The Promise and Perils of Aquaculture

AQUACULTURE OPERATIONS, such as this salmon farm in British Columbia, constitute a small but growing percentage of total fisheries production. Representative species from each of the major families used for aquaculture show the wide range of animals involved [*see box on opposite page*].

Aquaculture, or fish farming as it is often called, might appear to be the perfect solution to the dire problems facing many overly exploited varieties of marine fauna. If people can raise enough fish on farms, it stands to reason that they will be less inclined to hunt them from the sea. So the phenomenal growth of aquaculture in recent years might take some of the pressure off wild populations. Unfortunately, this seemingly logical supposition is surprisingly hard to confirm.

The complication is that aquaculture often exploits wild populations indirectly. Many of the species raised on farms are fed fish meal produced from capture fisheries. And countless farming operations rear juvenile fish taken from the ocean. For example, shrimp farmers in Latin America often shun larvae produced in hatcheries, because they believe that nature's shrimp are more robust. As a result, they will pay twice the price for captured larvae, and vast numbers of collectors take to shallow waters with fine mesh nets seeking them out. This intensive fishing constitutes a threat, but

Whether fish farming helps or hurts wild populations remains an open question

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one is hard-pressed to demonstrate that it has actually diminished the numbers of wild shrimp.

Such uncertainty is one reason for the difficulty in weighing the benefits of aquaculture against its biological and environmental costs. Another stems from the very diversity of this industry. Farmers raise everything from fish to crustaceans, from mollusks to aquatic plants. In all, they produce in excess of 25 million metric tons every year of more than 260 different species. And these farmers employ many kinds of equipment in the process, including cages of netting suspended offshore, indoor tanks recirculating filtered water and open-air ponds flushed with seawater. So broad statements—both those that disparage and those that support the practice of aquaculture—rarely apply universally.

To illuminate some of the subtleties involved, the following four pages spotlight two common subjects of this industry—shrimp and salmon. Rearing such animals in captivity rather than fishing for them could help foster conservation. But making sure that these enterprises truly benefit wildlife remains a significant challenge for the future. —*The Editors*

Commonly Raised Species

FISH

Asian seabass (*Lates calcarifer*)
Atlantic salmon (*Salmo salar*)
Atlantic cod (*Gadus morhua*)
Ayu sweetfish (*Plecoglossus altivelis*)
Bagrid catfish (*Chrysichthys nigrodigitatus*)
Bastard halibut (*Paralichthys olivaceus*)
Bluefish (*Pomatomus saltatrix*)
Cachama blanca (*Piaractus brachypomus*)
Channel catfish (*Ictalurus punctatus*)
Climbing perch (*Anabas testudineus*)
Common sole (*Solea vulgaris*)
European seabass (*Dicentrarchus labrax*)
Flathead gray mullet (*Mugil cephalus*)
Giant gourami (*Osphronemus goramy*)
Greasy grouper (*Epinephelus tauvina*)
Japanese eel (*Anguilla japonica*)
Japanese jack mackerel (*Trachurus japonicus*)
Kissing gourami (*Helostoma temmincki*)
Largemouth black bass (*Micropterus salmoides*)
Mangrove red snapper (*Lutjanus argentimaculatus*)
Milkfish (*Chanos chanos*)
Nile tilapia (*Oreochromis niloticus*)
North African catfish (*Clarias gariepinus*)
Northern pike (*Esox lucius*)
Pangas catfish (*Pangasius pangasius*)
Pike-perch (*Stizostedion lucioperca*)
Red seabream (*Pagrus major*)
Silver carp (*Hypophthalmichthys molitrix*)
Southern bluefin tuna (*Thunnus maccoyii*)
Snakeskin gourami (*Trichogaster pectoralis*)
Starry sturgeon (*Acipenser stellatus*)
Striped snakehead (*Channa striata*)
Turbot (*Psetta maxima*)

