CHAPTER 34

Applications of Fishery Biology Data for Mariculture

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Fish production was previously heavily dependent upon capture fishery and in particular the marine resources. However, the capture fishery cannot be expected to be a perennial protein donor. Moreover, a substantial portion of the marine catch is being utilized for making industrial products which are not directly consumed by man. Therefore, a viable alternative by which fish production could be increased through a popularized bio technique, called aquaculture. Aquaculture may be defined as the "farming and husbandry of economically important aquatic animals and plants under controlled conditions". The aquaculture sector is indeed remarkable for its diversity in operations, encompassing a very wide range of farming practices, species, environments and production systems, often with very distinct resource use patterns. The sector is also highly fragmented, ranging from smallholder ponds or cages providing a few kilos of fish per year to international companies with annual turnover in excess of USD1 billion. Indeed, despite having achieved good progress in terms of expansion, intensification and diversification, the aquaculture sector is confronted with a set of key issues and challenges that needs to be proactively addressed in order to contribute to green growth. In order to develop a sustainable aquaculture practice the various aspects to be carefully studied include: 1. Site selection, 2. Species selection, 3. Selection of culture types based on many factors as species combinations like monoculture, poly culture etc., culture systems like static systems like pond culture, tank culture or running water systems like race ways, cage culture systems or circulatory systems etc. all these requires a thorough knowledge on the biology of the species to be cultured. The following general factors should be considered when selecting a species for a successful aquaculture venture:

- Knowledge on biology, ecology, and life history
- Knowledge on reproductive culture methods
- Possibility of captive breeding and closing the life cycle under controlled farming conditions
- Ability to culture at high population densities in artificial holding facilities
- Ability to consume and efficiently grow on artificial formulated diets
- Ability to mimic the natural life cycle in a controlled environment
- Attainability of market size within economically feasible period of time
- Low vulnerability to pathogens

The ideal aquaculture species possesses all the above characteristics. However few if any species are ideal. More often there is some compromise in terms of these characteristics.

Why do we do research in fish biology?

Biological studies are the basic studies in any living organisms comprising plants or animals. It is a requirement in various branches of life sciences; and therefore of course fisheries sciences also for any type of management and/or culture of any living organisms or species or groups. Apart, gaps in biological knowledge often prevent progress in sustainable development process like aquaculture practices. Likewise, limitations in knowledge about any life species' physiology and its requirements during different life stages can hamper various stages of its culture from seed production to farming. The application of scientific knowledge for the development of the fishing industry lies in an intimate knowledge of the biology of fishes. Without proper knowledge of the life, habits and behaviour of fishes, it would not be possible to do any aquaculture practices for its increased production or plan, control and manage the resources in a satisfactory manner. Reviewing the process over the past 50 years, the rapid growth in aquaculture is clearly a result of developments in fish biology and its various applications like genetics, molecular biology, biotechnology etc. As a multidisciplinary subject the roles and mechanisms of fish phylogenies, development, growth, reproduction and behavior, and thereby exploiting the biotechnology applicable to genetic breeding and disease prevention, fish biology and biotechnology has provided the innovation and technology for rapid development of the aquaculture industry. Biology is the basis of all biotechnological applications and without biological base no manipulations are possible.

Site selection: The success of an aquaculture project depends to a large extent on the proper selection of the site to be developed into a fish farm or hatchery. Proper siting of aquaculture facilities is critical to reducing environmental and social impacts, and to improving long-term operations. The major factors to be considered for the site selection includes: 1. Ecological factors and 2.Biological & operational factors. Before a site can be selected for a project, the following should be ascertained: species to be cultured, its ecological features, tolerance limits, resources available, availability of stocking materials (spawners, fry or fingerlings), compatibility of the species etc. If we want to do mariculture we have to select an area with full saline waters; or area where plenty saline waters can be brought.

