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Fishery Biology In Conservation- How Successful are we?

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HISTORY OF MARINE CONSERVATION

Coastal human communities have been exploiting the sea as a source of food from time immemorial. Ancient communities have long had codes of conduct, largely undocumented, for judicial use of these bioresources. Some such practices are evident from the understanding of traditions of ancient hunter gatherer communities which have persisted up to modern times. The stone age Onge tribe of the Andamans practice discretion while hunting dugong and sea turtle and never harvest in excess. Examples of fishery conservation are several in Indian history. The edicts of Emporer Ashoka lays out rules for fishing. The fifth inscription of Delhi Shivliks bans activities of fishing and fish selling from Ashadh full moon to Paush full moon, on the days of Pusyankshtr in Paush, full moon, a day before full moon, no moon and both Pratipadas. Fishing permits find mention in Arthashastra of Kutilya as a means to conserve fishery resources.

In the Western world, early commercial fishing was unregulated and fishery resources considered as "commons" and open to exploitation by all. The first fishery conservation law dates back to 1816 when the Lofoten Fishery law was enacted in Norway allocating fishing fields to fishers in the famed cod fishery of the region. In 1936 the first Overfishing Conference was held in London to address issues plaguing North European fisheries. Unprecedented reduction in the population of whales prompted the International Convention for Regulation in Whaling to be held in 1946 after which the International Whaling Commission was set up. An integral part of the Convention is a legally binding Schedule which lays out specific measures that the IWC has collectively decided are necessary in order to regulate whaling and conserve whale stocks. In 1957 Ray Beverton and Sidney Holt, considered the fathers of fishery sciences, came up with their model to predict and manage fisheries, which went on to become the seminal work on which fisheries management the world over was based. The field of fish population dynamics saw rapid evolvement since then. From the 1960s to 1980s fisheries models evolved in a deterministic setting, with advances in age-structured models (Gulland, Pope, Doubleday), surplus production models (Pella, Tomlin-son, Schnute, Fletcher, Hilborn), growth models, bioeconomic models (C. Clark) and management control models (Hilborn, Walters) . A major advance in the 1990s was the development of Bayesian and time series methods. Currently, theory allows realistic modeling of age- and size-structured populations, migratory populations and harvesting strategies. These models routinely incorporate measurement error, process error (stochasticity) and time variation (Quinn, 2003).

In 1982 the United Nations Convention on the Laws of the Seas (UNCLOS) was adopted and the world saw the establishment of Exclusive Economic Zones (EEZs) and territorial waters whereby nations could stake claims to fisheries in their regions for an extent of 200 nautical miles. Signatory nations drafted and augmented legislation to safeguard their fishery resources. In 1995, the FAO

published the Code of Conduct for Responsible Fisheries (UNCCRF) for member countries of the United Nations to further augment their legislation on. "After two decades since its adoption, the Code continues to be a reference framework for national and international efforts, including in the formulation of policies and other legal and institutional frameworks and instruments, to ensure sustainable fishing and production of aquatic living resources in harmony with the environment" (FAO, 2018). In 1996 the Marine Stewardship Council (MSC), an independent non-profit organisation, was founded to set standards in sustainable fisheries. Marine products from fisheries assessed and certified by MSC as sustainable are entitled to bear their certification trademark, which gives them an edge in competitive customer preference. In 2004 the United Nations General Assembly issued a Resolution on Fisheries that prepared for further development of international fisheries management law which seeks to regulate new fisheries on the high seas which do not fall under the jurisdiction of individual nations. In 2005, the UBC Fisheries Centre at the University of British Columbia reviewed the performance of the worlds' major fishing nations against the mandate of the UNCCRF. The Aquaculture Stewardship Council was set up in 2010 on similar lines as MSC to cater to sustainable aquaculture enterprises the world over.

APPROACHES FOR CONSERVATION

The recent approaches for conservation are based on taxa or ecological structures and/or processes or a combination of both. Conservation measures based on **taxa** focus on a single species or a group of similar species. Eg: The conservation of swordfishes or sharks or whales or sea turtles. Most fisheries management practices fall under this category. Measures based on **ecological structures or processes** are concerned with the conservation of these within a well defined geographical limit. Eg: Conservation through Marine Protected Areas or No Take Zones. Some measures are a combination of both categories Eg: Coastal Zone Management or ECOPATH modelling.

