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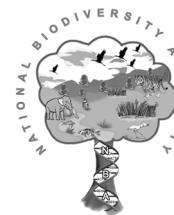


MANAGEMENT OF SPINY LOBSTER FISHERY RESOURCES

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and larval duration should also be attempted besides efforts to make them overcoming stress. Standardization of larval life feed, commercial Artemia replacement diets and formulation of larval feed are also equally important. Studies should be undertaken to get current estimates of stocks for all the species. What is worrying is the large scale exploitation of juveniles. A study conducted in the Kanyakumari region by a researcher in the Centre of Advanced Study in Marine Biology of Annamalai University showed that 70% of the landed lobsters were juveniles. This is a dangerous situation. If the stock position reveals fewer adults, a moratorium on lobster catch should be brought in so that the stocks will be in a position to rebuild themselves. The agencies which undertake and promote lobster fattening should be dissuaded from doing it as juveniles are held in culture facilities until they attain the marketable size and harvested. As no opportunity is given to these organisms for reproduction it is also detrimental to the lobsters. Among all the commercially important invertebrates, lobsters are graceful organisms. No stone should be left unturned in protecting and conserving the lobster resources.

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season have an adverse impact on the breeding stocks as it will affect release of eggs and thereby recruitment. Unfortunately peak fishing coincides with peak breeding season of the lobsters in most of the fishing areas. Seasonal closures around the time of breeding have been effectively used as a regulatory measure in single species fishery of the subtropical seas. Along the southwest and southeast coasts, the operation of trammel nets brings in substantial quantities of juveniles. Trammel net is a destructive gear for lobsters. With the beginning of live lobster export, exploitation of juveniles and undersized lobsters has been on the increase. The overseas demand is higher for smaller sizes. India exports undersized lobsters also while other countries have enforced strict regulations on size of these shellfishes fished and exported. This situation has affected the lobster resource of the country to a great extent. Therefore, regulatory measures need to be formulated and enforced for sustainable exploitation of lobsters in the country.

Radhakrishnan and Manisseri (2003) recommended the following management measures. Impose ban on both capture and export of egg bearing lobsters. Releasing of berried lobsters back into the sea is to be made mandatory. Enforce Minimum Legal Size for capture and export. Minimum Legal Sizes recommended are : *P. homarus* - 60 mm CL, *P. ornatus* - 80 mm CL, *P. polyphagus* - 70 mm CL, *T. orientalis* - 60 mm CL.

Conclusion

In order to avoid commercial extinction of lobsters in Indian waters, priority should be given for completing the larval life history of spiny lobsters in the laboratory/hatchery and for perfecting the technology for large scale production of phyllosoma and puerulus. This should be given top priority by all the institutes dealing with the fisheries and aquaculture. Genetic manipulation for shortening the larval life history

Introduction

Marine resources in Indian waters are common property resources. The role of Government as custodian of the marine resources on behalf of the general community is to ensure that marine resources are used in an ecologically sustainable manner and as efficiently as possible, while yielding a return to the community. Experience worldwide has shown that there is unrestricted use of marine resources and the consequent decline in the stocks. This is attributed to the following factors:

- Population growth
- Rise in the international demand for fish
- Improvements in the internal market infrastructure
- Modern technologies
- Environmental conditions
- High price for certain species and
- Poor fisheries management.

The situation warrants management. In carrying out the management of the resource, Governments have the responsibility of ensuring that the basis for the sharing of the resource among all users is clearly understood and accepted as equitable and that the allocation of fishery resources and their level of utilization are consistent with the needs of present and future generations. When scientific data or evidence on some biological parameter for a fishery is lacking, the management decisions will not be that effective and it is the responsibility of the scientists and the fisheries research institutes to provide scientific data and the management plans. In India such a plan is urgently and very badly needed for the lobster resources.

Lobsters are one of the most valuable and highly priced seafoods. In the past two decades, lobsters have become very popular in the world markets. Worldwide, the market price for lobsters tended to rise in response to supply and demand rather than the costs involved in the production (capture and processing). This attractive price encouraged fishermen to aggressively exploit the fishery with no concern to its long-term sustainability. As lobsters became scarcer, the price kept rising until some kind of consumer resistance developed towards high lobster prices. In spite of this resistance, lobsters continue to command a premium among the crustaceans along with shrimps.

Among them, the spiny lobsters (rock lobsters) especially the live ones fetch the highest price. Even though the lobsters in India form only 0.12 of the total marine landings, they are an important export commodity comprising of 1.07% in quantity and 2.59% in value (Radhakrishnan and Manisseri, 2003). Being the gourmet's number one choice and epicurean's delight heavy demand is there in the international markets and the lobsters are offered high prices. This has led to increased exploitation of lobsters in the recent years. The multispecies and multigear fishery involving both traditional and mechanized sectors poses problems for effective management. The various options available for their management are presented here.

