Rajiv Gandhi Chair Special Publication - 2008

GLIMPSES OF AQUATIC BIODIVERSITY

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Published by

RAJIV GANDHI CHAIR IN CONTEMPORARY STUDIES
SCHOOL OF ENVIRONMENTAL STUDIES
COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY
Kochi - 22

Glimpses of Aquatic Biodiversity - Rajiv Gandhi Chair Spl. Pub., 7 : 111 - 119 (2008).

ADAPTATION OF THE OIL SARDINE, *SARDINELLA LONGICEPS* TO SEAWATER WARMING ALONG THE INDIAN COAST

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A rise in temperature as small as 1° C could have important and rapid effects on the mortality of some organisms and their geographical distributions. The more mobile species should be able to adjust their ranges over time, but less mobile and sedentary species may not. Depending on the species, the area it occupies may expand, shrink or be relocated with changes in oceanic conditions. For fishes, elevated seawater temperature may strongly influence distribution and abundance (Wood and McDonald, 1997) through changes in growth, survival, reproduction, or responses to changes at other trophic levels (Beaugrand *et al.*, 2003). These climatic changes may have impacts on the nature and value of commercial fisheries. Fish species with more rapid turnover of generations may show the most rapid demographic responses to temperature changes (Perry *et al.*, 2005).

The oil sardine is a coastal, pelagic, tropical schooling fish, forming massive fisheries in India. It attains a maximum total length of about 22 cm and plays a crucial role in the ecosystem as a plankton feeder and as food for large predators. It is a cheap source of protein and forms a staple, sustenance and nutritional food for millions of coastal people. It has high population doubling time of less than 15 months and is probably the largest stock in the Indian Ocean (Fish Base, 2007). Like many other sardine species, the oil sardine also has shown population crashes and sudden recoveries in the past. It is known for its restricted distribution in the Malabar upwelling region along the southwest coast.

As the oil sardine *Sardinella longiceps* are sensitive to environmental variables especially to sea surface temperature, we examined the catch of the oil sardine along the Indian coast to find out how responsive is the fish to seawater warming, which is occurring as a consequence of man-made climatic change.

Methodology

For examining the response in the distribution of the oil sardine to temperature changes, two sets of data were used. The first data set was on sea surface temperature (SST) obtained from International Comprehensive Ocean – Atmosphere Data Set (ICOADS) (ESRL PSD *www.cdc.noaa.gov)* and 9-km resolution monthly SST obtained from A *VHRR satellite data (*provided by the NOAA/NASA at *http://podaac.jpl.nasa.gov/).* The annual average SST data were computed for a 47 year period from 1961 to 2007 and plotted in Surfer. The second data set was on annual oil sardine catch along each maritime state for the years 1961-2006 obtained from CMFRI, Kochi. The data were collected by qualified and well-trained technical staff of CMFRI by following stratified multistage random sampling technique in which the oil sardine landings was recorded by covering landing centres along the Indian coast at pre-determined frequencies. The catch data were weighted to estimate the annual catch for each maritime state and pooled to arrive at catch along the four regions, viz., the northwest coast (NW) comprising of Gujarat and Maharashtra; southwest coast (SW) comprising of Goa, Karnataka and Kerala; northeast coast (NE) comprising of West Bengal and Orissa; and southeast coast (SE) comprising of Andhra Pradesh and Tamilnadu. For plotting in

Surfer, the percentage contribution by each maritime state was converted into corresponding 2° latitude-longitude grid. (CMFRI, 2006)

In addition, chlorophyll a concentration were examined using satellite data from Sea-viewing Wide Field of view Sensor (SeaWiFS).

Results

Sea surface temperature: Warming of sea surface and expansion of warm water tongue towards the northern latitudes are evident in the Indian Seas (Fig. 1). For instance, the annual average SST, which ranged between 27.7° C and 28.0° C during 1961-1976 increased to 28.7°C-29.0°C during 1997-2007 between 9° N, 76° E and 11° N, 77° E (southwest coast). The warmer surface waters (29.0° C-29.2° C) expanded to a very large coastal area (between 8° N, 72° E and 14° N, 75.5° E) in the 47 year period. The cooler waters (25.2° C-25.5° C) in 23° N, 68° E (off Saurashtra coast) during 1961-1976 disappeared completely in the later years. Similar pattern of warming was evident in the Bay of Bengal too. The annual average SST increased by 0.2° C along the NE, SW and NE coasts, and by 0.5° C along the SE coast during 1961-2007.

