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CHAPTER 13

Global Change, Fisheries, and the Integrity of Marine Ecosystems: The Future Has Already Begun

Daniel Pauly

Given that the sun continues to shine as it does now, the physicists can tell us that further increases of greenhouse gases will cause the Earth's atmosphere to become warmer, a strong and most probably correct prediction. Meteorologists and other atmospheric scientists—especially those with access to global climate models—can predict the regional structure of the climate that should result, in two to five decades, from a generally warmer atmosphere (see e.g., contributions in MacCracken et al. 1990). I am not aware of substantial agricultural or agroforestry programs being implemented on the basis of these predictions, but at least they exist and are being refined, i.e., the science is being done.

Oceanographers, given these anticipated developments, are being asked to predict changes in regional oceanographic features. However, the prospects for these predictions to be precise enough for international organizations or countries to take preventive measures appear bleak, except perhaps for sea-level changes, which, although global, would have strongly differing impacts from region to region.

Where does this leave marine ecosystems and the fisheries they support, given the meteorologists' and the oceanographers' uncertainties? Put simply, I believe that fisheries scientists cannot predict what global changes will do regionally to marine fish stocks, and that if they could, it wouldn't matter, given the other forces at work, here illustrated by the case of Northern cod (Figure 13.1; Box 13.1).

Indeed, we often do not know accurately how large the existing fisheries are, and where they operate, because of widespread cheating and budget constraints for the national and international agencies mandated with monitoring fisheries. Thus it was only recently realized that over 25 percent of

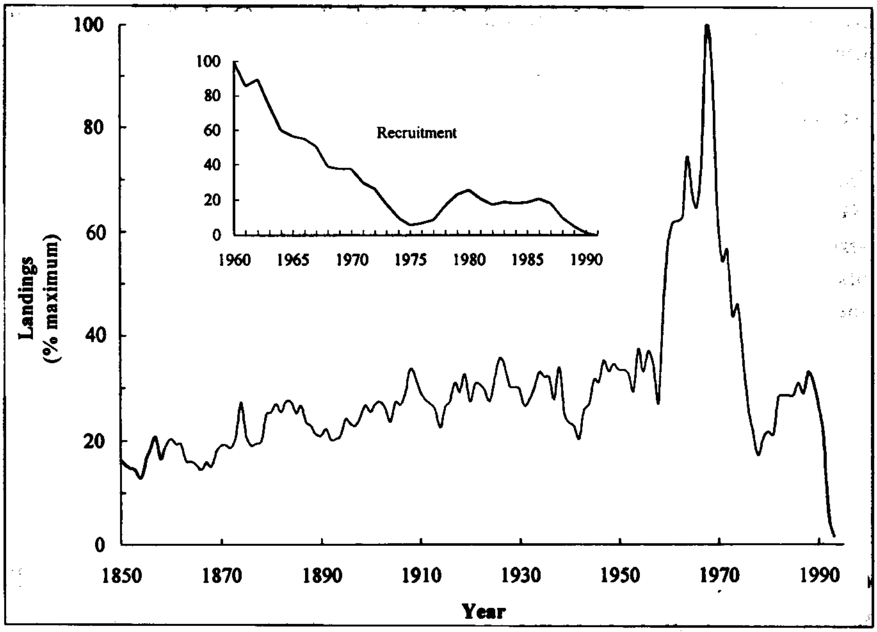

FIGURE 13.1

Time series of landings of Northern cod around Newfoundland, Canada, documenting the sustainable, inshore, small-scale fishery that caught 150–250,000 t per year for over one hundred years, until foreign deep-sea trawlers (1960s to mid-1970s) and the local trawl fleet that succeeded them (1980s) drove catches up, recruitment down, and the fishery into collapse (see insert; data from Myers et al. 1995).

the world catch of marine fish is discarded at sea (Alverson et al. 1994) and that globally, fisheries earn 50×10^6 U.S. dollars per year less than their cost, the rest being covered by government subsidies (see Beddington 1995, Christy 1997). Moreover, topping all this waste, fisheries destroy the structural integrity of marine food webs (Pauly et al. 1998). It is for these and a number of related reasons that marine fisheries resources and the ecosystems supporting them are now endangered, even before the global changes that will be induced by increased emission of greenhouse gases have begun to take hold (hence the second part of this chapter's title).