Level of production of lobsters in India

Even though lobsters have been caught since yore, the fishery improved in the twentieth century and consequently the stock position has become precarious. The fishery increased from 347 tones in 1965 to 2,991 tones in 1975. The highest landing of 4,082 was recorded in 1985. After that the catch has been fluctuating around 2, 400 tones.

Even though the lobsters are distributed throughout the coast line, northwest, southwest and southeast contribute more to the landing.

Management in India

Radhakrishnan and Manisseri(2003)compiled information about the management of lobsters in India. According to them currently, no management regulations are in force to control fishing of lobsters in India. There are no restrictions on fishing such as minimum size of capture, types of gears used, total number of crafts employed and season of fishing. Unlike the single species fishery of the temperate and sub-tropical countries, the lobster fishery in India is multi-species and exploited by divergent gears involving both traditional and mechanized sectors. The fishermen lured by the high prices offered for lobsters are exploiting the resource indiscriminately, in the absence of any regulation or control on fishing activity. Therefore framing and implementation of management measures will have to take into account the biological, social and economic aspects. On the northwest, available scientific information clearly indicates that the resources of the spiny lobster *P.polyphagus* and the sand lobster *Thenus orientalis* are overexploited. The current landing of lobsters in India constitutes only 58% of the peak catch once obtained in 1985 and consists of smaller specimens which bring lesser value. In Mumhai. average landing during 1996-2000 has come down by 57 compared to production during 1986-90. The situation is similar at Veraval and at other major fishing centres along the southwest and southeast coasts. At Tuticorin nearly 43% of the lobster landings are by trawlers and a situation similar to the northwest prevails here also. But, one of the major constraints is that lobsters appear only as by-catch in trawl fishery and no direct regulations can be enforced to control fishing of one resource alone. But restrictions on juvenile fishing in inshore waters by gill nets, doll nets, stake nets and cast nets will have to be enforced so that overexploitation could be contained. Similarly, large scale exploitation of egg bearing females during peak breeding

- i. changes in TACC (total allowable commercial catch) in subsequent years and
- ii. changes to the minimum size limit and changes to the fishing season.

Economic performance indicators

Based on the economic objectives for the fishery, the following performance indicators are used to assess the economic status of the lobster fishery:

1. Gross Value of Product (GVP);
2. cost of management programs compared with GVP;
3. return on Investment (ROI) and
4. determination of any major operating cost increases (eg. possible future loss of fuel rebate)

Management committee performance indicators

The primary responsibility for ecologically sustainable development of the lobster resource rests with the government. However, to assess the effectiveness and efficiency of the management of the resource, and to provide for transparency in the management process and improve accountability, performance indicators are required.

The primary performance indicators used to assess the effectiveness and efficiency of the management by government is the acceptance of advice from the enforcing agency and the quality of the information the government department supplies to the higher-ups.

In fact, of the total landings, 43.7% came from the coast of Gujarat and 25.4% from the coast of Maharashtra during 1996-2000. While Tamil Nadu contributed 14.6%, Kerala contributed 13% during the above period. The average size of lobsters landed has decreased considerably over the period of time (Radhakrishnan and Manisseri, 2003).

Species composition

Out of the 14 species of littoral and 6 species of deep sea forms occurring in India only 4 species of littoral species contribute to the fishery. While *Panulirus polyphagus* and *Thenus orientalis* are caught mainly from the northwest coast, *Phomarus* is caught from the southwest coast. *P. ornatus*, *P. homarus* and *Thenus orientalis* are caught from the southeast coast of India. *P. versicolor* is caught in Tuticorin waters along the southeast coast of India. large numbers. While the trawl net contributes much to the landings, gears such as traps, gill nets and trammel nets land the rest.

Biology of lobsters

Spiny or Rock Lobsters (Crustacea: Decapoda: Palinuridae) are common throughout tropical and subtropical seas (Holthuis, 1991) where they form some of the most important commercial fisheries of the world. Ecologically, palinurids are important links in marine food webs. A nocturnal species, the lobster is an omnivorous scavenger with a preference for mussels, while juveniles feed mostly on barnacles (Phillips and Kittaka, 2000). According to Phillips et al. (2000), palinurids are major predators of various benthic species (e.g. snails, clams, urchins) and important prey of larger predators (e.g. sharks and some finfishes).

