Effect of Temperature and Rainfall as a Component of Climate Change on Fish and Shrimp Catch in Pakistan

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ABSTRACT: *The impact of temperature and rainfall was analyzed on the catch of estuarine fish and shrimp species, including barramundi, mullet, bombay duck, silver whiting, sardinella, anchovy, white shrimp and grey shrimp during the period 1981 to 2006. On the whole there was no significant correlation found between the catch of various fish and shrimp species and temperature or rainfall. However, a significant negative correlation between average annual temperature and barramundi catch and between temperature and white shrimp catch was observed. Similarly a significant positive correlation between temperature and mullet catch and between rainfall and silver whiting catch was found. There is also a decrease in total amount of fish caught, decreasing from 474,665 metric tons in 1999 to 349,421 metric tons in 2006. Most recent statistics show that in 2009, the fish catch was around 338,773 tons while in 2008 it was 344,684 tons, showing a decline of 5,911 tons in just over a one-year period. Changes in temperature and rainfall altered the catch of some fishes as mentioned above but the other factors, such as over-fishing, pollution and the reduction in freshwater flow may have influenced the fish and shrimp catch. Therefore proper fisheries management and monitoring is required to meet the challenges of global climatic changes as well as other environmental issues.*

Keywords: estuaries, fish, shrimp, temperature, rainfall, Pakistan

1. Introduction

Global climate change is impacting the marine and estuarine fish and fisheries and will continue to do so in the future (Roessig *et al*. 2004). Most of the investigations of the effect of climate change on fish stocks have been on pelagic fish species such as tuna, (particularly *Thunnus albacares, T. thynnus* and *Katsuwonus pelamis*), mackerel (*Trachurus declivis* and *T. novaezelandiae*) and sardines (*Sardinops sagax* and *S. pilchardus*) (Klyashtorin 1998, Yanez *et al*. 2002, Loukos *et al*. 2003, Beare *et al*. 2004, Guisande *et al*. 2004, Lloret *et al*. 2004). The information of the effects of climate change on estuary dependent fish species is almost negligible, in spite of climate change also possibly affecting number of estuary dependent fish and shrimp species (Meynecke et al. 2006). Therefore, in different parts of the world an attempt has been made to show relationship between freshwater runoff (rainfall) and estuary dependent fisheries, such as, baramundi (*Lates calcarifer*), mullet (*Mugil* spp.), flathead (*Platycephalus* spp.), whiting (*Sillago* spp.), prawns (Family Penaeidae) and mud crab (*Scylla serrata*), (Vance et al. 1985, Gammelsrod 1992, Loneragan & Bunn 1999, Powell et al. 2002, Staunton-Smith et al. 2004, and Meynecke et al. 2006).

Pakistan lies in the subtropics with a coastline of 1050 km long bordering the Arabian Sea in the south of the country (Figure 1). Pakistan is bestowed with both inland as well as marine fisheries resources. The marine fisheries account for about 79 percent of the country's total fish catch. The marine fishing industry in Pakistan started in 1947, and at that time the entire fishing fleet was comprised of few boats which were non-mechanized and sail driven. Mechanization of boats started in 1956 and continued to grow with the passage of time. The mechanized boat operation increased from 1173 boats in 1983 to 4027 boats in 2004. The fish production of Pakistan in 1947 was approximately 33,000 metric tons, increasing to about 280,000 metric tons in 1983. The fish production continued to increase and reached a maximum of 499,195 metric tons in 1993. After that there has been a declining trend in fish production, from 400,500 metric tons in 2003 to 349,421 metric tons in 2006.

Like other parts of the world Pakistan is also affected by global climate change, and its fisheries, if not affected at present, will presumably be affected in the long run. According to Pakistan's Initial National Communication on Climate Change (2003) the temperature is expected to increase by 0.9 °C and precipitation is expected to increase or decrease by 3% by the year 2020. In the year 2050, the projected changes in temperature and rainfall will be double to that of 2020. The sea level rise is expected to be 20 cm for 2020 and 30 cm for 2050. These predictions are based on the study conducted by Pakistan Study Team, in consultation with experts from the Intergovernmental Panel on Climate Change (IPCC), in which they formulated a set of synthetic scenarios consistent with scenarios generated using the Model for Assessment of Greenhouse Gas Induced Climate Change (MAGICC) software used extensively by the United Nations Environment Program (UNEP) and other UN agencies.