Species selection: The choice of suitable species for aquaculture often is a balance between biological knowledge and economic necessities. The biological knowledge required to allow a successful culture of a species is manifold and needs thorough considerations of the applicable conditions. Prior to selecting a species for culture or for a (business) project, it is important to consider the species' biological requirements and the economics and market potential. At present, about 240 fish species are reared in aquaculture (among them about 60 marine species). Many novel aquatic varieties that have played a major role in aquaculture are the results of comprehensive and systematic studies on the biological characteristics of these species. Not all fish species are suitable for aquaculture. By the same token, some cultivable species are more appropriate for large-scale, commercial aquaculture rather than for small-scale operations, as exemplified by the high-value shrimps, the production of which can hardly be undertaken profitably on a small scale. Also, some species are best cultured using specific types of enclosures; for example, penaeid shrimps are best cultured in fish ponds rather than in fish pens and certain species are more acceptable in certain countries than in others. The choice of species for culture depends on a number of factors including the availability of suitable sites for culture, the biological characteristics of the indigenous or introduced/exotic species, their suitability for culture, and their acceptability in the local or international markets, and the availability of technology and other requirements for their culture.

Air breathing fishes in areas where water availability is less or in marshes and in this condition culture of other fishes are not possible. Similarly fresh water fishes only can be cultured in in areas where nothing other than fresh water is available. Cold water fishes require plenty oxygen supply and can live only in Cold Water areas.

The following general factors should be considered when selecting a species for a successful aquaculture venture:

(i) It must withstand the climate of the region in which it will be raised. Thus, purely marine fishes like cobia; carangids etc. need high saline waters during its culture. Pure freshwater fishes cannot live in even brackish water systems. Similarly the rearing of cold water fish like salmonids and trout is limited to temperate regions or mountain areas of tropical countries because they cannot tolerate warm water with its low oxygen content.

(ii) Its rate of growth must be sufficiently high. Small species, even if they reproduce well in ponds and accept formulated diets, are not the most suitable for rearing. Also, the best culture species are those which are low in the food chain, e.g., plankton feeders, herbivores, and detritivores. Their culture is also least expensive, even on an intensive scale, because they do not need to be given diets which have a high content of animal protein.

(iii) It must be able to reproduce successfully under culture conditions. Species for culture should be able to reproduce in captivity/confinement without needing special conditions that have to be fulfilled, and which give high returns on eggs and fry. Although it is possible to rear species whose reproduction in confinement is not possible at all (e.g., some carps) or whose reproduction under hatchery conditions has not yet been possible on a commercial scale (e.g., milkfish in the Philippines), the sustainability of the grow-out operations is hampered by the seasonal unavailability of wild fry for stocking in fish pens and/or fish ponds.

(iv) It must accept and thrive on abundant and cheap artificial food. Culture species which feed on cheap artificial feeds and give low feed conversion ratios (FCRs) also tend to give very good production rates, thus bringing in better financial returns.

(v) It must be acceptable to the consumer. Even if all the foregoing criteria are met by a candidate species, it is not worth culturing if there is no market for it. It is possible, though, to promote acceptability of or encourage consumption of a particular species to ensure that it will eventually sell in the market. (This was the situation with tilapia in the Philippines prior to the introduction of the bigger-sized, lighter coloured *O. niloticus* in the early 1970s.)

(vi) It should support a high population density in ponds. Social and gregarious species which can grow well to marketable size even under high density conditions in ponds or tanks (e.g., tilapia) are preferable to those which can be grown together in dense numbers only up to a certain age beyond which they eat each other (e.g., pike).

(vii) It must be disease-resistant. Reared fish must be resistant to disease and accept handling and transport without much difficulty. Tilapia is an ideal species for culture because of its high resistance to disease even in highly intensive culture systems.