The spiny lobsters have a particular preference for coral and rocky reefs that are washed by sandy surfs. They inhabit mostly clear waters with low runoff on islands or continents. They are among the

largest of crustaceans: the total body length sometimes attaining a length of 60cm (Lipcius and Eggleston, 2000). The body parts are divided into cephalothorax, which consists of the fused head and thorax, and an abdomen with their respective appendages (Phillips and Kittaka, 2000). Appendages on the cephalothorax include the eyes, the antennae and antennules, which provide protection, mechanoreception and chemoreception (Lipcius and Eggleston, 2000); the mouthparts, which include the mandibles, maxillae and maxillipeds; and five pairs of walking legs. The ventral portion of the cephalothorax forms a sternum, which bears the gonopores at the bases of the 3rd pair of pereopods in females and 5th pair in males.

In the abdomen of the males, the first two pairs of pleopods are often formed into copulatory organs, whereas in mature females the pleopods become setose to enclose the external egg mass (Lipcius and Herrnkind, 1987). Posteriorly, the 6th abdominal somite forms the tail fan, consisting of uropods and telson, which enables the swift backward escape response (Cobb and Wang, 1985).

Life history of lobsters:

The spiny lobsters carry eggs externally and clutch size varies according to the size of the lobster. Gardener and Frusher (2000) reported that the size of the egg clutch is also influenced by the size of the sperm packet that the female received at mating. In general, it ranges between 35,000 to over 750,000 eggs (Mohan and Al-Amri, 1998; CSIRO Fact Sheet, 2003). Incubation period for the eggs is relatively short, being about three to five weeks (Cobb and Wang, 1985) but the larval period, however is lasting about 11 months (Johnson and Al-Abdulsalaam, 1991).

Biological reference points

Considering the stated biological objectives for the fishery, the following reference points are used to assess the stock status of the lobster fishery:

exploitation rate - indicates the level of available lobsters taken by the fishery.

catch rate - directly relative to current stock abundance.

egg production - reflects reproductive capacity of the fishery.

abundance of pre-recruits - provides a forecasting tool on future stock abundance.

mean size of rock lobster - indicates changes in stock structure.

In determining the annual reference points to measure performance of the fishery, the management committee is guided by the following principle: to maintain and improve the average catch rate above the particular level to maintain the spawning biomass at a level which sustains the reproductive capacity of the stock.

When one or more of the reference points described are reached or exceeded, the management committee undertakes the following actions:

1. notify the government agencies and participants in the fishery as appropriate,
2. undertake an examination of the causes and implications of 'triggering' a reference point and
3. consult the need for alternative management strategies or actions, which include:

Other management practices include

1. Limited entry fishery-limiting number of boats/traps. However when the number of – traps boats was restricted, fishermen made good by intensively using the allowed pots.
2. Introducing quota system-total allowable commercial catch (TACC). It is in vogue in many countries including Australia.
3. Maintaining of commercial catch logbook to be made compulsory.
4. Closure of fishery during peak period of reproduction and
5. Creation of lobster sanctuaries

Reference points and performance indicators

Reference points and performance indicators are also used in management. These are agreed quantitative measures used to assess performance of the fishery based on clearly defined management objectives.

Reference points begin as conceptual criteria which capture in broad terms the management objectives for the fishery. To implement management the conceptual reference point is converted into a technical reference point, which is calculated or quantified on the basis of biological or economic characteristics of the fishery (Caddy and Mahon 1995).

Reference points used for rational exploitation of lobster resources are placed in two categories: target reference points and limit reference points. Target reference points are considered as indicators of stock status which are a desirable management target, whilst a limit reference point is an agreed level at which stock stress may occur, and immediate action is required to remedy the situation before long term damage to resource productivity may result.

Fertilization is external; the male deposits a spermatophoric mass on the female's sternum. Fertilization occurs when the eggs are extruded onto the abdomen and pleopods (Lipcius and Herrnkind, 1987). The female carries the eggs on the abdomen until hatching. Unlike other crustaceans, eggs of spiny lobsters pass through a naupliar phase before hatching into the distinctive phyllosoma larvae (Sastry, 1983) which are transparent and measure about two mm in length (CSIRO Fact Sheet, 2003). However it should be checked for the Indian lobsters.

The spiny lobsters have long pelagic larval phases, during which time the larvae can be transported long distances by oceanic currents (Griffin, 2004). It has been reported that the larvae are transported over thousands of miles. This early pelagic larvae are known as phyllosoma stage that have an extended oceanic larval period of up to 11 months before returning to inshore waters as pueruli where they settle into small holes and crevices in the reefs and seabed (Johnson and Al-Abdulsalaam, 1991; CSIRO Fact Sheet, 2003). The number of pueruli settling on the fishing grounds every year may depend on the success of the previous year's migration and breeding (Phillips et al., 2000).

Spiny lobsters exhibit 5 major phases within their life cycle: egg, phyllosoma larva, puerulus (post-larval stage), juvenile and adult (Phillips and Sastry, 1980). During growth lobsters like other crustaceans undergo moult (shedding of hard outer shell). Shortly before reaching adulthood many spiny lobsters undergo movements (migrations) from the nursery habitat to the characteristic deeper reef habitats, where reproduction occurs (Herrnkind, 1980).

