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Dr. A. Gopalakrishnan
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Aerial view of the seaweed farm at Thondi, Tamil Nadu.

(Photo Credit: Johnson, B. )

**Marine Fisheries Information Service** Technical and Extension Series envisages dissemination of information on marine fishery resources based on research results to the planners, industry and fish farmers, and transfer of technology from laboratory to the field.

Lead Paper

# Seasonal Fishing Ban: Need for collecting and applying right type of scientific information

**E. Vivekanandan**
Principal Scientist (Retd.), ICAR-Central Marine Fisheries Research Institute, Kochi-682 018, Kerala
E-mail: evivekanandan@hotmail.com

## Introduction

Increasing fishing intensity and consequent decline in fish stocks has led to considerable investment to manage the fisheries and arrest the declining trend. Globally, several input and output control measures are adopted for management of fisheries and it has been reported that better assessed and managed fisheries are recovering. With improved management practices, the stock biomass relative to MSY target has increased up to 2.0 off Alaska, US west coast, EU Atlantic, Australia and New Zealand (Hilborn, 2019). This is an encouraging trend that gives hope to the fisheries fraternity that all will be well if proper approaches are adopted and implemented. The fisheries that are winning the battle against overfishing have adopted output control measures such as catch quotas and total allowable catch, supplemented by input control measures such as closure of fishing season and area, restriction on number of boats, etc. In India, mainly input control measures are followed for management of marine fisheries. Among the several input control measures in the Marine Fishing Regulation Act, seasonal fishing ban (SFB) is being followed diligently in all the maritime States and Union Territories (UTs). While Kerala started implementing SFB in 1988 other States and UTs followed to implement it in different years from 1989 to 2001. Thus, the SFB is being followed every year across the maritime states of India for the last 18 to 30 years. All mechanised boats (with a fixed engine and a wheelhouse) are covered by the SFB. Motorised boats (with outboard motor and open deck), are covered by the SFB based on the engine horsepower of the fishing vessels. In certain States, boats operating with horsepower 10 and above and in others, those above 25 hp only, are covered by the SFB. When SFB was introduced it was observed for 45 to 47 days, during the southwest monsoon period of June to August by the States and Union Territories (UTs) on the west coast and during April and May on the east coast. In 2015, based on the recommendations of an appointed Technical Committee, the Union Ministry of Agriculture (MoA), raised the fishing ban period to 61 days along both the west and east coasts. Since then, the SFB is followed for 61 days during southwest monsoon months from June 1 to July 31 along the west coast (including Lakshadweep Islands) and during summer months from April 15 to June 14 along the east coast (including Andaman & Nicobar Islands).

For fixing the timing and duration and achieving the objectives of SFB, we require right type of accurate scientific information. For example, if protecting the spawners is the prime objective of SFB, information on the spawning seasonality of important species are required as input and data on the improvement in spawning stock biomass (SSB) as the result of the SFB is needed. These data should be collected accurately by adopting rigorous and time-tested methods. Achieving the objectives of SFB is a good example of a strong science-policy nexus. If the scientists supply quality information by following suitable, reliable methodologies the SFB will deliver the intended outcomes.

## Objectives of SFB

SFB has the potential to address a bouquet of intended and incidental objectives (Table 1). It may not be possible to achieve all the objectives simultaneously, but the result could be a bunch of 2 or 3 outcomes. Based on the intended objectives, the specific management measures will differ. Hence, we should be clear about the key issues, intended objectives and expected outcomes for enforcing SFB. It may be noted that the outcomes are often a combination of management measures other than SFB, such as mesh size regulation, Minimum Legal Size, etc.