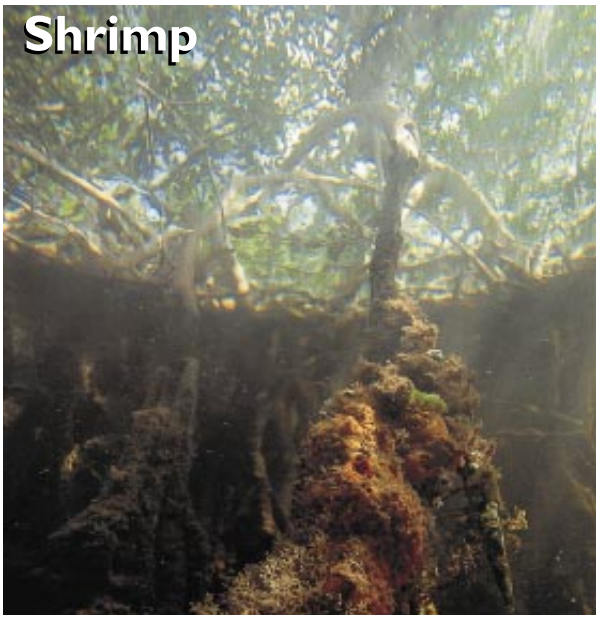
CRUSTACEANS

American lobster (*Homarus americanus*)
Chinese river crab (*Eriocheir sinensis*)
Danube crayfish (*Astacus leptodactylus*)
European lobster (*Homarus gammarus*)
Giant tiger prawn (*Peneaus monodon*)
Giant river prawn (*Macrobrachium rosenbergii*)
Indo-Pacific swamp crab (*Scylla serrata*)
Longlegged spiny lobster (*Panulirus longipes*)
Red swamp crawfish (*Procambarus clarkii*)
Whiteleg shrimp (*Peneaus vannamei*)
Yabby crayfish (*Cherax destructor*)

MOLLUSKS

Blood cockle (*Anadara granosa*)
Blue mussel (*Mytilus edulis*)
Common edible cockle (*Cerastoderma edule*)
European abalone (*Haliotis tuberculata*)
Giant clam (*Tridacna gigas*)
Globose clam (*Mactra veneriformis*)
Japanese corbicula (*Corbicula japonica*)
Japanese pearl oyster (*Pinctada fucata*)
Northern quahog (*Mercenaria mercenaria*)
Pacific cupped oyster (*Crassostrea gigas*)
Pacific geoduck (*Panopea abrupta*)
Peruvian calico scallop (*Argopecten purpuratus*)
Pink conch (*Strombus gigas*)
Sand gaper (*Mya arenaria*)

Giant Questions about Shrimp



CHIP CLARK, *Smithsonian Institution*

The explosive growth of shrimp aquaculture in recent years has created worries about the environmental toll from this industry. One of the charges voiced by environmentalists is that the people constructing shallow ponds for shrimp farming all too often destroy mangroves, salt-tolerant trees that line the coast in much of the tropical world (*green on map above*). These partially inundated mangrove forests filter excessive nutrients washed off the land before they reach the sea, and the submerged roots (*left*) shelter a variety of creatures, including young fish. Although the destruction of man-

Notes from an Adviser to the Shrimp Industry

It cannot be denied that a great deal of environmental damage has arisen from poor planning and management by shrimp farmers and lax government agencies in countries where this form of aquaculture is widespread. But shrimp farming is not always harmful to the environment. Unfortunately, some environmentalists have unfairly made sweeping condemnations of the entire industry.

CONNER BAILEY

PROPERLY CONSTRUCTED SHRIMP PONDS cost tens of thousands of dollars per hectare to build. So their owners have great incentive to ensure that they do not have to be abandoned after a short while.

One charge leveled against shrimp farming is that rich investors make quick profits and then abandon farms. Here the critics are just plain wrong. Although some shrimp farms have proved unsustainable and been abandoned, these farms usually were small, often consisting of only one or two cheaply constructed ponds, which were situated on unsuitable sites and operated without sufficient capital and expertise. Properly sited and well-constructed shrimp farms cost from $10,000 to $50,000 per hectare of pond and are expensive to operate. Such large investments cannot be recovered quickly, so owners want to make sure that their farms are productive for many years.

Shrimp farming is an interesting example of a situation in which a disproportionate amount of the environmental damage has resulted from smaller operators rather than from bigger ones. But it is possible for small-scale farmers to pool their resources in cooperatives or producer associations and greatly improve their management. Well-run operations require many workers up and down the line—for hatcheries, farms and processing plants—typically creating one or two jobs for each hectare of pond in production. Shrimp farming also stimulates local economies and provides import earnings for many developing nations.

So it would be a sad loss for many people if shrimp aquaculture disappeared. The trick is to manage these operations sensibly. Many shrimp farmers are, in fact, acutely aware of the damage that shrimp farming can do. They have learned that their long-term success depends on maintaining healthy conditions for their shrimp and that their prosperity is linked directly to environmental quality along nearby coasts. Degradation of the coastal zone makes aquaculture more difficult, so it is easy to convince most shrimp farmers that they have a vested interest in being good environmental stewards.

