Indian Journal of Animal Sciences **80** (4) (Suppl. 1): 78–84, April 2010

Fishery biology research: glimpses on practices and application for genetic resource conservation

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ABSTRACT

India is bestowed with rich natural resources in which the freshwater, coastal and marine living resources are of prime importance in view of the total dependence of the humanity on these resources for its well-being. Sustained anthropogenic activities such as fishing, coastal industries, shipping and ports, ship breaking, dredging, agriculture and land based industries have profound impacts on these resources ranging from least serious to most serious in nature prompting appropriate regulatory and conservation measures. Voluminous research findings on the biology of these living organisms are extensively useful for the formulation and implementation of the regulatory measures of conservation. An estimated 650 million fish eating people out of the total population of 1,300 million require 7.2 million tons at the rate of 11kg/year/head. Out of 24,618 species about 2500 occur in Indian waters in which 1570 are marine and nearly 200 species are of commercial importance. Almost all the species exhibit faster growth rate and attain maturity within a year, have a high fecundity, more than one spawning in a year. South-west and north-east monsoons have a profound influence on these resources. Single species dominance is noticed in pelagic resources and due to continued exploitation pelagic resource emerges as a dominant one in recent times. Most of the species studied are exposed to higher fishing pressure with symptoms and indications of over-fishing and as such the marine fisheries suffer due to inappropriate exploitation, over-dependence on trawling, target fishing, habitat degradation and resource degradation. An extensive study on various aspects of biology of different resource has lead to formulation of various Act and Rules on fishery regulation on limited entry, temporal restriction, spatial restriction, gear restriction, mesh size regulation and fishing holidays. Determination of spawning season helps fixing the months of fishing ban.

Determination of fecundity and number of spawners helps finding out biomass spawning stock biomass and spawner-recruitment relationship. This, in turn, is helpful to regulate fishing effort. The estimates on growth, (based on length frequency or on otoliths) is used to further estimate the mortality and stock biomass, which are necessary to understand the status of exploitation, and further to regulate fishing effort and to fix catch quotas. Analysis of length-weight relationship, gonadosomatic index and Kn values are useful to understand the well-being of the fish. Studies on food and feeding habits are used to understand the tropho-dynamics and energy flow in an ecosystem, which are recently used for trophic modeling and for ecosystem-based fisheries management. Estimation of length-at-maturity is used to find out whether the fish are allowed to spawn at least once in their life and to recommend Minimum Legal Size. Estimation of juveniles in the exploited populations is used to suggest optimum mesh size of fishing gear. Collection of continuous data on species composition in the landings is helpful to identify the species, whose contribution decreased once the time period is over, and to take appropriate measures to conserve the species. Shrimp larval biology studies lead into commercial shrimp hatchery. Carp biology, induced breeding techniques, studies on shrimp biology and feeding lead into successful carp and shrimp farming and development of feeds. Studies on ornamental fish breeding biology lead into ornamental fish hatchery of the clownfish etc. Studies on fish behaviour and aggregation lead into development of artificial reefs & FADS. Biological characteristics studies have resulted in recommendations for conservation of whales, dolphins and porpoise. Biodiversity studies have helped to understand the vulnerability of coral reefs and to develop plans for restoration of coral reefs. Biological studies on reservoir fisheries lead into stocking of fingerlings in reservoirs and harvesting fish catch. Remote sensing has helped to locate the Potential Fishing Zones (PFZ) pertaining to mostly pelagic fishery resources. Sea ranching has helped the artificial propagation of seeds of different depleted species in the natural environment. Artificial reefs enhance the livelihood and socio-economic condition of the coastal fisher-folk as they not only enrich the biological components of the area concerned but also congregate the fish population leading to the improvement in the quality and quantity of the living resources of the area. Prevention of trawl operation in shallow waters will develop the area into nursery grounds for different fishery resources. Many more technological interventions are Mussel culture, Edible Oyster culture, Pearl Oyster culture, Finfish culture and Seaweed culture. Further continued research in different aspects of biology, environment and climate change is essential for proper conservation of the natural resources.