Most conservation efforts are based on scientific management tools which in turn rely on sound biological data and derivations from the same for framing the management recommendations.

Fishery management related inputs

Perpetuation of the resource through judicious exploitation is the aim of all conservation efforts through fisheries management strategies. The inputs required to successfully formulate management constructs for any given fishery bioresource falls under the category of fishery inputs and biological inputs.

Fishery inputs used are as follows:

- Gear-wise annual catch and effort
- Gear-wise age structure of target species
- Fishing grounds and season
- Value of catch at different stages of marketing
- Census of fishers, vessels and gears

Biological inputs used are as follows:

- Age structure of stock (through analysis of length frequency distributions, tagging experiments, counting rings on hard parts such as otoliths, scales, vertebrae or fin rays)
- Age and maturity criteria (SSD, MSM, SCM, L_m)
- Length weight relationship
- Growth rate (VBGF, L_c, L_∞)
- Maturity stages and Fecundity
- Sex ratio
- Natural mortality (M)
- Fishing mortality (F)
- Spawning behaviour and grounds
- Nursery grounds
- Foraging grounds
- Migratory habits
- Food and feeding habits

(Annala & Eayrs, 2010; Roff and Zacharias, 2011)

Some approaches employed for stock assessment

Stock assessment of fisheries is done for the purpose of fisheries management using the above inputs and a few basic constructs which have been explained below:

Catch per Unit Effort: It is the simplest approach used for resource stock assessment. It is based on the measurement of landings of a stock and the fishing effort expended to land that stock. At the beginning of a fishery, the CPUE will be high which will lower as the fishery progresses. In a well managed fishery, the CPUEs decline is arrested and stabilizes at the sustainable level as the fishery matures. In poorly managed fisheries the CPUE continues to decline until the fishery finally collapses. Computations of maximum sustainable yield using Surplus Production Models and models such as Schaefer Fox model are based on CPUE. Errors and inaccuracies using these models often occurs due to the inherent problems of using CPUE. Primarily, all errors in recording or assessing catch data reflects in the CPUE. It also does not account for technological advances or changes in fishing methods which renders comparisons over time periods erroneous. A practical difficultly in fishery management is that often by the time meaningful usage of CPUE is used for assessing a fishery, it is already in decline.

Maximum Sustainable Yield (MSY) is theoretically the maximum catch that can be harvested from a species stock which will not result in long term depletion of the resource. It is based on the assumption that the fished species produces surplus numbers in each spawning than required for

maintaining the population size and that this surplus stock can be exploited at a maximum level without damaging the stock. When a population is small, the number of recruits to a fishery is limited and hence the yield small. However for an intermediate sized population, the number of reproducing individuals are large which produces surplus recruits which in turn can be harvested. At half the carrying capacity of the population, reproductive rate is at maximum. In modern fisheries the MSY averages about 30% of the unexploited population size for most fish species. The concept of MSY was the main method relied upon by fishery managers ranging from international bodies such as IWC and ICNAF to individual countries from the 1950s to 1970s after which the deficiencies of using this simple concept as a mainstay became apparent in the form of collapsed fisheries. Inspite of its deficiencies MSY was drafted into the United Nations Laws of the Seas (UNCLOS) in 1982 making it a management goal for most countries which incorporated it into national and international legal instruments. The MSY concept is now refined and combined with Virtual Population Analysis by most fishery managers who use the FAO recommended **FAO-ICLARM Stock Assessment Tool (FISAT)** for fish stock assessment. Fishery biology parameters such as L_∞, K, t_0, M, F, Z are all part of this routine and form the basis on which the prediction models such as Thompson and Bell model are used. Correct and accurate estimation of these parameters is vital to computations through population dynamics models. The MSY is not a fixed figure for a given population and must be reassessed periodically as recruitment patterns are subject to variation influenced by factors such as environmental fluctuations and fishing effort.

