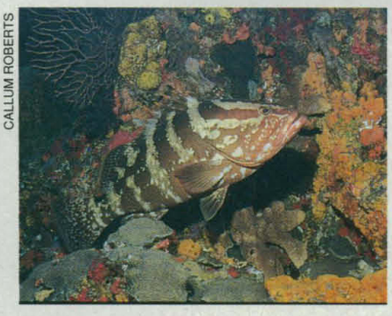
Extinction on the High Seas

Biologists have long assumed that the oceans are too vast, and their inhabitants too prolific, for humans ever to extinguish any marine species. But now that assumption is under attack

When former marine ecologist Ted Tutschulte got the news, he could hardly believe it. Thirty years ago, as a graduate student, he had taken a deep breath, dived into the shallow seas off California's Catalina Island, and scooped up as many of the big marine snails called abalone as he could hold. Later, as part of his doctoral work, he estimated that a single hectare of his study area harbored up to 10,000 white abalone, one of the three abalone species he was studying. But last month, as Tutschulte sat in his Mariposa, California, home, he learned that a recent census in his old study area had turned up just three white abalone, and scientists were predicting that the species would soon be extinct in the wild. "It just doesn't seem possible," he said.

JAMES WATT/ANIMALS, ANIMALS



CALLUM ROBERTS

Red-listed. Great white shark *(right)* and Nassau grouper *(below)*.

Tutschulte is not alone in his thinking. For centuries, biologists have doubted that humans could ever extinguish white abalone or any other species that spends its whole life in the ocean. According to conventional wisdom, the sea was just too big and deep—and its inhabitants too numerous, prolific, and widespread—for humans to leave that kind of permanent biological scar. Even the most persecuted marine creatures, biologists said, would always be able to find refuge somewhere in an ocean's vastness and eventually repopulate the seas.

Such views are reflected in government lists of endangered and threatened species and in the scientific literature. Currently, there are just a handful of marine creatures on the national and international lists of species known to be in danger of extinction. In the United States, for instance, just one fish that spends its entire life cycle in the sea, the Gulf of California's totoaba, is protected under the Endangered Species Act. Similarly, over the last 200 years, scientists have documented the extinction of only one totally marine mammal, the stellar sea cow, and just four marine mollusks.

But despite such reassuring evidence, the conventional wisdom about marine extinctions is, itself, now under threat. A small but growing number of scientists say that widespread, human-caused marine extinctions are a possibility. And one researcher—Marjorie Reaka-Kudla of the University of Maryland, College Park—argues that we have already erased thousands, if not hundreds of thousands, of species from the sea. "Humans have already caused many more extinctions in the marine environment than we are aware of," says Reaka-Kudla. She estimates that at least 1200 marine species have become extinct in the last few hundred years, mostly unknown species that inhabited coral reefs. To Reaka-Kudla and like-minded biologists, the paucity of documented extinctions only shows how few marine biologists are out there looking for missing forms of marine life.

Marine myths

Few marine biologists endorse numbers as high as Reaka-Kudla's, but many have lost the old complacency about the resilience of marine life. They point out that Earth's growing human population is putting unprecedented pressure on life in all parts of the sea. Pollution, overfishing, the introduction of exotic species, and habitat destruction already have wrought dramatic changes in shallow coastal waters. Now, new technologies—from ruthlessly efficient deep-water fishing nets to rugged, seabed mining equipment—have opened up even the deep sea to exploitation. And these scientists no longer take comfort in what had been received wisdom: that most marine creatures have sex lives that render them "extinction proof."

"Many of us who study the ocean have been embarrassingly slow to reject widespread myths that purport to describe the reproductive lives of the majority of marine organisms," says Jeremy Jackson of the Smithsonian Tropical Research Institute in Balboa, Panama. In particular, Jackson rejects "the dangerous notion that most marine species are 'extinction-proof' because they produce huge numbers of planktonic larvae that drift vast distances with the current, and hence have large populations with very wide geographic ranges. ... People invoke this idea that the ocean holds this homogeneous larval soup that rains down everywhere," he says. "So they assume that we can remove a population of fish or mollusks from one place, and that there will always be a 'somewhere else' that is a source of replacements."