What scientists can do, on the other hand, is to try to identify key processes impacting marine fisheries and ecosystems, with a comparable scientific basis to, for example, the physical laws behind the prediction of the greenhouse effect. One could then infer some trends that might prevail, given the social and ecological conditions that might obtain two to five

BOX 13.1

A Lesson: The Collapse of Northern Cod

Northern cod (*Gadus morhua*) sustained vibrant fisheries for centuries and is indeed one of the key factors behind the colonization of Newfoundland, now a province of Canada. These fisheries, which used handlines or traps, left refuges—in deeper waters—for the large adults producing the recruits that sustained the fisheries.

In the 1970s, European trawler fleets started exploiting this resource, concentrating on the deeper waters. Catches shot up, and predictably, the spawning stock declined. In the 1980s, with the advent of the new Law of the Sea, the foreign fleet lost access to the cod stocks, now within the Canadian Exclusive Economic Zone, and was replaced by a new national fleet. In the early 1990s, the stock was completely devastated, and the century-old fishery for Northern cod was closed.

While the overwhelming preponderance of scientific evidence points at overfishing as the *sole* cause for the debacle (Hutchings and Myers 1994), there is evident support within the agency that managed the fishery for an account in which "environmental effects" conspired to destroy Northern cod, low temperatures and seals being most frequently blamed. However, the available time series of catches, dating back to 1850 and spanning several periods of intense cold, do not provide any support for low temperatures being a cause for the demise of Northern cod (Figure 13.1). And if seal predation has become relatively more important than it was before, it is because the cod biomass was reduced by fishing.

Following the collapse of Northern cod, a trawl fishery on bottom invertebrates developed around Newfoundland, targeting organisms that were low in the food web and that were earlier spurned by fishers. There is little need here to emphasize that catching these organisms is not going to help toward rebuilding, around Newfoundland, the population of this bottom-feeding fish.

I believe that these events reflect a generic feature of marine fisheries: our technical ability to catch fishes and their prey, left unchecked, will destroy all marine fisheries resources and ecosystems of the world, one after the other, and we will blame the "environment," or El Niño. In a few years, we will blame "global change."

decades hence (as represented by "scenarios" *sensu* Jamieson 1988). Examples of four such processes follow.

The first process is demographic: the same one that drives the production of greenhouse gases, i.e., the growth of the human population and the resulting increase of demand for food including fish, especially as income increases in parts of the world. Here, I abstain from presenting a graph: the depressing trends are well known, as are their largely inescapable projections into the future.

Figure 13.2 shows the evolution of global marine fish catches since World War II. Note the rapid increase from the 1960s to 1970s, and the recent flattening of this curve, whose changes are now largely determined by the ups and downs of the population of a few species (e.g., Alaska pollock, *Theragra chalcogramma*; Peruvian anchoveta, *Engraulis ringens*).

Just as some are now trying to anticipate what catches may be in the next decades, attempts were made a few decades ago to predict the world's marine fisheries catches (black dots in Figure 13.2). As might be seen, the fisheries themselves refuted the lowest among these estimates a few years after they were made. The jury is still out on the highest estimates (not shown), which reach into the billions of tonnes per year because they include unconventional species (e.g., large zooplankton such as krill), which humans might still decide to harvest on a large scale. However, one can predict,