The estuaries and mangrove systems serve as the nursery and spawning grounds for number of shrimp and fish species. Keeping in view the importance of climate effect on estuarine dependent fish and shrimp species, an attempt has been made to analyze the relationship between the two primary climatic parameters, temperature and rainfall, on the catch

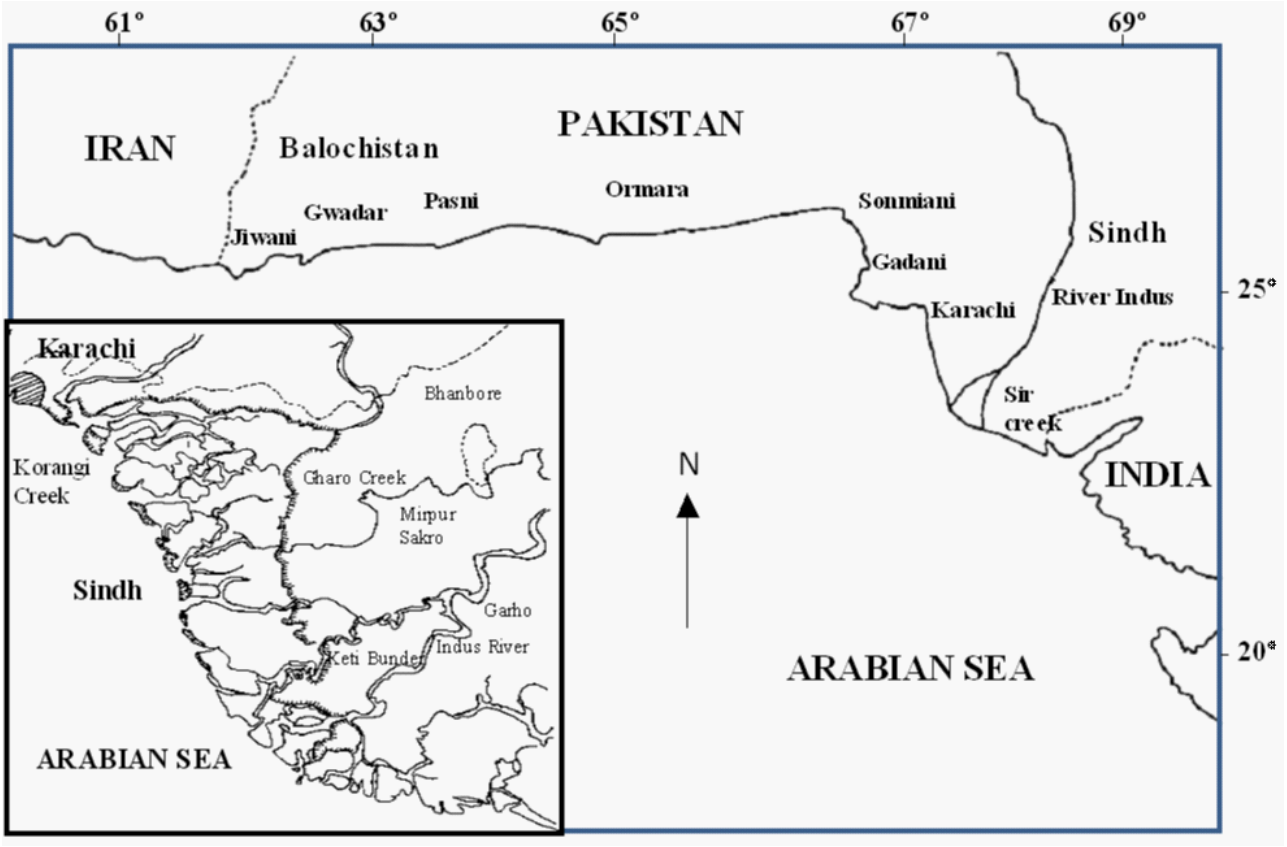

Figure 1. *Map showing the coastline of Pakistan. Inset is a view of Indus Delta creeks and mangrove systems.*

of some of the selected estuarine dependent fish and shrimp species.

2. Material and Methods

To study the effect of annual changes in air temperature and rainfall on the catch of commercially important estuarine dependent fish and shrimp species, data from 1981 to 2006 was analyzed. The fisheries catch data is based on the fish catch statistics of Pakistan, published by Marine Fisheries Department (Anon 1990, 1995, 2003, 2006). The air temperature and rainfall data of Karachi (the same temperature and rainfall is experienced along the coast of Pakistan) was provided by the Pakistan Meteorological Department, Government of Pakistan. The abundant groups of fish present in the coastal waters of Pakistan are shown in Table 1. The table is prepared from the available data on the catch of fish in Pakistan (Anon 1990, 1995, 2003, 2006) at Karachi Fish Harbour. The fish and shrimp which were selected for the present study include barramundi, mullet, bombay duck, silver whiting, sardinella, anchovy, white shrimp and grey shrimp (their scientific name are shown in Table 2). The 1050 km coastline of Pakistan from Sir creek in south to Jiwani in the west is divisible into Sindh and Balochistan coast (Figure 1). The Sindh and Balochistan experiences almost the same temperature and rainfall ranges along the coastline: warm-hot summer (21° to 39° C) and mild winter (10° to 20° C) and rainfall is low, <150 mm annually. The creeks, mangrove systems and lagoons in Pakistan occupy an area of approximately 132,000 hectares of which 129,000 hectares belong to Indus Delta, Sindh (Figure 1) while the remaining to Balochistan. Correlation analyses (Zar, 1996) were performed in order to examine the relationships between the fish catch data and climatic parameters.