This idea is false, says Reaka-Kudla, "because the reality is that many macroscopic marine organisms have limited ranges." The misperception, she concluded in the 1995 book *Biodiversity II* (Joseph Henry/National Academy Press), has at least two sources. One is the fact that marine biologists have tended to study larger, more visible marine organisms, such as starfish, crabs, and fish. These larger organisms generally do produce relatively long-lived larvae that can drift great distances. But the majority of marine species, she says, are smaller and tend to produce fewer, shorter lived larvae that do not travel far.

Another source of the misperception is that biologists have long assumed that widely distributed organisms belong to a single species. New genetic studies, however, have revealed that many commonly found organisms are in fact groups of distinct, "concealed sibling species" that can have smaller ranges and significantly different life histories. In 1988, for example, researchers discovered that the popular, edible blue mussel, found throughout the North Atlantic and North Pacific, was actually three species. The same year, scientists discovered that two commercially important deep-water crabs were in fact 18 distinct species.

Human ignorance of such basic biological facts can have dire consequences for marine species, such as the white abalone, researchers say. At first glance, a big range and a

Seas Yield a Bounty of Species

How many marine species are there? Concerns that a wave of marine extinctions may be taking place (see main text) have made that a pressing question. Biologists are now coming up with some stunningly high estimates.

Only about 275,000 marine species have actually been described, says University of Maryland, College Park, biologist Marjorie Reaka-Kudla, out of a total of 1.8 million known species in all habitats, on land and in the sea. But she says such numbers dramatically undercount marine species, because life in the sea has been studied so little.

But assuming that tropical seas harbor the kind of biological diversity found in tropical forests, Reaka-Kudla estimates that the ocean's coral reefs alone support at least 1 million species, and possibly up to 9 million. The deep sea's expansive floor, once thought to be barren, may be home to another 10 million species, estimates Fred Grassle of Rutgers University in New Brunswick, New Jersey. He and his colleagues arrived at that estimate after finding more than 1500 deep-sea species, including polychaete worms, crustaceans, and mollusks, in North Atlantic sea-floor samples collected in the early 1990s. Many of the species in the samples were rare: Almost one-third of them were collected only once.

While the total number of species in the ocean is still unknown, scientists are already certain that the sea boasts a world's record when it comes to body plan variations—the basic designs that distinguish large groups of organisms. Reaka-Kudla notes that while land hosts 28 phyla, or major groups of living organisms, the sea harbors 43. –D.M.

fecundity that is remarkable by human standards makes *Haliotis sorenseni* an unlikely candidate for extinction. The snail lives along 1200 kilometers of Pacific coastline south of California's Point Conception, clinging to rocky reefs 26 to 65 meters, or deeper, below the surface. A single, mature female can release 15 million eggs a year.

Commercial abalone divers began harvesting the species in 1965, after they had overfished stocks of other abalone species living in shallower water. To regulate the fishery, California officials imposed minimum size limits. In theory, the scheme allowed the animals to reproduce for several years before harvest, assuring a steady supply of marketable snails. In practice, however, the fishery collapsed in just 9 years. And what biologists didn't realize for almost another 20 years was that the species had been pushed to the brink of extinction.

An early sign of trouble came in 1980 and 1981, when National Park Service biologist Gary Davis and a team of divers surveyed the sea floor around the Channel Islands National Park. The area had been an abalone hotbed, but they found only 21 snails in a hectare of prime habitat. Over the last 5 years, Davis has conducted broader and more thorough searches. But his team found a total of only eight live white abalone on 8 hectares of sea floor. The same habitat supported between 16,000 and 82,000 abalones 20 years ago, Davis notes, citing Ted Tutschulte's doctoral work. Other research suggests similar declines have occurred throughout the white abalone's range.