Oil sardine catch: The oil sardine catch is known for interannual fluctuations. After several rises and falls during 1961-2006, the catch along the Indian coast reached the lowest of 44,273 tonnes in 1994. Since then the catch consistently increased and reached a peak of 3,98,173 t in 2003 and 3,94,598 t in 2006 (Fig. 2).

The catch was strikingly different between the four regions. The annual average catch was 1,938 t, 1,71,035 t, 115 t and 19,656 t along the NW, SW, NE and SE coasts, respectively (Fig. 3). The catch along the SW coast, "the home" of the oil sardine, fluctuated widely. It decreased from 3,00,775 t in 1963 to a mere 3,187 t in 1994, but increased consistently thereafter and reached an all time peak of > 3,40,000 t in 2003 and along the NW coast, 73% was during 1986-2006. Along the SE coast, the increase in catch was more striking. Of the cumulative catch along the SE coast in 47 years, 98.8% was during 1986–2006. The oil sardine emerged as a major fishery along the SE coast since 1990, and in the late 1990s, it emerged as the largest fishery along the Tamilnadu coast. Along the NE coast, the oil sardine catch was recorded for the first time in 1984 along the Orissa coast. Since then, it is contributing a minor fishery regularly along the Orissa coast, and from 1996 along the West Bengal coast.

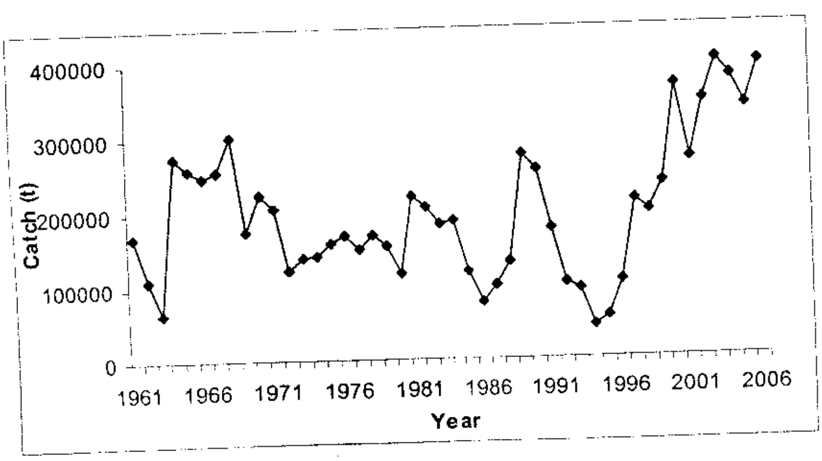

Fig. 2: *Oil sardine catch along the Indian coast*

Emergence of oil sardine as a major fishery along the SE coast, and as a minor fishery along the NW and NE coasts during 1986-2006 reduced the percentage contribution of SW coast to the all-India oil sardine catch. The contribution of the SW coast, which was as high as 99.2% to the all- India oil sardine catch during 1961-65, reduced to 60.4% during 1991-95, but recovered to 85.7% during 2000-06. The contribution of SE coast to the all-India oil sardine catch, which was nil during 1961-65, increased to 39.0% during 1991-95, but decreased to 12.7% during 2000-06.

Relationship between SST and oil sardine catch: We found a correlation between SST and oil sardine catch, and the increase in catch is associated with warming of sea surface. The trendline in Figure 4 shows that about 0.5°C increase in SST (from 28.22°C to 28.69°C) is associated with about 1,10,000 t increase in catch along the SW coast; increase from 27.15°C to 27.60°C is associated with about 4,000 t increase along the NW coast; and increase from 28.10°C to 28.58°C with 41,000 t along the SE coast. Thus there is a spatial difference in the magnitude of increase in catch with increasing SST. The magnitude of increase is perhaps associated with features such as productivity of the region. For instance, the catch at 28.5°C was 40,000 t along the SE coast, but at the same SST, the catch was much higher at 1,80,000 t along the SW coast. Figure 4 also shows that the "take off" catch is related to the temperature of the region concerned, rather than a common pivotal temperature. The catch "take off" occurred at 27.6°C along the NW coast, but at 28.45°C along the SW coast.