Works on biology of lobsters in India

In India studies on biology and fishery of important species have been carried out by Central Marine Fisheries Research Institute (CMFRI)

at Veraval. Mumbai. Calicut. Vizhinjam. Tuticorin. Mandapam and Chennai. Growth, as in other crustaceans, is manifested by periodical shedding of exoskeleton (moulting). Studies on food and feeding habits of lobsters show that these animals generally feed on smaller crustaceans, molluscs and polychaetes. *Palnutirus polyphagus* is normally found in muddy substrates and sometimes on rocky bottoms whereas *P. homarus* and *P. ornatus* inhabit rocky and reef areas. Berried females of *P. homarus* are normally observed in inshore areas. Size of lobsters in the fishery generally ranges from 35 to 125 mm in carapace length. *P. homarus* attains a total length (TL) of 320 mm, *P. polyphagus*, 450mm and *P. ornatus* 500 mm. Growth is identical in juveniles but differential in the adults. In *P. polyphagus*, sexual maturity (50% level) is attained at 175 mm TL for females, whereas majority of males mature at 265 mm TL. *P. polyphagus* breeds almost throughout the year. but maximum number of females in berried condition are noticed during August-October when about 80% of females are egg bearing . Spiny lobsters here are highly fecund and fecundity ranges from 50,000 to 1, 000.000 eggs depending upon the species and the size of lobster. In *P. polyphagus*, recruitment of young lobsters measuring below 100 mm (<50g) generally takes place during December-January. The occurrence of berried females in the 25-40 m depth zone indicates that there is no large scale movement of females to deeper waters for breeding. *P. homarus* attains sexual maturity at 55 mm carapace length and majority of females start breeding at sizes above 60 mm CL. Though the species breeds throughout the year, peak breeding is from November to December along the southwest coast and January-March along the southeast coast. *P. ornatus*, on the other hand, starts breeding at 90mm CL (250mm TL). *P. homarus* normally breeds in the shallow waters. Occurrence of adult *P. ornatus* at 40-60 m depth indicates that the species breeds probably at relatively deeper waters (Radhakrishnan and Manisseri, 2003).

It is well known that spiny lobsters gather in sunken ships. This is due to the behaviour of lobsters, which hide in dark places during the day. Because of this, laying structures imitating lobster habitats may lead to the formation of fishing grounds (JRGFE, 1976). A major feature of the Cuban lobster fishery has been the introduction of the artificial shelters known as Persqueros. Similarly, the spiny lobster fishery in Mexico uses artificial shelters called Casitas.

However, the use of artificial reefs to increase fishery production remains controversial due to the hypothesis that the use of artificial shelters could lead to overexploitation of the resource as they attract naturally dispersed animals to aggregate and thus increase vulnerability to capture (Phillips and Kittaka, 2000). Another important concern is that increased predation pressure at or near artificial reefs could outweigh the benefits from potential increases in production. Hence, a detailed ecological study should be undertaken before deciding to implement artificial shelters to augment lobster stocks.

Evaluation of enhancement programmes is also in place in many countries.

Introduction of pots which can trap only larger lobsters

Pots of various sizes and shapes are used throughout the world. Lobsters traps made of canes besides beehive pots of wire mesh on steel frames or weldmesh moulted plastic are used in the fishery. The size varies depending upon the species involved. Pots are usually set overnight and hauled in the morning. Elsewhere hydraulic or mechanical pot haulers are used.

One of the reasons for failure was the mismanagement of the lobster potting system. The performance of imported pots may not be appropriate for the local condition as the growth rate and size at maturity differ.

Contrary to this, some argue that if survival of pueruli in nature is low, then the removal of some pueruli for ongrowing could result in better production. In New Zealand, thousands of pueruli and juveniles are collected for commercial ongrowing by those retiring from commercial fishing in exchange of their quota (Synthesis of Workshop Discussion, 2004). A different approach is being considered in Australia to return cultured females to the wild to appease those objecting to the removal of pueruli. Several spiny lobster species can be ongrown from puerulus or juvenile stage to market size in 1 or 2 years time although many problems such as high costs, feed conversion and survival persist and still need to be addressed. They further state that in the long term pueruli cultured from eggs will be more acceptable and that will also lead to a more regular and predictable supply of stock.

Artificial shelters

Careful consideration has to be applied to the nature of artificial habitat creation. Simply creating a collection of boulders on the seabed may be totally inappropriate to form an artificial reef specifically for lobsters. Lobster puerulus and post-puerulus prefer to live in small holes only slightly larger than their body sizes (Yoshimura and Yamakawa, 1988). If such holes are not available then this juvenile stage is unlikely to survive. Hence, habitat selection is an important criterion when dealing with enhancement tasks.