Another practice employed in stock assessment is to calculate the **Spawning Potential Ratio (SPR)** which compares the spawning ability of a fished population to that of an unfished population. The spawning ability is then compared with mortality to estimate the stock. To assess the spawning ability, the number of eggs produced per recruit in the population until caught is divided by the number of eggs produced by the recruit over its entire lifetime if not caught. This SPR when calculated using biomass or weight of adult stock or biomass of mature females or biomass of eggs produced is called **Spawning Stock Biomass (SSB).** When SSB is calculated per recruit the it is called **Spawning Stock Biomass Per Recruit (SSBR).** SPR also employs age determination of the recruit through length-weight constructs or through measurement of otoliths.

Ecosystem Based Fisheries Management (EBFM)

The difficulties and deficiencies caused by basing fisheries management on single species or groups brought a paradigm shift in approach to EBFM during the 1990s. A more holistic approach which included ecological relationships between the species, their physical environment and human influence was applied to fisheries management. Fishery biology, prey predator relationships, environmental stressors, oceanic parameters, prevalent diseases, all these were accounted for in the EBFM models.

Ecopath

The main software in use for EBFM is called Ecopath which was developed by Jeffrey Polovina of NOAA and further modified by Carl Walters and Villy Christensen at the UBC Fisheries Centre of the University of British Columbia to include Ecosim and Ecospace.

"**Ecopath with Ecosim** (EwE) is a free ecological/ecosystem modeling software suite. EwE has three main components: *Ecopath* – a static, mass-balanced snapshot of the system; *Ecosim* – a time dynamic simulation module for policy exploration; and *Ecospace* – a spatial and temporal dynamic module primarily designed for exploring impact and placement of protected areas. The Ecopath software package can be used to evaluate ecosystem effects of fishing; explore management policy options;analyze impact and placement of marine protected areas, predict movement and accumulation of contaminants and tracers (Ecotracer). model effect of environmental changes and facilitate end-to-end model construction.... The latest release of Ecopath with Ecosim is version 6.5, released in July 2016." (Ecopath.org, 2018)

An Ecopath model describes the trophic interactions, synthesizing ecological and fisheries data of an ecosystem at a given time. These models account for the biomass of each functional group of species, their diet composition, production per unit of biomass (P/B, per year), consumption per unit of biomass (Q/B, per year), mortality rate from natural causes (M) and fishing (F), accumulation of biomass and net migration rate (all rates being annual). The principle behind this ecosystem modelling approach is that, on a yearly basis, biomass and energy in an ecosystem are conserved.

Ecopath models rely on the truism that:

Production = biomass accumulation + fisheries catch + mortality due to predation + other mortality + loss to adjacent systems.

Groups are linked through predators consuming prey, where:

Consumption = production + non-assimilated food + respiration (Lopez,2016)

FISHERY MANAGEMENT STRATEGIES

These are broadly categorised into the restrictions that are based on inputs that go into the fishing operations ie input controls and restrictions on the outcome of the fishing operations ie output controls.

Input Controls:

- Restriction on fishing types Eg: Dynamite fishing
- Restriction on gear types: Eg: Limits on fish traps, number of poles or lines per fisherman
- Prescribing minimum mesh sizes and promoting certain designs such as diamond shaped cod end meshes.
- Limiting the average potential catch of a vessel in the fleet by imposing restrictions on the vessel or crew size, number of units of gear deployed, electronic gear and other physical "inputs"
- Prohibiting bait. Eg: Ban on light fishing
- Restricting the number of simultaneous fishing vessels Eg: Ban on pair or bull trawling
- Limiting a vessel's average operational intensity per unit time at sea, limiting average time at sea

- Restricting area or season of fishing Eg: Marine Protected Areas and trawling ban seasons.

All fishery management methods currently employed in India are based on input controls.

Output controls

These catch limit methods have been employed in other countries and are especially useful where there are stocks in decline.

- **Total Allowable Catch (TAC):** Limit set on the total weight or numbers of bioresorces harvested in a given period of time. Eg: Pacific halibut fishery
- **Individual Fishing Quota (IFQ):** A certain portion of the TAC is allocated to individual vessels or fishers based on initial qualifying criteria. Eg: Alaska halibut, sablefish, wreckfish fisheries in USA.
- **Individual Vessel Quota (IVQ):** TAC is divided amongst all vessels registered in a fishery and not amongst individuals. Eg: Canadian and Norwegian fisheries.