Table 1. *The abundant groups in the fish catch of Pakistan at interval of 5 years.*

Fish group	PERCENTAGES					
	1981	1986	1991	1996	2001	2006
Sardinellas	24.36	5.25	16.35	13.22	8.29	8.86
Thryssas	0	0.71	2.56	3.56	3.48	1.99
Sharks	7.87	4.86	6.54	8.71	5.76	3.06
Rays	19.33	3.49	4.34	3.94	3.94	2.54
Catfish	4.44	3.55	6.77	12.50	8.34	8.21
Mullets	0.44	0.57	1.68	4.46	2.75	2.59
Croakers	7.20	4.42	3.61	5.04	5.50	4.20
Cobia	0.61	0.23	0.25	13.58	0.72	0.55
Queenfish	2.51	1.81	2.42	4.04	3.37	2.75
Tunas	3.74	3.36	5.17	4.78	6.93	9.93
Silver whiting	0.16	0.10	0.08	0.07	0.08	0.12
Bombay Duck	0.00	0.13	0.05	0.03	0.01	0.01
Groupers	1.43	0.72	0.90	2.48	4.17	4.12
Ribbonfish	2.16	1.14	1.02	2.29	4.07	6.72

Table 2. *List of estuary dependent fish and shrimp species selected for the study.*

Common name	Scientific name
Baramundi	*Lates calcarifer*
Mullet	*Liza* spp., *Mugil* spp.
Bombay Duck	*Harpadon nehereus*
Silver Whiting	*Sillago sihama*
Sardinella	*Sardinella longiceps*, *Sardinella* spp.
Anchovies	*Thryssa* spp.
White shrimp	Penaeus merguiensis, P. penicillatus
Grey shrimp	Metapenaeus affinis

3. Results

Abundant groups in fish catch of Pakistan

More than 40 groups of fishes are represented in the fish catch of Pakistan. Among these, the fishes that are abundant in the landings are shown in Table 1 and included sardinellas, sharks, rays, catfish, croakers, tunas, etc.

Climatic factors

The fluctuation in air temperature during the period 1981 to 2006 is shown in Figure 2. The lowest average temperature (25.6° C) was recorded in the year 1984 and the highest (27.9° C) in the year 2001. The fluctuation in rainfall during the period from 1981 to 2006 is shown in Figure 2. The highest rainfall was recorded in the year 1994 which amounted to 481.5 mm and the lowest (0 mm) was observed in 1987. The average temperature has increased approximately by 1° C during the last 25 years as is evident in Table 3, while rainfall has decreased during the last 10 years (Table 3).

Relationship between number of fishing vessels and catch

As the number of fishing vessels increased from 1981 onwards, a sharp increase in fish catch was observed

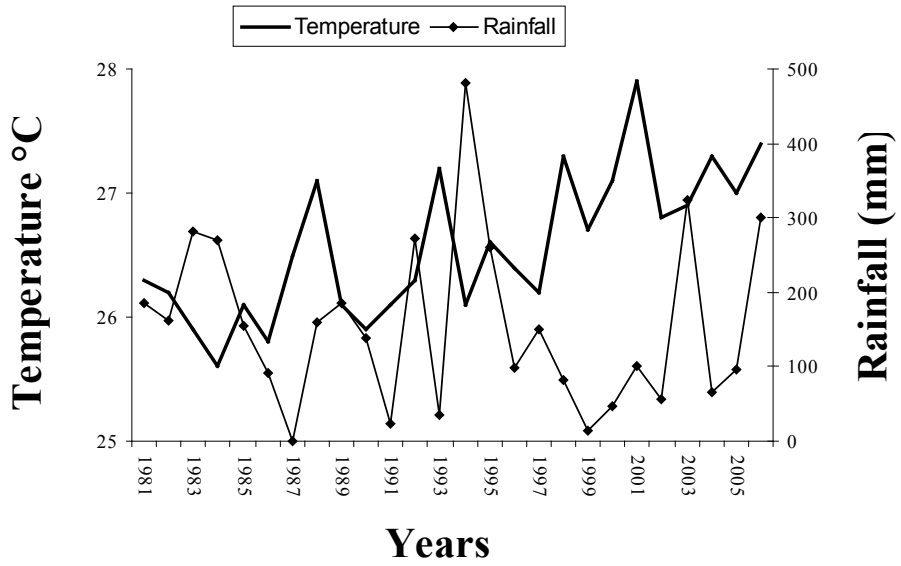

Figure 2. *Average annual rainfall and temperature at interval of 5 years in Karachi over the time period 1981-2006.*