Key words: Biology, Capture, Culture, Fishery

Decades of research on several aspects of fishery biology have helped to increase fish production from capture and culture fisheries, and to conserve the fish genetic resources to a great extent. Capture-based fishery biology research has concentrated mostly on maturation and spawning, growth, mortality, stock assessment and trophic-dynamics. Culture-based biological research has concentrated on natural and induced breeding, larval development, growth and nutritional biology.

Practices and application

The following are some of the fishery biology related research, which has high value of application for conservation:

- Determination of spawning season helps fixing the months of fishing ban.
- Determination of fecundity, number of spawners helps to find out spawning stock biomass and spawner-recruitment relationship. This, in turn, is helpful to regulate fishing effort.
- The estimates on growth, (based on length frequency or on otoliths) are used to further estimate the mortality and stock biomass, which are necessary to understand the status of exploitation, and to regulate fishing effort and to fix catch quotas.
- Analysis of length-weight relationship, gonado-somatic index and Kn values are useful to understand the well being of the fish.
- Studies on food and feeding habits are used to understand the trophic-dynamics and energy flow in an ecosystem, which are recently used for trophic modeling and for ecosystem based fisheries management.
- Estimation of length-at-maturity is used to find out whether the fish are allowed to spawn at-least once in their life; and to recommend Minimum Legal Size.
- Estimation of juveniles in the exploited population is used to suggest optimum mesh size of fishing gear.
- Collection of continuous data on species composition in the landings is helpful to identify the species whose contribution decreased once the time period is over, and to take appropriate measures to conserve the species.
- Shrimp larval biology studies lead into commercial shrimp hatchery.
- Carp biology and induced breeding techniques and studies on shrimp biology and feeding lead into successful carp and shrimp farming; and development of feeds.
- Studies on ornamental fish breeding biology lead into ornamental fish hatchery of the clownfish.
- Studies on fish behaviour and aggregation lead into development of artificial reefs & FADS.
- Biological characteristic studies have resulted in recommendations for conservation of whales, dolphins, and porpoise.
- Biodiversity studies have helped to understand the vulnerability of coral reefs and to develop plans for restoration of coral reefs.
- Biological studies on reservoir fisheries lead into stocking of fingerlings in reservoirs and harvesting fish catch.

The application value of few of the above mentioned biological studies are outlined here.

CAPTURE FISHERY

Maturity and Spawning

Knowledge of length/age at maturity, fecundity, spawning season and spawning area has provided valuable clues for understanding and even predicting the changes, which the population as a whole undergoes. This has led to inferences on the rate of regeneration of stocks and further to management and rational exploitation of the resources. Information on the length at first maturity has provided basis for the rational choice of the mesh sizes to prevent overfishing of the juveniles. Identification of the season and the area of spawning helps in the prevention of exploitation of spawners. Further, knowledge of the fecundity and the reproductive capacity is a dynamic factor influencing the choice of the exploitation level. Information on these aspects is not available for a number of fish species in the Indian waters.

Length At First Maturity (L_m)

Maturity is clearly linked with the growth rate of fishes and hence, two phases in the life of fish – pre-maturity and post-maturity should be clearly distinguished. For the determination of the length at first maturity (L_m), most of the research workers have considered only the female and assumed that the onset of maturity may not be different in the male (Qasim, 1973). The length at which 50% of fish had ovary in stage III and above, is normally considered as the L_m. From the information available on several species of finfishes in the Indian waters, it could be deduced that the fishes attain first maturity at 30 to 80% of their respective $L\infty$ and nearly 40% of the fish species attain first maturity when the length is 50 to 60% of their $L\infty$. The species that attain first maturity at a very late stage of their life (L_m at >70% of $L\infty$) are the small pelagics like the oil sardine and the Indian mackerel. On the other hand, the species which attain first maturity at very early stage of their life (L_m <40% of $L\infty$) are the large pelagics, viz. the ribbonfish *Trichiurus lepturus*, the seerfishes *Scomberomorus guttatus* and *S. lineolatus* and the dorab *Chirocentrus dorab*. The growth rate of fishes decreases after they attain maturity. The small pelagics, which have fast growth rate and short longevity, delay the process of maturation and prolong the body growth process for a comparatively longer duration in their life than the large pelagics.