Lonely at the bottom

The abalone population plummeted, Davis and other biologists say, because regulators overlooked a critical fact about the snail's reproductive biology: To breed successfully, the snails must be close together so that the eggs and sperm released into the water can find each other. "We're dealing with animals that need to be within a meter of each other to have effective reproduction," Davis says. "The harvest apparently reduced their population density below a critical level. It looks as if the last successful breeding season was in 1969, and those animals have been dying from natural causes ever since. Extinction is imminent unless there is human intervention."

Some state biologists and commercial divers disagree, claiming that remnant white abalone populations remain in deep water. But even if that's true, researchers point out that the white abalone is "ecologically" extinct. "Even if the species is not biologically extinct," says Paul Dayton of the Scripps Institution of Oceanography in La Jolla, California, "its population has been reduced so low that it cannot exert its former ecological role."

Currently, white abalone is the only totally marine species that scientists confidently claim is in immediate danger of extinction due to overexploitation. Some researchers worry, however, that even apparently prolific commercially exploited fish could also have hidden vulnerabilities in their population biology. "There is no reason to reject the idea that many marine fish also have critical but unknown population thresholds," argues Carl Safina, who directs the National Audubon Society's Living Oceans Program. Just because cod, tuna, and other common food fish can produce millions of wide-ranging larvae, he says, does not mean "that reproduction will always compensate for the rate at which we are killing them."

That idea is the subject of a heated debate, however, which was sparked by a decision last year by the International Union for the Conservation of Nature (IUCN) to add 118 marine fish, including overexploited food-fish species such as Atlantic cod, haddock, and bluefin tuna, to its Red List of threatened animals. At the center of the debate are IUCN criteria calling for species with populations that have

The next passenger pigeon? Redfish netted in the northwest Atlantic.

ROBERT VISSER/GREENPEACE

dropped by at least 20% in 10 years to be categorized as "vulnerable" to extinction, and species with 50% declines to be categorized as "endangered." While species appearing on the Red List gain no legal protection, listing does give them increased visibility in national and international policy forums.

Many biologists say the criteria and the categories are not appropriate for many fish species, because they experience dramatic natural population fluctuations from year to year. "Anybody who has worked with marine fish knows that the IUCN categories are meaningless for many commercial species, which have high reproductive potentials or extreme natural population fluctuations," says John Musick of the Virginia Institute of Marine Science in Norfolk, Virginia, who was on the IUCN scientific team. "Often, the goal in fisheries management is to reduce the standing stock by at least 50%, so even commercial species that are properly managed could be classified as endangered under these criteria. So would species, such as herring, that might naturally have 100,000 individuals one year and millions the next."

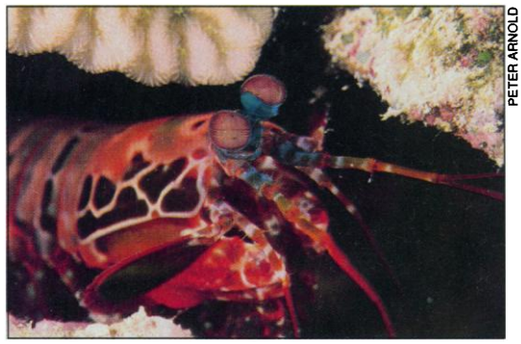
"I believe we can demonstrate that population fluctuations that would be of concern in terrestrial vertebrates are simply not relevant for many marine species," says Jake Rice, a fisheries biologist who is leading a special scientific review of the issue for Canada's Department of Fisheries and Oceans. "Atlantic cod may have been severely overexploited in parts of its range, but it is not threatened with extinction. There are still billions of cod on the Canadian side of the Atlantic alone."

"The passenger pigeon was one of the most abundant birds in the world 75 years before it became extinct in 1914—there is a humbling lesson in that," responds Elliott Norse of the Marine Conservation Biology Institute in Redmond, Washington. He contends that fisheries biologists don't know enough about marine ecology to predict confidently that even seemingly prolific fish species can cope with what he calls "multiple assaults" on the ocean environment, from fishing to pollution.

