaeus, 1758); (5) BENMACRO: bentho-demersal macro-carnivores usually found as solitary individuals (the genera *Synodus* and *Trachinus*); (6) RAYS: large-sized benthic chondrichthyes (*Dasyatis* spp., *Gymnura altavela* Linnaeus, 1758, *Myliobatis aquila* Linnaeus, 1758, *Squatina squatina* Linnaeus, 1758, *Taenuria grabata* Linnaeus, 1758). In addition, *Pagellus* spp. was analysed individually, as it was the most important taxa contributing to differences between controls and the sea-cage fish farm in the previous "post-impact" study (Boyra *et al*., 2004). We also analysed individually the gilthead sea bream *Sparus aurata*, since observed specimens probably escaped from the cages. Occasional species (observed in less that 3% of the counts) and pelagic schooling species with high spatial and temporal patchiness (e.g. *Sardina* spp., *Boop boops* Linnaeus, 1758) were not included in the analysis.

MULTIVARIATE STATISTICAL ANALYSIS

To visualize the extent of differences among assemblages before and after the impact and among the farm and control locations, non-metric multidimensional scaling (MDS) was selected as an ordination technique to generate a two-dimensional plot using the PRIMER statistical package (Clarke, 1993). Prior to calculating the similarity matrix, the data were pooled by summing the 4 counts at each site within each location and sampling time. Data were then fourth root transformed to weight the contributions of common and rare species in the similarity coefficient, and a triangular similarity matrix was calculated using the Bray-Curtis similarity coefficient (Clarke, 1993; Clarke & Warwick, 1994). Average dissimilarities between the fish farm and the two controls were calculated by means of the SIMPER procedure (Clarke, 1993) before and after the cessation of farming. A two-way crossed ANOSIM (Clarke, 1993) was used to examine the significance of the differences on the overall fish dataset among the three locations before and after the cessation of farming.

UNIVARIATE STATISTICAL ANALYSIS

Following the criteria appropriate for "beyond-BACI" designs, four–way asymmetrical ANOVA models were used to compare mean abundances of each fish category between the two periods ("before" and "after"), among times within each period, among the three locations (including "impact vs. controls" and "between controls") and between sites within locations (Underwood, 1993, 1994, 1997). First, we analysed all data as though there were no asymmetries. Second, we re-analysed the data while omitting the perturbed location. The asymmetrical components were further calculated by subtractions and additions of components. The "impact vs. controls" term was considered fixed, while the term "between controls" was random. Sites were randomly nested within locations. The two analyses were carried out as a fully orthogonal design of "before vs. after", "locations" and its nested "sites", and "times" within "before" or "after". The interpretation of statistical interactions following Underwood's indications (Underwood, 1993, 1994, 1997) was used to assess the effect of the considered experimental factors. Prior to ANOVA, Cochran's test was used to test for heterogeneity of variances. In all cases, data was transformed to ln (x + 1) to achieve homogeneity of variances.

RESULTS

A total of 15204 fishes comprising 15 families and 23 fish taxa were recorded for the studied sea-cage fish farm and the two adjacent natural control locations throughout the study (Table I). Demersal fish were 45 – 52 times more abundant beneath the farm compared with the two nearby control locations during the period when the farm was in full operation. In contrast, abundances of fish were only 1.6 – 1.8 times higher beneath the farm than the controls after farming ceased. *Pagellus* spp. (n = 11308 fish) and POM feeders within the Mugilidae family (n = 1164) were the most abundant taxa at the sea-cage fish farm before the cessation of farming, while *Synodus* spp. (n = 82) and *Trachinus draco* Linnaeus, 1758 (n = 46) within the macro-carnivores were the most abundant species after the cessation of farming. The sparids *Spondyliosoma cantharus* (n = 343) and *Diplodus annularis* Linnaeus, 1758 (n = 336) dominated in terms of abundance in the two controls before and after the cessation of farming. Table I lists the overall abundance of each fish taxa recorded at the sea-cage fish farm and the two controls before and after the cessation of farming.