Spawning Season

One of the often-wanted information is the spawning season of fishes. Closure of fishing when several fishes spawn in high intensity will help to conserve the spawners, and thereby, it is expected to enhance recruitment to the fishery. It is known that the tropical fishes are continuous spawners. The species that have prolonged spawning season are those in which the ovary includes several batches of eggs, which will mature and spawn periodically. In these species, the population consists of fishes of variable stages of maturity. In perennial spawners, almost all conceivable stages of maturity occur in the population throughout the year (for example, the grenadier anchovy *Coilia dussumieri* Devaraj *et al.* 1997), and hence, utmost care should be exercised to determine the spawning season accurately. However, for determining the spawning season of Indian marine fishes, the ova diameter frequency or the monthly percentage frequency distribution of stage V and above of female are the methods considered by most research workers.

Most of the information on the spawning of different species of marine fishes inhabiting the east and west coasts indicate that there are prolonged peak spawning seasons lasting for several months. Qasim (1973) also reached similar conclusion after reviewing the available information during the 1960s and the 1970s on 30 species of Indian marine fishes. There are also wide variations in the spawning season of different species. For example, some species spawn during the premonsoon, others during the monsoon, a few others during the postmonsoon, and yet others during the onset of summer and also during peak summer. The popular belief that most fishes spawn during the monsoon does not seem to hold good. The peak spawning of many species along the north-west and south-west coasts is during November and December and November to March, respectively and not during the south-west monsoon months, i.e. June to September. Similarly, the peak spawning of many species along the south-east coast is during January to July and not during north-east monsoon months, i.e. October to December. Mohanraj *et al.* (2002) reviewed the literature and concluded that 41 species spawn in January and only 26 species in November along the south-east coast.

Spawning in fishes is initiated by a surge of gonadotropin (GtH) secretion from the pituitary gland. An important factor controlling the induction of GtH ovulatory surge is the gonadotropin releasing hormone which is believed to be influenced by the external factors like food supply, temperature, rain, photoperiod, salinity and so on. The prolonged/continuous spawning activity among the tropical fishes involves intricate physiological mechanisms for the secretion of gonadotropin. It is almost impossible to recognize any particular environmental factor as the determinant of spawning.

In spite of the exhaustive data on the length at first maturity and the spawning season of several species, information on many crucial aspects related to reproduction and population dynamics is not available. Studies on the reproductive capacity and fecundity would yield valuable information on the stock-recruitment relationship. However, most estimates of fecundity provide information only on the number of eggs in the ovary at the time of observation and, at the maximum, provide a relationship between the size of the fish and the number of eggs. It may not be possible to apply these observations for solving purposeful biological problems. To estimate the annual recruitment to the fishery, it is important to determine the spawning frequency and the annual fecundity. The fecundity estimates have to adopt any of the following methods so as to establish stock-recruitment relationship (Bakhayokho, 1983): (i) The number of ripe ova in the ovary (known as potential fecundity) at the pre-spawning stages multiplied by the number of spawnings gives the total individual fecundity. (ii) The relative fecundity can be calculated by dividing the batch and total fecundity by body weight. (iii) The reproductive capacity of the population could be estimated by integrating the total individual fecundity, the size structure of the exploited stock, the sex ratio, the size at first maturity and the abundance.

Feeding and Growth

The main energy input to the animal is the food consumed. Unlike in laboratory studies, there is no control over the quantity of food consumed by the animal in the wild, or the composition of diet. The food and energy intake have to be estimated indirectly.

