Lanternfish Heaven: the Future of World Fisheries?

RICHARD
H. PARRISH

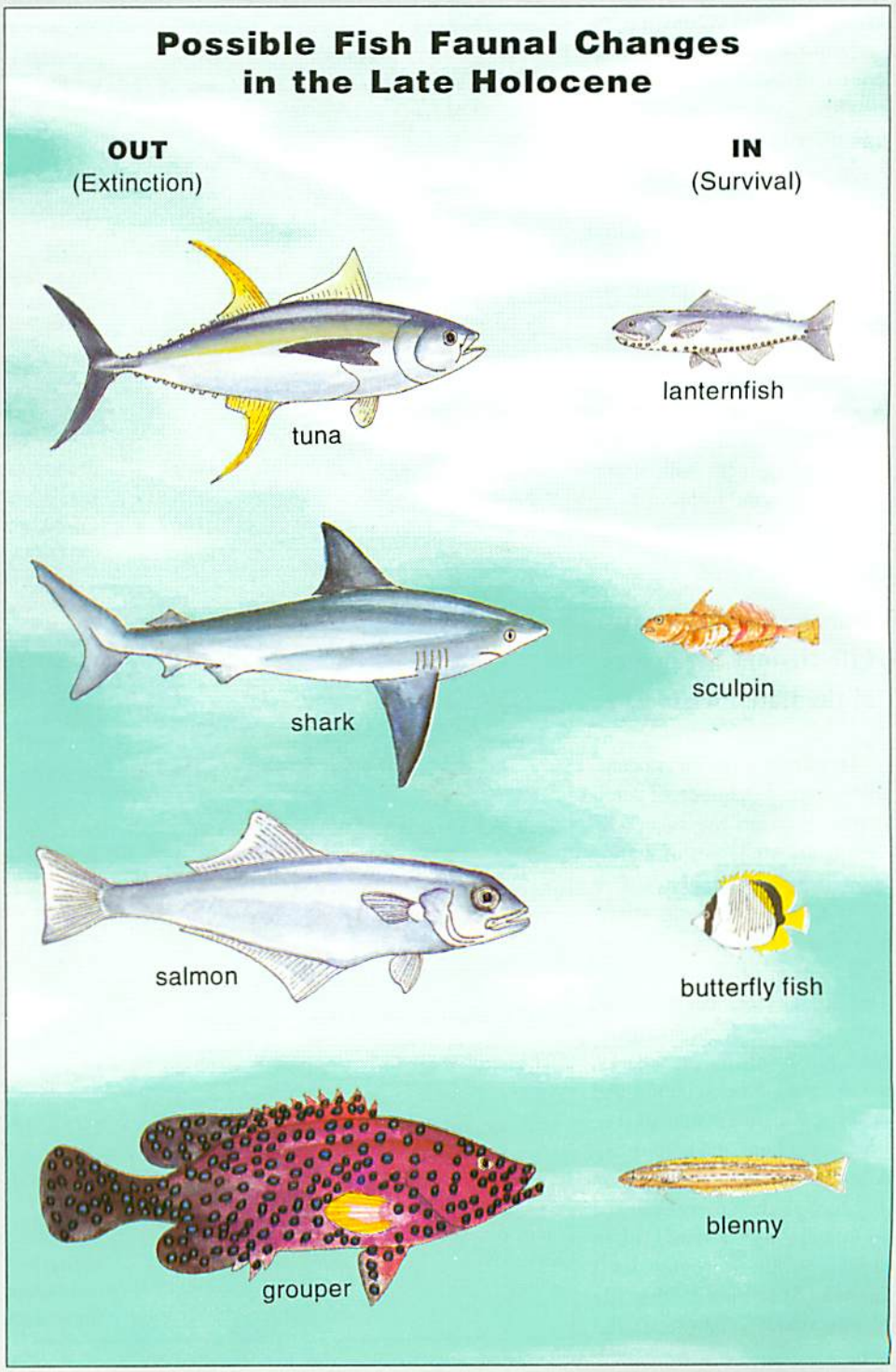
The differences between fishes in their size, behavior and food make them more or less vulnerable to fishing pressure. Large predators, long-lived fish, most trawl species and pelagic schooling fishes will possibly become extinct, to be replaced by small nonschooling unpalatable species.

Introduction

The descendants of the fish fauna which evolved in the warm seas of the Paleocene and Eocene, when alligators were found north of the Arctic Circle and temperatures at the bottom of the ocean were above 13°C, today dominate the tropical and subtropical ocean. The largest component of today's marine fish fauna is the tropical Indo-Pacific fauna. The other two major fauna, i.e., the North Pacific and North Atlantic cold-temperate fauna, are descendent from the high latitude fauna of the Panthalassa. These cold-temperature fauna were undoubtedly displaced from high latitudes to the mid-latitudes by the climatic deterioration which started with the buildup of Antarctic glaciation in the Miocene, and accelerated in the late Pliocene and Pleistocene. Polar seas and deepwater regions are depauperate in marine fishes due to the small amount of time which has been available for fishes to evolve to the very cold marine climatic conditions which developed with the onset of extensive northern hemisphere glaciation about 2.4 million years ago.