Physical characteristics of the shelters are important as multiple den openings, shaded cover etc could provide safe hiding for communal lobsters. In addition to these physical characteristics, local habitat features are also important in determining the success of artificial shelters in attracting and concentrating lobsters. Sites without or distant from habitats rich in lobster food should be avoided when placing artificial shelters (Sosa-Cordero et al., 1998).

Stock assessment

In a recent study by CMFRI on *P. polyphagus* from Mumbai waters, the age and growth was determined based on the length-frequency method. Growth during the first 3 years was found to be identical in both sexes. The species attained 85 mm, 145 mm and 205 mm at the end of I to III year respectively. Thereafter, the males grew faster than females, measuring 265 mm, 315 mm, and 355 mm successively till the end of sixth year. Females measured 255 mm, 290mm, 320 mm, 345 mm and 365 mm respectively by the end of 4 to 8 year. The frequency of moulting is more and the intermoult period is shorter in juveniles. With the advance in age, the intermoult period gets prolonged and the number of moults gets reduced. The length increment per moult is nearly constant during the juvenile and adult phases. Six to seven broods appear to be recruited annually to the fishery. November — December is the peak period of recruitment for small sized juveniles. Stock studies reveal that total mortality coefficient 'Z' is 1.76 for males and 1.15 for females and the natural mortality coefficient 'M' is 0.33 for males and 0.35 for females. The fishing mortality coefficient 'F' deduced from these equals 1.43 for males and 0.8 for females. The total stock estimated is 453 t, the standing stock 271 t and the maximum sustainable yield 168 t (Radhakrishnan and Manisseri, 2003).

Fishery management objectives and strategies

Fisheries management is the objective of many maritime countries to protect and sustain their valuable fishery resources for the well being of their present and future fishing industry. Its complexity may depend on the extent of the fishery itself as countries with long coastlines and diversified fishery resources have far more problems than smaller countries. India is a very good example for this. With many species of commercially important species, varied gears used in

exploitation and diversity (multi-ethnic) among people engaged in fishing, India has many problems in managing the fishery resources, lobsters notwithstanding.

The fishery management plan should be prepared keeping in mind that there may be several reasons for regulating a fishery. In addition to conserving the resource and improving economic performance, fishery management measures are used to prevent or mitigate conflicts among user groups to encourage the distribution of benefits among users and to protect social values and life styles. There are five main issues that fishery managers must consider when deciding which management measures to apply:

1. Biological Consequences
2. Economic Consequences
3. Social Consequences
4. Administrative Consequences and
5. Environmental consequences

Biological Consequences:

The main objectives here are:

1. To main rock lobster populations at sustainable levels across the fishery and
2. To harvest rock lobster at a size likely to provide for adequate levels of recruitment.

Accurate data that describes both the fishery and the markets relevant to the fishery are important components in its effective management. Policy makers should have before them three sets of basic figures:

experiments have mainly focused on refinement of hatchery technology. Survival rates obtained for different species of lobsters at different labs upto stage IV or puerulus stage vary from 10% to 88.6%.

Larval survival rate is the crucial limiting factor in lobster culture. Successful larval rearing to metamorphosis (post larval and juvenile stage) has been achieved by only a few institutions. As a result, large-scale larval culture of spiny lobsters has still not been achieved despite significant advances in the understanding of their biology and life history.

Recent study of Tasmanian Aquaculture Institute suggests that they have succeeded in reducing the larval development period from two years to just one year (Fish News, 2004). Further research should focus on improving the survival rates of larvae. Key to this is better understanding and control of larval health (Colin Buxton, 2005).

It takes up to 3 to 4 years or more under optimum conditions for spiny lobsters to reach commercial size from hatching. The long culture period required for attaining to attain market size particularly when compared with some cultured finfish or shrimp species is the main constraint to commercialization of lobster culture.

In spite of significant developments in lobster hatchery technology and grow-out techniques, there is a tendency to rely on wild sources of juveniles for on growing which in itself could negatively impact the wild fishery (Lobster Propagation Workshop, 1999). It was stated that survival of pueruli could be greatly increased in culture than in wild, provided catches of pueruli are a small proportion of those available. Meagher (1994) concluded that lobster culture based on wild sourced juveniles appears to have commercial prospects, but it should not proceed unless it can be concluded that the harvested pueruli are excess to those required for maintenance of the existing wild-catch fishery.

Training in quality enhancement of lobster catches through better post catch handling techniques also contributes to improved returns from the fishery by specifically targeting the high value niche markets requiring fresh and live lobster supplies. This also encourages fishermen to use traps to land lobsters unharmed.