Several recent developments indicate that shrimp farmers are indeed moving toward environmentally friendly forms of production. The Australian Prawn Farmers Association established a formal code of practice for its members; the Association of Southeast Asian Nations Fisheries Network

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groves also comes about for many reasons besides the construction of shrimp ponds, all these losses bode badly for the affected shores and ocean nearby. The essays here present two perspectives on this concern and other environmental problems arising from shrimp farming.

published a manual of good shrimp farm procedures; and the Food and Agriculture Organization of the United Nations presented technical guidelines for responsible fisheries that apply to shrimp farming. In addition, the Network of Aquaculture Centers in Asia-Pacific has created a detailed plan to improve the sustainability of aquaculture in general.

What is more, several recent scientific and trade meetings have focused on the connection between shrimp farming and the environment. Most countries now require environmental impact assessments for new shrimp farms. Thailand has instituted regulations in an effort to make sure that shrimp farmers adopt the best management practices possible. A particularly important development is the recent formation of the Global Aquaculture Alliance. This industry group is fostering responsible shrimp aquaculture, developing an elaborate code of practice and promoting consumer awareness with an "eco-label" for environmentally friendly shrimp. *—Claude E. Boyd*

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Comments from an Environmental Advocate

Many businesspeople see natural resources as free for the taking. They count as costs only the labor and investment needed to extract them. There is no thought given to the cost of replacement or maintenance for the resources they use. Nowhere is this blindness more true than with shrimp aquaculturists, who often depend on access to public resources that, traditionally, have been used by many different groups.

Shrimp farmers must decide if they indeed want to address the environmental problems their industry has created. True, all economic activities have environmental consequences. Nevertheless, the goal of shrimp producers should be to reduce the deleterious effects on the environment as much as possible.

Some practices that would make shrimp farming more sustainable are already used by more progressive and well-financed shrimp producers. Around the world, however, there are hundreds of thousands of shrimp farmers. Each one makes decisions that affect his or her own future as well as those of others in this business. Shrimp aquaculture as it is conducted today in most parts of the world is not sustainable for very many decades into the future.

Perhaps an ideal, indefinitely sustainable system for shrimp farming is not possible, at least with current knowledge. Yet most shrimp farmers and others affected by this industry could agree that some practices are better than others, and the industry as a whole would benefit from the swift adoption of these improved techniques.

There are a number of business reasons to adopt more efficient and sustainable methods of shrimp production. For example, increasing the survival rates of young shrimp from less than 50 to 75 percent or more will reduce the initial outlays required for each crop. Similarly, more effective ways of feeding shrimp can reduce expenditures on food by a quarter to a half. These two simple changes would reduce the cost of cleaning effluents and moving ponds periodically. Ecuadorian shrimp farmers have been able to double their profits by such means.

ALFREDO QUARTO

CLEARING OF MANGROVES results from a variety of human activities, including shrimp farming, which accounts for perhaps as much as 10 percent of the total global loss of these forests.

Although other improvements may be more expensive, the boost to income in many instances will compensate for the required expenditures. Yet it is important to understand that some investments will not result in increased efficiency. These costs will have to be passed on to consumers, who are, after all, the ultimate polluters in the economic system. Regulations might bring increased prices. Or perhaps "green" shrimp will prove to command a premium from environmentally conscious consumers.

But producers who try to differentiate their product to gain market advantage must be able to prove their claims. People will pay more only if a reliable third party has verified assertions about the product being environmentally benign. Because there are no "name brands" of shrimp, such assurances will be difficult to judge.

Who should establish the guidelines for sustainable shrimp production? Today environmentalists, producers and some governments are each developing their own guidelines for sustainable shrimp aquaculture. But no single group, certainly not the producers themselves, will be able to create a credible system. Attaining that goal will require that these diverse groups agree on general principles, which can then be adapted to specific local conditions. Only through the adoption of such sustainable production systems will shrimp aquaculture be part of the solution for the next millennium rather than just another environmental problem that must be put right. *—Jason W. Clay*

JASON W. CLAY, a research fellow at the World Wildlife Fund in Washington, D.C., has taught at Harvard University. He has also worked for the U.S. Department of Agriculture and for Cultural Survival, a human-rights organization.

TOM AND PAT LEESON *Photo Researchers, Inc.*

Struggles with Salmon

DEFYING GRAVITY on their way to spawn, salmon struggle against sundry obstacles. Some people fear that salmon farms nearby might harm these wild populations.