The recent or Holocene period started at the end of the last ice age, about 10,000 years ago, and for the purposes of this paper I have divided it into the early Holocene and the late Holocene. I take the advent of the internal combustion machine as the transition point from early to late Holocene and look not at the next century but the next small increment in geological time, i.e., the next 10,000 years.

The late Holocene period can be characterized by the presence of modern fishing vessels employing a diverse array of technological improvements which greatly increase their capacity to harvest fishes.



Estimates of the world's marine fish catch prior to the introduction of the internal combustion engine are unavailable but probably did not exceed 3 million t. The great increase in the world's catch during this century has primarily been due to the expansion of fishing to species and stocks which were previously unexploited or lightly exploited. It is clear that in many regions, fisheries yields have approached, or even exceeded, levels that will be sustainable: the percentage of the annual primary production required to support existing fisheries and bycatch has already reached 25% in the world's upwelling ecosystems and 35% in the world's nontropical shelf ecosystems (Christensen and Pauly, this issue). The potential for fisheries expansion in the future appears to be limited primarily to oceanic regions.

Here, I examine the life history strategies of marine fishes which were successful in the Pleistocene and early Holocene and compare them with strategies which would appear to be advantageous or disadvantageous in the late Holocene.

Successful Vertebrate Life History Strategies of the Late Pleistocene

At the end of the Pleistocene, there were a number of similarities between the successful life history strategies of marine and terrestrial vertebrates. One of the most conspicuous strategies was the reduction of mortality by acquisition of large size. This strategy has been utilized by a wide range of pelagic fishes (i.e., tunas, billfishes, sharks, molas, and some scianids and skates) and marine mammals (i.e., whales, sea lions and porpoises). A second strategy, aggregation to reduce predation, was utilized by mobile, highly social, often migratory, lower trophic level animals. Species with this life history strategy (i.e., terrestrial herding herbivores, flocking waterfowl, and marine schooling planktivores) dominated the vertebrate biomass of terrestrial and marine environments at the end of the Pleistocene. Two other strategies, small generalist and small specialist, were utilized by a large number of highly diverse species. Fishes with these strategies are often territorial and they generally do not achieve large population sizes.

Obvious Losers in the Late Holocene

Large- to moderate-sized, predaceous, territorial reef fishes and rockfishes which have 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, softbottom predators which are susceptible to bottom trawling.	Cods, flounders, soles, rockfishes, croakers, skates
Large- to moderate-sized schooling midwater fishes susceptible to midwater trawling.	Hakes, rockfishes, armorheads, roughyes
Shelf-dwelling, pelagic, estuarine dependent or anadromous fishes which have restricted spawning grounds or have low fecundity.	Herrings, shads, capelin, eulachon, salmon, sharks
Large- to moderate-sized shelf dwelling, schooling, pelagic fishes.	Bonitos, sierras, jacks, trevallies, corvina, weakfish, barracudas, salmon
Any species with exceptionally high monetary value.	Bluefin tuna, red snappers, halibuts, medicinal fishes, aquarium fishes, groupers, salmon, red mullets, billfishes

Obvious Winners in the Late Holocene

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

Life History Strategies At Risk in the Late Holocene

There are a number of life history strategies which will be particularly at risk in the late Holocene (Box). The marine fishes which are most likely to disappear quickly are high trophic level predators which have suddenly themselves become prey to modern fishing vessels. The most susceptible of the long-lived predaceous fishes are those which have relied on the king-of-the-reef strategy (i.e., large territorial fishes such as many of the serranids, lutjanids, lethrinids, sciaenids, sparids and scorpaenids).

Fishes susceptible to capture by bottom trawls (such as the shelf-dwelling gadids, pleuronectids, bothids, sparids and scorpaenids) are likely to have high extinction rates. Many of these species have a delayed age at maturity which is associated with their large size. In addition to the delayed maturity problem, skates and demersal sharks are particularly at risk due to their low fecundity. Many of the smaller species which are presently not targeted by bottom trawl fisheries but whose habitat is subject to trawling, are likely to face increased exploitation as the primary trawl species become less abundant. They also face increased mortality through incidental capture and decreased productivity through alterations in habitat caused by many centuries of trawling. Schooling midwater or epibenthic species which are susceptible to midwater trawling, such as hakes, armorheads, roughyes and some scorpaenids, will also be at risk.

Pelagic schooling fishes are particularly susceptible to capture by modern purse-seines and gillnets. Prior to their exploitation by humans, small pelagic fishes such as sardines, anchovies and herrings, and mid-sized

pelagic fishes like mackerels and jack mackerels, achieved real reductions in mortality by aggregating in dense schools. This behavioral pattern, which was highly successful in the early Holocene, now results in greatly increased mortality when these species are targeted by a fishing fleet using modern fishing technology. Aggregation of fishes into dense schools allows a modern purse-seiner to kill all, or nearly all, of the fish in a school in a single set.