Lobster stock enhancement

There are numerous examples of lobster stock enhancement studies involving a range of species from the tropics to temperate regions. For *Homarus americanus*, some groups in North America raise the animals to their first benthic stage (Stage IV larvae of clawed lobsters) after two weeks in culture and then place them directly on cobble and other heterogeneous habitats. These animals are approximately 15mm total length. Other groups hold the lobsters in a hatchery environment until they are 40 - 50mm total lengths and then similarly distribute them to the seabed. Other groups grow animals to 80 – 100 mm total length, and mark them with plastic/genetic tags before releasing them in the wild for studying the efficiency of stock enhancement programmes.

Many studies and practical investigations have been undertaken in Japan to promote the increase of this resource. Research on spiny lobsters began in 1899 with the experimental hatching and rearing of the phyllosoma in Japan (Nonaka et al., 2000). Kittaka (1989) was the first to achieve success in completing the development of larval stages up to puerulus stage in *Panulirus japonicus*. Thus, a period of almost 100 years elapsed between the initial research and the achievement of this goal. Since then many attempts have been made to improve the survival rates of cultured larvae. The main obstacle is the extremely long development period and the poorly understood requirements of the phyllosoma larvae (Van Olst et al, 1980). Therefore, the earlier

- the best current estimates of the potential sustainable yield from the stock
- the present catch levels and
- plans for increase in the catch

It is necessary that biologists, economists and administrators are then required to interact with each other to understand the respective objectives, the data required and finally manner in which the data should be integrated to provide for an effective management strategy. Unfortunately, detailed data are not available covering the entire length of the country. Reliable information on the biology of all the lobster specie, estimates of available stock of all the species and historical management efforts to increase the stock are not readily available. Most importantly, there is no major programme to collate fishery data for the lobster. Data exist in terms of taxonomy, seasonal availability, size range and distribution along the coast of India.

More importantly, an appreciation of the need for such data has arisen as the importance of the lobster resource has been realized.

The collation of valuable information relating to lobster population dynamics has been ignored. Understanding the movement of the phyllosoma larvae, the settlement of puerulus, the growth of juvenile animals, and the dynamics of the fishable stock including an estimate of the relative abundance of the female breeding populations is highly relevant to the management of the fishery. Routine assessments of the fishery are required that include an estimate of the exploitable biomass (weight or number of lobsters above the legal size), the relative impact of harvesting on recruitment to the fishery (this is normally egg production as stock recruitment relationships are difficult to obtain) and a harvest strategy evaluation model that allows predictions of the consequences

of change in management (increasing or decreasing the allowable catch, increasing or decreasing the fishing effort). The important issue is not the value but the trend. Thus the data needs to be collected over a number of years to see whether under the current management regime, egg production and exploitable biomass is increasing or decreasing.

The second component of biological research is an understanding of natural variability in the resource. This is very complex issue and requires an understanding of the processes that result in good and bad larval recruitment and the factors that regulate survival from larval settlement to recruitment to the fishery. Attention should also be directed towards the potential impact of the frequent incidents of upwelling and harmful algal blooms on the larval and juvenile populations. Only limited data are available on such important environmental issues. In addition, the impacts of global warming and change of ocean currents on the lobster populations could also reveal whether the collapse of fishery if any is due to mismanagement or in part, to natural phenomena, as Bell (2004) stated that ensuring sufficient spawning stocks to produce an abundant supply of eggs is no guarantee that there will be consistent supply of pueruli. The vagaries associated with the survival of planktonic stages and the variations in the oceanic currents will mean that pueruli supply changes each year. The possible impact of environmental parameters on the survival and recruitment of lobsters has to be evaluated.

Another area of research involves the potential for remediation (supplementation) of over fished stocks and/or the enhancement of stocks. The general objective should be to conduct high quality research focused on critical issues such as:

- Improving prediction of population changes (both short term and long term)

- A maximum legal size to protect larger females
- A closed window size to protect mature nonovigerous females
- A maximum trap entrance size to exclude smaller lobsters
- Increased minimum legal size to permit more lobsters to spawn before their catch

However, it is necessary that studies should be done before arriving at management measures introduced in a fishery.

The current debate over lobster conservation has focused on whether the egg production from the female population is sufficient to maintain the stocks. While the issue of “recruitment over fishing” is critical to the future of the fishery, the issue of “growth over fishing” is also important. In the short term, implementing restrictive management controls will mean lower incomes to the fishermen. This needs to be addressed by the government. When lobster fishing is restricted to only a few coastal locations, the governments provide support during periods of enforced conservation measures. This even includes temporary financial compensation and other forms of social welfare assistance. In the longer term, properly enforced conservation measures start to positively impact the fishery, so ensuring the economic independence of fishermen for future generations. The best example of such a successful management approach is the Western Australian lobster fishery, where well planned management approach with strict enforcement yielding results with a consistent output of over 11,000 tons each year (Phillips *et al*, 2000; Hilborn *et al.*, 2003). The Marine Stewardship Council has accredited the western Australian rock lobster fishery as environmentally and commercially sustainable in 2000 for the first time for any fishery in the world.

the biomass. In general it is reasonable to say that a stock is growth overfished in the biological sense if F exceeds F_{MSY} . The term biological is used to indicate that only the yield in terms of biomass measured in weight units is considered. Thus the value of the yield and cost of fishing are being disregarded here.