Producing almost 800,000 metric tons a year, salmon aquaculture has become a worldwide industry. Norway raises nearly half this tonnage, with Chile contributing 24 percent, Scotland 14 percent and British Columbia 4 percent. In all, aquaculture accounts for about a third of the salmon consumed annually. This now thriving industry burgeoned after wild stocks of salmon became too depleted to satisfy demand.

Populations of Atlantic salmon may have first begun to falter in the face of intensive fishing as early as the 1860s, and during the ensuing decades many fishers on both sides of the Atlantic moved to the western coast of North America to take advantage of the salmon there. Nevertheless, by the early 1970s, the numbers of Atlantic salmon had fallen sharply. The salmon fishery of the Pacific Northwest also proved fragile, essentially collapsing in 1994. Today in the U.S., only the Alaskan salmon fishery survives at a significant level.

To compensate for the failing production from capture fisheries, salmon farmers began setting up operations at coastal sites, beginning in Norway during the 1970s. These farmers learned to simulate the natural life cycle of wild salmon, which live most of their days in the ocean but lay their eggs in freshwater streams. The newly hatched fish typically spend up to a year meandering their way to the sea, where they migrate north to cold, nutrient-rich waters, allowing them to feed more easily. Three years later they return to breed in the same freshwater streams where they hatched. Although Pacific salmon die shortly after spawning, Atlantic salmon (the type used predominantly for aquaculture) can make the circuit twice.

On a farm, aquaculturists hatch eggs in freshwater and grow the fish for a year in tanks before transferring them to pens of netting suspended near shore in bays or estuaries. They feed the salmon pellets composed primarily of fish meal, vegetable matter and vitamins and, after three years, harvest and sell the fattened fish.

The success of salmon farms has been a boon for consumers, who have seen prices drop. But for others the results have been mixed. For example, some environmentalists are concerned about uneaten food and fish feces building up underneath densely stocked pens where currents are weak, resulting in a large deposit of nutrient-rich sediment on the seafloor. They fear that this sludge will overload bottom-dwelling organisms living in the vicinity [see "Enriching the Sea to Death," by Scott W. Nixon, on page 48].

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UNDERWATER PENS suspended offshore in bays or estuaries contain the farmed salmon as they grow to adulthood. Some worry that escapees or the high concentration of nutrients could harm the surrounding natural environment.

Insufficient flushing may also foster the spread of disease among farmed salmon. This problem for farmers becomes an environmental concern if the salmon get loose. Fish can escape by accident during transport or through holes in faulty nets, and when released they are free to roam the oceans and coastlines. So disease-carrying salmon from farms could, at least in theory, pass pathogens to wild stocks.

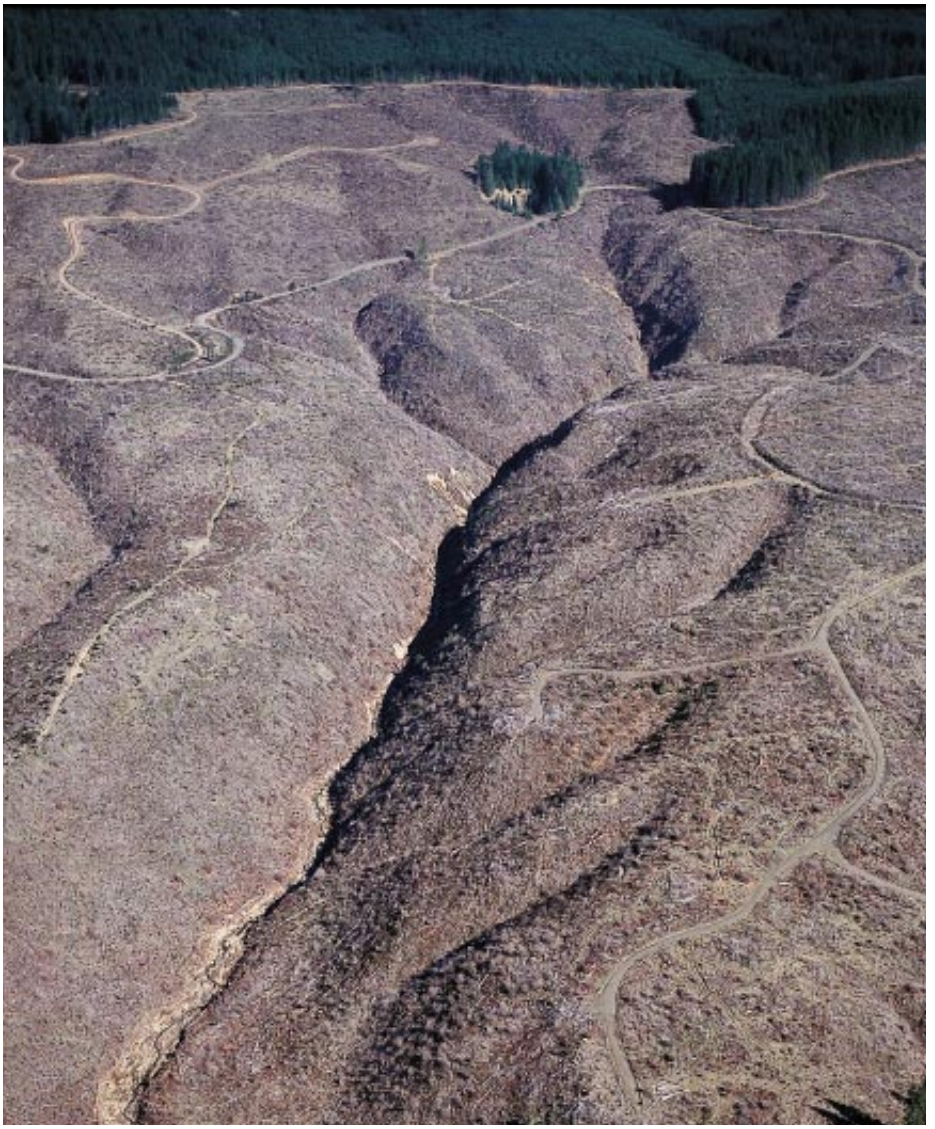
On the western coast of North America, escaped Atlantic salmon can interact with the native Pacific species, and some people worry that the nonnative Atlantics could take over. Despite the large numbers involved (the government of British Columbia reported that more than 60,000 Atlantic salmon had slipped from their nets in 1994 and 1995 alone), thus far there is no evidence that Atlantic salmon pose any serious danger.

