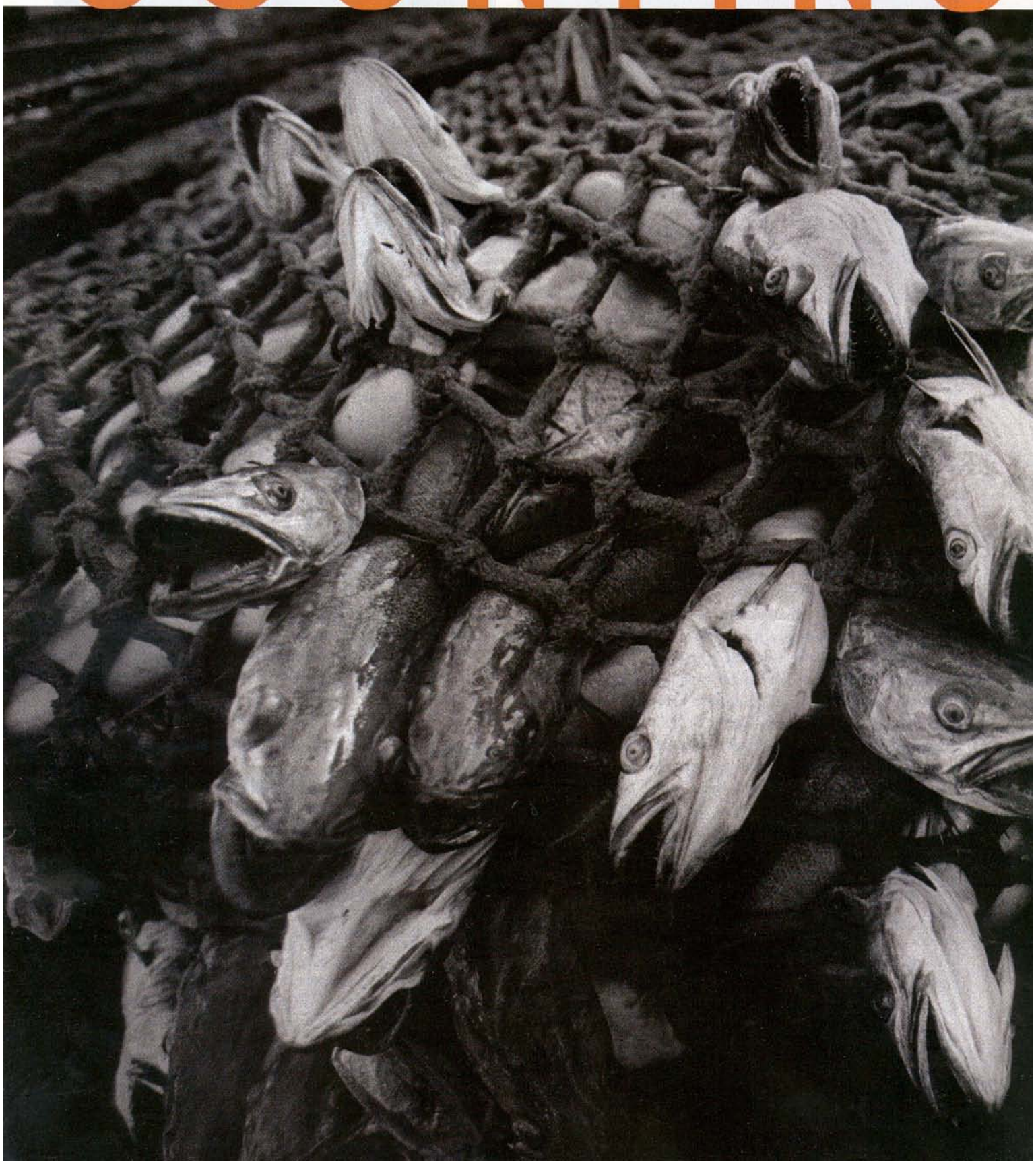
