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Coastal aquaculture and conservation can work together

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Current fishing practices are regarded as unsustainable (Pauly et al. 2002) yet our appetite for seafood grows. To meet the growing gap, there are increasing calls for mankind to tame the ocean through aquaculture (Marra 2005). Close to the coast, rapid expansion of marine aquaculture is already well underway throughout the world. Sea-cages enclose 2.5 million tons of fish, while 12 million tons of mussels, oysters and clams hang from floating ropes or grow on racks or trays (FAO 2004). Aquaculture structures are now ubiquitous to many coastlines. As the expansion continues, how can we best manage the interaction between natural communities and aquaculture?

Negative impacts of marine aquaculture on the environment are well known (see review: Naylor et al. 2000). Caged fish escape and mix with natural populations (Naylor et al. 2005) and natural habitats are altered, either to make space for farms (Menasveta 1997) or through a build-up of nutrients and sediment beneath farms (Karakassis et al. 2000). The use of millions of tons of small pelagic fish each year to make fish food also places heavy fishing pressure on some natural fish stocks. Against this backdrop, the recent concept of creating Marine Protected Areas (MPAs) around coastal aquaculture installations (Dempster et al. 2002, 2005) seems like ecological heresy. How could the goals of an exploitative, industrial activity be compatible with the conservation-oriented goals of MPAs? Recent studies have opened a black box on the interactions between coastal aquaculture and wild fish. This work powerfully demonstrates that while aquaculture sites are incompatible with the goals of MPAs designed to conserve habitats and their biodiversity, they are ideally suited to the goal of boosting coastal wild fisheries.

Worldwide, over 330 species of fish use logs, jellyfish and seaweeds that float in the ocean as natural habitat (Castro et al. 2002). Aquaculture structures mimic these natural floating objects and are highly attractive habitats for many species of wild fish. Fish-farms covering an area of just 1 hectare may have up to 40 tons of wild fish around them (Dempster et al. 2004). These fish would typically be scattered across hundreds to thousands of hectares (Dempster et al. 2002). The phenomenon is widespread across the globe; large aggregations of wild fish occur around fish-farms in Mediterranean Spain (Dempster et al. 2002), Greece (Smith et al. 2003, Thetmeyer et al. 2003), the Canary Islands (Boyra et al. 2004, Tuya et al. 2005, 2006), Scotland (Carss 1990), Norway (Bjordal and Skar 1992), Indonesia (D. McKinnon pers. comm.) and Australia (Dempster et al. 2004, Felsing et al. 2005). Mussel farms also aggregate wild fish (Brehmer et al. 2003).

Wild fish that gather at farms tend to be large adults (Dempster et al. 2002). This is important as the 'big ones' do most of the spawning and produce the next generation (Birkeland & Dayton 2005). The constant supply of high protein food available around farms when feed is lost through the cages also means these big fish are in better body condition than their wild counterparts elsewhere in the sea (Skog et al. 2003, Fernandez-Jover et al. 2006). Better condition increases the spawning success of fish (Izquierdo et al. 2001). Higher-order predators, such as large pelagic fish, rays and dolphins, are also present at farms to feed on the aggregated wild fish (Dempster et al. 2002, 2005, Boyra et al. 2004). Many of the fish species that occur at farms in high numbers are commercially important to coastal fisheries and are already subject to heavy fishing pressure.

MPAs designed to enhance fisheries generally aim to increase the number of large-sized fish to enhance the spawning stock and enable 'spillover' of both larvae and adults into surrounding areas (Roberts et al. 2001). This is achieved by protecting particular areas of habitat from fishing so fish can grow to become large adults. Aggregation of large numbers of adult wild fish at fish-farms and the increase in their condition achieves the goals of an MPA almost perfectly. Only protection is missing. Partial protection from fishing exists in a handful of areas, but no restrictions apply in the vast majority of countries that practise coastal aquaculture.

Another good reason to keep wild fish near fish-farms is that they reduce the impact of farms on the seafloor (Dempster et al. 2005). Nutrient and sediment wastes flow out from fish-farms in the form of food and faeces. If the amount of such wastes is high, the diversity of the seafloor flora and fauna in the surrounding areas can change dramatically. Most of the

wild fish beneath farms eat lost food from the cages, thereby reducing the wastes that reach the seafloor by up to 80% (Vita et al. 2004, Felsing et al. 2005). Removing these wild fish from the surrounds of farms by fishing will only lead to greater waste accumulation and altered biodiversity in nearby ecosystems.

Creating no-fishing MPA zones at fish-farms will not relieve the pressure that culturing carnivorous fish species places on stocks of small pelagic fish that are used to make fish food (Naylor et al. 2000), nor will it be a panacea for all the environmental ills of coastal aquaculture. But it will provide greater resilience for fish stocks where coastal aquaculture is practiced. Increased catches of commercial species next to fish farms in the Mediterranean Sea have recently been documented (Machias et al. 2005).

We estimate that prohibiting fishing around the many thousands of coastal aquaculture sites worldwide would protect many tens of thousands of tons of adult spawning stock of wild fish when they are aggregated in high numbers and vulnerable to fishing. Without protection from fishing at farms, coastal stocks of wild fish will inevitably be fished more heavily and overfishing will increase. As wild fish stocks diminish and oil prices rise, fishermen will naturally seek profitable alternatives and heavily target aggregations of wild fish near aquaculture sites.

To solve the key environmental problems of marine aquaculture, management must be based on ecology (Goldberg & Naylor 2005). New ecological knowledge shows that creating no-fishing Marine Protected Areas at coastal aquaculture sites will both boost coastal fish stocks and fully harness the ability of wild fish to lessen negative impacts upon the seafloor. Over the last 20 years, marine aquaculture and conservation have been largely

opposing forces. To secure the best deal for coastal fish stocks, fish-farmers and conservationists should work together.

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