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Short research note

Extensive aggregations of wild fish at coastal sea-cage fish farms

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Abstract

We present evidence of a largely undocumented environmental effect of coastal sea-cage fish farms on wild fish. We estimated the total abundance and biomass of wild fish aggregated in the immediate vicinity of nine fish farms in the Mediterranean Sea and one farm off the east coast of Australia. Estimates of wild fish aggregations ranged from 2000 to 86 000 individuals and from 100 kg to 38.5 tons of fish per farm and were always greater than control locations. Particularly large aggregations (>30 000 fish, >12 tons) occurred at half of the farms. Aggregations were temporally stable for weeks to months and most wild fish associated with farms (88%) were of adult size. Potential effects of such large aggregations of wild fish in the immediate vicinity of fish farms include increased vulnerability to fishing and pathogen transfer between caged and wild fish. We suggest specific legislation should be enacted wherever large aggregations of wild fish occur around fish farms to enhance the positive and reduce the negative effects of association.

Introduction

Ecological impacts of coastal sea-cage fish farms on marine ecosystems have been widely documented (Naylor et al., 2000). However, impacts upon wild fish species, particularly those that aggregate in the immediate vicinity of fish farms in warm-water locations, are relatively unknown, as most studies have focussed upon effects on salmonid populations in high latitude locations (Gausen & Moen, 1991; Crozier, 2000; Volpe et al., 2000; Bjorn et al., 2001). Fish farms may affect the presence, abundance, diet and residence times of fishes in a given area (Carss, 1990). As sea-cage fish farming continues to expand in subtropical and tropical locations throughout the world (e.g. >500 farms in the Mediterranean Sea: Theodorou, 1999; Sanchez-Mata & Mora, 2000), a great variety of wild fish species may be affected through close association with sea cages.

Pelagic fish are known to be strongly attracted to floating structures in the pelagic environment (Freon & Dagorn, 2000; Castro et al., 2002). Floating fish farms attract fish by providing structure, and the unused feed that falls through the cages may enhance the attractive effect (Bjordal & Skar, 1992). While community compositions of wild fish at coastal sea-cage farms have been described and attraction to farms demonstrated (Carss, 1990; Bjordal & Skar, 1992; Dempster et al., 2002), no study has estimated the total amount of wild fish that farms attract. In this study, we aimed to determine the total aggregated abundance and biomass of wild fish at 10 fish farms in warm-water locations to gauge the magnitude of potential environmental effects upon wild fishes.

Materials and methods

Using rapid visual counts on SCUBA, we determined the size of the attractive effect of fish farms for wild fish by comparison with control counts 200 m distant from the nearest sea-cage. Estimates were made with 5-min rapid visual counts on SCUBA that covered a transect volume of approximately 11 250 m^3 (15 m wide × 15 m deep × 50 m long). The nine Mediterranean fish farms studied were located on the southeastern coast of Spain along a 300 km stretch of coastline (37° 24′ N, 1° 33′ W to 38° 34′ N, 0° 02′ W). At each of the nine Mediterranean locations, six counts were conducted within each farm and six control counts were performed more than 200 m from each farm on three random days during September and October 2001. Fish were counted in groups of 1, 2–5, 6–10, 11–30, 31–50, 51–100, 101–200, 201–500 and 500+ to minimise error (Harmelin-Vivien et al., 1985), and the average total length of each group was recorded. Further details of the count method are given in Dempster et al. (2002). Biomass conversions were made for each species using published length–weight relationships, and all raw data were arranged using ecoCEN software (Bayle et al., 2002). Abundance and biomass were scaled up to the total farm volume by multiplying the average per count for each farm over the three times by the total number of counts possible in the farm volume. Farm volumes were defined as the volume within which cages were present, minus the volume enclosed by the cages. Controls were scaled up by the same amount as their respective farm volume. Total abundance and biomass at the Mediterranean farms were compared among farms and times with an analysis of variance with the factors 'farms' and 'times nested within farms'. At the Australian farm, located at Port Stephens, New South Wales (32° 44′ S, 152° 13′ E), two 11 250 m^3 rapid visual counts were made at the farm and control locations on six separate days between May 2000 and February 2001. Abundance and biomass estimates were made as for the Mediterranean farms.

Results and discussion

We demonstrate strong attraction of wild adult fish to nine fish farms along the southeastern coast of Spain and one farm on the east coast of Australia. Abundance (52–2837 times) and biomass (2.8–1126 times) of wild fish were greater in counts at fish farms than controls at all locations (Fig. 1).