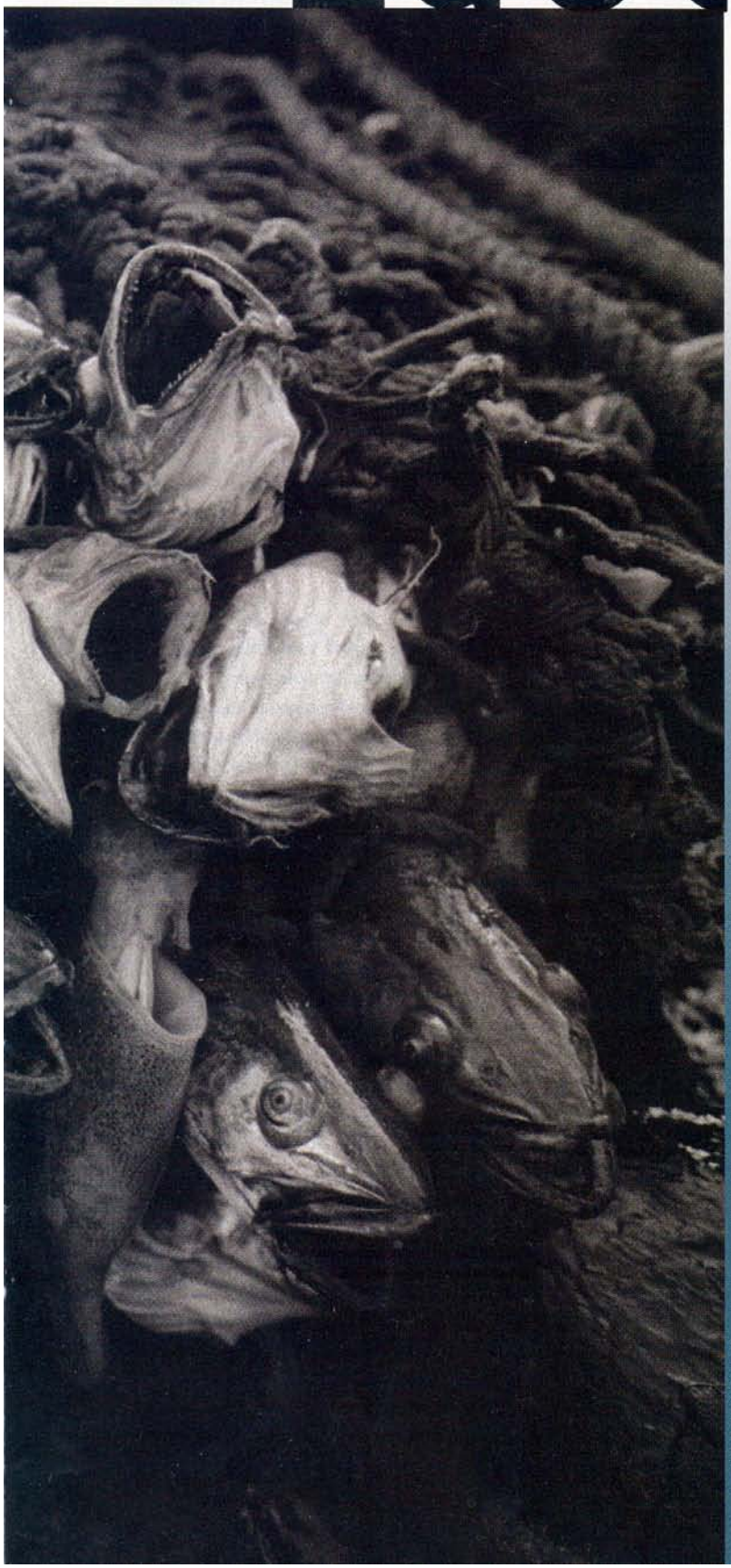
COUNTING