Table 3. *The average temperature and rainfall during intervals of 5 years.*

Period	Average Temp. °C	Rainfall (mm)
1981-1985	26.02	210.58
1986-1990	26.28	114.84
1991-1995	26.46	214.86
1996-2000	26.74	78.58
2001-2005	27.18	128.84

in the years 1993 and 1999. Despite the increase in number of fishing vessels after 1999, a downward trend in the fish catch was evident (Figure 3). The correlation between number of fishing vessels and fish caught during the period 1981 to 1999 shows a significant positive correlation ($r = 0.88$; $P<0.01$) however this trend was significant but negative ($r = -0.85$; $P<0.01$) during 2000-2006.

Relationship between catch and rainfall or temperature

Separate correlation analyses were performed to show the relationships between the species of fish and shrimp and interdependent variables temperature and rainfall (Table 4). In case of silver whiting annual catch and rainfall, a positive and marginally

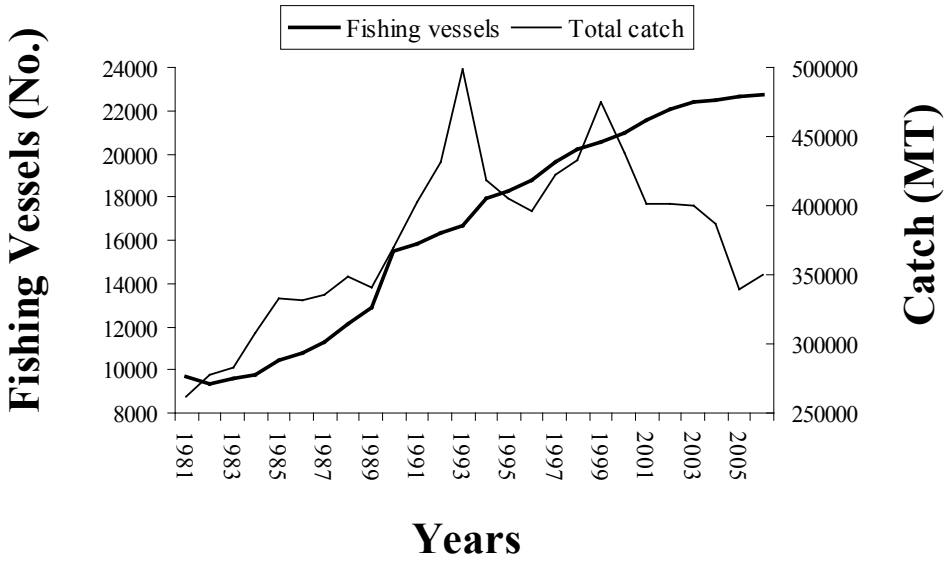

Figure 3. *Total fish catch in Pakistan and the number of fishing vessels operating during the period from 1981 to 2006.*

significant correlation (r = 0.357; P<0.10, n=26) was found (Figure 4). However, there was no significant correlation between annual rainfall and the catch of barramundi, bombay duck, mullet, sardinella, anchovy, white shrimp and grey shrimp (Table 4).

The data for annual catch of bombay duck, silver whiting, sardinella, anchovy, and grey shrimp showed no significant correlation with average annual temperature (Table 4). However, there was significant negative correlation between average annual temperature and barramundi catch (r = -0.526; P<0.01, n=23) (Figure 5) and positive correlation between average annual temperature and mullet catch (r = 0.493; P<0.05, n=26) (Figure 6). There was a marginally significant correlation between average annual temperature and white shrimp catch (Table 4 & Figure 6).

