COMMENTARY

When will we tame the oceans?

In fisheries across the world, fish stocks are declining fast. Future preservation and management of the ocean's resources will require a transformation of our relationship with the seas, argues **John Marra**.

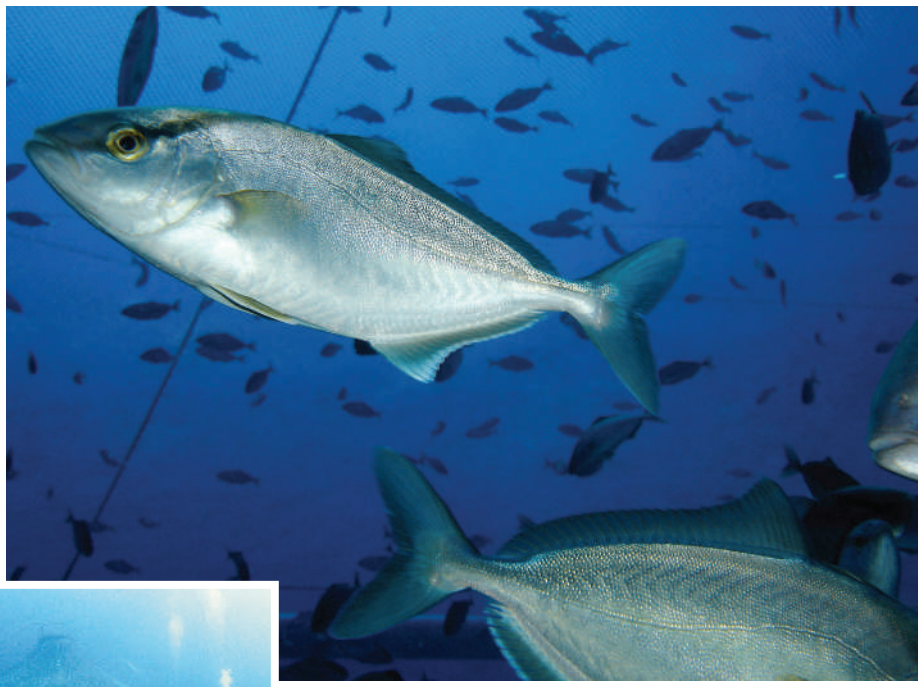
Fishing in the ocean is no longer sustainable. Worldwide, we have failed to manage the ocean's fisheries — in a few decades, there may be no fisheries left to manage[1]. So what should be done?

Following the cultivation of land for food, society must take the next step: largescale domestication of the ocean. Last month, the US National Oceanographic and Atmospheric Administration proposed legislation to expand fish farming in US federal waters up to 200 miles from the coast, and to increase the numbers of species that can be farmed. Many reacted with dismay to this announcement[2]. But I believe these people are ignoring the inevitable.

Aquaculture is entirely responsible for the increase in world fish harvests that has occurred in the past 18 years[3]. We have already accepted domestication of the land; now is the time to accept the same for the seas. The land was transformed with little consideration for the consequences. For the ocean, we will have to decide, and soon, how domestication should take place, so that it is managed in ways that maintain environmental health and sustainability.

Since the end of the last ice age, and increasingly since the beginning of the industrial revolution, humans have affected the evolution of plant species, found uses for animals, and caused losses of wildlife[4]. In short, we have altered land-based ecosystems to serve our own ends, reaping the benefits (civilization) and also bearing some of the costs (for example, increases in animal-borne disease). Similar changes have occurred in the ocean, albeit more slowly because of its size and inhospitable nature. So far, changes in the ocean mirror what has happened on land: habitat destruction, major shifts in the communities of plants and animals, and the loss of larger animal species.

Fishing, which is essentially hunting in the ocean, is a direct or indirect cause of many of these changes — from the loss of large marine mammals to habitat destruction. Incessant hunting, with increasing technological proficiency, has decimated fish populations worldwide. Catches of large marine species, such as swordfish and tuna, have declined by 80% over the past 20 years[5]. Northern cod, historically a dietary mainstay, and a species once thought inexhaustible, is all but commercially extinct in the western North Atlantic. In many areas, bottom trawls have scoured the seabed clean. These are just a few examples of the "long and miserable record" of hunting in the ocean[6].



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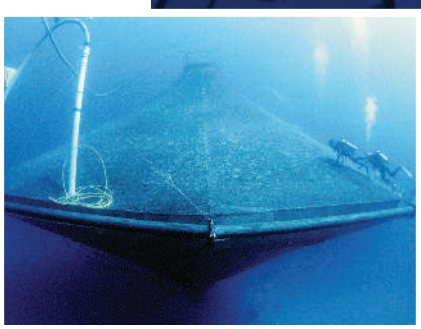

CATES INTERNATIONAL

Hemmed in: giant offshore fish pens are currently being developed as a means to harness the sea's resources.

If history is a guide, the ability of the ocean to supply the fish we take will soon reach its limit despite the best efforts at management, such as environmental restoration[7] or ecosystem-based fisheries management[8]. The collapse of ocean fisheries comes at a time of accelerating demand for food, especially of animal protein. World food production must double in the next 50 years to keep pace with population growth[9], and the world's oceans must play an increasingly important role as a food source. In the past 20 years alone, farming of marine fish and shellfish along coastlines has grown about 10% per year[10].