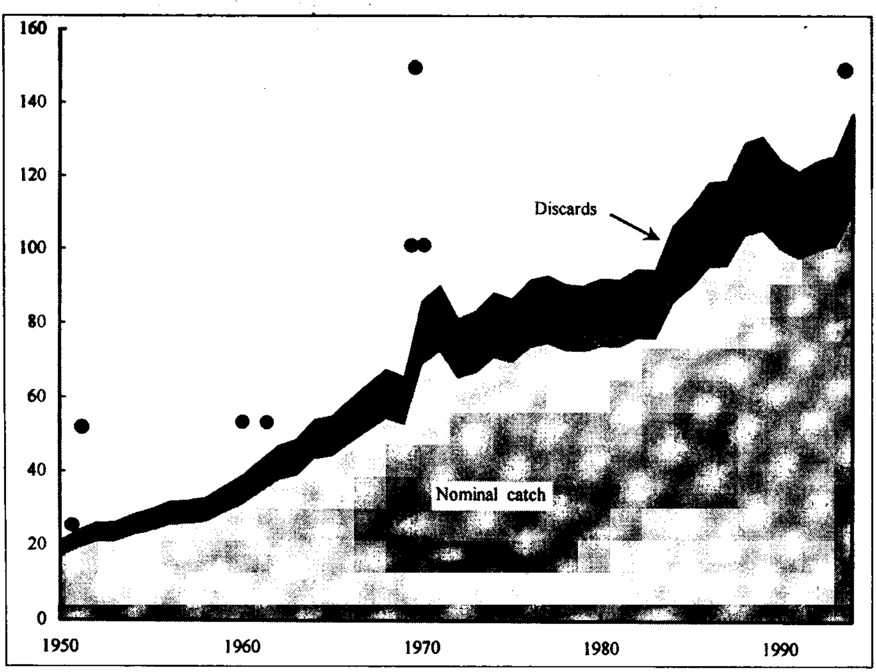

FIGURE 13.2

Marine global fisheries catches in million of tonnes (1950s to 1990s). Based on nominal catch series of the Food and Agriculture Organization of the United Nations. The estimates of discarded by-catch (for the early 1990s) of Alverson et al. (1994) were here assumed proportional to catches for the entire series. The estimates of global potential catch (full dots) plotted against their year of publication are documented in Pauly (1996b).

given the overall shape of the trend in Figure 13.2, and the increasing occurrence of collapses such as in Figure 13.1, that the catch of what is conventionally viewed as "fish" will not keep up with the increasing demand of the next decades. This leads to our second process: given increased demand and a stagnating supply, we can expect price increases on fish products.

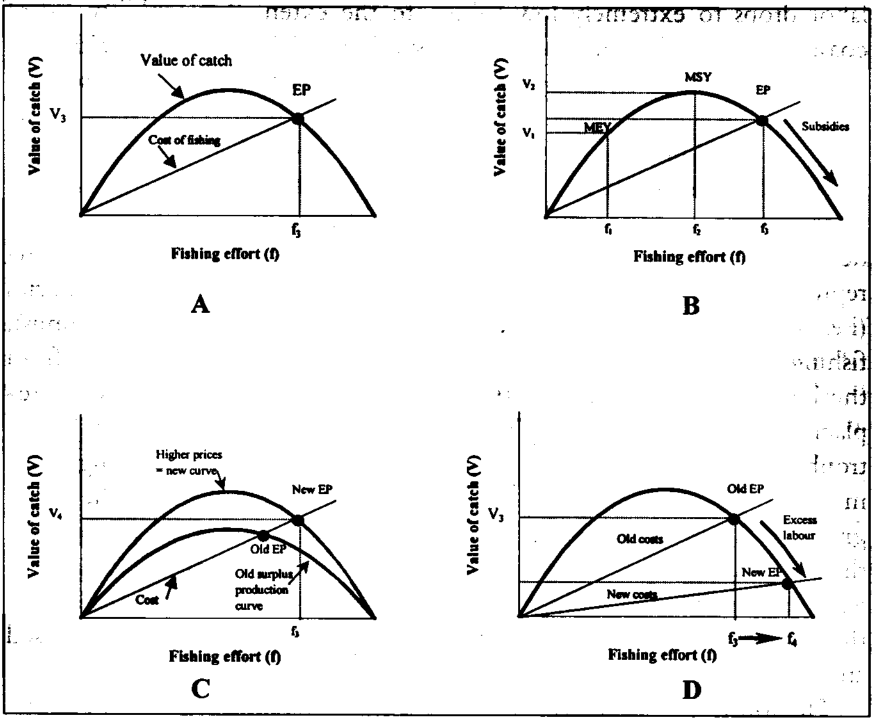

FIGURE 13.3

Schematic representation of the key economic factors affecting open-access fisheries. A: Basic model, in which fishing costs are assumed proportional to fishing effort (f), and gross returns proportional to catches (parabola). B: Under open access, f will increase past Maximum Economic Yield (MEY) at f_1 (where the economic rent, i.e., the difference between total costs and gross returns, is highest), and past Maximum Sustainable Yield (MSY) at f_2, until the equilibrium point (EP) at f_3, where costs and returns are equal, i.e., where the economic rent is completely dissipated. In this situation, subsidies, by reducing costs, increase the level of effort at which EP occurs, and thus decrease catches. C: Price increases, by increasing gross returns, increase the level of effort at which the rent will be dissipated (i.e., from f_3 to f_4), and hence foster overfishing, just as subsidies do. D: In small-scale fisheries, labor is a major cost factor; when its value tends toward zero (as occurs when there is a large excess of rural labor), resources may become severely depleted, leading to Malthusian overfishing (Pauly 1994, 1997).