THE Last Fish

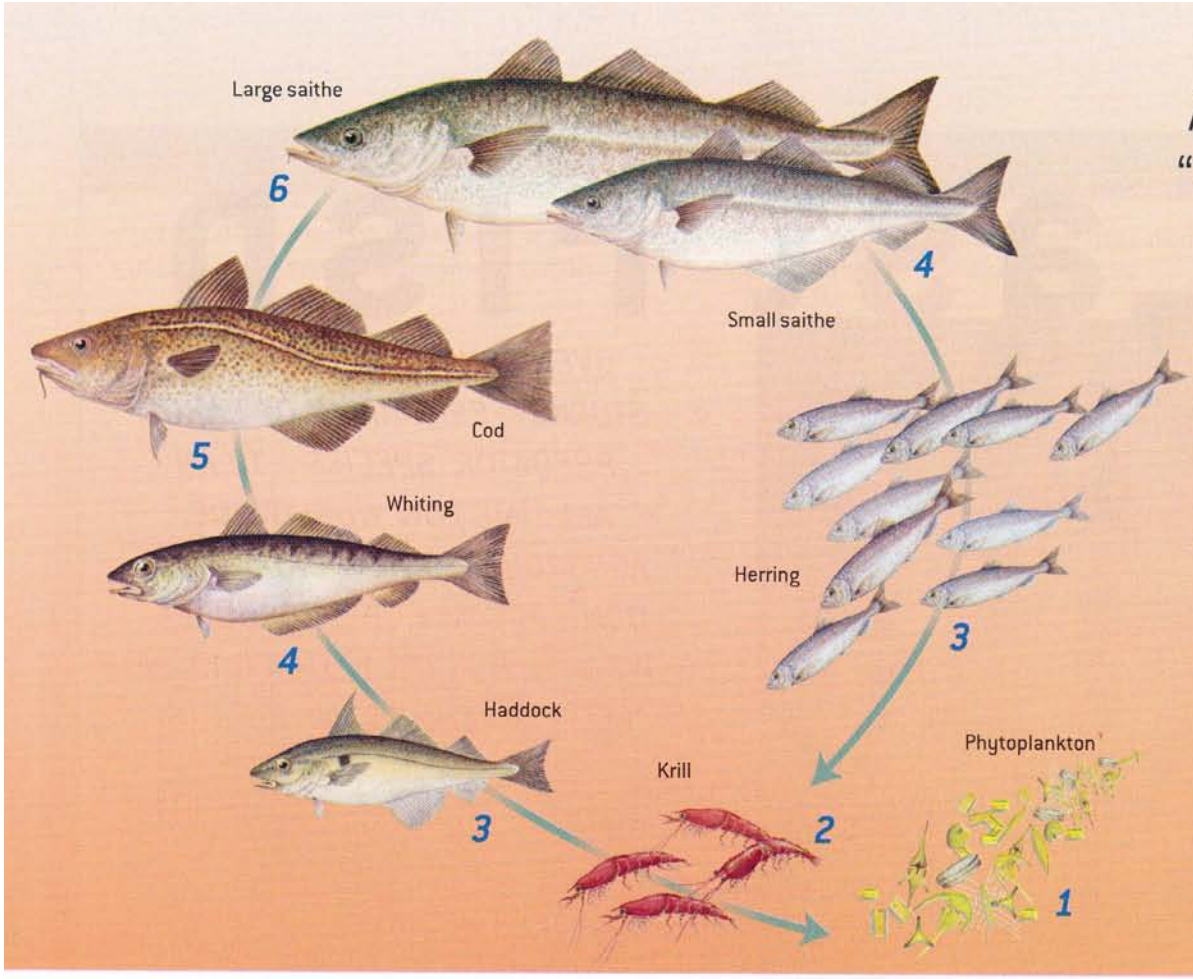


JEAN GAUMY *Magnum*

OVERFISHING HAS SLASHED STOCKS—ESPECIALLY OF LARGE PREDATOR SPECIES—TO AN ALL-TIME LOW WORLDWIDE, ACCORDING TO NEW DATA. IF WE DON'T MANAGE THIS RESOURCE, WE WILL BE LEFT WITH A DIET OF JELLYFISH AND PLANKTON STEW

By Daniel Pauly and Reg Watson

Georges Bank—the patch of relatively shallow ocean just off the coast of Nova Scotia, Canada—used to teem with fish. Writings from the 17th century record that boats were often surrounded by huge schools of cod, salmon, striped bass and sturgeon. Today it is a very different story. Trawlers trailing dredges the size of football fields have literally scraped the bottom clean, harvesting an entire ecosystem—including supporting substrates such as sponges—along with the catch of the day. Farther up the water column, longlines and drift nets are snagging the last sharks, swordfish and tuna. The hauls of these commercially desirable species



An Example of "Fishing Down"

FOOD WEBS contain fewer steps, or trophic levels, when overfishing occurs. After fishers have taken the largest members of a slow-growing predatory species—such as saithe—they must turn to smaller individuals that have not yet achieved full size. Unlike older saithe, these younger fish are not large enough to catch cod, which normally consume whiting, which in turn usually eat krill-grazing haddock (*left*). Instead the small saithe must eat even smaller fish, such as herring, which feed directly on krill (*right*). Wiping out larger saithe therefore shortens the food web to four levels instead of six, disrupting ecosystems. Note that actual trophic levels rarely reach six because large fish eat a variety of other fish.

are dwindling, and the sizes of individual fish being taken are getting smaller; a large number are even captured before they have time to mature. The phenomenon is not restricted to the North Atlantic but is occurring across the globe.