Chlorophyll concentration and catch: The adults of oil sardine feed on phytoplankton and the juveniles on zooplankton. Hence, chlorophyll *a* concentration is likely to drive the distribution and abundance of oil sardine. Available data indicate that the chlorophyll *a* concentration flutuated along the Indian coast without any definite trend. As an example, Figure 5 is given here to show that the chlorophyll *a* concentration along the SE coast has fluctuated without a trend during 1999-2007 and it has not impacted the oil sardine catch. Similar pattern was noticed along the other three regions as well. This shows that the chlorophyll concentration is sufficient to support the fishery at the present level.

Discussion

Our analysis indicates that the human-induced sea warming has helped extension of distributional range of the oil sardine *Sardinella longiceps* towards northern and eastern boundaries along the west and east coasts of India. Considering catch as a surrogate of abundance, the analysis shows that the abundance also has increased as a consequence of warming, which is evident from increase in catch along the SW coast. The oil sardine is a tropical fish preferring temperature range of 27-29°C (Chidambaram,1950; Fish Base 2007). With warming of the sea, the fish is able to find temperature to its preference in the northern latitudes and eastern longitudes, thereby extending the distributional boundaries and establishing fisheries in larger coastal areas. It is expected that the abundance may increase along Gujarat and West Bengal coasts in the coming years assuming further increase in sea temperature. However, if the SST in the southern latitudes increases beyond the physiological optimum of the fish, it is possible that the population may be driven away from the southern latitudes, which will reduce the catches along the SW and SE coasts.

Perry *et al.* (2005) showed that the distribution of more than 20 species of exploited and nonexploited North Sea fishes has responded remarkably to increase in sea temperature, with all but one species shifting northward. Unlike the North Sea fishes, our analysis shows extension of boundaries (not shift) of distribution and increase in abundance, which are indications of adaptation of a tropical fish to sea warming. This is evident from the increasing catch along the SW coast.