Table 1. Potential objectives of a seasonal fishing ban

| # | Objectives | Specific measures required | Other measures required | Indicator | Expected outcome |
|---|---|---|---|---|---|
| 1 | Protecting fish spawners | Ban fishing during peak spawning period | Ban fishing in intense spawning areas | Increase in fish recruitment | Enhanced fish regeneration; increase in spawning stock biomass |
| 2 | Reducing annual fishing effort/capacity | Ban fishing for adequate number of days | Overseeing (i) fishing effort not spilling over to non-ban period; (ii) fishing capacity does not increase | Reduction in annual fishing effort/capacity | Reduced fishing mortality; Increased stock size |
| 3 | Giving respite to seafloor from bottom trawling | Seasonal ban on bottom-contact gears | Restrict use of bottom contact gear in all months | Recovery of bottom flora and fauna | Ecosystem function maintained |
| 4 | Reducing low-value bycatch | Seasonal ban on gear generating low-value bycatch | Prescribe Minimum Legal Size and mesh size regulation | Reduction in the amount of annual bycatch | Reduced growth overfishing |
| 5 | Protecting the endangered, threatened species | Seasonal ban on fishing during abundance of the identified species | Restrict fishing in 'hotspot' areas; promote use of Bycatch Reduction Devices | Reduction in the bycatch of endangered, threatened species | Ecosystem structure and function restored |
| 6 | Reducing carbon footprint | Seasonal ban on boat types with high carbon emission | Introduce fishing technologies to reduce carbon emission | Reduction in (i) carbon emission; (ii) expenditure on fuel | Green fishing systems put in place |
| 7 | Reducing fishermen fatality at sea | Ban fishing during seasons of unfavourable weather conditions | Cyclone forewarning, better communication, use of sea safety appliances | Reduction in human fatalities and boat damage | Risk reduction measures in place. |

While protecting spawners (fish, crustaceans and molluscs) has been projected as the major objective of SFB in the marine fisheries in India, another important objective is reducing the annual fishing effort. To address these two prime objectives, we need right type of high quality and validated data. The data required to meet these two objectives are (i) accurate spawning seasonality/months of major species; and (ii) monthly/annual fishing effort and capacity of major craft/gear types. For evaluating the performance of SFB against the stated objectives, we need validated data on (i) Spawning Stock Biomass (SSB); (ii) fishing mortality; and if possible, (iii) yield-per-recruit. In the absence of the above-mentioned science-based evidences, the underlying assumptions and the resultant conclusions on SFB can be seriously wrong. For example, visual observation of gonadal condition without validation, would lead to serious misunderstanding on the spawning seasonality of fishes. Similarly, measuring fishing effort alone, without considering fishing capacity, will not provide the required information for control of fishing activity.

The present review is an attempt to examine the data that are available to address and evaluate the output for the two key objectives, i.e., protecting fish spawners and reducing fishing effort/capacity indicated in Table 1. For this, answers to the following questions were attempted:

I. What are the conclusions of the previous studies/reports on the effectiveness of SFB in marine fisheries in India as well as elsewhere?
II. Are right type of data available to meet the objectives as well as assess the performance of SFB in India?
III. If not, what could be the right approach?

To find answers to Question 1, the available publications/reports on the subject were reviewed. For Questions 2 and 3, the conventional and time-tested methods of (i) analysing the spawning characteristics of fishes such as maturity stages, fecundity, spawning frequency, SSB, etc; and (ii) estimating the fishing effort/capacity were reviewed. This exercise re-visits the conventional methodologies that may be adopted for collection of reliable scientific data.

## Review of studies/reports in India

The purpose of SFB is to ensure that a large number of fish will breed and spawn, enhancing the recruitment of young ones into the fishery. Hence protection of fish occurs during the times and at places where the fish are reproductively active, *i.e*. when they are most vulnerable. The SFB could be easily enforced as it is often accepted by fishers because of its simplicity. However, in the last three decades, the SFB has drawn mixed reaction from different sections of stakeholders on its timing and duration as well as its effectiveness. In addition, (i) the fishermen complain about loss of livelihood and demand higher compensation; (ii) mechanised boat owners demand all the motorised boats to be brought under the ban; (iii) motorised boat owners want total exemption from the ban. Thus, in a situation of many types of fisheries and target species, the difficulties of the various stakeholders to adjust to the SFB are evident. Consequently, the Department of Animal Husbandry, Dairying & Fisheries periodically constituted technical committees to take an informed position on the SFB. In 2014, the technical committee to review the duration of fishing ban reported the following important observations (DAHDF, 2014):