MULTIVARIATE RESULTS

The two-dimensional MDS (Fig. 2) revealed a clear-cut separation of the sites beneath the fish farm throughout the four sampling times before the cessation of farming (left-side of the plot) from the sites within the two control locations throughout the four sampling times before and after the cessation of farming (right-side of the plot). ANOSIM permutational tests detected that these differences were significant ($P < 0.01$, Table II). Sites beneath the fish farm throughout the four sampling times after the cessation of farming lie in the middle of the two above-mentioned groups, indicating a 'transition' in the structure of the fish assemblage towards control locations. However, differences in the structure of the fish assemblages between the fish farm and the two controls were persistent after the cessation of farming, as indicated by pairwise comparisons using the ANOSIM permutational test ($P < 0.01$, Table II). This change in the structure of the demersal fish assemblage beneath the sea-cages of the fish farm can be appreciated when comparing the average dissimilarities between the fish farm and the two controls before and after the cessation of farming (Table II). For example, average dissimilarity between the fish farm and control 1 was reduced from 98.8 to 86.1%. It is worth noting, moreover, how sites within the two control locations are randomly spread throughout the right-side of the ordination space (Fig. 2), highlighting the broad natural variation in the structure of fish assemblages at the control locations before and after the considered 'impact'.

UNIVARIATE RESULTS

While the sea-cage fish farm was operating, abundances of the bentho-demersal meso and macro-carnivorous fish categories and *Pagellus* spp. varied between the two control locations [Figs. 3(d), 3(e) 3(g), Table III: "T(Bef) X C" was significant]. In the same period, significant differences were observed between the sea-cage fish farm and the average of the two controls for the mean abundances of the POM feeders, RAYS, *Pagellus* spp. and *Sparus aurata* [Figs. 3(a), 3(f), 3(g), 3(h), Table III: "T(Bef) X I" was significant]. Therefore, all of these taxa showed short-term temporal variability before the cessation of farming.

POM feeders, RAYS, and the gilt-head sea bream, *Sparus aurata*, were more abundant at the sea-cage fish farm before the cessation of farming compared to the two controls [Figs. 3(a), 3(f), 3(h)], and almost completely disappeared after the cessation of farming compared to controls [Figs. 3(a), 3(f), 3(h), Table III: "T(Bef) X I vs. T(Aft) X I" were significant, whereas "T(Bef) X C vs. T(Aft) X C" were non-significant]. Mean abundances of *Pagellus* spp. similarly decreased significantly after the cessation of farming at the sea-cage fish farm compared to controls [Fig. 3(g), Table III: "T(Bef) X I vs. T(Aft) X I" and "T(Bef) X I vs. T(Bef) X C" were significant, whereas "T(Bef) X C vs. T(Aft) X C" was non-significant"], although this species showed short-term temporal variability between controls before the cessation of farming (Table III, factor "T(Bef) X C" was significant). As a result, we detected significant decreases in the mean abundances of POM feeders, RAYS, *Sparus aurata*, and *Pagellus* spp. at the sea-cage fish farm after the cessation of farming, while no differences existed between before and after the cessation of farming at control locations for these taxa.

Short-term temporal variability for the sparids before the end of farming was negligible (Table III: "T(Bef) X C", "T(Bef) X I" were non-significant). Abundances of this group increased significantly after the cessation of farming at the sea-cage fish farm, with no before/after interactions between controls [Fig. 3(b), Table III: "B X I" was significant, while "B X C" was non-significant]. In fact, all sparids were observed at the sea-cage fish farm after the finalization of farming [Fig. 3(b), Table I], while control locations did not differ from before to after the cessation of farming (Table III: "T(Bef) X C vs. T(Aft) X C" was non-significant).

Temporal trends in the mean abundances of the herbivorous fish was similar among the three locations before the cessation of farming [Fig. 3(c), Table III: "T(Bef) X C" and "T(Bef) X I were non-significant], despite the observation of a large group of *Sarpa salpa* at the fourth sampling time [Fig. 3(c)]. Moreover, temporal trends in mean abundances of the herbivores did not differ significantly between the two controls, as well as between their average trends and that at the sea-cage fish farms from before to after the cessation of farming (Table III: "B X C" and "B X I" were non-significant). Consequently, no change was detected throughout the study for the mean abundances of the herbivorous group.

Control locations showed different trends in the mean abundances of the bentho-demersal meso and macro-carnivores from before to after the cessation of farming [Figs. 3(d), 3(e), Table III: “T(Bef) X C vs. T(Aft) X C” was significant]. For the bentho-demersal meso-carnivorous group, temporal variability, at both short and long-scales, was largely attributable to the observation of large groups of *Mullus surmuletus* in the first sampling time before the cessation of farming [Fig. 3(d)]. However, for both the bentho-demersal meso and macro-carnivores, we observed similar abundances at the sea-cage fish farm before and after the cessation of farming [Figs. 3(d), 3(e)], resulting in the lack of significance of all the potentially affected terms in the ANOVA (Table III: “T(Bef) X I”, “T(Bef) X I vs. T(Aft) X I”, “T(Bef) X I vs. T(Bef) X C”, “B X I vs. B X C” were non-significant”). We therefore did not register a significant change in the mean abundances of the meso and macro-carnivorous categories at the sea-cage fish farm throughout the study. However, mean abundances of the bentho-demersal macro-carnivores were larger at the sea-cage fish farm compared to the two controls over the entire study period [Fig. 3(e)].