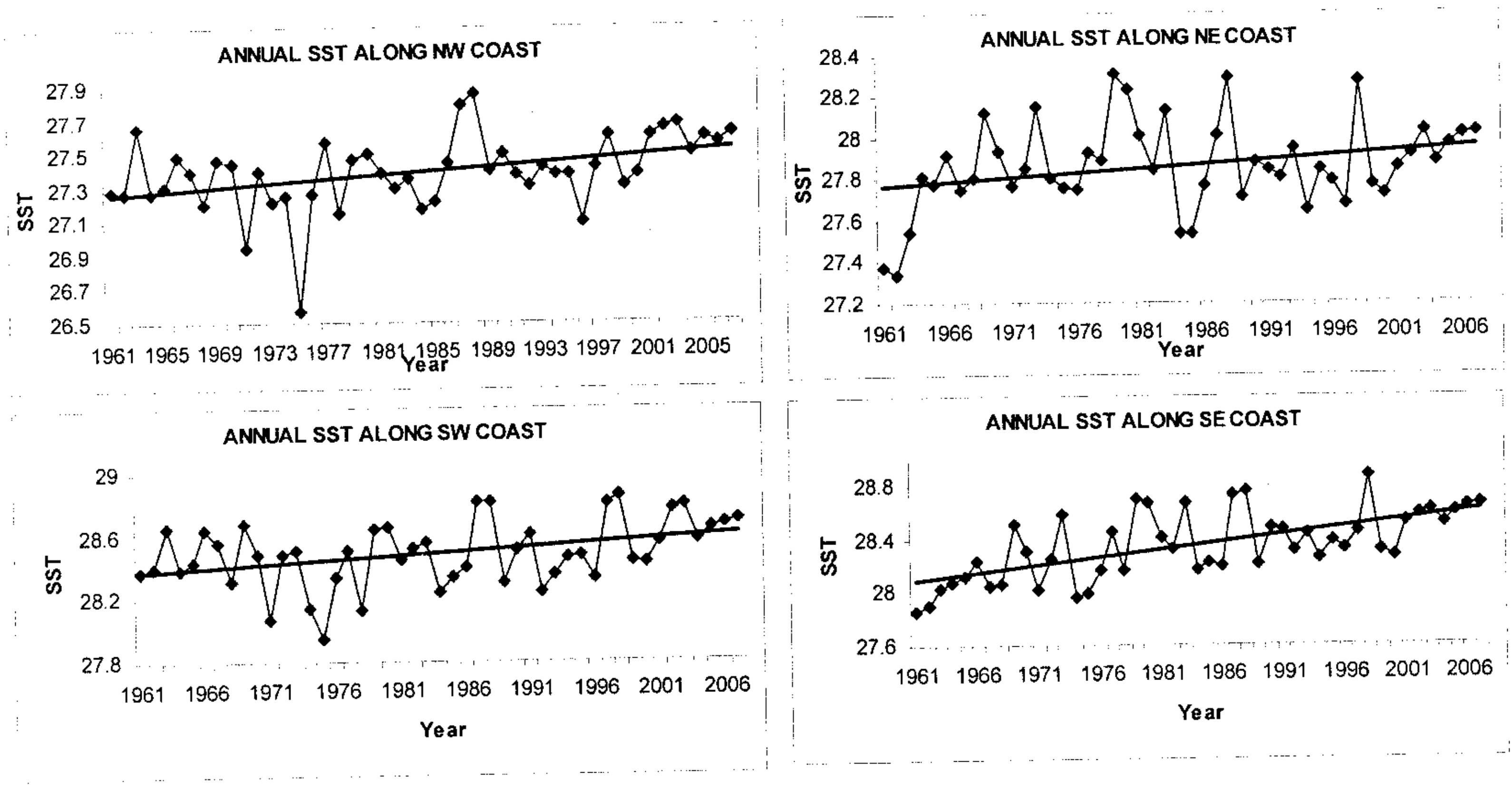

Fig. 1: *Increase in Sea Surface Temperature Along the Indian Coast During 1961-2007*