Table 4. *Pearson correlation coefficients (r) between fish and shrimp catches and rainfall/temperature during the period 1981-2006 (*P<0.10; **P<0.05; ***P<0.01).*

Common name	Temperature	Rainfall	N
Baramundi	-0.526***	0.105	23
Mullet	0.493**	-0.049	26
Bombay Duck	-0.063	-0.276	24
Silver Whiting	-0.172	0.357*	26
Sardinella	0.242	-0.032	26
Anchovies	0.288	0.103	22
White shrimp	-0.376*	-0.214	26
Grey shrimp	-0.315	-0.175	26

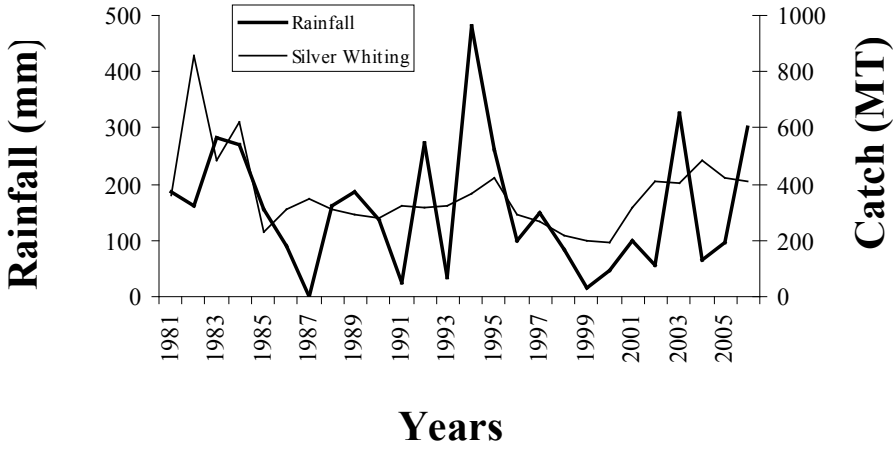

Figure 4. *Rainfall versus silver whiting catch (1981-2006) along the coast of Pakistan.*

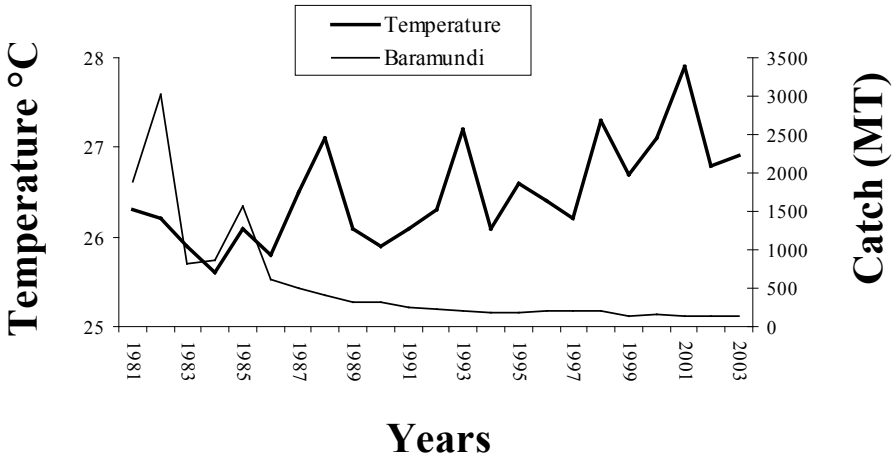

Figure 5. *Temperature versus mullet and white shrimp catch (1981-2006) along the coast of Pakistan.*

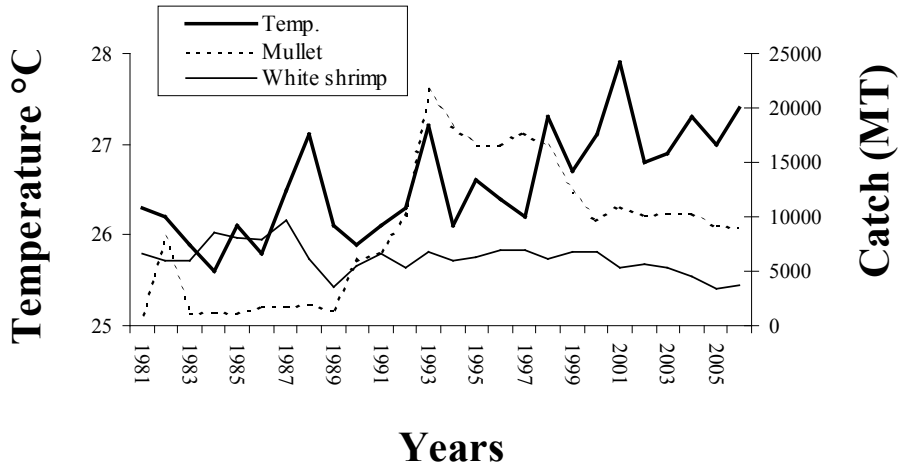

Figure 6. *Temperature versus baramundi catch (1981-2003) along the coast of Pakistan.*

4. Discussion and Conclusion

In the present study an attempt was made to analyze relationship between the pattern of temperature and rainfall and the catch of estuarine dependent fish and shrimp species. On the whole, there was no significant correlation found between the catch of various fish and shrimp species and temperature or rainfall. However, a significant negative correlation between average annual temperature and barramundi catch and between temperature and white shrimp catch was observed. Similarly a significant positive correlation between temperature and mullet catch and between rainfall and silver whiting catch was found. Changes in temperature and rainfall altered the catch of some fish, as mentioned above, but the other factors, such as over-fishing, pollution and reduction in freshwater flow may also have influenced the fish and shrimp catch. As the data about these factors were not available, the study has been focused on two climatic factors. However, this study does throw some light on the relation between climatic parameters and fish catch and provides direction for research on this issue in Pakistan.

