CMFRI

Winter School on

Impact of Climate Change on Indian Marine Fisheries

Lecture Notes

Part 1

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EFFECT OF ENVIRONMENT ON MARINE FISHERIES

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Introduction

The oceans cover 70% of world's surface and are of critical importance economically, environmentally and socially. They are a valuable source of food, minerals and fossil energy; provide essential and biodiverse habitats; account for almost 50% of the world's carbon fixing potential; and offer opportunities to exploit renewable energy resources such as wind and tidal power.

The characteristics of the marine environment in marine fisheries are very important as the conditions in the sea play a vital role in the availability of the fish. The variations in the physical, chemical and biological oceanographic conditions have a marked influence on the periodic and seasonal migration of fishes in the sea. The research work carried out by the Central Marine Fisheries Research Institute over the years has helped to understand how these mechanisms work. This knowledge can be incorporated into the management and conservation of the marine living resources in Indian waters, and to know about the impact of climate change. The major parameters which have an influence on marine living resources are temperature, salinity, pH upwelling, primary and secondary production.

The influence of various environmental factors on marine fisheries is briefly discussed below:

Temperature

Temperature is an indicator of complex ocean processes. The changes in surface seawater temperature affect the abundance and diversity of phytoplankton, which are the food for smaller fish. Generally, most of the species of fishes have fairly narrow range of optimum temperatures. In the Exclusive Economic Zone (EEZ) of India, generally, the mean sea surface temperature (SST) is about 29ºC during summer (April-May), which cools down during the advancement of monsoon reaching 25ºC during August-September. The variations in the SST are considered as an indicator of abundance of fish. The SST and ocean frontal zones, where the water temperature suddenly changes, are used in locating the potential fishing zones using remote sensing techniques.

Thermocline

The temperature drops rapidly below the surface waters forming a layer known as thermocline. Generally, the thermocline in the Indian Seas is shallow during the southwest monsoon, moderate in the summer and deeper during the winter. During June-September, the thermocline occurs between 30m and 80m depth along the southwest coast and the Gulf of Mannar but it descends to 80-120m during December-February. The availability of fish stocks in our inshore waters is related to the seasonal variations in the depths of thermocline influenced by the monsoon. The mackerel and sardine fisheries along with the southwest coast of India start with the onset of southwest monsoon. During southwest monsoon (June-September) when the thermocline moves towards the surface and coast along with the southwest coast of India, there is a concentration of pelagic and demersal fishes. Tunas gather around the areas of upwelling and in the areas where the thermocline is shallow. In the waters of Lakshadweep, large shoals of skipjack tuna are found during December when shallow thermocline takes place. Generally, strong thermocline keeps the pelagic fishes like the coastal tunas and small pelagics above it and the demersal fishes below, therefore forming a natural barrier in between. During purse seining, shallow and strong thermocline makes fishery very effective.

Ocean warming

Temperature is a pervasive environmental factor with direct effects on nearly all aspects of the ecology, physiology, morphology, and behaviour of poikilotherms. There is a vast scientific literature describing the temperature-dependence of physiological processes and thermal ecology of individuals of a given species. Less is known about population and ecosystem level responses to temperature change but we know enough to make fairly strong, general predictions about the consequences of warming at least at the species level.

All species are adapted for life over a relatively moderate range of temperatures compared with the extremes experienced from the poles to the tropics. Temperatures below the optimal range slow the rate of metabolism, and if too low, can become lethal. Temperatures above the optimal range increase metabolism and, because warmer water contains less dissolved oxygen, a thermal threshold is reached where respiratory demand exceeds the capacity for oxygen uptake, sometimes referred to as the "temperature-oxygen squeeze". Hence, temperature is one of the primary environmental factors that determine the geographic range of a species. Minimum winter temperatures often determine the high-latitude boundary (the northern boundary in the northern hemisphere) while summer maxima determine the low-latitude limit of a species. Even within the normal range of a species, the dynamics of populations often show strong correlations with temperature trends.

While scientists can use the thermal physiology of a species to predict how it might respond to the direct effects of ocean warming, there are indirect effects at the ecosystem level that complicate the overall impact considerably. In temperate regions, for example, the complex of species found at given latitude is a mixture of those adapted to colder or warmer thermal regimes. These species are interconnected through a web of predatory, competitive, pathogenic, parasitic, and mutualistic interactions that influence the abundance of species. Invasive species also sometimes get a foothold more easily in systems undergoing disturbance. In addition, changes in temperature may influence the overall primary productivity of ecosystems in either positive or negative directions, which may ultimately impact fisheries yields.

In general, the impact of ocean warming should be most evident at the northern and southern boundaries of the distribution of a given species. These boundaries tend to be shared among numerous species, and they tend to occur where there are sharp discontinuities in thermal gradients. Hence, there are certain regions of the world oceans that are transitional zones for numerous species. It is within these transitional regions where we are likely to first see the strongest impacts of climate change.