Taxonomy in aquaculture: It has become clear that taxonomic information is not a luxury – it is a real need in a world with a still-growing human population generating enormous pressure on natural resources. Although the need for taxonomic expertise has never been as pronounced as it is today, this has not translated into training more taxonomists and providing more funding for necessary developments in taxonomy. More and more organisms are shipped around the world and marketed continents away from their origins, thus generating an increased need for global fish identification tools to provide reliable information to consumers, customs officers and fishery inspectors. However, worldwide, there exist more than 32 500 species of finfishes and the amount of information required to separate them all is extremely difficult to process; therefore, fish identification is usually conducted at local or regional scales. The increasing globalization of fishery products thus introduces new challenges to the identification of aquatic organisms. For many decades, FAO has been collecting global statistical catch data and analyzing the results in two of its flagship publications: (i) *The State of World Fisheries and Aquaculture* and (ii) the *Review of the state of world marine fishery resources*. The collection of species- and population-specific information for the purpose of sustainable fishery management has a long tradition however also it is very important in the future of aquaculture where species diversification is the need of the hour.

Seed identification: In recent decades, many new and promising techniques for the identification of fishes have emerged, in particular based on genetics, interactive computer software, image recognition, hydro-acoustics and morpho-metrics. In recent decades, many new and promising techniques for the identification of fishes have emerged, in particular based on genetics, interactive computer software, image recognition, hydro-acoustics and morpho-metrics. However, with few exceptions, such advances in academic research have not yet been translated into user-friendly applications for non-specialists and still require further investments to mature into globally applicable tools. In CBA seed identification is another area; especially fishes like mullets it is very difficult to identify the small seeds; and only when it grows only many of the farmers could realize that it is not the species they planned. When it comes to the aquaculture practice it is necessary to identify each and every seed in the beginning itself otherwise it leads to wastage of many things.

Food and feeding: The study of the food and feeding habits of fish is a prime step in any fisheries research program. The dietary analysis of fishes indicates the trophic segregation pattern among the members of the fish community in that area. In general, growth of a fish is influenced by the quality and quantity of food materials available and consumed. This variation is due to changes in the composition of food organisms occurring at different seasons of the year. Thus, any variation in quality and quantity of food materials will affect growth rate of the fish. The qualitative and quantitative variations of natural food materials in a water body are under the influence of several abiotic and biotic factors. These variations could be documented by qualitative and quantitative analysis of gut contents of a fish and or by the estimation of Gastro-somatic index. The study of food and feeding habits of fish help to know what fish eat how it grow it in its habitat and it can be used for feeding the fish while its culture. Feeding habits of fish is also help to know the inter-specific relationship and the productivity of the water bodies. The knowledge of feeding biology helps to produce optimum yield by utilizing all the available potential food of the water bodies properly without any competition. By studying the food and feeding habits, one can understand what program should be follow for the development of the water bodies to produce more fishes. According to Polling (1993), whose studies on food and feeding habits of fish help to determine the ecological condition of fish, niche in the ecosystem, preferred food items. A thorough knowledge on the food and feeding habit of fishes provide keys for the selection of cultivable species and much information is necessary for its successful farming. Food and feeding habits of carps has been a field of interest to fisheries researchers since a long back. The objectives of the dietary studies of *Labeo dyocheilus* include how it lives and grows, what can influence its abundance, distribution and the relative quality of feeding condition. This study has both theoretical and practical importance, so that it can be determine directly the exact type of food that the experimental fish consumes in its natural habits.