(Roff and Zacharias, 2011)

CONSERVATION MEASURES PRACTISED IN INDIA

Legal instruments for conservation of marine fishery resources

The maritime states of India have so far enacted 23 legislations to conserve fishery resources in India. The oldest piece of legislation is the Indian Fisheries Act, 1897 and the latest is the Lakshadweep Marine Fishing Regulation Rules, 2004.

Major provisions covered by these **Marine Fisheries Regulation Acts** and other notifications and ordinances are:

- Mandatory registration of motorised and mechanised crafts
- Demarcation of areas for fishing for different types of crafts
- Prescription of mesh size for various gears
- Proclamation of closed seasons
- Ban on certain types of fishing
- Ban on bait fishing
- Restriction of fishing time
- Restriction of landing of catch to certain ports
- Inclusion of turtle excluder devices in certain regions

Other major laws concerning fisheries, marine organisms and habitats are **The Wildlife (Protection) Act, 1972 (IWPA)** and its seven amendments and the **Coastal Zone Regulation notification (1991, 1994, 1996)** under **The Environment (Protection) Act, 1986**. Under the various Schedules of the IWPA, 03 endangered species of marine mammals, 06 reptiles, 10 fishes, 24

molluscs, all sea cucumbers, corals and sponges are accorded protection from hunting, trade and exploitation as trophies. Specific areas are demarcated as wildlife protected areas and all species within such areas are also given protection under this Act. Coastal areas upto 500 m from the High Tide Line are protected under the CRZ notification by classifying them into four zones with various constructional and usage restrictions being imposed on each.

Protection is also accorded to marine organisms through international treaties such as the **Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)** under which more than 5000 species of animals and 29000 species of plants are listed under three Appendices as per the level of threat to their existence and the degree of control on their trade. India, since 1976, is one of the 183 parties who are signatories of this treaty. 11 species of Indian elasmobranchs are listed under Appendix I and II of CITES. The **Convention on Migratory Species (CMS)** aims to protect species such as whales which perform transboundary migrations and require the cooperation of different countries whose territorial waters they occupy or pass through from time to time.

Monsoon Trawling Ban

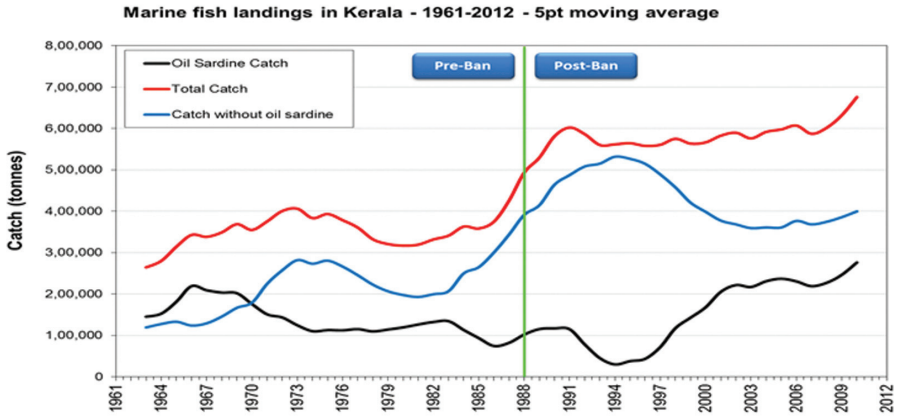
All maritime states of India have effected a period of conservation of marine bioresources through a seasonal fishing ban which ranges from 45 to 61 days. The ban aims at alleviating fishing pressure from spawners and fingerlings and thus avoid growth and recruitment overfishing, allowing an opportunity for replenishment of stocks. The monsoon is chosen as the timing for the ban as several fish and crustacean species record peak spawning periods during this season. Following are the dates from which the ban is currently followed in the various states:

- Gujarat: Since past two decades no fishing from 10 June to 15 August.
- Maharashtra: 1 June to Nariyal Poornima (2nd week of August)
- Goa: 4 June to 25 July
- Karnataka: 1 June to 31 July
- Kerala : 15 June to 31 July
- East coast maritime states : Since 1999, 46 days closure from 16 April to 31 May
- Andaman & Nicobar Islands: 15 April to 31 May for bottom trawlers & shark fishing vessels; 1 May to 30 September for sea shell fishing

These dates are generally adhered to though small changes may be made in any given state year to year.