Many people are under the mistaken impression that pollution is responsible for declines in marine species. Others may find it hard to believe that a shortage of desirable food fish even exists, because they still notice piles of Chilean sea bass and tuna fillets in their local fish markets. Why is commercial fishing seen as having little if any effect on the species that are being fished? We suspect that this perception persists from another age, when fishing was a matter of wresting sustenance from a hostile sea using tiny boats and simple gear.

Our recent studies demonstrate that we can no longer think of the sea as a bounteous provider whose mysterious depths contain an inexhaustible resource. Over the past several years we have gathered and analyzed data on the world's fisheries, compiling the first comprehensive look at the state of the marine food resource. We have found that some countries, particularly China, have overreported their catches, obscuring a downward trend in fish caught worldwide. In general, fishers must work farther offshore and at greater depths in an effort to keep up with the catches of yesteryear and to try to meet the burgeoning demand for fish. We contend that overfishing and the fishing of these distant stocks are unsustainable practices and are causing the depletion of important species. But it is not too late to implement policies to protect the world's fisheries for future generations.

Overview/*Fish Declines*

- New analyses show that fisheries worldwide are in danger of collapsing from overfishing, yet many people still view the ocean as a limitless resource whose bounty humanity has just begun to tap.
- Overfishing results from booms in human populations, increases in the demand for fish as a nutritious food, improvements in commercial fishing technology, and global and national policies that fail to encourage the sustainable management of fisheries.
- Solutions to the problem include banning fishing gear such as dredges that damage ecosystems; establishing marine reserves to allow fisheries to recover; and abolishing government subsidies that keep too many boats on the seas chasing too few fish.

The Law of the Sea

EXPLAINING HOW THE SEA got into its current state requires relating a bit of history. The ocean used to be a free-for-all, with fleets flying the flags of various countries competing for fish thousands of miles from home. In 1982 the United Nations adopted the Convention on the Law of the Sea, which allows countries bordering the ocean to claim exclusive economic zones reaching 200 nautical miles into open waters. These areas include the highly productive continental shelves of roughly 200 meters in depth where most fish live out their lives.

The convention ended decades—and, in some instances, even

CLEO VILETT

centuries—of fighting over coastal fishing grounds, but it placed the responsibility for managing marine fisheries squarely on maritime countries. Unfortunately, we cannot point to any example of a nation that has stepped up to its duties in this regard.

The U.S. and Canadian governments have subsidized the growth of domestic fishing fleets to supplant those of now excluded foreign countries. Canada, for instance, built new offshore fleets to replace those of foreign nations pushed out by the convention, effectively substituting foreign boats with even larger fleets of more modern vessels that fish year-round on the same stocks that the domestic, inshore fleet was already targeting. In an effort to ensure that there is no opportunity for foreign fleets to fish the excess allotment—as provided for in the convention—these nations have also begun to fish more extensively than they would have otherwise. And some states, such as those in West Africa, have been pressured by others to accept agreements that allow foreign fleets to fish their waters, as sanctioned by the convention. The end result has been more fishing than ever, because foreign fleets have no incentive to preserve local marine resources long-term—and, in fact, are subsidized by their own countries to garner as much fish as they can.