Formulation of feeds and feeding schedules for aquaculture is basically based on the food and feeding studies. The nutritional requirement of each and every fish is different and we can understand it based on these studies; and it can be used for the feed formulations in future when mariculture of diverse fishes is possible. We can also use these data for the discovery of alternate sources of protein and food materials for fish feeds. The amount of feed to be given at different stages of development and growth also can be decided based on these studies. It is because of the feeding information made the application of cleaning of nets using pearl spots in brackish waters and rabbit fishes marine conditions in cage culture. Similarly the combinations of fishes in a rearing system can also be decided based on these studies. Therefore snappers are stocked along with sea bass in cages for the complete utilization of feeds as sea bass is a column feeder and snapper feed on leftover food at the bottom of the cages. Another area of similar nature is the cleaner Fish Biology and Aquaculture Applications; where new knowledge on the biology of the utilized cleaner fish species, and provides protocols in cleaner fish rearing, deployment, health and welfare. Cleaner fish are increasingly being deployed in aquaculture as a means of biological control of parasitic sea lice, and consequently the farming of wrasse and lumpfish, the main cleaner fish species in current use in salmon farming, is now one of the fastest expanding aquaculture sectors with over 40 hatcheries in Norway alone. The latest knowledge is presented in a book addresses the questions of sustainability of cleaner fish use in aquaculture, bottlenecks to the optimum production of cleaner fish, and improvements and best practice in on-farm deployment methods, for optimum survival and enhanced welfare of cleaner fish. Contributions from over 60 leading researchers and producers give an exciting mix of information and debate on this subject.

Age and growth: Growth is a complex mechanism, and it is the outcome of the interactions among several biotic and abiotic factors operating on behavioural and physiological processes. The age and growth of fishes are important in the estimation of fish production in terms of quantity, in a body of water in relation to time. In the studies of biological profile of a species, age and growth form the most fundamental aspect. Knowledge of these parameters provides dynamic features of the population and forms the basic key to determine the quantity of fish that could be produced in a fish population against time. The effective management of fish populations as well as developmental activities like aquaculture and their seed production require these types of knowledge on each group/species of fish. Once the addition (weight) in a fish stock in relation to time is determined, the optimum size at age can be fixed for rational exploitation of a fishery. According to

Pillay (1958) a comprehensive study of all available age groups, covering all the seasons and environment of its occurrence is essential in order to obtain a correct picture of nutrition and feeding adaptations. These are the fundamental information required for the selection of species for aquaculture otherwise a fish which take a long time for its growth cannot be selected for aquaculture. The criteria for selection of aquaculture species, first documented by Fan Lee nearly 2500 years ago in a treatise devoted to pond culture of freshwater fishes stated that high priority should be given to species that grow rapidly, are tasty, not cannibalistic, hardy, and inexpensive to culture. Again the information on age growth of a species is very important in aquaculture point of view as it is observed in many species from the mugilidae family which take long time to attain marketable size. Again the age at first maturity is always needed for the breeding and hatchery production of seeds.

Fish population studies: It means a fishery in an area with an associated fish or aquatic population which is harvested for its commercial /recreational value. Fisheries can be wild or farmed. Population dynamics describes the ways in which a given population grows and shrinks over time, as controlled by birth, death, and migration. It is the basis for understanding changing fishery patterns and issues such as habitat destruction, predation and optimal harvesting rates. The population dynamics of fisheries is used by fisheries scientists to determine sustainable yields.

A fishery population is affected by three dynamic rate functions:

- Birth rate or recruitment. Recruitment means reaching a certain size or reproductive stage. With fisheries, recruitment usually refers to the age a fish can be caught and counted in nets.
- Growth rate. This measures the growth of individuals in size and length. This is important in fisheries where the population is often measured in terms of biomass.
- Mortality. This includes harvest mortality and natural mortality. Natural mortality includes non-human predation, disease and old age.

Population dynamics and potential of fisheries stock enhancement is very important in the culture based fisheries. It is a management approach more common in freshwater than in marine systems. Stocking of hatchery fishes has been practiced on a large scale since the mid-nineteenth century, and systematic transfers of wild juveniles probably have a much longer history. Stock enhancement is a fisheries management approach involving the release of cultured organisms to increase abundance and yield of natural stocks. Releases may be carried out on a long-term basis to raise yields above the level supported by natural recruitment, or temporarily to rebuild depleted populations. Stock enhancement describes a continuum of hatchery release and associated harvest regimes, the extremes of which are culture-based fisheries and supplementation. In culture-based fisheries or ranching systems, recruitment is largely or entirely based on hatchery releases, and release and harvesting regimes may be designed to maximize production. By contrast, in supplementation, hatchery fish are released to booster the natural spawning stock. Many marine fish species have experienced dramatic declines in spite of considerable efforts to manage their populations (Pauly et al., 2002; Dulvy, 2003). Despite numerous restocking attempts, wild populations have shown few signs of recovery (Hutchings, 2000), and there are few data demonstrating that releases of hatchery-reared fish actually benefit wild stocks (Hilborn, 1992; Coronado and Hilborn, 1998; Salvanes, 2001).