DISCUSSION

The cessation of farming produced qualitative and quantitative changes in the composition and structure of the demersal, non-cryptic, wild fish assemblages beneath the sea-cage fish farm at Arguineguín (Gran Canaria Island) compared with nearby control locations under the influence of natural variability. The significant differences caused by the cessation of farming were clearly species or group-specific. The different taxa and ecological categories of wild fish considered by our study responded differentially to the finalization of farming. Abundances of POM feeders, RAYS, *Pagellus* spp. and *Sparus aurata* declined significantly, whereas fish within the HERB, The bentho-demersal meso and macro-carnivores were not significantly affected by the cessation of farming.

In terms of overall abundance of wild fish, the aggregative effect due to the existence of the farm decreased from approximately 50 times compared to nearby controls when the farm was in full operation to <2 times when only the farm structures remained. Therefore, the ‘daily feeding and presence of caged fish’ effect was far stronger than the added structure due to cages and moorings or ‘artificial reef’ effect in aggregating wild demersal fish at the farm. This result implies that aggregations of demersal wild fish may decrease markedly if levels of food loss and POM output to the environment from operating farms are reduced.

WILD FISH AFFECTED BY THE CESSATION OF FARMING AT THE FISH FARM

The attraction and increase in the abundances of demersal wild fish populations to soft bottoms beneath sea-cage fish farms in temperate latitudes seems to be mediated by the persistent artificial food input and the chemical attraction due to the presence of farmed fish, in addition to the increase in habitat complexity (Dempster *et al*., 2002; Boyra *et al*., 2004; Tuya *et al*., 2005). Apparently, the great attraction of POM feeders, large chondrichthyid rays, and *Pagellus* spp. is due to either the input of food originating from the farm into the system or the presence of tons of farmed fish.

Food beneath fish farms is available to wild fish in the vicinity as large food pellets lost through the cage, dead cultured fish, and as a ‘soup’ of POM of broken pellets and faeces from caged fish (Dempster *et al*., 2002, 2005). We observed large mugilids feeding directly upon this soup of POM at the farm while it was working. The same pattern seemed to occur for *Pagellus* spp. This genus feeds on a wide variety of food items in the Canarian Archipelago, including worms, molluscs, small crustaceans, small fish, and algae (Fanlo *et al*., 1996). The disappearance of both taxa after the cessation of farming could be indicative of attraction to the fish farm to feed on food pellets not consumed by caged fish and lost from the cages towards the bottom. Nonetheless, an important drawback of this approach is the lack of direct quantification of the consumption of the soup of POM. Further research should focus on this point, for example, using analyses of gut contents. In the Mediterranean Sea, several POM-feeding fish species (*Trachurus mediterraneus* Necrasov, 1966, *Trachinotus ovatus* Linnaeus, 1758, *Sardinella aurita* Valenciennes, 1847, *Boops boops*, large mugilids) consume food available around farms (Dempster *et al*., 2002), and when they occur in high abundances they may greatly influence the dynamics of nutrient flows (Vita *et al*., 2004; Dempster *et al*., 2005).

Large-sized rays were also abundant beneath the sea-cage fish farm while it operated; high concentrations of rays beneath farms are typical in the Canarian Archipelago (Boyra *et al*., 2004; Dempster *et al*., 2005; Tuya *et al*., 2005). We do not know if these rays fed upon lost feed, as well as on benthic infauna as they typically do (Gray *et al*., 1997; Ebert & Cowley, 2003), when they foraged on the bottom. However, we saw several specimens feeding on dead cultured fish during the study. Their disappearance beneath the farm after fish culturing activities ceased may have been in response to the loss of this source of large food items.

Small escapes of caged fish (10s to 100s of fish) are due to the periodic loss of fish during harvesting, while mass escapes (1000s to 100000s of fish) are caused by operational accidents that damage nets or sporadic storms. We observed 10s of gilthead sea bream (*Sparus aurata*) in some counts at the fish farm before the finalization of farming, indicating some degree of fidelity of escapees to the fish farm. The lack of observations of individuals after the cessation of farming either resulted from heavy fishing pressure in the study area or migrations to nearby rocky reefs, which is the preferred habitat of wild *Sparus aurata* in the Canarian Islands (Brito *et al*., 2002).