Despite the abundance of studies on the feeding habits and on the growth of the marine fishes, the relationship between these two vital parameters has not been properly addressed so far for the fish populations in the Indian waters. Such a correlation is crucial for a proper understanding of the exploited fish populations and for modeling the ecosystems, as they are relevant to the management of multi-species fisheries, where one commercially important species feeds upon the other. It is vital to understand the predator-prey relationship, which determines predation mortality, which is a major component of natural mortality. Hence, a series of attempts to develop and refine the methodologies for establishing a relationship is necessary.

There are several estimations on the food consumption of aquatic populations based on the quantity of food in the stomach of the animals sampled in the wild. The weight of the food in the stomach provided an estimate of the food consumed by the fishes in the sample.

By employing this method, Devaraj (1998a,b,c) and Vivekanandan (2001) reported that the estimated feeding rates of the seer fishes, and the threadfin bream and the lizardfish, respectively were within the range of values reported for the tropical fishes based on laboratory experiments.

Regulation of mesh size

The purpose of controlling the mesh size, especially in the cod end of the trawls, is to permit the escape of juveniles hoping that their growth would largely compensate the loss and increase the exploitable biomass, which might be available to the fishery later. Minimum mesh sizes are often emphasized as essential by the scientists as there is general agreement that protection of young fish is necessary. It is often argued that if fishing on immature fish is intense, the abundance of the species may be so reduced before it approaches maturity that there would be insufficient adult fish surviving even if there is no fishing on them. It is also postulated that long term yields would increase by permitting the faster growing immature fish to attain sexual maturity before exploitation, primarily because growth is most rapid in young fish. Under these assumptions, the biomass of a cohort maximizes at about the age at first maturity.

The cod end mesh size (CEMS) of the trawls prevalent in India is uniformly very small (generally about 15 mm stretched knot to knot; but quite often, much less than this). Most fishery scientists have suggested a minimum stretched mesh size of 30 mm. Kalawar *et al*. (1985) advocated a compulsory mesh regulation by legally imposing a minimum stretched CEMS of 35 mm, that would help to protect significant number of juvenile fishes as well as shrimps. According to Garcia and Le Reste (1981), mesh regulation would be useful for shrimps in the long term due to the following reasons: (i) since shrimps have a short life span and rapid growth, the possible annual increase would be obtained before the completion of the first annual cycle. (ii) increasing the mesh size leads to an increase in age and individual average weight and price/kg. The possible increase in value would be proportionately greater than the increase in tonnage.

In order to achieve an integrated management of the exploitation of demersal stocks, one should consider not only the shrimps but also the fishes. This becomes practically difficult in a multi-species fishery, where the body shapes of different species are diverse. The body shape of different species is one of the important factors, which determines the mesh size selection. The body shape, measured as depth ratio (finfish and crustaceans: standard length/maximum depth of body; cephalopods: dorsal mantle length/maximum girth of body) also ranges from 1.0 (*Drepane punctata*) to 45.0 (the eel, *Thyrsoidea macrura*). There is, therefore, no single mesh size, which is optimum for all the species. The suggestion of optimum mesh size for the trawl fishery as a whole depends on finding a balance between different species. This usually involves making a number of assumptions, among other things (Pauly, 1988): (i) that a given set of growth parameters (usually K and L_a of the VBGF) can be used to represent the growth of a group of species reaching similar sizes; (ii) that a given set of M values or (M/K values) can be used to express the natural mortality of fish of similar size occurring in the same environment; and (iii) that the recruitments of different species remain in the same ratio over a wide range of fishing mortality. Given these assumptions, optimum mesh size can be computed for different groups using yield per recruit analysis. These can then be used to calculate an overall optimum mesh size.