Fishing mortality rate

The term Fishing Mortality Rate (FMR) is a technical term referring to the instantaneous rate at which animals are removed from the population by fishing. In the lobster fishery, it refers primarily to lobsters that are landed in the catch.

Exploitation rate

Information on this is very important in management. It is referring to the fraction of deaths caused by fishing. For managing the lobster fishery resources it is important to calculate the exploitation rate which gives the maximum sustainable yield.

Management strategies in other countries

Various management measures followed in other countries are aimed at maximizing reproduction. These include a minimum legal size limit and the prohibition of landing gravid females. However, considerable attention is now being focused on issues like quota or limitation on the number of traps that each fisherman can have in the water and a limit on the number of lobsters that can be harvested commercially. For example, Nova Scotia lobster fishery follows the following management measures to increase egg production (Miller, 2003):

- Release of ovigerous females
- Tail notching ovigerous females so that they cannot be taken even if nonovigerous

- Defining processes and mechanisms that contribute to natural availability of populations
- Defining relationships between habitat characteristics and productivity
- Providing alternative measurement approaches
- Strengthening collaborative approaches in biological, economical and administrative issues
- Restoring and enhancing stocks and
- x Determining the viability of aquaculture to support stock enhancement

As a consequence of biological research outcomes, the management measures can be undertaken in the form of size limits, gear restrictions, catch targets, closed areas and seasons etc.

Economic Consequences:

The main objectives here are:

1. To maintain the economic returns from the fishery at a level which provides for fair and reasonable benefits to fishers.
2. To optimize yield from the fishery.
3. To recover an economic return from lobster fishers sufficient to cover attributed costs of management, research and compliance for the fishery.
4. To provide for economic efficiency and flexibility in management arrangements by developing harvesting strategies that minimize costs and

5. To protect the resource through the provision of adequate compliance resources.

Although economic research need not be a continuing process, periodic surveys have to be undertaken to gain an understanding of the economic consequences of the regulations imposed on the fishery. This should also be performed before any actual regulatory measures are imposed to gain a feeling of what will be the economic consequences if the conservative measures are imposed.

In general, economic consequences include changes in the net economic benefits to harvesters, processors, distributors, marketers and consumers. The net benefits are related to landings (amounts and seasonal patterns); fishing patterns; harvesting capacity; harvesting practices (fishing techniques, product handling); by catch; product utilization (discard rate, grading); landed product forms; harvesting costs; gear conflicts; gear loss; employment in harvesting and processing; safety; sales/revenues etc. In the market sector, net benefits are related to prices (levels and seasonal patterns); product quality and forms; product utilization; product availability patterns; imports and exports; and consumption patterns.

The management plans should be designed and implemented in such a way that the plan offers the most favorable economic consequences to the lobster fishing industry. A good management plan should ensure better incomes for those associated with the fishery in the long term while costs decline through consolidation. One should also expect growth in net incomes over time when stock conditions improve. In case a system is introduced where the lobster fishers require licenses, provisions such as permission to sell their own fishing licenses (in case of any restriction imposed earlier as a control measure – limited entry to fishing) would offer economic benefits to the fishermen and

Recruitment overfishing:

A lobster resource can be considered over fished when it is harvested at a rate that results in egg production from the resource, on an egg-per-recruit basis, that is less than 25% of the level produced by an unfished population. The average female lobster should be allowed to live long enough to produce at least 25% of the eggs that she would produce if she lived her natural life. It may be impossible to judge the egg production from an unfished population, since the lobsters have been fished for many years. However, it should be easier to calculate the fecundity of a female that lived its natural life as specific biological parameters such as how often a female produces eggs, how many eggs it spawns each time and longevity of a female are well known from studies of Palinurid species in other fisheries.

Overfishing often refers to depleted stocks. Stock depletion and stock collapse are caused by recruitment over fishing, such that the adult population is fished so heavily that it did not have the reproductive capacity to replenish itself. Even if lobster recruitments are good as seen in Western Australia, scientists are concerned that there is a high risk of recruitment over fishing.

The relationships between stock and recruitment and estimations of natural mortality have proved to be one of the most difficult things to quantify. Therefore, the most difficult thing to achieve is to win over support, particularly from fishermen, about the benefits of protecting breeding stocks.