Ocean acidification

Knowledge of the potentially devastating impact of reduced pH on aquatic ecosystems is not new. Decades ago, it became evident that acid rain was afflicting numerous freshwater ecosystems leading to declines and extinctions of numerous fish and macro-invertebrate species from certain lakes and streams that lacked a natural buffering capacity. What is new is the recognition that acidification of entire oceans is possible. It is caused not by acid rain, however, but from increased CO_2 in the atmosphere, which in turn leads to increased carbonic acid in the ocean. Most of our knowledge of the direct effects of ocean acidification on marine organisms focuses on species known as "marine calcifiers" (e.g., corals, molluscs) that build skeletons or shells made of calcium carbonate. Many of these species will suffer impaired ability to build skeletons as pH decreases. We know less about the direct impacts of acidification on harvested species like fishes and squids. In these species, the response to acidification is likely to involve physiological diseases including acidosis of tissue and body fluids leading to impaired metabolic function. Egg and larval stages are likely to be much more susceptible than adults, suggesting that reduced reproductive success will be among the first symptoms to appear. The indirect effects of acidification on fisheries will include loss of reef habitat constructed by marine calcifiers. Many fishes depend on the physical structure provided by coral skeletons or shell-building organisms such as oyster reefs as essential habitat for one or more life stages. In addition, food web alterations will likely affect harvested species through bottom-up effects on the food chain resulting from pH-induced shifts in the plankton community. More research is needed to understand these complex interactions.

Salinity

The salinity of the water has significant influence on fisheries. The monthly mean sea surface salinity in the southeastern and central eastern Arabian Sea indicates two peaks, one during May-June before the onset of southwest monsoon and another during September-October immediately after the southwest monsoon. The monthly mean surface salinity varies from 32.5 ppt to 36.1 ppt. The salinity maximum characteristics of the tropical ocean are found at depths of 100 m to 150 m during northeast monsoon and 30 to 50 m during southwest monsoon. The northern region of the Arabian Sea was reported as favourable for the mackerel fishery while the southern region for the sardine fishery. The reason attributed was that the sudden increase in salinity occurring northwards from the region off Mangalore during major part of the year.

Sudden temperature fluctuations influence salinity tolerance of an organism. In such changes, high temperature has an adverse effect compared with normal temperature. Salinity and temperature together influence certain physiological responses such as growth, metabolic rates and blood iron.

Upwelling

The colder bottom water rich in nutrients rise to the surface near the coast. This process known as upwelling occurs during certain seasons when the winds shift surface water from the coast to offshore. This upwelling of bottom waters provides nutrients for the growth of microscopic plants and animals that fish feed on, thus promoting growth of the fish population. Upwelling takes place mainly along the coasts of Peru, Western North America, Northwest and southwest Africa, Somalia, the Arabian Peninsula and Antarctica. During upwelling, oxygen minimum rich layer emerges from 100 to 150 meter depth to the surface. As a result, some fish populations move into shallow surface water while the others move offshore, away from the centre of strong upwelling. Pelagic fishes like mackerel, oil sardine and whitebaits avoid temporarily the areas of intense upwelling and tend to concentrate into dense schools close to the surface and the coast in the nearshore ground, affording good catches. With the progress of monsoon and upwelling towards north, pelagic shoals also follow the trend and spawn intensively during January to September, when the availability of larval food is maximum.

Primary and secondary production

Primary production is the synthesis of new plant matter by floating microscopic plants of seawater through the process of photosynthesis. Most marine animals depend directly or indirectly on these microscopic organisms for survival. The fishery for oil sardine and mackerel are entirely dependent on the phytoplankton blooms along the west coast of India. The first arrival of oil sardine along the west coast coincides with the diatom bloom and migration of oil sardine is timed to coincide with two seasonal blooms of the diatom, *Nitzschia oceanica*. Along the southwest coast of India, the phytoplankton bloom is rich during southwest monsoon. The average primary productivity of west coast of India within the surface and 50m depth is 1.19gC/m^2/day and it is equivalent to an annual gross production of 434 gC/m^2/day which is high compared to several other parts of the world.

Zooplankton includes microscopic protozoans such as copepods, water fleas and jellyfishes, which constitute the secondary producers. Zooplankton forms the vital link in the pelagic food chain.

Several attempts have been made to relate primary productivity to that of potential yield or optimum sustainable yield. From our EEZ of 2.02 million km^2, the total estimated production is 283 million tonnes of carbon. Therefore, the calculated harvestable fishery resource from our EEZ would amount to about 5.5 million tonnes (0.02% of the calculated primary production) of pelagic (70%) and demersal (30%) resources. Secondary production along the Indian coast ranges from 1.4 mgC/m^2/day to 57.3 mgC/m^2/day. The seasonal higher productivity in the eastern Arabian Sea is found to be mainly through upwelling during summer and cooling during winter.

Suggested reading

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