So far, most of the expansion in aquaculture has come from farming freshwater species, such as tilapia and catfish, in ponds. But marine aquaculture, or mariculture, is also growing, and given eventual limits to space on land, moves towards expanded mariculture, such as the recent US proposal, will accelerate in the years to come. The demise of ocean fisheries and the destruction of marine habitats help to explain why ocean domestication is inevitable. But we need to carefully consider how this domestication should happen to avoid many of the pitfalls cited by environmentalists and scientists[1–3].

As with the rearing of land animals, fish farming can harm the environment in many ways; indeed, some mariculture operations have caused whole-scale destruction of coastal ecosystems[1]. First, marine farming can pollute in ways that are aesthetically, chemically and genetically destructive. Coastal mariculture systems spoil ocean views and affect property values. Chemicals added to fish feed,

such as colourings and hormones, find their way into the seabed, from where they can enter benthic food webs. And genetic pollution, whereby domesticated species escape their enclosures and infect the gene pool of wild fish stocks or replace endemic species, is a troubling prospect. Second, crowding in aquaculture enclosures or ponds can easily amplify disease and cause it to spread more quickly than it would in the wild. Third, the mariculture of carnivorous species puts additional pressures on fisheries to provide ever-larger quantities of wild fish for feed[3], exacerbating the decline of wild fish populations. In some fish farms, the consumption of small pelagics, such as anchovy or sardine, by commercial fish (salmon, for example), actually exceeds commercial-fish production, in terms of biomass.

There is no question that these are significant problems to overcome; such environmental ills echo those visited on the land since the advent of farming. But if we recognize that domestication of the ocean is starting to happen, we can craft a research agenda to mitigate the problems and maintain both economic and ecological sustainability.

Research questions for the mariculture industry span basic and applied research, and policy — from marine biology and physical oceanography, to engineering and the law. Which fish species can be adapted to captivity, that is, domesticated throughout their life cycle? How can their health and diets be maintained? Are there alternatives to the small pelagics currently fed to farmed fish, such as by-catch? Where should mariculture systems be situated, in terms of ocean dynamics and the surface wave environment? How should they be constructed and maintained? Answering these questions in turn raises legal and policy concerns.

One solution to many of the problems associated with coastal mariculture is to move the systems further offshore — to the waters of the outer continental shelves, and beyond to the open ocean. Generally, offshore systems cause less coastal pollution, but can dramatically increase costs. Nevertheless, pilot projects under development illustrate the potential for creative solutions.

For example, giant versions of coastal fish pens (containing about 100,000 m^3 of water) are being designed to drift freely in the ocean[11]. Prototypes, shaped as two cones sandwiched together at their base, are currently being tested in some coastal sites, while remaining tethered to the sea floor. Under certain proposals[12], fingerling fish will eventually be placed in pens in Florida. Then, the Gulf Stream and North Atlantic currents will carry the pens with their contained fish across the Atlantic, feeding them along the way. Designed to drift at depths well below the surface, the pens' interference with shipping will be minimal. Arriving in Europe many months later, the fish will have grown to a marketable size. After harvesting, the pens can be reloaded with fingerlings for a return voyage. But such systems represent a significant engineering challenge: feeding, maintenance of an ideal depth and communication via satellite must all happen automatically, for months at a time.

IMAGE UNAVAILABLE FOR COPYRIGHT REASONS

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Pollution caused by fish farming in coastal waters could be reduced by moving the farms further offshore.

Another development concerns tuna 'herding' at sea. Many species of tuna are attracted to anything that is sufficiently different from their surroundings. Fishermen take advantage of this behaviour by using a fish aggregating device or FAD. This can be as simple as a floating log, or a more complicated buoy system, or even a disturbance at the ocean surface. Fishing boats directing a fire hose behind them create just such a disturbance, and can thereby attract a following of tuna. The tuna attracted to FADs can be fed, maintained, and a portion eventually harvested[13]. Although their use is controversial[14], FADs could increase yields. Tuna will never be domesticated, as are sheep or cattle, but the analogy of herding on the 'high plains' of the sea still holds.

These are only two examples of how we might enhance ocean fish yields without further damaging ocean ecosystems through fishing, and solve the problems caused by mariculture near coastlines. But we need to be clear about the wider consequences of domesticating the ocean: first, like the hunters and trappers of the American west 150 years ago, fishermen will largely disappear; game fish will be taken by a regulated number of recreational fishers; and the bulk of the fish we eat will come from more limited varieties. In such a future, we will have to accept an ocean with fish that can be cultured, and we will have to accept less freedom of the seas.

Internationally, domestication will entail a reordering of the status quo. Today, governments and fishermen have become accomplices in the over-exploitation of fish stocks and over-capitalization of the fishing industry. Instead of competing for a rapidly dwindling resource, maritime nations will have to negotiate agreements concerning the shared use of the ocean. Governments also have a role to play in fostering research to find ways to cultivate fish in the open sea, and more environmentally sound ways to conduct mariculture near shore. The common goal should be to maintain the ocean as a sustainable source of food, both economically and ecologically. As on the land, sustainability of the ocean's food supply for the world's population means domestication of the seas. ■

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