In the present study, no correlation was observed between the catch of most of the fish and shrimp species and rainfall; however there have been instances when an increase in the total fish catch was found after the rains, which has also been reported from other countries. The study of wild capture data analysis from Queensland Australia, (Meynecke et al. 2006) has related the overall catch of estuarine dependent fish to the increase and decrease in rainfall, according to them the wet years produced higher catches. The same influence of rainfall on non-estuarine dependent species, mackerel and tuna has been reported respectively by Yanez et al. (2002) and Lehodey et al. (2003). The significant positive relationship between annual catch and total rainfall (or freshwater runoff) in the same year or previous year has been reported by Vance et al. (1985), Gammelsrod (1992), Chen et al. (1994), Galindo-Bect et al. (2000) and Staunton-Smith et al. (2004) .

In the present study a significant correlation between average annual temperature and barramundi catch, mullet catch and shrimp catch was observed, as has been reported by Whitfield & Harrison (2003) and Whitfield (2005), who state that temperature has a major impact upon the richness and diversity of fish in African estuaries. Similarly in tropical coral reefs, the changes in fish community due to climate change effects have been reported (Parker and Dixon, 1998; Spalding and Jarvis, 2002). Recently Balston (2009) has shown that the long-term climate cycle may affect the life cycle stages of baramundi by influencing climate variables such as rainfall, stream flow and temperature and hence nutrient availability and nursery habitat suitability in Australian waters. Although it is expected that increasing temperature would not have a measurable influence on the taxa of the tropical and subtropical environment (Smith, 1990) but the studies have shown that the temperature has affected the fish community.

The fish and shrimp taken in account in the present study are marine species, but depend in one way or another during their life on estuaries, creeks

and mangroves, as their as breeding and nursery grounds. Baramundi is coastal and estuarine species but always enter to marine environment for spawning. Bombay ducks are primarily marine but one species, *Harpadon nehereus* inhabits coastal waters and estuaries. Most of the species of mullet spawn at sea and the juveniles enter the estuaries which serve as their nursery grounds. Silver whiting is a near-shore species which penetrates the estuaries and remain there for long periods, and go to mouth of sea to spawn. Sardinella juveniles enter the lagoons and estuaries. Anchovies (*Thryssa* spp.) inhabit coastal waters and enter estuaries for growth (Jhingran and Talwar 1991). Similarly the white and grey shrimp spawn respectively in open waters and inshore coastal waters but their larvae drift towards the estuaries and creeks, which serve as their nursery grounds. The studies conducted in the mid-90s on the abundance of juveniles of fish and shrimp species in the backwater and creeks along the coast of Pakistan have showed the abundance of mullets, silver whiting, killifish, anchovies (*Coilia* spp.), anchovies (*Thryssa* spp.), grey shrimp and white shrimp. However, anchovies (*Thryssa* spp.) and grey shrimp were more abundant at Kharo Chaan and Jhangi Sir, the two areas comparatively with lower salinities. (Ahmed and Abbas 1999a, Ahmed and Abbas 1999b, Ahmed et al. 1999, Ayub and Ahmed 2002). The creeks and estuaries in Pakistan are now under stress due to pollution, reduction in freshwater flow and mangrove cutting for domestic use. Therefore it shows that along with temperature and rainfall which is influencing the catch of certain fish and shrimp, the deteriorate condition of the estuaries and creeks is another factor influencing the catch. Many studies have emphasized that freshwater inputs are vital to estuarine productivity and fish diversity (Whitfield 1994, Schlacher and Wooldridge 1996, Livingston 1997).

Although this study does not show a clear relationship between fish catch and temperature or rainfall, a decrease in total fish catch is evident, as it has decreased from 474,665 metric tons in 1999 to 349,421 metric tons in 2006. Latest statistics showed that in 2009 the fish catch was around 338,773 tons while in 2008 it was 344,684 tons, showing a decline of 5,911 tons in just one-year (personal communication). According to Mohammad Moazzam Khan, Director General, Marine Fisheries Department, a decline of 29 per cent, or 138,534 tons over the last 10 years is because of over-fishing and marine pollution, which wiped out some species and resulted in a reduction in catch of several other species (Daily "The News" Saturday, May 01, 2010).