Ecosystem-Based Fisheries Management

As far back as half a century ago (1955), the UN Technical Conference on the Conservation of the Living Resources of the Sea recognized the importance of an ecosystem approach to fisheries management. However, the impetus to this approach was given only in 1995 in the FAO Code of Conduct for Responsible Fisheries. Since then, several developed countries have begun the process of adopting the ecosystem-based fisheries management. Unlike the single species models in fisheries management, an ecosystem approach is an effective tool since it takes into account the complexity of the marine and coastal ecosystems and it is now believed that such an approach could provide a lasting solution to the problems of declining aquatic biodiversity and fish stock biomass. An ecosystem-based approach to fisheries management, according to the NMFS (1999), should take into account the following four aspects: (i) the interaction of a targeted fish stock with its predators, competitors and prey species; (ii) the effects of weather and hydrography on the fish biology and ecosystem; (iii) the interactions between fish and their habitats; and (iv) the effects of fishing on fish stocks and their habitats, especially how the harvesting of one species might have an impact upon the other species in the ecosystem. The National Research Council of the USA has advocated one more aspect to this approach, *i.e*., recognizing humans as components of the ecosystems they inhabit and use, thereby incorporating the users of the ecosystem in the approach (NRC, 1999).

An ecosystem approach could help manage fisheries in the following ways (Mathew, 2001): (i) Conservation of fisheries resources, protection of fish habitats, and allocation to fishers are the three most important considerations in fisheries management. The vantage point to start from is the fishing gear group, because without its cooperation, it would not be possible to adopt effective conservation measures and protect fish habitats from fishery-related stress. The ecosystem models estimate the carrying capacity of the ecosystems and the biomass at each trophic level by taking into consideration the weather and hydrography of the ecosystem and fish biology. It also quantifies the number of craft and gears required for sustainable harvest from the given ecosystem. It helps bring about a greater control over large-scale operations of nonselective fishing gears. (ii) The approach can facilitate a better understanding of the tropho-dynamics in an ecosystem, and also the impact of fishing gear selectivity on marine living resources. Programs designed to conserve marine mammals and turtles may become counterproductive when these resources multiply in large numbers and compete with fish stocks as well as fisheries.

CULTURE FISHERIES

Stock Enhancement

Augmenting the stock of fish has been the most common management measure that is followed in the reservoirs in most countries of the world. Ever since the reservoirs were considered as a fishery resource, it had become apparent that the original fish stock of the parent river was insufficient to support a fishery.

Augmentation of the stock is also necessary to prevent the unwanted fish from utilizing the available food niches and flourish at the cost of economically important species. However, the policies and guidelines on the subject, wherever available, are often erratic and even arbitrary.

Stocking of reservoirs with fingerlings of economically important fast growing species to colonize all the diverse niches of the biotope is one of the pre-requisites in reservoir fishery management. This has proved to be a useful tool for developing fisheries potential of such small aquatic systems. However, stocking is not merely a simple matter of putting appropriate number of fish into an ecosystem but needs evaluation of an array of factors, viz. the biogenic capacity of the environment, the growth rate of the desired species and the population density as regulated by predatory and competitive pressures.

Fish seed production has made rapid advances in the country during the last few decades either through indigenous or imported technologies. Consequently, a number of hatcheries have come up for large-scale production of fish seed under the public and private sectors.

Hatchery Technologies

Breakthrough in induced breeding through hypophysation (Chaudhuri and Alikunhi, 1957) was achieved during the fifties with a thrust on mass production of quality spawn in controlled environment, thereby reducing dependence on natural seed collection. Scientists have successfully induce-bred different carp species like *Labeo rohita, Cirrhinus mrigala, C. reba, L. bata and Puntius sarana* by injecting carp pituitary extract. This technique has been adopted widely and forms a regular part of fish culture programme in India (Jhingran *et al.* 1991).