These, however, have the same effect on fisheries as subsidies, i.e., other things being equal, they tend to foster overfishing (Figure 13.3).

Similarly, a reduction in the value of rural labor (which can be expected for many developing countries, whether or not the dire predictions concerning the future of their agricultural systems come to pass) will have the effect of increasing fishing effort in small-scale fisheries, and thus of fostering overfishing of coastal stocks (Pauly 1997). Indeed, when the price of labor drops to extremely low values, to the extent that mobility *out* of coastal fisheries does not occur, the syndrome I have called Malthusian overfishing (Pauly 1994, 1997) can set in, further depleting coastal resources (Figure 13.3D).

As our third process, we consider an important biological feature of fish stocks that is also likely to shape future fisheries and to strongly impact the integrity of marine ecosystems. Generally, the species that are the first to decline under exploitation are top predators, usually large fish with a low reproductive and/or population growth rate. Thus, in multispecies fisheries (i.e., virtually all bottom-trawl fisheries, especially those targeting shrimps), fishing itself induces replacements, with small, fast-growing species from the lower parts of food webs (i.e., with low trophic levels) gradually replacing (in the landings, and/or in the discarded by-catch) the fish with high trophic levels (Pauly et al. 1998; Figure 13.4). This process of "fishing down marine food webs" sometimes induces a reduction of the value of the catch, given that larger fish are usually more valuable than smaller ones. However, this effect can also be masked by changes in relative market valuations, leading over time toward higher prices for smaller fish (Sumaila 1999), and thus go on until the integrity of the supporting ecosystems is compromised and species are lost (Parrish 1995, 1998).

The fourth process considered here is also a masking effect: the cultural pattern in which successive generations of resource users (and scientists!) tend to forget the ecosystem features and fisheries resources that the generations preceding them took for granted, while continuing to overexploit what is left. The result is what I have called the shifting baseline syndrome (Pauly 1995). It is illustrated in Figure 13.5, and elaborated upon in Pitcher and Pauly (1998).

I see three possible scenarios within which these four processes may act and interact:

1. *Finis mundi.* The apocalyptic scenario that will result if nothing is done to avert the greenhouse effect, and that would probably lead to various resource wars as the warming enters some runaway stage. This is not an impossible scenario, but one that even science fiction authors cannot adequately cover—though they have tried (see Lem 1980 for a critique of the resulting "catastrophism").

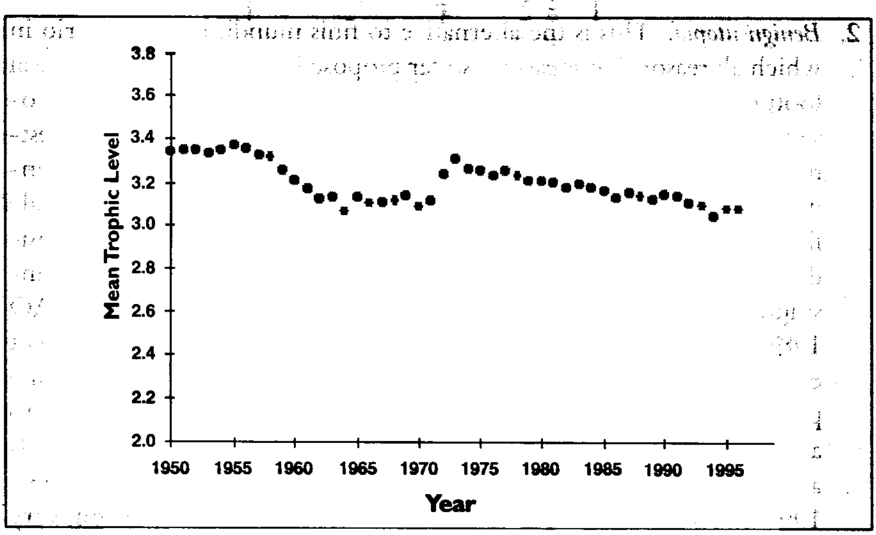

FIGURE 13.4

Mean trophic level of global marine fisheries catches, reflecting increasing targeting of species at the bottom of food webs (i.e., with low trophic levels), and depletion of top predators. Based on nominal catch series of the Food and Agriculture Organization of the United Nations and trophic level estimates in FishBase (see www.fishbase.org; see also Pauly et al. 1998).