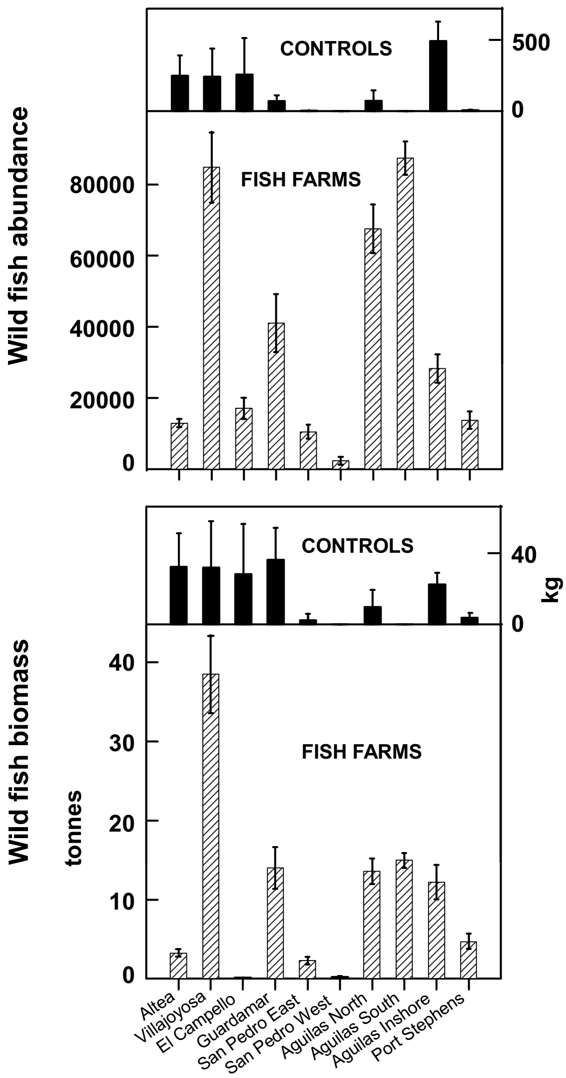

Figure 1. Total abundance (number of individuals) and biomass (fish farms in tons, controls in kg) of wild fish associated with nine fish farms located in the southwestern Mediterranean Sea and one fish farm on the east coast of Australia (Port Stephens). Error bars are SE. Scales for abundance and biomass at fish farms are given on the *y*-axes with those for controls given on the *yy*-axes.

At the 10 farms studied, 38 species were seen, with species from two families, Sparidae and Carangidae, most abundant. Size class information indicated that 88% of fish attracted to the immediate vicinity of farm cages were adult.

Biomass of fish differed greatly between the nine Mediterranean farms ($F_{8,18} = 15.41$, $p < 0.001$). Villajoyosa (average 84 000 fish and 38.5 t) and four other Mediterranean farms had remarkably large aggregations (between 30 000–88 000 fish and 12.2 and 15 t; Fig. 1). Assemblages of fish at Mediterranean farms were relatively stable (We used an ANOSIM: $R_{global} < 0.26$ at 7 of the 9 farms), suggesting that many of the species associated are resident for periods of weeks to 2 months. Residence of wild fish for periods of 1–7 months around a salmon farm in Norway has previously been demonstrated through a tagging study (Bjordal & Skar, 1992).

The very large differences in abundances of pelagic fish observed between fish farm and control sites at all locations (between 1 and 3 orders of magnitude, Fig. 1) may be partly due to the highly variable nature of schools of pelagic fish in natural conditions. While this study provides the first estimates of the total numbers and biomass of pelagic fish aggregated at fish farms, better estimates of the capacity of fish farms to re-distribute pelagic fish in a given area could be obtained through techniques that provide more detailed spatial and temporal information on the distribution of fish surrounding farms. Advanced acoustic techniques and analysis have been applied to study the distribution of pelagic fish around other floating objects (fish aggregation devices, Josse et al., 2000) and could be applied readily to fish farm settings.

Negative ecological links between aquaculture and wild fish stocks are widely documented (Naylor et al., 2000). However, aggregation of wild fishes at fish farms could be beneficial to wild fish stocks if coupled with spatial protection from all forms of fishing. Such protection occurs through legislation in some areas (e.g. south west coast of Spain), but not in others (e.g. New South Wales, Australia). Benefits of protection include increased production of local fisheries through spillover of adults (McClanahan & Mangi, 2000) and increased spawning-stock biomass, which may subsequently magnify larval recruitment (Chiappone & Sullivan, 2000). Consumption of the persistent supply of unused artificial food at farms by wild fish may enhance growth and therefore contribute to both effects. Feeding of wild fish around sea cages may also diminish the amount of food that reaches the sea floor and reduce effects upon the benthos (Katz et al., 2002). In contrast, at farms where fishing is permitted, beneficial effects will be negated and overfishing may result.

While evidence exists for non-direct transfer of pathogens form caged to wild fish for salmonids (Bjorn et al., 2001), there are no comprehensive studies on the impacts of fish farms on parasite loads of other species of wild fish. However, where large aggregations of wild fish occur in the immediate vicinity of fish farms and remain associated for a minimum of weeks to months, the potential for transfer of pathogens between caged and wild fish is heightened.

Conservation and exploitation are generally viewed as diametrically opposed approaches to the marine environment, with few examples of innovative solutions that combine the two. Our data on wild fish stocks around coastal fish farms show, however, that with planning such solutions can occur. We suggest legislation is necessary to enhance benefits and minimise negative effects of the close association of wild fish with fish farms. Spatial protection of wild fish from all types of fishing within farm leasehold areas should be enacted to ensure aggregation at fish farms does not increase the vulnerability of stocks. Further, populations of closely associated wild fish and their parasite loads should be routinely monitored as part of the continuing environmental assessment of each farm. Such legislation is required in all countries where large aggregations of wild fish occur around fish farms.

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