Growth overfishing

Growth overfishing occurs when the effort is so high that the total yield decreases with increasing effort. The lobsters are caught before they can grow to a sufficiently large size to substantially contribute to

participants) but the efforts have resulted in a much-improved industry compared to previous years when management was poor. However its practicality in India should be checked.

The immediate need in India is to establish a reliable statistical database on landings and fishing effort, to start focusing on high quality scientific studies of lobster population dynamics and their biology; establish a suitable and effective management plan based on the outcome of the research and finally to implement the plan with strict surveillance and enforcement.

Environmental consequences

The objectives here are:

1. To minimize the environmental impact of spiny lobster fishing and
2. To minimize potential conflicts with other users of marine resources

The strategies involved here are promoting environmentally sensitive fishing practices in the industry and promote actions that reduce fishery impacts and identifying the potential for conflicts with other marine resource users and determine strategies to reduce these conflicts.

Other aspects to be pondered

The managers should also be familiar with the following aspects such as:

- **Recruitment overfishing**
- **Growth overfishing**
- **Fishing mortality rate and**
- **Exploitation rate**

motivate the financial sector to offer fishermen more favorable terms on credit, especially when combined with improved prospects for stock rebuilding. These provisions make good sense, particularly when adequate stocks are rebuilt and a percentage of fishermen are willing to retire due to age, health reasons or personal circumstances.

Social Consequences:

The main objectives here are

1. To maintain and provide for reasonable levels of public access to the spiny lobster resource.
2. To ensure a high level of awareness of occupational health, safety and welfare issues in the fishery.
3. To keep the community informed regarding the status of the rock lobster fishery and
4. To maintain the development nature of the spiny lobster fishery.

Studying marine resource-dependant communities is essential when dealing with fishery management plans. The coastal fishermen communities are marine resource-dependant communities in our country. In regions where the lobsters resources are more such as in northwest, southwest and southeast coasts of India, in view of good prices, the communities are very much dependent upon these resources.

A plan that allows lateral mobility into and out of the lobster fishery is likely to offer the most benign social consequences both in short term and long term (in case entry to fishing will be restricted in future to rebuild the stocks). To the extent that new entrants from other fisheries are not perceived to damage the well-being of currently active fishermen, the linkages and relationships between lobster producers

and producers in other fisheries will be strengthened. Only then would a stronger sense of community emerge.

There would be little or no disruption to employment, demographics, family stability, social stress and social networks in the communities, at least in the short term. However, if open access leads to further stock depletion, this will lead to economic hardship in the lobster industry and the social health of these communities could suffer in the long run.

Hence, it is essential that any fishery management plan first attempts to conserve the stocks for a certain period, ensuring that adequate stocks are rebuilt and only then permit for increased access granted in a gradual step by step manner. Once, implemented, this access plan is likely to be perceived as fair among many fishermen and other community members. No privileged class of lobster fishermen is created by the plan and there are no “haves” and “have-nots” created. All who want to enter the fishery may do so, and they compete on a level playing field with others in the fishery. If the open access is perceived a threat for the sustainability of resources or if the fishermen do not support the measure as the value of their license (when it is introduced in India) will be reduced, then the quota system should be continued and rights to transfer of licenses should also be permitted in order to ensure social harmony.

Administrative Consequences:

Administrative consequences include changes in the amount of enforcement resources and associated costs; compliance and enforcement problems; industry acceptance and cooperation or resistance; information demands; costs of monitoring resources and research requirements; and data degradation including misreporting of

landings and fishing activities. Administrative consequences also include the extent to which lobster fishermen encourage their representatives to become involved in the implementation of management measures. Such influences are well known for their ability to thwart the ability of fishery management authorities to effectively manage the fisheries for which they are responsible.

The administration, during the initial stages of the management plan faces rising costs on one side and resistance from the other. Apart from costs incurred on research, data collection and establishing conservation measures, the authorities need funds to communicate the importance of such measures to the fishermen and educate them as to why such measures are required. It is very important that any fishery management plan requires support from its main stakeholders that is the fishermen. Without their active participation and their wholehearted support, any management plan is likely to fail.

It is a fact that effective administration and enforcement means a substantial cost to the administrative authority. But it should be perceived, as a social investment in the interest of the nation and the government should not have reservations over such an approach. In the long term, a well managed industry should become self-financing through increased production and tax revenues which can support management costs.

Some of the best examples are the various Australian Spiny Lobster Industry Management Plans (Victorian, Tasmanian, South Australia etc), Cuban and the Rhode Island Lobster Management Plan (USA). The respective administrations initially spent substantial sums on research and data collection before arriving at a comprehensive management plan. They continue to incur costs on research, surveillance and enforcement (although these costs are recovered from the industry