While schooling is likely to be a very poor strategy for the late Holocene, shoaling (i.e., when numerous fish schools are in close proximity) is even worse. When shoaling occurs in some species (i.e., clupeids and engraulids), a modern fishing fleet can kill several hundred thousand tonnes (i.e., more than 10 billion fish) in just a few days. In most small pelagic fishes, the survivors from one day of fishing re-aggregate the following day in schools which are less numerous but essentially the same size as the previous day. This behavioral trait is particularly maladapted for the late Holocene as it results in a situation where mortality rates due to fishing do not decrease as the population size decreases. The behavioral traits which allowed many small schooling fishes to reduce their mortality rates from predation in the early Holocene now often result in greatly increased mortality rates from modern fishing fleets.

On the positive side, there will be a reduction in predation rates for many of the small pelagic fishes as fishing will reduce the numbers and diversity of their predators. The tradeoff between increased fishing mortality and decreased predation mortality may allow some small pelagics to increase both their ranges and population sizes while others will be at risk of extinction. Generally, the tropical small pelagics will be more likely to have population and range increases as predation rates tend to be higher in the tropics. Also tropical species are more likely to mature at an early age and to be indeterminate spawners, which may allow them to maintain or even increase their fecundity under the altered physical environments, species composition and age structures of the late Holocene. Cold-temperate and subpolar small pelagics are the most likely to be at risk as they have higher ages at maturity and tend to spawn only once per year at established locations.

Life History Strategies Likely to be Successful

Population dynamics factors will be important in the determination of which species will be successful during the late Holocene. Fishes which have low absolute growth rates (i.e., small maximum size) but high relative growth rates (i.e., they reach adult size quickly) will be favored. Fishes with an early age at maturity, high fecundity rates, and a high recruit to adult ratio will be favored. Fishes which have a relatively plastic age at maturity and/or indeterminate spawning, factors which allow excess energy to be readily used to increase annual fecundity, will have an advantage over those with a set age at maturity and set annual fecundity. Fishes able to persist under high mortality rates (i.e., those with a low natural mortality rate relative to their age at maturity or to their recruit-adult ratio) will also be favored. Fishes whose population size and or range has been limited by large or schooling predators could have great increases in their distribution and abundance, as the abundance and distribution of predators are reduced.

Behavioral traits which will be favored through the late Holocene include nearly any trait which spreads out the population or makes it difficult for fishers to locate or harvest them. For example, it will be advantageous to be solitary or to live in small groups, to have an age-dependent habitat distribution, to be nonterritorial, to be nomadic but to have little seasonal pattern in migrations.

Some habitats will be less affected by fishing and environmental alteration than others. Oceanic fishes will be less at risk than estuarine and neritic fishes; mesopelagic and bathypelagic fishes will be less at risk than epipelagic, benthic, and reef fishes.

Political and Fisheries Management Regimes

One of the early fisheries science concepts was that prior to exploitation there was some sort of an equilibrium state and that we would be able to achieve an "optimum" yield from a population if we could just get fishing mortality at the right level. In many areas of the world we currently have the knowledge to tell when stocks are overharvested and depleted; but very few areas of the world have political regimes capable of managing a stock at a fishing mortality rate which would even approach "optimum" levels.

The political and fisheries regimes that I am most familiar with, those of the USA, are typical examples of fisheries management at the beginning of the late Holocene. Both the Pacific and Atlantic coasts of the USA have bellwether fisheries which have been exploited for several centuries, have great economic and cultural importance, have many decades of well funded multidisciplinary research, and extensive state-of-the-art fishery management regimes. The bellwether fishery on the Atlantic Coast is the Georges Bank groundfish fishery and on the Pacific Coast is the salmon fishery. The fisheries regimes for both fisheries are based on the concept of achieving the "optimum yield" of the individual regulated species. The groundfish fishery harvests a mixture of marine fishes whereas the salmon fishery harvests just a couple of anadromous species but each species has/had many isolated genetic stocks. Evidence was available for each fishery which clearly showed that the principal stocks were being overharvested and that the populations were in an extended state of decline. The management regime in each of these fisheries can only be credited with the collapse of its fishery.

It is possible that a fisheries management regime based on long-term preservation of species diversity will someday prevail. Fisheries management regimes are of course primarily dependent upon political regimes which, history teaches us, are very ephemeral. One should therefore not be led to the conclusion that any fishery management regime will last longer than the political regime it was based on. In my opinion a strategy of reliance on fisheries management appears to be inferior to one based on being a small, quick growing, early maturing, nonschooling, offshore fish which is unpalatable to primates.

I would place my bet that the late Holocene will become a lanternfish heaven.

R.H. Parrish is a Fisheries Biologist of the Pacific Fisheries Environmental Group, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, United States Department of Commerce, PO Box 831, Monterey, CA 93942 USA.