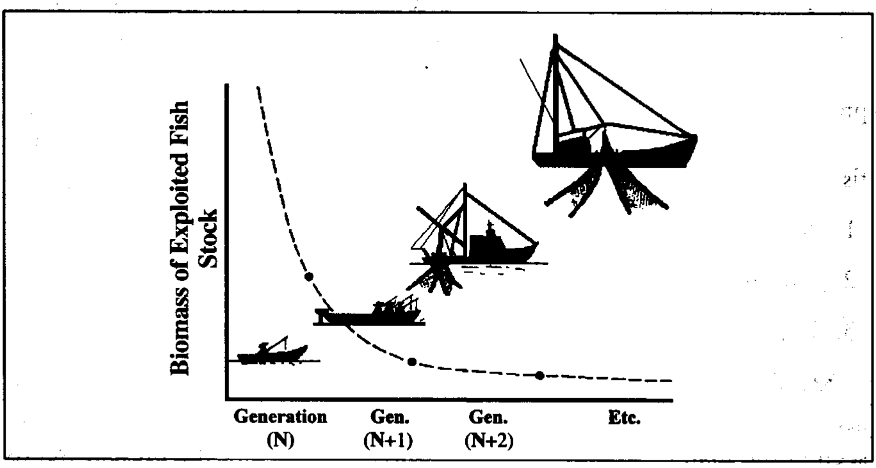

FIGURE 13.5

Schematic representation of the shifting baseline syndrome wherein the rapid decline of sensitive species that occurred in the past, at low levels of fishing effort, is not recalled by the following generations of naturalists or biologists, who tend to use the abundance level prevailing at the start of their careers as the baseline. This leads to a gradual shift of baselines, undermining the very notion of sustainability (Pauly 1995, Pitcher and Pauly 1998).

2. *Benign utopia.* This is the alternative to finis mundi, i.e., a scenario in which all reasonable measures so far proposed to reduce the ecological footprint of humans (Rees, chapter 8, this volume) on the Earth's ecosystems are rapidly implemented. These would include massive investment to foster "decarbonized" and/or otherwise "dematerialized" industrial processes, massive reforestation, and sustainable small-scale farming. For fisheries, this would include the rapid abolition of subsidies for distant and other industrial fleets (Bonfil et al. 1998), the transition to small-scale fisheries wherever possible (see Thomson and FAO 1988, and contributions in Pitcher et al. 1998), the strict enforcement of regulations that limit fishing, and the establishment of large marine protected areas to maintain patches of ecosystem integrity, but also to act as sources of recruitment to the surrounding areas (Bohnsack 1994) and to serve as insurance against recruitment failure (Sumaila 1998a, 1998b). Overall, this would imply a commitment to reregulation, very much at odds with the present trend toward deregulation. Indeed, I am well aware that if we had the institutional capacity for benign utopia, our fisheries would not be threatening the integrity of their resource base, as they are now.

3. *Muddling through.* This likely scenario would consist of doing at the last possible moment what is needed to avoid the immediate consequences of a problem, without necessarily resolving the problem itself (see e.g., Ausubel 1991).

Table 13.1 presents some possible effects on global fisheries of the four processes presented above, in the context provided by these three scenarios.

Three types of approaches have been proposed to deal with the global fisheries crisis and its regional and local manifestations:

1. Market-based approaches
2. Community-based approaches
3. Ecology-based approaches

Market-based approaches are meant to provide an alternative to "open access," the still predominant state of most marine fish stocks, and widely seen as the major cause of the global fisheries crisis and the present trends toward fishing down marine food webs.

The most important tool so far proposed to limit open access is Individual Transferable Quotas (ITQs) (see e.g., contributions in Munro and Pitcher 1996).

The applicability of ITQs to the developing-country fisheries, which

TABLE 13.1

Impact of Key Processes on the Future State of Global Fisheries Resources

Processes/Scenarios	Price Increase	Malthusian Overfishing	Species Replacement	Baseline Shift
Finis mundi	Rapid, then none	Rapid increase, then none	Terminal fauna/flora (if any) determined by temperature and water trends	na
Benign utopia	Countered by abundant supply of alternative food	Solved by rural development and reduced populations	Countered by large marine protected areas	Past populations used as reference for resource rehabilitation
Muddling through	Will cause the loss of numerous fisheries and resources systems	Will cause the loss of numerous fisheries and resource systems, e.g., coral reefs	Will soon cause the loss of many sensitive species	Strong effect, possibly all the way to gradual loss of most wild fauna and flora

nowadays contribute over half of the world catches, has been questioned (Pauly 1996a). Indeed, ITQs do not appear useful under the conditions leading to Malthusian overfishing, which is likely to become more widespread in the next decades if tropical agricultural systems indeed make large numbers of rural workers redundant (see earlier text).