Chinese carps were also successfully bred in 1962 adopting similar techniques (Alikunhi *et al.* 1963). The technique of induced breeding of carps by hypophysation has been followed in different species by several workers (Chaudhuri, 1960, 1963; Moitra and Sarkar, 1975; Varghese *et al.* 1975; Bhowmick *et al.* 1986). Further, the use of various synthetic formulations including Ovaprim has largely replaced the use of pituitary and the technology has become more farmer-friendly. Now, Ovatide and WOVA-FH are also becoming popular.

Strain Development

Several intergeneric and interspecific hybrids have been produced in the last four decades for genetic improvement (Chaudhuri, 1959, 1973; Bhowmik *et al.* 1981). Monosex production by breeding six inverted broodstock in grass carp, common carp and silver carp has been reported for their production enhancement in open water system (Naggy *et al.* 1981, 1984). The genetic engineering practice, which is becoming popular during recent years is gynogenesis, polyploidy and transgenics (Das *et al*. 1986; Das and Ponniah, 1991). Sterile triploid hybrids have been produced by crossing common carp with IMC males (Khan *et al.* 1988). Reddy *et al*. (1990) succeeded in producing triploidy and tetraploidy in rohu and catla by giving heat shocks to the fertilized eggs. Further, Reddy *et al*. (1998) induced triploidy in common carp. Pandian and Varadaraj (1987) produced triploids and tetraploids in tilapia by heat shock. Varadaraj and Pandian (1989 a, b) employing judicious combination endocrine sex reversal, selective breeding and gynogenetic techniques produced super male tilapia.

Carp Polyculture

The research and development efforts during the last five decades have greatly enhanced average fish yields in the country making carp culture an important economic enterprise. It has grown in geographical coverage, diversification of culture species and methods, besides intensification of farming systems. The three Indian major carps, viz. catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*) were the principal species cultured by the farmers in ponds since ages and production from these systems remained significantly low (600 kg ha^{-1} $year^{-1}$) till the introduction of carp polyculture technology. The introduction of exotic species like silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*) and common carp (*Cyprinus carpio*) into the carp polyculture system during early sixties added a new dimension to the aquaculture development of the country. With the adoption of technology of carp polyculture or composite carp culture, production levels of 3–5 tonnes ha^{-1} $year^{-1}$ could be demonstrated in different regions of the country. Probably it is the technology of carp polyculture that has revolutionized the freshwater aquaculture sector from a level of backyard activity to that of a fast growing and well organized industry and placed the country on the threshold of blue revolution.

Brackishwater Aquaculture

The importance of brackishwater aquaculture technologies was recognized in the early seventies and All India Co-ordinated Research Project (AICRP) was initiated in 1973 in West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Kerala and Goa (Rao and Ravichandran, 2001).

CMFRI initiated research at its Narakkal Prawn Hatchery

Laboratory (NPHL) in 1976 for developing a comprehensive system of producing penaeid prawn seed in hatcheries. Intensive and sustained research by a team of scientists resulted in successful evolution of an indigenous, low cost hatchery technology for the Indian white prawn, *Penaeus indicus* (CMFRI, 1978; Muthu, 1980). Seed production technology for other commercial shrimp species such as *P. monodon, P .semisulcatus, P. merguiensis and P. japonicus* was also developed later (1985) by NPHL of CMFRI. The CMFRI and CIBA had also successfully demonstrated the proven technology of selective farming of *P.indicus, P.monodon and P.semisulcatus* under different ecological environments. Research on broodstock development for *P.monodon* and protocol for developing eco-friendly sustainable shrimp farms are being conducted at CIBA, Chennai. The technology on mud crab culture and fattening was developed and transferred.

REFERENCES

Alikunhi K H, Sukumaran K K and Parameswaran S. 1963. Induced spawning of Chinese carps *Ctenopharyngodon idella* (Cuv.) and *Hypophthalamichthys molitrix* (Cuv.) in ponds at Cuttack *Curr.Sci* **52**: 103–06.

Bakhayokho M. 1983. Biology of the cuttle fish *Sepia officinalis hierredda* off the Senegal coast. In "*Advances in Assessment of World Cephalopod Resources*" (J.F.Caddy, Ed.), *FAO Fish. Tech. Pap* **231**: 452.