Robert R. Stickney, a fisheries researcher at Texas A&M University, points out that efforts to establish Atlantic salmon populations on the western coast began as early as the last century. Since then, there have been multiple attempts, but none were successful. Because those projects failed repeatedly, it is unlikely that renegade Atlantic salmon could pose a threat to the Pacific species. "It's a nonissue as long as you use the right fish," Stickney remarks. Atlantic salmon are good for farmers because they grow quickly and are more docile than the Pacific species, so the likelihood of them taking over local salmon runs is slim. William K. Hershberger of the Western Regional Aquaculture Center at the University of Washington agrees. "Results indicate that the competition with native fish is not a serious issue," he says, "but it is wise to continue monitoring the situation." John M. Epifanio, a geneticist with Trout Unlimited, a national nonprofit organization, is less optimistic. He notes that "the risk of displacing the native salmon is probably low." But he warns that "if the scale at which [salmon aquaculture] is happening is large enough, it'll happen eventually."

Another worry about the mass production of salmon arises because the densely populated pens tend to attract predators. Marine mammals and seabirds tear holes in the nets, releasing fish and swallowing profits. Farmers have tried everything from sonic devices to plastic whales to deter these animals, but to date their only successful recourse has been to shoot them. For example, between 1989 and 1997 more than 3,800 harbor seals and sea lions were reported killed by salmon farmers in British Columbia alone; the actual number of creatures involved is very likely to be much higher. Although these killings do not significantly threaten future populations of these animals, the public generally disapproves when farmers resort to using guns against wildlife.

Competing with marine mammals, seabirds and farmers are the people involved in commercial salmon fisheries. Farms have produced enough to lower prices, making fishing for salmon much less profitable.

Were overfishing the only cause of the decline of wild salmon, this development might be welcomed by those interested in protecting marine life. But the fact that the numbers of wild salmon are not rebounding shows that the recent declines probably have more to do with the loss of habitat than with the problems of overfishing or aquaculture. With many rivers and streams blocked by dams, polluted by chemicals and choked by silt, salmon have found spawning runs increasingly difficult to make. People who fish for these creatures want to maintain large populations and understand that to do so freshwater habitats have to be protected. So, ironically, these fishers—the very group most threatened by the rise of salmon aquaculture—may turn out to be among wild fish's strongest advocates. —*Krista McKinsey,* staff writer



GARY BRAASCH

DESTRUCTION OF SALMON HABITAT occurs in the Pacific Northwest when the forests bordering streams and rivers are clear-cut of timber and sediments wash down the slopes (*above*). Dams for irrigation and hydroelectric power generation have also been responsible for the demise of spawning runs for this migratory fish.