Community-based approaches are not new. Communities largely regulated the sustainable fisheries of past centuries (e.g., the cod fishery in the early part of the period covered by Figure 13.1).

However, the industrialization of global fisheries in the 1950s and 1960s, which led to the increase of catches shown in Figure 13.2, largely marginalized small-scale fisheries and the local communities that depended on them. These new industrialized fisheries appear for the most part largely unsustainable (see, e.g., Figure 13.1), however, and their low catch/energy consumption ratio will make them untenable when carbon emissions are taxed (Cairncross 1991). This may enable a market-led reallocation of at least inshore resources to small-scale fisheries, which tend to have lower ecological footprints.

Ecology-based approaches are required to mitigate the damage caused by fishing, and are based on an understanding of what enabled preindustrial (and most small-scale) fisheries to operate sustainably: the fact that a part of an exploited stock (often the large spawners) could not be caught, and hence remained to generate the recruits for that same stock (as was the case for the cod in Figure 13.1 and Box 13.1). However, using modern echolocation and geopositioning technology, industrial vessels can locate and catch the last spawners of a fish stock, and thus drive it into extinction (Figure 13.1). Hence our list of marine fish that will not "survive" (Table 13.2). Also note that the fish that can be expected to survive are not particularly appetizing (Table 13.3).

A sensible response to the implications of Tables 13.2 and 13.3 is the establishment of no-take marine protected areas (MPAs), which recreate the natural refuges that sustained fisheries (Bohnsack 1994). MPAs have the advantage that they both reduce risk and accommodate imperfect knowledge (Sumaila 1998b), an advantage that is likely to become worse as global climate changes begin to strongly modify the environments of marine fisheries.

Moreover, MPAs represent our only answer to the creeping losses of biodiversity that "muddling through" will cause, given the trend of species replacement in ecosystems whose integrity has been compromised (see Figure 13.4) and our propensity to allow our biodiversity baselines to shift (see Figure 13.5 and Table 13.1).

Rapid implementation in each country of market-based, community-based, and ecology-based mitigating measures might get fisheries out of the crisis they are in. However, this—in my opinion—is unlikely to happen for the same reasons that make benign utopia unlikely. I will not venture any opinion as to which of the remaining scenarios I think is more likely; I can only hope we will muddle through.

TABLE 13.2

Marine Fish That Will Not Survive, Given Continuation of Present Trends

Large- to moderate-sized, predaceous, territorial reef fishes and rockfishes with late age at maturity, very low natural mortality rates, and low recruitment rates vs. adult stock size	Snappers, sea basses, emperors, rockfishes, sea breams
Large- to moderate-sized shelf-dwelling, soft-bottom predators susceptible to bottom trawling	Cods, flounders, soles, rockfishes, croakers, skates
Large- to moderate-sized schooling midwater fishes susceptible to midwater trawling	Hakes, rockfishes, armorheads, rougheyes
Large- to moderate-sized shelf-dwelling, schooling, pelagic fishes	Bonitos, sierras, capelin, eulachon, salmon, sharks
Any species with exceptionally high monetary value	Bluefin tuna, red snappers, halibuts, medicinal fishes, aquarium fishes, groupers, salmon, red mullets, billfishes

Source: Adapted from Parrish 1995, 1998.

TABLE 13.3

Marine Fishes That May Survive, Given Continuation of Present Trends

Small offshore, nonschooling, mesopelagic, or epipelagic fishes	Lanternfishes, bristlemouths, deep-sea smelts, flying fish
Small, solitary, ugly, shore fishes	Blennies, sculpins, poachers, prickbacks, kelpfish
Small unpalatable, reef and slope bottomfishes	Lizardfish, sand lances, gobies, leatherjackets, toadfish
Small, reef- and slope-dwelling generalists	Cardinalfish, damselfish, soldierfish, wrasses, butterflyfish
Small, early-maturing pelagics with indeterminate spawning	Tropical anchovies, tropical herrings, round herrings, scads, jacks, frigate mackerel

Source: Adapted from Parrish 1995, 1998.

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