Overall in Pakistan to meet the demand of local consumption, increased seafood export, increase in fishing fleet and mechanization and modernization of fishing fleet in the last decade has increased the pressure on fish stocks. The use of harmful fishing nets of small mesh size by certain individuals in the creeks are causing destruction of marine life and also hindering the replenishment of stock. The mangroves, which are the nursery grounds of fish and shrimp, are also under stress due to decreasing availability of fresh water, scant rain and discharge of effluents and the cutting of mangroves. All this indicates an inadequate management and implementation of policies by the government. Throughout the world due to heavy fishing, measures have been implemented to save the stocks; therefore there is need for proper fisheries management and monitoring to meet the challenges of global climatic changes as well as other environmental issues. In this regard in Pakistan a closed season is compulsory in order to save the shrimp and fish stocks from collapse, fishing in the estuaries should be prohibited as the fish and shrimp caught in that area are small sized, restricting each trawler for the amount of fish caught, and specification of the gear that may be employed for fishing.

5. Acknowledgements

This paper has been produced within the CLIMA Project, with the financial assistance of the European Union-Asia Link Programme. The contents of this document are the sole responsibility of the authors and can under no circumstances be regarded as reflecting the position of the European Union.

6. References

Ahmed, M. & Abbas, G. (1999a). Abundance of finfish and shellfish juveniles in the tidal creeks of Bhanbhore, Sindh (Pakistan). *Pakistan Journal of Zoology* 31: 129-140.

Ahmed, M. & Abbas, G. (1999b). Abundance of finfish and shellfish juveniles in the intertidal zone of Miani Hor Lagoon in Balochistan, Pakistan. *Pakistan Journal of Zoology* 31: 187-195.

Ahmed, M., Ayub, Z. and Zaib-un-nisa (1999). Distribution and abundance of juvenile and subadult fishes in Sindh creeks and backwaters (Pakistan). *Pakistan Journal of Zoology* 31: 327-338.

Anon (1990). *Handbook of Fisheries Statistics of Pakistan*. Volume 15. Published by Marine Fisheries Department Govt. of Pakistan, Karachi, Pakistan.

Anon (1995). *Handbook of Fisheries Statistics of Pakistan*. Volume 16. Published by Marine Fisheries Department Govt. of Pakistan, Karachi, Pakistan.

Anon (2003). *Handbook of Fisheries Statistics of Pakistan*. Volume 17 & 18. Published by Marine Fisheries Department Govt. of Pakistan, Karachi, Pakistan.

Anon (2006). *Handbook of Fisheries Statistics of Pakistan*. Volume 19. Published by Marine Fisheries Department Govt. of Pakistan, Karachi, Pakistan.

Ayub, Z. & Ahmed, M. (2002). Distribution and abundance of penaeid shrimp juveniles in the backwaters and creeks along the coast of Sindh (Pakistan). *Pakistan Journal of Zoology* 34: 19-28.

Balston, J. (2009). An analysis of the impacts of long-term climate variability on the commercial barramundi (Lates calcarifer) fishery of north-east Queensland, Australia. *Fisheries Research* 99: 83-89.

Beare, D., F. Burns, E. Jones, K. Peach, E. Portilla, T. Greig, E. Mckenzie and D. Reid (2004). An increase in the abundance of anchovies and sardines in the north-western North Sea since 1995. *Global Change Biology* 10: 1209-1213.

Chen, Y.L., Chen, H. Y., and Tzeng, W. N., 1994. Reappraisal of the importance of rainfall in affecting catches of *Anguilla japonica* Elvers in Taiwan. *Australian Journal of Marine Freshwater Research* 45: 185-190.

Galindo-Bect, M.S., Glenn, E. P., Page, H. M., Fitzsimmons, K., Galindo-Bect, L. A., Hernandez-Ayon, J. M., Petty, P. L., Garcia-Hernandez, J. and Moore, D. (2000). Penaeid shrimp landings in the upper gulf of California in relation to Colorado River freshwater discharge. *Fishery Bulletin* 98: 222-225.

Gammelsrod, T. (1992). Variation in shrimp abundance on the Sofala Bank, Mozambique and its relation to the Zambezi River runoff. *Estuarine, Coastal and Shelf Science* 35, 91-103.

Guisande, C., Vergara, A. R., Riveiro, I. and Cabanas, J. M. (2004). Climate change and abundance of the Atlantic-Iberian sardines (*Sardina pilchardus*). *Fisheries Oceanography* 13: 91-101.

Jhingran, A. G. and Talwar, P. K. (1991). *Inland Fishes of India and Adjacent Countries*. Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi, Bombay, Calcutta. 1: 1-1158.