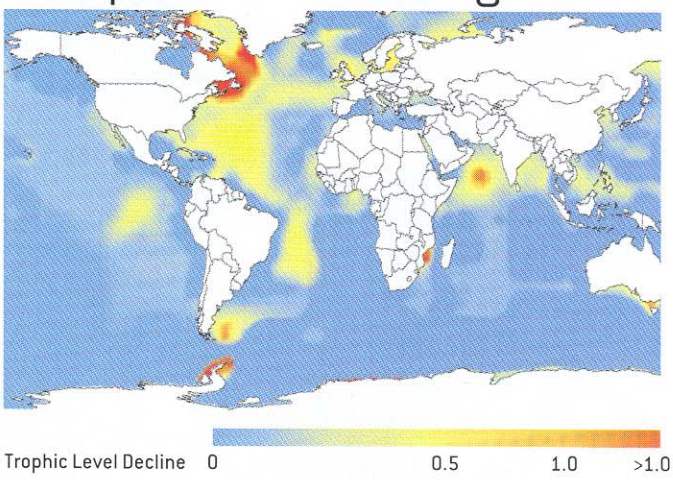
The expansion made possible by the Convention on the Law of the Sea and technological improvements in commercial fishing gear (such as acoustic fish finders) temporarily boosted fish catches. But by the late 1980s the upward trend began to reverse, despite overreporting by China, which, in order to meet politically driven "productivity increases," was stating that it was taking nearly twice the amount of fish that it actually was.

In 2001 we presented a statistical model that allowed us to examine where catches differed significantly from those taken from similarly productive waters at the same depths and latitudes elsewhere in the world. The figures from Chinese waters—about 1 percent of the world's oceans—were much higher than predicted, accounting for more than 40 percent of the deviations from the statistical model. When we readjusted the worldwide fisheries data for China's misrepresentations, we concluded that world fish landings have been declining slowly since the late 1980s, by about 700,000 metric tons a year. China's overreporting skewed global fisheries statistics so significantly because of the country's large size and the degree of its overreporting. Other nations also submit inaccurate fisheries statistics—with a few overreporting their catches and most underreporting them—but those numbers tend to cancel one another out.

Nations gather statistics on fish landings in a variety of ways, including surveys, censuses and logbooks. In some countries, such as China, these data are forwarded to regional offices and on up through the government hierarchy until they arrive at the national offices. At each step, officials may manipulate the statistics to meet mandatory production targets. Other countries have systems for cross-checking the fish landings against import/export data and information on local consumption.

The most persuasive evidence, in our opinion, that fishing is wreaking havoc on marine ecosystems is the phenomenon that one of us (Pauly) has dubbed "fishing down the food web." This describes what occurs when fishers deplete large predator fish at the top of the food chain, such as tuna and swordfish, until they become rare, and then begin to target smaller species that would usually be eaten by the large fish [*see illustration on opposite page*].

Hot Spots of Overfishing



OVERFISHING caused the complexity of the food chains in important fisheries to drop by more than one trophic level between the years 1950 and 2000. The open ocean usually has few fish.

Fishing Down

THE POSITION A PARTICULAR ANIMAL occupies in the strata of a food web is determined by its size, the anatomy of its mouthparts and its feeding preferences. The various layers of the food web, called trophic levels, are ranked according to how many steps they are removed from the primary producers at the base of the web, which generally consists of phytoplanktonic algae. These microscopic organisms are assigned a trophic level (TL) of 1.

Phytoplankton are grazed mostly by small zooplankton—mainly tiny crustaceans of between 0.5 and two millimeters in size, both of which thus have a TL of 2. (This size hierarchy stands in stark contrast to terrestrial food chains, in which herbivores are often very large; consider moose or elephants, for instance.) TL 3 consists of small fishes between 20 and 50 cen-

THE AUTHORS

DANIEL PAULY and *REG WATSON* are fisheries researchers at the Sea Around Us Project in Vancouver, where Pauly is the principal investigator and Watson is a senior scientist. The project, which was initiated and funded by the Pew Charitable Trusts, is based at the Fisheries Center at the University of British Columbia and is devoted to studying the impact of fishing on marine ecosystems. Pauly's early career centered on formulating new approaches for fisheries research and management in tropical developing countries. He has designed software programs for evaluating fish stocks and initiated FishBase, the online encyclopedia of fishes of the world. Watson's interests include fisheries modeling, data visualization and computer mapping. His current research focuses on mapping the effects of global fisheries, modeling underwater visual census techniques and using computer simulations to optimize fisheries.

NINA FINKEL

POPULAR FISH—including many of the fillets and steaks that can be found in piles at fish markets (*above*)—have been decimated by overfishing. Fishers must use increasingly complex technology and fish farther offshore and at greater depths to catch such fish. The National Audubon Society and other organizations have issued wallet cards (*right*) so that consumers can avoid overfished species (*red*) or those whose status is cause for concern (*yellow*). The entire card can be downloaded at www.audubon.org/campaign/lo/seafood/cards.html

timeters in length, such as sardines, herring and anchovies. These small pelagic fishes live in open waters and usually consume a variable mix of phytoplankton and both herbivorous and carnivorous zooplankton. They are caught in enormous quantities by fisheries: 41 million metric tons were landed in 2000, a number that corresponds to 49 percent of the reported global marine fish catch. Most are either destined for human consumption, such as canned sardines, or reduced to fish meal and oil to serve as feed for chickens, pigs and farmed salmon or other carnivorous fish.