I. SFB has been found to be an ideal tool from implementation angle as well as wider acceptability in India.
II. Biological studies have indicated that there is an improvement in the recruitment of some demersal species into the fishery immediately after the ban, which lasts for a short duration of one to two months. While no significant difference in catch and catch per unit effort (CPUE) trends was observed before and after introduction of fishing ban for different fish species/groups along the west coast, there was marginal improvement in the same for different fish species/groups along the east coast.
III. Increase in catches along the Indian coast in the last two decades is essentially due to increase in efficiency of craft and gear and spatial extension of fishing to offshore regions (and not due to SFB).
IV. Almost all tropical species have a prolonged spawning season lasting for 6 to 7 months, with one or two peak spawning in a year. As these spawning peaks occur during different months for a variety of species, a common time period covering spawning period of most species could not be identified. Studies showed no indication that fishing ban alone has helped recovery of stocks. Seasonal closure of mechanised fishing has certainly helped to keep in check the increasing annual fishing effort apart from giving respite to different habitats. Perhaps, a combination of several other regulatory measures would be needed for achieving replenishment of fish stocks.
V. Consultations with stakeholders revealed diverse views of fishers on different issues but a near consensus prevailed on the need for a SFB. In general, while there were concerns about the adverse impact of loss of jobs and livelihoods, majority opinion converged on the benefits of ban.

Twenty five years after inception of SFB along the Kerala coast, detailed analysis showed that the positive impact on fishery yields continued for 9 years and the yield declined thereafter, indicating that the positive impact on fishery yields was not sustainable. The economic analysis also indicated that in value terms the benefit of SFB was prevalent for 12 years, after which there was a decline in the value of the fisheries in Kerala (Mohamed *et al.*, 2014). In a study on economic valuation of net social benefit of SFB in five maritime states in India, Narayanakumar *et al.* (2017) reported that the value of enhanced annual catch estimated at ex-dock centre price ranged from ₹13 crores in Andhra Pradesh to ₹ 28 crores in Tamil Nadu and indicated that continuation of SFB will be beneficial.Using semi-structured interviews with randomly selected participants before, during and after SFB in Tamil Nadu and Puducherry, Colwell *et al.* (2019) reported unintended consequences of fisheries regulations. Some fishers shifted their fishing effort to unrestricted fishing when the fishery opened after the ban and though this post-ban race for fish was exemplified by all gear types, an illegal, unregulated gear type, locally termed *surukku valai* (ringseine) exhibited the largest increase in effort. According to the authors, lack of fishing-related employment options during the ban period led to high levels of unemployment and food security concerns. Thus the previous studies have reported conflicting results on the performance of SFB. The recent annual reports of Central Marine Fisheries Research Institute that show that the stocks of many fish species are declining over the years due to overfishing which need to be taken into consideration while evaluating the effectiveness of SFB.

## Lessons from international experience

The performance of SFB has been documented for a number of fisheries in different countries. In general, the SFB is adopted for specific fisheries such as shrimp fishery or lobster fishery in designated locations and it is intended to meet specific management goal(s) for each fishery. Similar to India, the conclusions on the performance of SFB are mixed. While seasonal closures have been evaluated by managers as useful and beneficial management strategies for some fisheries have emerged, there are also some reservations (Table 2), particularly when SFB is used as the sole management strategy for a particular fishery. It also has been suggested that seasonal