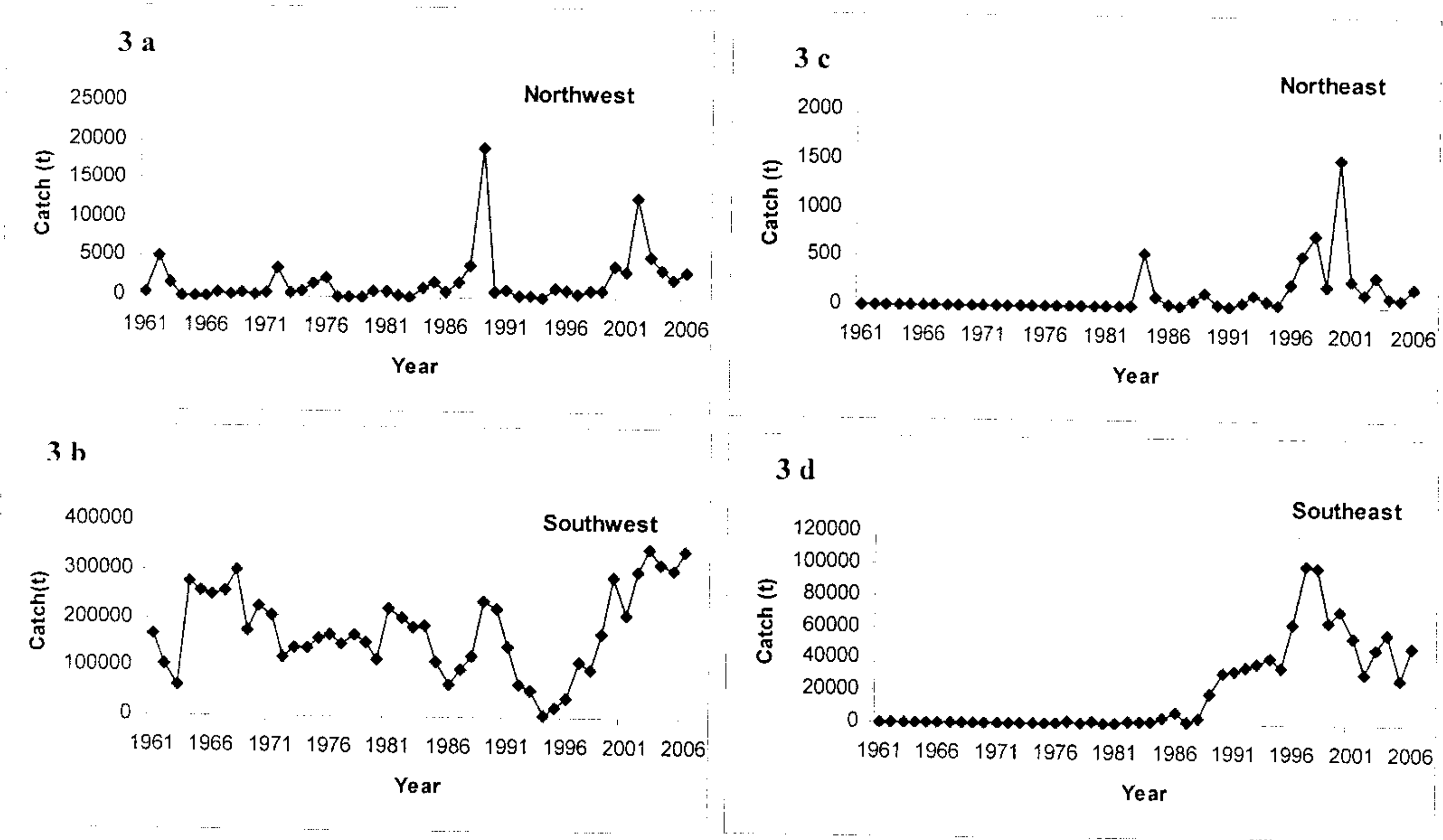

Fig. 3: *Oil sardine catch along the Indian coasts during 1961-2006*

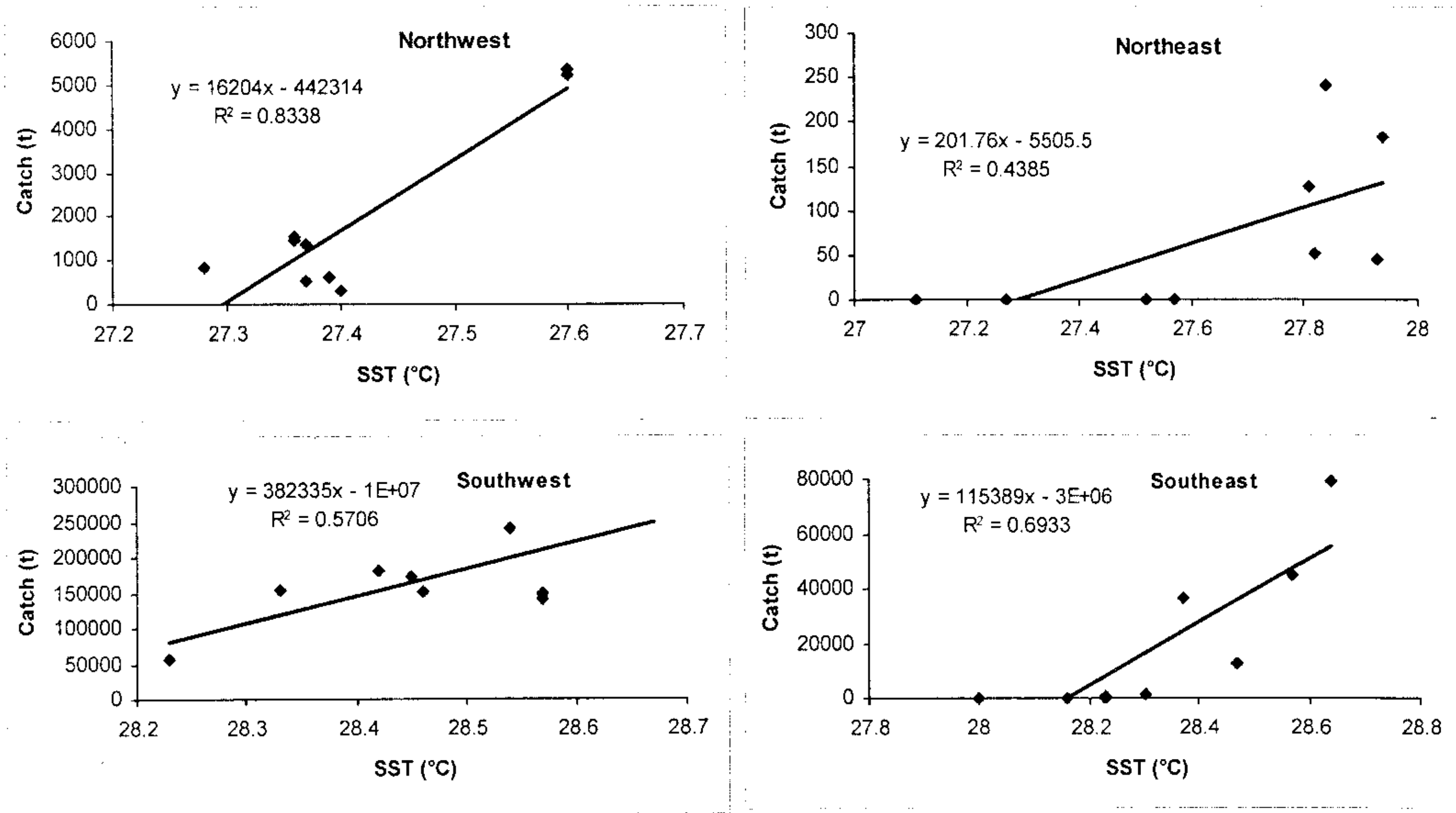

Fig. 4: *Relationship between sea surface temperature