The population decline of the blue swimming crab *Portunus pelagicus* (Linnaeus, 1758) in Kung Krabaen Bay is currently in crisis due to overharvesting. Apparently, the reproductive status of the crabs is directly affecting larval recruitment. In fact, this problem has not only occurred in Thailand but also in Southeast Asian countries such as the Philippines, Vietnam and Indonesia (National Fisheries Institute Crab Council 2013). The population decline of the blue swimming crab *Portunus pelagicus* (Linnaeus, 1758) is believed to be the result of problems such as overharvesting by efficient fishing gear, destruction of nursery habitat, harvesting ovigerous females and inefficiency of crab management. The Govt. and researchers the studied and found that these difficulties were related to the limited biological and ecological knowledge of *P. pelagicus* among the fishers. Based on these results, a sustainable management program for *P. pelagicus* was proposed as follows: (i) closing the bay during the spawning season, (ii) restoration of the *Enhalus acoroides* seagrass beds, (iii) restocking crab larvae in the bay and (iv) educating and networking all stakeholders to develop a better understanding of the ecology of the crab to support sustainable fishery management in Kung Krabaen Bay. As a result the population of the blue swimmer crabs has increased and exploitations is now started.

Reproductive biology and larval studies: Study of reproductive biology of any fish species is important to get information for successfully continuing its culture. Reproduction is one of the important physiological systems that are crucial in the life cycle of living organisms including fish. The main objective of the reproduction is to maintain the existence of the species and therefore fish have a strategies and tactics to achieve this objective. The reproductive behaviours are important to be studied in relation to know the population dynamic of fishes and their spawning seasons. This information is very crucial in relation to the development of breeding technology for aquaculture and conservation (restocking) purposes. In general the reproduction can be defined as a biological process of living organism to inherit the properties of its parent to their offspring in order to ensure the continuing survival of the concerned species. In fish, there are some tactics and strategies used by fish to ensure their offspring survive. Studies on reproductive biology of fish are crucial needed and a basic requirement to plan a better conservation and management strategies of fishery resources (Ali and Kadir, 1996; Ezenwaji et al., 1998; Brewer et al., 2008; Grandcourt et al., 2009; Muchlisin et al., 2010), examination of basic life-history information and for evaluating the impacts of environmental variability on the dynamics of fish populations (Schlosser, 1990). In addition, information on the reproductive system is essential for the development of the commercial aquaculture of an aquatic species (Muchlisin, 2004).

The reproductive strategy of a fish species is the overall pattern of reproduction common to individuals of within species, whereas the reproductive tactics are those variations in response to fluctuations in the environment (Wootton, 1990; Roff, 1992). Knowledge on the reproductive behavior of fishes is necessary for the development of the commercial aquaculture industry. Study on reproductive biology of any fish species is essential for assessing commercial potentialities of its stock, life history, culture practice and actual management of its fishery5In order to make success in fish culture, it is important to assess the yearly breeding cycle of cultivable fishes. Spawning of fish occurs during a particular phase of the reproductive cycle; some of them breed once annually while others at regular intervals throughout the year. Knowledge of gonadal development and the spawning season of a species allow subsequent studies on spawning frequency. Study of sex-ratio, length at first sexual maturity, cycle of maturation and spawning periodicity etc. are important aspects of reproductive biology study of any fish specie.