Bhowmick R M, Kowtal G V and Jana R K. 1986. Some observation on the use of various hormones and clomiphene citrate in hypophysation of Indian major carps. *Veterinarski Arhiv* **56**: 285–92.

Bhowmick R M, Jana R K, Gupta S D, Kowtal G V and Rout M. 1981. Studies on some aspects of biology and morphometry of the intergeneric hybrid, *Catla catla* (Hamilton) × *Labeo rohita* (Hamilton) produced by hypophysation. *Aquaculture* **23**: 367–71.

Chaudhuri H and Alikunhi K H. 1957. Observations on the spawning in Indian carps by hormone injection. *Curr.Sci* **26**: 381–82.

Chaudhuri H. 1959. Experiments on hybridization of Indian carps. *Proc. Indian. Sci. Congr* **46**: 20–21.

Chaudhuri H. 1960. Experiments on induced spawning of Indian carps with pituitary injections. *Indian J.Fish* **7**: 20–49.

Chaudhuri H. 1963. Induced spawning of Indian carps. *Proc. Nat. Inst. Sci.* India **29B**: 478–87.

Chaudhuri H. 1973. Fertility of hybrids of Indian carps and preliminary studies on the generation of caro hybrids. *J. Inland Fish. Soc. India* **5**: 195–200.

CMFRI. 1978. Larval Development of Indian Penaeid Prawns. CMFRI *Spl. Publn.,* No **67**: 35.

Das P, Kumar D and Mahanta P C. 1986. Genetic improvement of fish stock and resource conservation. *Bull.No.I, NBFGR*, Lucknow, India, 29 p.

Das P and Ponniah A G. 1991. Research needs on fish breeding and genetics in aquaculture for the year 2000. *In*: Sinha,V R P and Srivastava H C (eds). *Aquaculture Productivity*, Hindustan lever Research Foundation, Oxford and IBH Pub.Co. Pvt. Ltd., New Delhi 181–95.

Devaraj M. 1998a. Food and feeding habits of the kingseer, *Scomberomorus commerson* in the seas around the Indian peninsula. *J. mar. biol. Assn. India* **40**: 69–90.

Devaraj M. 1998b. Food and feeding habits of the streakedseer, *Scomberomorus lineolatus* in the Gulf of Mannar and Palk Bay. *J. mar. biol. Assn. India* **40**: 91–104.

Devaraj M. 1998c. Food and feeding habits of the spottedseer, *Scomberomorus guttatus* in the Gulf of Mannar and Palk Bay. *J.mar.biol.Assn.India* **40**: 105–24.

Devaraj M, Kurup K N, Pillai N G K, Balan K, Vivekanandan E and Sathiadhas R. 1997. Status, prospects and management of small pelagic fisheries in India. *In:* Devaraj M and Martosubroto P, (eds) *Small Pelagic resources and their Fisheries in the Asia-pacific Region.* Proc.of the APFIC Working Party on marine fisheries, First Session, 13-6 May 1997, Bangkok, Thailand RAP Publn. 1997/**31**: 91–197.

Garcia S and Le Reste L. 1981. Life cycles, dynamics, exploitation and management of coastal penaeid shrimp stocks. *FAO Fish. Tech. Pap* **203**: 215pp.

Jhingran A G. 1991. Water resources development in India in the context of environment perturbations. Presented at the meeting on Preserved Planet Earth. Rotary International on 27.4.91, 17p.

Kalawar A G, Devaraj M and Parulekar A. 1985. Report of the expert committee on marine fisheries in Kerala. CIFE, Bombay, 467pp.

Khan H A, Gupta S D, Reddy P V G K, Tantia M and Kowtal G V. 1988. Production of sterile intergeneric hybrids and their utility in aquaculture and reservoir stocking. *In*. Keshavanath and Radhakrishnan (eds) *Carp seed Production Technology. Proc. Workshop Carp Seed production*, Asian Fisheries Society, Indian Branch, Manglore, India: 41–8.