and oil sardine landings during in Indian coasts 1961 - 2005*

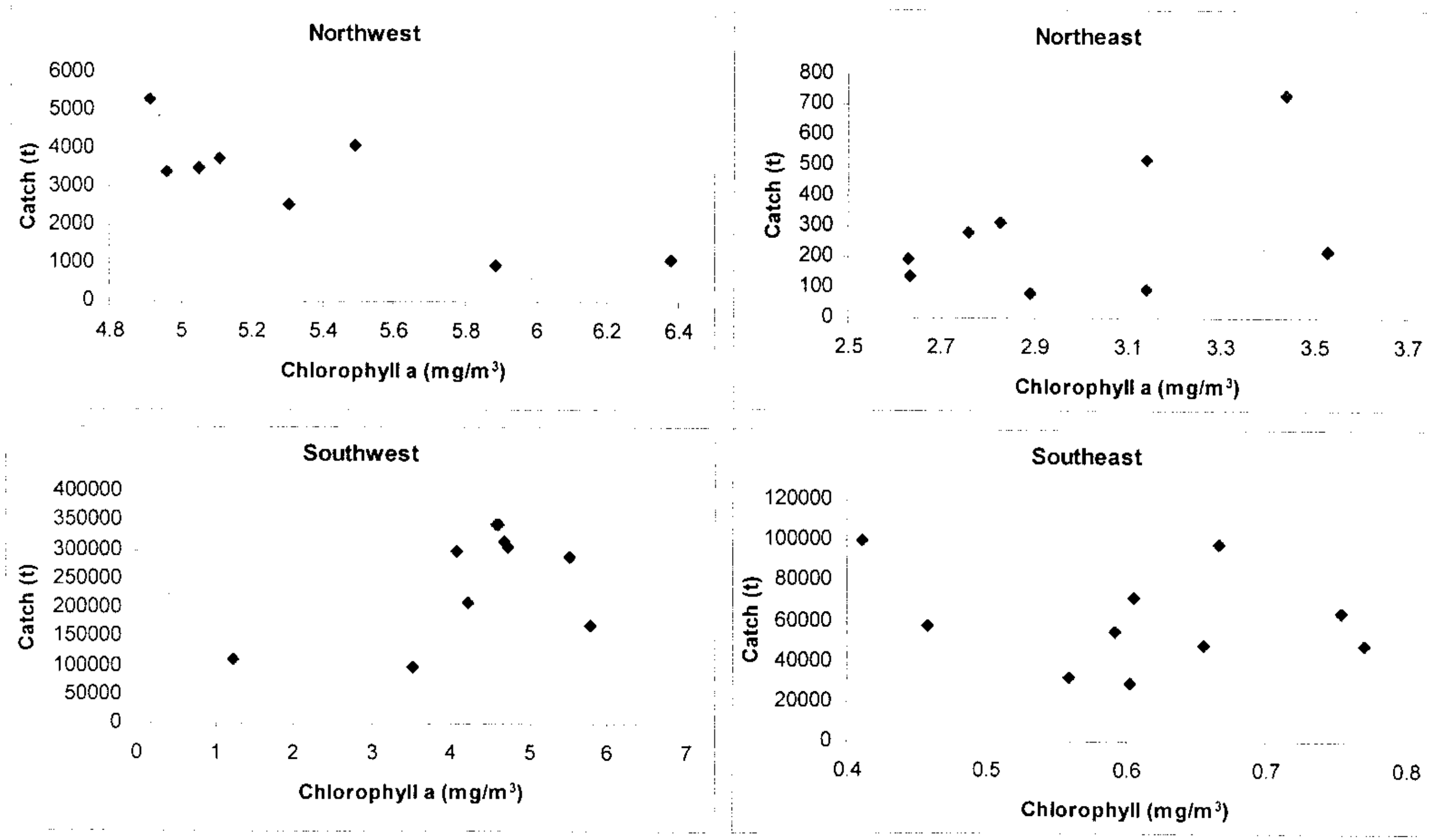

Fig. 5: *Relationship between chlorophyll a concentration and oil sardine catch along the Indian coast*