Klyashtorin, L.B. (1998). Long term climate change and main commercial fish production in the Atlantic and Pacific. *Fisheries Research* 37: 115-125.

Lehodey, P., Chai, F. and Hampton, J. (2003). Modelling climate-related variability of tuna populations from a coupled ocean-biogeochemical-populations dynamics model. *Fisheries Oceanography* 12: 483-494.

Livingston, R. J., (1997). Trophic responses of estuarine fishes to long-term changes of river runoff. *Bulletin of Marine Science* 60, 984–1004.

Lloret, J., Palomera, I., Salat, J. and Sole, I. (2004). Impact of freshwater input and wind on landings of anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) in shelf waters surrounding the Ebre (Ebro) River delta (north-western Mediterranean). *Fisheries Oceanography* 13: 102-110.

Loneragan, N. R. and Bunn S. E. (1999). River flows and estuarine ecosystems: implications for coastal fisheries from a review and a case study of the Logan River, southeast Queensland. *Australian Journal of Ecology* 24: 431-440.

Loukos, H., Monfray, P., Bopp, L. and Lehodey, P. (2003). Potential changes in skipjack tuna (*Katsuwonus pelamis*) habitat from a global warming scenario: modeling approach and preliminary results. *Fisheries Oceanography* 12: 474-482.

Meynecke, J. O., Lee, S. Y., Duke, N. C., Warnken, J., (2006). Effects of rainfall as a component of climate change on estuarine fish production in Queensland, Australia. *Estuarine Coastal and Shelf Science* 69: 491-504.

Pakistan's Initial National Communication on Climate Change (2003). Government of Islamic Republic of Pakistan, Ministry of Environment, Islamabad-Pakistan.
Available from: **unfccc.int**/resource/docs/natc/paknc1.pdf

Parker, R. O. and Dixon R. L. (1998). Changes in a North Carolina reef fish community after 15 years of intense fishing – global warming implications. *Transactions American Fisheries Society* 127: 908-920.

Powell, G. L., Matsumoto, J. and Brock, D. A. (2002). Methods for determining minimum freshwater inflow needs of Texas Bays and estuaries. *Estuaries* 25: 1262-1274.

Roessig, J., Woodley, Cech, C. J. and Hansen, L. (2004). Effects of global climate change on marine and estuarine fishes and fisheries. Review in *Fish Biology and Fisheries* 14: 251-275.

Schlacher, T. A. and Wooldridge, T. H. (1996). Ecological responses to reductions in freshwater supply and quality in South Africa's estuaries: lessons for management and conservation. *Journal of Coastal Conservation* 2: 115–130.

Smith, L. D. (1990). Patterns of limb loss in the blue crab, *Callinectes sapidus* Rathbun, and the effects of autotomy on growth. *Bulletin of Marine Science* 46: 23-36.

Spalding, M. D. and Jarvis, G. E. (2002). The impact of the 1998 coral mortality on reef fish communities in the Seychelles. *Marine Pollution Bulletin* 44: 309-321.

Staunton-Smith, J., Robins, J. B., Mayer, D. G., Sellin, M. J. and Halliday, I. A. (2004). Does the quantity and timing of fresh water flowing into a dry tropical estuary affect year-class strength of barramundi (Lates calcarifer)? *Marine and Freshwater Research* 55: 787-797.

Vance, D. J., Staples, D. J. and Kerr, J. D. (1985). Factors affecting year-to-year variation in the catch of banana prawns (*Penaeus merguiensis*) in the Gulf of Carpentaria, Australia. *Journal Conseil International pour l'Exploration de la Mer* 42: 83-97.

Whitfield, A. K. (1994). Abundance of larval and 0þ juvenile marine fishes in the lower reaches of three southern African estuaries with differing freshwater inputs. *Marine Ecology Progress Series* 105: 257–267.

Whitfield, A.K. (2005). Fishes and freshwater in southern African estuaries - a review. *Aquatic Living Resources* 18: 275-289.

Whitfield, A. K. and Harrison T. D. (2003). River flow and fish abundance in a South African estuary. *Journal of Fish Biology* 62: 1467-1472.

Yanez, E., Silva, C., Nieto, K., Barbieri, M. A., Martinez, G. and Ramyrez, B. (2002). Prediction of Probable Fishing Grounds in Northern Chile from Pelagic Fisheries Distributions and Environmental Conditions. *Global Ocean Ecosystem Dynamics* Report 16, Plymouth. 24-26.

Zar, J. H. (1996). *Biostatistical Analysis*. Third Edition. Prentice-Hall, Englewood Cliffs, NJ. Pp. 662