Table 2. Effectiveness of SFB in different countries

| Fishery | Result |
|---|---|
| Gulf of Mexico shrimp fishery | Increase in overall yield and values in the first year, but no benefits in the second year |
| Florida lobster fishery | Beneficial to the fishery |
| Taiwan and East China Sea fisheries | Right spawning season should be identified for effectiveness |
| Southern coast of England | Increased abundance and biomass of benthic fauna |
| Browns and Georges Banks, north-eastern US | Recovery of heavily depleted barndoor skate |
| Bangladesh | Effective for successful spawning of Hilsa |
| Shrimp trawl fishery in Saudi Arabia | Effective in sustaining the fishery |
| Snapper-grouper fishery in the South Atlantic | Did not reduce overfishing |
| Pacific Halibut fishery | Failed to reduce fishing effort and was considered to be of limited conservation value |
| New England groundfish fishery | No impact on the decline of groundfish stocks |
| Hawaiian longline swordfish fishery | Not effective in conservation of sea turtles |

ban will be effective for those species that aggregate for spawning during specific seasons. In many fisheries, seasonal closures are the initial management strategy employed and subsequently they have been supplemented or replaced with more effective measures.

## Approaches to assess the effectiveness of SFB to protect the spawners

To find an answer to the question whether the SFB is actually protecting the spawners and improving the reproductive output, we have to make incisive scientific analysis of the subject based on the following questions.

### Are there enough spawners in the sea?

The hypothesis that fishing during the spawning period reduces production of fertilized eggs per spawning female cannot be disputed. However, before we talk about protecting the spawners, we have to ascertain whether enough number of spawners are available for spawning. In other words, the emphasis is to reduce the exploitation rate and allow more fish to survive and participate in the reproduction process. It is intuitively obvious that, if there are only a few mature fish available to spawn, relatively fewer eggs are produced, whether or not spawning act is disrupted by fishing. Hence, the overriding importance is to be given for estimating the spawning stock biomass (SSB) and whether it is sufficient to support the fish harvest in a sustainable way. SSB is the combined weight of all individuals in a fish stock that has already spawned at least once, or that is ready to spawn during the reference year. It is an important Biological Reference Point (BRP) that has to be estimated regularly on a stock-by-stock basis. The assessment of SSB helps in detecting "recruitment overfishing" that happens when the parental biomass is reduced by fishing, resulting in a reduction in the production of new individuals, which in turn leads to reduced number of reproductively active mature fish. SSB and its associated reference point, the SSB at Maximum Sustainable Yield ($SSB_{MSY}$) (the level capable of producing the MSY) need to be estimated from appropriate quantitative assessments based on the analysis of catch-at-length (including discards). Achieving or maintaining a healthy stock status requires that SSB values are equal to or above $SSB_{MSY}$. Generating time-series data on SSB and $SSB_{MSY}$ is an important step to understand the availability of spawners as well as evaluate the performance of SFB.

It is reported that the contribution of SSB ranges from 18% to 80% to the total standing stock biomass for different species in commercial fish landings (CMFRI, 2018). These estimates, in most instances, are simply the estimated biomass of individuals in length groups above length-at-first-maturity of the respective species. To determine the SSB, it is necessary to have estimates on the number of fish by length group, average weight of the fish in each length group and the number of mature fish in each length group. The SSB could be better expressed as a relative measure, i.e., from catch-per-unit effort (CPUE). Yield-per Recruit analysis expanded to include maturity and fecundity would provide SSB per recruit, or $SSB_R$ that gives the data on the stock to replace itself.

## Do we have accurate information on spawning season and spawning frequency?

Tropical fishes are known to spawn for prolonged duration. Extended spawning seasons provide a number of reproductive opportunities, which have the potential to increase recruitment. While SFB has the potential to maintain or increase the reproductive output and may provide a cost-effective enforcement option, protection of spawners needs accurate information on the season, strength and variability of spawning within and among locations and species. This information is an important requirement for developing meaningful temporal management protocols. It is also important to collect information on the major fishing grounds from where the fish are captured.