Even researchers who are skeptical about the extinction threat to many fish species agree that some, such as sharks, have a reproductive strategy that puts them at risk. Musick, for example, notes that "some sharks take decades to sexually mature and then produce a relatively small number of young," explaining why he pushed to have six sharks added to the Red List. "I believe you could drive some sharks to extinction. Despite their expansive ranges, they often live in coastal populations and tend not to cross the open ocean. If the economic incentives were strong enough, the fishery could move from population to population until you've wiped out the species."

Deep disturbances

The growing demand for seafood has put even fish living in the deep sea at risk. In the 1980s, for example, pioneering New Zealand fishers developed deep-sea netting techniques for catching orange roughy—a fish that lives more than a kilometer down—and reduced some populations by 70% in just 6 years. Although the species is not threatened with biological extinction, researchers with the Fisheries Research Centre in Wellington, New Zealand, documented "significant" reductions in genetic diversity in three major spawning populations. Such losses could make it more difficult for the species to adapt to future environmental changes, the researchers say.



PETER ARNOLD

Homebody. Smaller species of mantis shrimp *(above)* generally have smaller ranges, which may make them more vulnerable to extinction.

Increasing use of a common fishing technique known as trawling—in which nets are repeatedly dragged across the sea floor—is also putting new pressures on sea-floor creatures, including ones that are not the intended catch. The technique, which Leslie Watling of the University of Maine's Darling Marine Center in Walpole compares to "ransacking a house two or three times a year," is particularly damaging to organisms, such as some tubeworms, that lose the ability to rebuild their homes as adults. Creatures dwelling on the deepest sea floors may have particular difficulty coping with such physical disturbances because they grow slowly: A clam less than 2.5 centimeters long, for example, may be more than 100 years old.

Unless greater steps are taken to protect these and other vulnerable marine species, Maryland's Reaka-Kudla fears that the number of marine extinctions could soon be staggering. For example, she estimates that unless steps are taken to slow coral reef destruction, up to 1.2 million reef species alone could be extinct within 40 years. Her estimate, calculated using equations originally developed to predict how many species can live on an island of a certain size, rests on theoretical assumptions that coral reefs are as species-rich as tropical forests and that 30% of reefs will be gone in 40 years.

Other biologists are wary of such predictions, noting that Reaka-Kudla's theoretical work has yet to be backed by documented examples of coral reef extinctions. But they say the work that she and other biologists are doing is prompting growing interest in the issue and discussions of what should be done to reduce the risk of marine extinctions. Canada's Jake Rice, for example, says that governments around the world are increasingly concerned about the ecological impacts of fishing and are looking for advice on how to avoid potentially mortal blows to their fisheries. The trick, he says, will be gaining a better understanding of the biology of marine organisms, so that proposed solutions match the problems. The best strategy for protecting a mollusk threatened by habitat destruction, he says, could be quite different from the best one for protecting an overexploited fish. Other researchers note that the increasing use of marine reserves may help preserve some species, but afford others little protection (see next page).

While scientists try to sort out these issues, they may be missing marine extinctions occurring just outside their labs, says James Carlton, director of the Williams College–Mystic Seaport Maritime Studies Program in Mystic, Connecticut. As Carlton points out, the demise of even once-common creatures can pass unnoticed. He should know. In 1991, he became the first scientist in modern history to document the extinction of a marine invertebrate: a limpet that lived along the North Atlantic coast. About 1930, the limpet apparently succumbed after a blight killed most of its major food source, eelgrass. "What does it tell us that we didn't notice for 60 years that a once-common species became extinct, literally under the noses of marine biologists?" Carlton asks, noting that the New England coastline is "dotted with some of the nation's most prestigious marine biological laboratories."

Many other marine creatures have not even been described yet (see sidebar), making it all the more likely that no one would note their passing. Moreover, the world's classically trained marine taxonomists and biogeographers—who would be the first to notice the disappearance of a species—are themselves dying out. "Future historians of science may well find a crisis was upon us at the end of the 20th century," Carlton concluded in a 1993 *American Zoologist* paper on marine invertebrate extinctions. "[It was] the extinction of the systematist, the extinction of the naturalist, the extinction of the biogeographer—those who could tell the tales of the potential demise of global marine diversity."

–David Malakoff

David Malakoff is a writer in Bar Harbor, Maine.