The typical table fish—the cod, snapper, tuna and halibut that restaurants serve whole or as steaks or fillets—are predators of the small pelagics and other small fishes and invertebrates; they tend to have a TL of between 3.5 and 4.5. (Their TLs are not whole numbers because they can consume prey on several trophic levels.)

The increased popularity in the U.S. of such fish as nutritious foods has undoubtedly contributed to the decline in their stocks. We suggest that the health and sustainability of fisheries can be assessed by monitoring the trends of average TLs. When those numbers begin to drop, it indicates that fishers are relying on ever smaller fish and that stocks of the larger predatory fish are beginning to collapse.

In 1998 we presented the first evidence that "fishing down" was already occurring in some fishing grounds, particularly in the North Atlantic, off the Patagonian coast of South America and nearby Antarctica, in the Arabian Sea, and around parts of Africa and Australia. These areas experienced TL declines of 1 or greater between 1950 and 2000, according to our calculations [*see map on preceding page*]. Off the west coast of Newfoundland, for instance, the average TL went from a maximum of 3.65 in 1957 to 2.6 in 2000. Average sizes of fish landed in those regions dropped by one meter during that period.

Our conclusions are based on an analysis of the global database of marine fish landings that is created and maintained by the U.N. Food and Agriculture Organization, which is in turn derived from data provided by member countries. Because this data set has problems—such as overreporting and the lumping of various species into a category called "mixed"—we had to incorporate information on the global distribution of fishes from FishBase, the online encyclopedia of fishes pioneered by Pauly, as well as information on the fishing patterns and access rights of countries reporting catches.

Research by some other groups—notably those led by Jeremy B. C. Jackson of the Scripps Institution of Oceanography in San Diego and Ransom A. Myers of Dalhousie University in Halifax—suggests that our results, dire as they might seem, in fact underestimate the seriousness of the effects that marine fisheries have on their underlying resources. Jackson and his colleagues have shown that massive declines in populations of marine mammals, turtles and large fishes occurred along all coastlines where people lived long before the post–World War II period we examined. The extent of these depletions was not recognized until recently because biologists did not consult historians or collaborate with archaeologists, who study evidence of fish consumption in middens (ancient trash dumps).

JASON ESKENAZI (*photograph*); LIVING OCEANS PROGRAM, AUDUBON (*wallet card*)

Myers and his co-workers used data from a wide range of fisheries throughout the world to demonstrate that industrial fleets generally take only a few decades to reduce the biomass of a previously unfished stock by a factor of 10. Because it often takes much longer for a regulatory regime to be established to manage a marine resource, the sustainability levels set are most likely to be based on numbers that already reflect population declines. Myers's group documents this process particularly well for the Japanese longline fishery, which in 1952 burst out of the small area around Japan—to which it was confined until the end of the Korean War—and expanded across the Pacific and into the Atlantic and Indian oceans. The expansion decimated tuna populations worldwide. Indeed, Myers and his colleague Boris Worm recently reported that the world's oceans have lost 90 percent of large predatory fish.

Changing the Future

WHAT CAN BE DONE? Many believe that fish farming will relieve the pressure on stocks, but it can do so only if the farmed organisms do not consume fish meal. (Mussels, clams and tilapia, an herbivorous fish, can be farmed without fish meal.) When fish are fed fish meal, as in the case of salmon and various carnivores, farming makes the problem worse, turning small pelagics—including fish that are otherwise perfectly fit for human consumption, such as herring, sardines, anchovies and mackerels—into animal fodder. In fact, salmon farms consume more fish than they produce: it can take three pounds of fish meal to yield one pound of salmon.