Finally, sparids occurred beneath the sea-cages only after the cessation of farming, while they appeared in similar abundances at the two natural control locations both before and after the cessation of farming. This pattern may be related to the recovery of a seagrass meadow of the marine phanerogam *Cymodocea nodosa* beneath the sea-cage fish farm after the end of farming (F. Tuya, pers. obs.), which is typical natural habitat for sparids such as *Diplodus annularis* and *Spondyliosoma cantharus* in the Canarian Archipelago (Tuya *et al*., 2005).

WILD FISH NOT AFFECTED BY THE CESSATION OF FARMING AT THE FISH FARM

Both before and after farming ceased, the bentho-demersal macro-carnivores showed greater mean abundances beneath the sea-cages compared to nearby control locations. To a lesser degree, a similar pattern was recorded for the bentho-demersal meso-carnivores. This fact supports the hypothesis that the increase in the physical structure of the system *per se* plays a partial role in structuring certain nearshore fish assemblages associated with shallow soft bottoms in warm-temperate environments (Jenkins & Wheatly, 1998; Guidetti, 2000; Guidetti & Bussotti, 2002; Pihl & Wennhage, 2002; Tuya *et al*., 2005) with a relatively consistent effect through time (lack of differences from before to after the cessation of farming). The increased habitat complexity due to the sea-cage moorings creates many niches for fishes, providing a fixed substrate as shelter, and favoring the establishment of epiphytic algae and sessile invertebrates that are consumed by higher trophic levels such as carnivorous fish (Bell

& Pollard, 1989; Klumpp *et al.*, 1989; Jenkins & Wheatly, 1998; Guidetti, 2000; Guidetti & Bussotti, 2002). Moreover, sea-cage fish farms act as 'recruitment points' for larvae of inshore fish (e.g. *Oblada melanura*; Valle, 2005), and even for decapod crustaceans (M. Davis unpubl. data; www.hboi.edu/aqua). These larvae may be a source of food for species within the bentho-demersal macrocarnivorous group; stomach content analyses are needed to test this hypothesis.

IMPLICATIONS FOR MANAGEMENT OF COASTAL FISH FARMS

Impacts of sea-cage fish farms on the benthos have been shown to be reversible, to some extent, after farms have been removed in other areas (e.g. Greece; Karakassis *et al.*, 1999). We show here that the large scale aggregation of wild fish at a coastal fish farm was also partially reversible after the cessation of farming, with assemblages returning towards the 'normal' state represented by the wild fish assemblages at sandy sediment control locations after 2 years. An important implication for coastal management arising from this study is that natural assemblages of wild fish can be partially restored to particular areas if a fish farm ceases farming. We further hypothesize that with complete removal of the fish farm cages and mooring structures, demersal wild fish assemblages would shift further towards those observed at natural control locations.

Marine aquaculture installations have been described as competing for space with future potential Marine Protected Areas (MPAs) (www.wwf.org). While sea-cage fish farms may be incompatible with MPAs designed to protect biodiversity as assemblages shift away from those naturally observed, they may not be incompatible with MPAs designed to enhance fisheries. An alternative solution to coastal managers adopting a 'one-or-the-other' approach to allowing fish farms or declaring MPAs in a given coastal area may be to adopt a more sophisticated management framework that incorporates ecological knowledge of the wild fish that associate with farms (Dempster *et al*., 2002, 2005). This study showed that a fish farm, once farming ended, did not greatly affect the demersal wild fish assemblage on a sandy bottom for more than a short period (< 2 yr). Further, while farms are in place, they concentrate large numbers of a variety of demersal fish species which constitute a portion of the available spawning stock (Dempster *et al*., 2002; Boyra *et al*., 2004; Dempster *et al*., 2005; Tuya *et al*., 2005; this study), which is the stated aim of MPAs designed for fisheries purposes. Rather than competing for space with MPAs designed for fisheries purposes, sea-cage fish farms should be designated as 'no-fishing zones' and incorporated into the management of coastal areas along with MPA zones. Nineteen farms operated in waters in the Canarian Islands in 2003 (www.apromar.es); however, no management measures to protect aggregations of wild fish in their vicinity from fishing are currently in place. Future management of the impacts of sea-cage aquaculture in the Canarian Archipelago should consider protection of wild fish aggregations as an option to ensure sustainable development of the industry.

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