The relationship between changing climatic factors and fish distribution/abundance is complicated and the diagnosis of the impact of climate change on fisheries is challenging. One of the problems in assessing the impact of climate change on fish abundance/catch is the complexity of segregating the climate-induced changes in fish population from other human-induced changes such as fishing. Technological advancements in fishing have substantially influenced the catch and abundance thereby masking the climate-induced changes. These non-climatic factors often obscure climate related trends in fish abundance, distribution and catch. It may be argued that oil sardine catch would have increased following introduction of motorized boats in the late 1980s, which improved the mobility of traditional boats, and became very popular along the entire Indian coast in the last two decades. Introduction of efficient gears such as ringseine along the SW coast also would have contributed to higher catches. These arguments have no standing due to the following reasons: (i) For several years after the introduction of motorization and ringseine, the oil sardine catch was very low (annual catch from 1992 to 1998: < 1 lakh tonnes) along the Kerala coast. The catch exceeded 1 lakh t in 1999 and showed remarkable increase since then. As the abundance of oil sardine increased during this period, the number of ringseiners increased resulting in netter catches. (ii) Along the Tamilnadu coast, several species of lesser sardines, which belong to the same genus *Sardinella,* are regularly caught by gillnets and bagnets for the last one century. The lesser sardines are co-inhabiting species with oil sardine, and the craft and gear employed to catch lesser sardines and oil sardine are the same. During 1961 – 2006, the annual average lesser sardine catch was around 35,000 t along the Tamilnadu coast. The fact that the oil sardine is forming a major fishery only from 1990 shows that the fish is abundantly available along the Tamilnadu coast for less than two decades.

This analysis provides valuable clues on the impact of climate change on the distribution and abundance of marine fisheries. The tropical mobile species appear to adopt, at least temporarily by moving to favourable areas. It appears that small fishes with rapid turnover of generations may be able to adapt to climate change. This trend will alter the species mix in the oceans and alter the biodiversity. The abundance of fish populations and the composition of communities are likely to change in unexpected ways. It is much more difficult to project how populations will behave under radically different conditions.

References

Beaugrand, G., Brander,K.M., Lindlet, J.A., Souissi, S. & Reid, P.C. 2003. *Nature,* 426: 661.

Chidambaram, K. 1950. Studies on length frequency of the oil sardine, *Sardinella longiceps* and on certain factors influencing their appearance in the Calicut coast of Madras Presidency. *Proc. Ind. Acad. Sci.,* 3: 252-286.

CMFRI, 2006. *Annual Report 2005-06. Central Marine Fisheries Research Institute, Kochi,* 141.

Done, T.J., Turak, E.I., Wakeford, M., Kininmonth, S., Wooldridge, S., Berkelmans, R., Van Oppen M.J.H. & Mahoney, M. 2003. Testing bleaching resistance hypotheses for the 2002 Great Barrier Reef Bleaching Event. *Report to TNC. Australian Institute of Marine Science,* 95.

FishBase, 2007. www. fishbase.org

Perry, A.L., Low, P.J., Ellis, J.R. & Reynolds, J.D. 2005. Climate change and distribution shifts in marine fishes. *Science,* 308: 1912-1915.

Qasim, S.Z. 1973. An appraisal of the studies on maturation and spawning in marine teleosts from the Indian waters. *Indian J. Fish.,* 20: 166-181.

Vivekanandan, E. & James, D.B. 1986. Population dynamics of *Nemipterus japonicus* in the trawling grounds off Madras. *Indian J. Fish.*, 33: 145-154.

Vivekanandan, E., Srinath M. & Somy Kuriakose. 2005. Fishing the food web along the Indian coast. *Fisheries Research*, 72: 241-252.

Walton, C.C., McClain, E.P. & Sapper J.F. 1990. Recent changes in satellite- based multichannel sea surface temperature algorithms, *Rep. MTS 90, Mar. Technol. Soc., Washington, D.C.*, September 1990.

Wood, C.M. & McDonald, D.G. 1997. *Global Warming: Implications for Freshwater and Marine Fish.* Cambridge Univ. Press, Cambridge.