One approach to resolving the difficulties now besetting the world's fisheries is ecosystem-based management, which would seek to maintain—or, where necessary, reestablish—the structure and function of the ecosystems within which fisheries are embedded. This would involve considering the food requirements of key species in ecosystems (notably those of marine mammals), phasing out fishing gear that destroys the sea bottom, and implementing marine reserves, or "no-take zones," to mitigate the effects of fishing. Such strategies are compatible with the set of reforms that have been proposed for years by various fisheries scientists and economists: radically reducing global fleet capacity; abolishing government subsidies that keep otherwise unprofitable fishing fleets afloat; and strictly enforcing restrictions on gear that harm habitats or that capture "bycatch," species that will ultimately be thrown away.

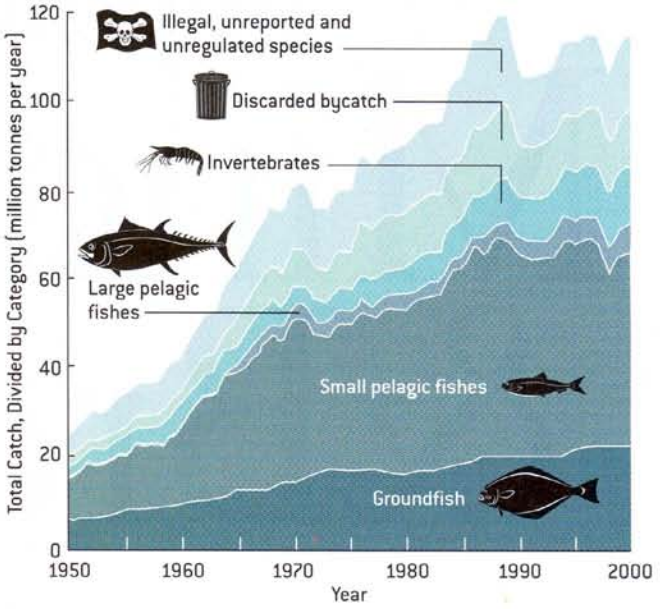
Creating no-take zones will be key to preserving the world's fisheries. Some refuges should be close to shore, to protect coastal species; others must be large and offshore, to shield oceanic fishes. No-take zones now exist, but they are small and scattered. Indeed, the total area protected from any form of fishing constitutes a mere 0.01 percent of the ocean surface. Reserves are now viewed by fishers—and even by governments—as necessary concessions to conservationist pressure, but they must become management tools for protecting exploited species from overfishing.

A major goal should be to conserve species that once maintained themselves at deeper depths and farther offshore, before fishers developed improved gear for going after them. This type of fishing is similar to a nonrenewable mining operation because fishes are very vulnerable, typically long-lived, and have very low productivity in the dark, cold depths. These measures would enable fisheries, for the first time, to become sustainable.

NATIONAL GEOGRAPHIC CHANNEL always wander

A segment based on this article will air June 26 on *National Geographic Today*, a program on the National Geographic Channel. Please check your local listings.

Catching More Fish



AMOUNT OF FISH LANDED has more than quintupled over the past 50 years. As the world's population has grown, commercial fishing technology has advanced, and demand for fish in some countries has surged.

MORE TO EXPLORE

Effect of Aquaculture on World Fish Supplies. Rosamond L. Naylor, Rebecca J. Goldburg, Jurgenne H. Primavera, Nils Kautsky, Malcolm C. M. Beveridge, Jason Clay, Carl Folke, Jane Lubchenco, Harold Mooney and Max Troell in *Nature*, Vol. 405, pages 1017–1024; June 29, 2000.

Historical Overfishing and the Recent Collapse of Coastal Ecosystems. Jeremy B. C. Jackson et al. in *Science*, Vol. 293, pages 629–638; July 27, 2001.

Systematic Distortion in World Fisheries Catch Trends. Reg Watson and Daniel Pauly in *Nature*, Vol. 414, pages 534–536; November 29, 2001.

In a Perfect Ocean: The State of Fisheries and Ecosystems in the North Atlantic Ocean. Daniel Pauly and Jay Maclean. Island Press, 2003.

Rapid Worldwide Depletion of Predatory Fish Communities. Ransom A. Myers and Boris Worm in *Nature*, Vol. 423, pages 280–283; May 15, 2003.

More information on the state of world fisheries can be found on the Web sites of the Sea Around Us Project at **www.saup.fisheries.ubc.ca** and of FishBase at **www.fishbase.org**

NINA FINKEL [*graph*] AND CLEO VILETT [*illustrations*]