A fact sheet published by the Ministry of Environment, Forests and Climate Change and Deutsche Gesellschaft für Internationale Zusammenarbeit (2016) states that about 10.36 million fishing hours are reduced due to Seasonal Fishing Ban (SFB), equivalent to 408,000 tonnes of CO2 emitted with a savings of 156.58 million litres of diesel. In 2014, an amount of Rs 8.3 billion (US$ 137m) was saved on diesel during fishing ban. The Factsheet stated that the estimated economic value (based on landing price) of the incremental growth of fish attained due to a fishing ban of 45-60 days was a

total of 1.07 billion (US$ 18m) in the five states. The transaction cost, which includes information to fishermen and enforcement of the ban amounts to Rs 45.78 million (US$ 0.76m) in the five states. Estimated net social benefit due to SFB in five states was Rs 1.09 million (US $18,167). However, The Committee To Evaluate Fish Wealth/ Impact Of Trawl Ban Along Kerala Coast in its concluding remarks stated that as per the analysis of the effects of the trawling ban in Kerala, "The economic analysis indicates that in value terms the benefit of the trawl ban was present only up to the year 2000, after which there has been a decline in real value of the fisheries and ultimately incomes to fishermen in spite of increase in nominal value. The growth rate analysis also clearly indicates that growth rate in the mechanized sector is negative after the year 2000, and the benefit of the trawl ban was not sustained after 2000."



(Mohamed et al., 2014)

Both the MoEFCC & GIZ and the above Committee recommend the extension of the trawling ban period for better and more effective results. In addition to the trawling ban, CMFRI and MoEFCC & GIZ also recommend other management measures, such as an minimum legal size, ecosystem-based approach, marine protected areas including no-take zones, regulated entry, catch quotas and certification.

Minimum Legal Size:

The menace of juvenile fishery has led to the fast depletion of marine bioresources along the Indian coasts. Fishes that have not yet had the opportunity to spawn are termed as juveniles. These are mainly fished in the seasons following spawning by using small mesh sized nets. Majority of the juvenile fish catch sent to fish meal plants. Though fetching immediate gains it is a great economic loss for fishers as small sized fishes fetch low price as compared to what price it would have fetched had the fishes been allowed to grow to larger sizes. It is also ecologically damaging as stocks do not get replenished leading to growth overfishing. It leads to decline and collapse of stocks especially vulnerable low growth rate, low fecundity or restricted distribution species. Juveniles also form the

bulk of low value byecatch (LVB) especially that of trawlers. 25 species of finfihes, 16 species of crustaceans and 15 of molluscs recorded as LVB in India, several of which are juveniles of commercially valuable species. In addition, low value byecatch species are prey items of larger commercially valuable fishes. (Ganga *et al*., 2014)

Imposition of a **Minimum Legal Size** (MLS) of fish species landed through mesh size selectivity is a management tool being used to combat the menace of juvenile fishery of commercially important fish species. MLS has been computed and imposed for 40 commercial finfish, 13 crustacean and 05 molluscan species in Kerala through an ordinance. The Government of Kerala implemented MLS initially for 14 fishes on 24.07.2015 notified vide GO (P) no.40/15/ F &PD and recently on 17.05.2017 another 44 species were added and updated vide GO(P) No.11/2017 F&PD. For detection of violations random species-wise subsample of the catch (about 25-50 numbers) are measured and considered as a violation if more than 50% of the catch sample is composed of fishes at or below the prescribed MLS. In this manner some mitigation is envisaged for curbing the growth overfishing which entails uncontrolled exploitation of juvenile fishes for fish meal plants resulting in resource depletion and economic loss. Imposition of MLS ensures that juveniles survive to grow and spawn, controls the numbers and sizes of fish landed, maximizes marketing and economic benefits and promotes the aesthetic value of fishes. Fishery biologists determine the maturity stages of the fishes through long term observation of catches for arriving at the MLS. Various criteria employed for computing the MLS of fishes are:

CRITERIA	LOGIC	EXAMPLES
Size at sexual differentiation into male and female (SSD)	Used to prevent juvenile exploitation and female growth overfishing in those stocks which are very abundant, have high reproductive potential and whose biomasses are not affected by high fishing pressure.	*Sardinella longiceps Trichiurus lepturus Megalapsis cordyla*
Minimum size at maturity or size of smallest mature fish (MSM)	Used to prevent growth overfishing in stocks which are moderately resilient to fishing pressure	*Scomberomorus commerson Nemipterus randalli Saurida tumbil Coryphaena hippurus*
Size at first maturity or size at which 50% of the fishes are mature (SFM)	Used to prevent growth overfishing completely and recruitment overfishing partially. Can be used in situations where the stock is depleted or rebuilding.	*Scomberomorus guttatus Rachycentron canadum*
Size at complete maturity or size at which 100% of the fish are mature (SCM)	Can be used to prevent recruitment overfishing by capping maximum legal size of capture. Seasonally applicable to fishes which grow to large size and exhibit slow growth rates. (Sunil Mohamed et al., 2014)	Sharks, rays and skates
Weight at First Maturity (WFM)	Used exclusively for lobsters. Notified by MPEDA	Lobsters

Fishing of juveniles can be avoided through strictly following the net and mesh size regulations prescribed by the Trawl Ban Committee Report (2014). The success of MLS as a management measure encourages similar provisions to be adopted by other maritime states in India. A recent preliminary

study of the impact of MLS found that income of fishers has come down temporarily by 3 % in the mechanised sector and 2.1% in the motorised sector but increased by 0.4% in the non-motorised sector due to MLS adoption. Violation of rules by fishers belonging to other states where there is no legislation on catch landed is a major constraint experienced by fishers adopting MLS (Meharoof, 2018).

Marine Protected Areas

Designating coastal and marine areas of high diversity as protected areas and placing them under special laws is a management strategy which has been employed with foresight and expectations as has been done for their counterparts in the terrestrial realm in India. MPAs are classified into three major types based on the degree of protection and management practices in play. **Multiuse MPAs** are those where sustainable use of the resources of the MPA by humans is permitted. In **No-take MPAs** no kinds of human usage of the resources is permitted. **Marine Biosphere Reserves** are a combination of both with fully protected core areas, an intermediate buffer area and outer transition zone where activities such as sustainable fisheries is permitted. Other areas where conservation is mooted but not declared as national parks or sanctuaries by law are **Ecologically and Biologically Sensitive Areas (EBSAs)** and **Community Reserves.**

In India 6.79% of the total coastline under MPAs. 25 MPAs are located in mainland India covering an extant of 8214 sq.km which is 4.92% of the total Protected Areas. Maximum number (105) of MPAs are located in in the Andaman & Nicobar islands and one in Lakshadweep (Sivakumar, 2013). The areas were chosen based on the richness in biodiversity, existence of fragile habitats or areas important to the stages in the lifecycle of flagship marine species. Major MPAs in India area Gulf of Kachch Marine National Park, Gulf of Mannar Marine Biospehere Reserve, Sunderbans National Park, Bhitarkanika Wildlife Sanctuary and Coringa Wildlife Sanctuary. 25 wetlands have been designated as Ramsar wetlands by GOI.

17,795 species of marine organisms are conserved in these MPAs which amounts to a biodiversity of about 6.75% of the worlds known marine species (Sivakumar et al., 2013). While the primary aim of the MPAs is to provide sanctuary to marine organisms and preserve fragile ecosystems such as mangroves and coral reefs, parts of these are also of tourism value.

Though at present conservation methods are based on input controls in India where fisheries management is a complex effort owing to the multispecies multi-gear nature of its fisheries, the future will bring in more focus to include output controls as well as ecosystem based fisheries management. The input control measures introduced so far have limitations as enforcement remains a major consideration and desired outcomes fall short of targets due to noncompliance by some, rather than failure of the method adopted. Synchronicity in the application of the management measures for example the timing of the monsoon fishing ban along the west coast or the adoption of MLS by all maritime states will be essential for their success in totality. Overcapacity of the fleet and unsustainable practices resulting in declining trends in conventional commercial resources will ultimately result in situations where stringent management measures will have to be adopted. The current effort of managers is to avoid such situations by maintaining the fisheries at its peak in a sustainable manner.

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