Mathew S. 2001. Small scale fisheries perspective on ecosystem-based approach to fisheries management. *Conf. On Responsible Fisheries in the Marine Ecosystem*, Reykjavik, Iceland, 20pp.

Mohanraj G, Vivekanandan E, Subramanian V T, Sarvesan R, Meiyappan M M and Nammalwar P. 2002. Spawning seasonality of major fishery groups along the north Tamil Nadu-south Andhra Pradesh coast. *Proc. V Indian Fisheries Forum* 267–70.

Moitra S K and S K Sarkar. 1975. A new method of induced breeding by hypophysation of some major carps in dry buns of Bankura, West Bengal. *Proc. Zool. Soc*., Calcutta **2**.:8: 41–50.

Muthu M S. 1980. Development and culture of penaeid larvae- A review. *In*: T.Subramaniam and Sudha Varadarajan (eds), *Progress in invertebrate reproduction and aquaculture* 203–226.

Nagy A, Bercsenyi M, Csanyi V. 1981. Sex reversal in carp (*Cyprinus carpo*) by oral administration of methyl testosterone. *Can. J. Fish. Aquat. Sci* **38**: 725–28.

Nagy A, Csanyi V, Bakos J and Bercsenyi M. 1984. Utilization of gynogenesis and sex reversal in commercial carp breeding: growth of the first gynogenetic hybrids. *Aquaculture hungarica* (*Szarvas*) **4**: 7–16.

NMFS. 1999. Ecosystem based fisheries management: A report to the congress of the Ecosystem Principles Advisory Panel. http://www.nmfs.noaa.gov/sfa/reports.htm.

NRC. 1999. Sustaining marine fisheries. National Academy Press, Washington D.C., 177pp.

Pandian T J and Varadaraj K. 1987. Techniques to regulate sex ratio and breeding in tilapia. *Curr Sci.,* **56**: 337–43.

Pauly D. 1988. Fisheries research and demersal fisheries of Southeast Asia. In '*Fish Population Dynamics*' (Gulland J A, Ed.), John Wiley and Sons, Chichester 329–48.

Qasim S Z. 1973. Some implications of the problem of age and growth in marine fishes from the Indian waters. *Indian J. Fish*. **20**: 351–71.

Rao G R M, K and P Ravichandran. 2001. Sustainable brackishwater aquaculture. *In*: Pandian T J., (eds) *Sustainable Indian Fisheries*, National Academy of Agricultural sciences 134–51.

Reddy P V G K, Khan H A, Gupta S D, M S Tantia and G V Kowtal. 1990. On the ploidy of three inter generic hybrids between common carps (*Cyprinus carpio* communis L.) and Indian major carps. *Aquaculture*, Hungarica (Szarvas) **VI**: 5–11.

Reddy P V G K, Kanta Das Mahapatra, Saha J N and Jana R K. 1998a. Effect of induced triploidy on the growth of common carp (*Cyprinus carpio* var.communis L.). *J. Aqua. Trop* **13**: 65–72.

Varadaraj K and Pandian T J. 1989a. First report on the production of super male tilapia by integrating endocrine sex reversal with gynogenetic technique. *Curr Sci* **58**: 434–41.

Varadaraj K and Pandian T J. 1989b. Introduction of allotriploids in the hybrids of *Oreochromis mossambicus* female × red tilapia male. *Proc. Indian Acad. sci* **98**: 351–58.

Varghese T J, G P Satyanarayan Rao, Devaraj K V and Chandrasekhar B. 1975. Preliminary observation on the use of marine catfish pituitary gland for induced spawning of the Indian major carps. Curr.Sci **44**: 75–7.

Vivekanandan E. 2001. Production efficiency of two demersal fish species in the trawling grounds off Veraval. *Indian J. Fish* **48**: 123–32.