The ovaries of tropical fishes have several batches of eggs destined to mature and shed periodically. In tropical species, the population consists of fishes of variable stages of maturity and hence utmost care should be exercised to determine the spawning season accurately. During the spawning season, oocyte development is a continuous process involving all stages of oocytes, with a new spawning batch maturing every week to 10 days in peak spawning months. Fishes from the temperate waters, on the contrary, have a definite spawning season, either short or long. Environmental conditions in temperate waters, particularly during winter are adverse for prolonged spawning and hence each individual puts all its reserves into a single spawning. In temperate water species, the gonads show clear seasonal change and at any particular time of the year, the stages of maturity are fairly uniform throughout the population, and hence, it is easier to collect accurate information on spawning season of these fishes.

# Information available on spawning season of the marine fishes of India

Consolidated information on the spawning months of 98 species based on reports and publications during 1980-2010 of ICAR-CMFRI (Vivekanandan *et al*., 2010), indicated that on an annual basis, majority of fishes spawn for 4 to 6 months, 22.5% spawn for 3 months or less and 20.4% spawn for 10 months or more (Fig.1). Moreover, of the 43 and 55 species analysed from the west and east coasts respectively, every month witnesses spawning by more than 20 species (Fig. 2).

Information on the spawning season of 63 species collected by Qasim (1973) also showed prolonged spawning of marine fishes in Indian seas, but the average duration of spawning calculated from the data gathered was 4.8 months compared to 6.1 months by Vivekanandan *et al.* (2010). While many species overlap between the two publications, large differences in the number of months of spawning of the same and related species reported by the two publications underline the uncertainties in generalising the spawning seasonality of fishes. To determine and generalise the months and duration of spawning in multiple spawning fishes with prolonged spawning periods , is a huge challenge for researchers. Hence, it is important to painstakingly follow time-tested

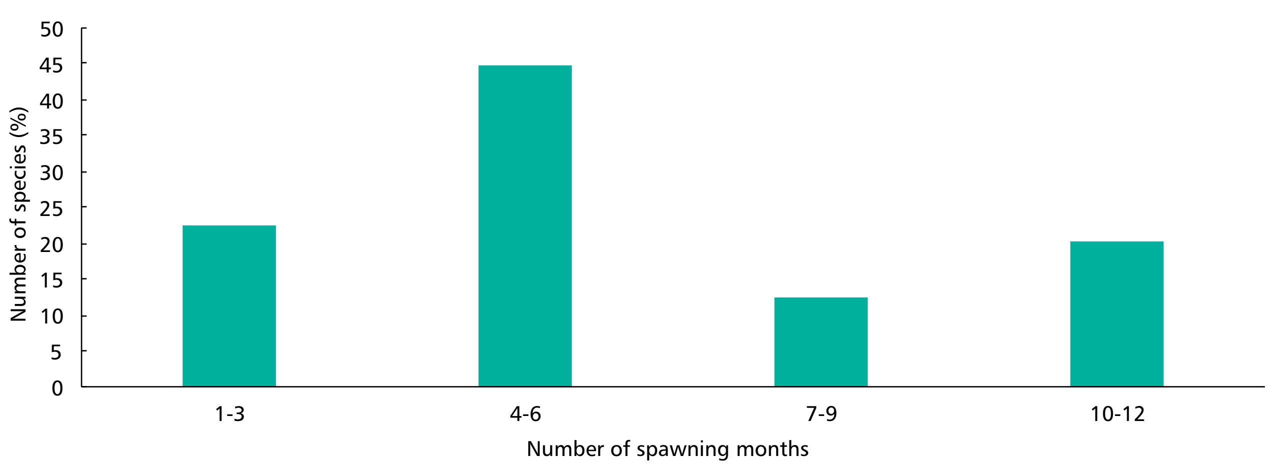


Fig. 1. Number of spawning months for marine fish species in India (n = 98; Data source: Vivekanandan *et al.*, 2010)

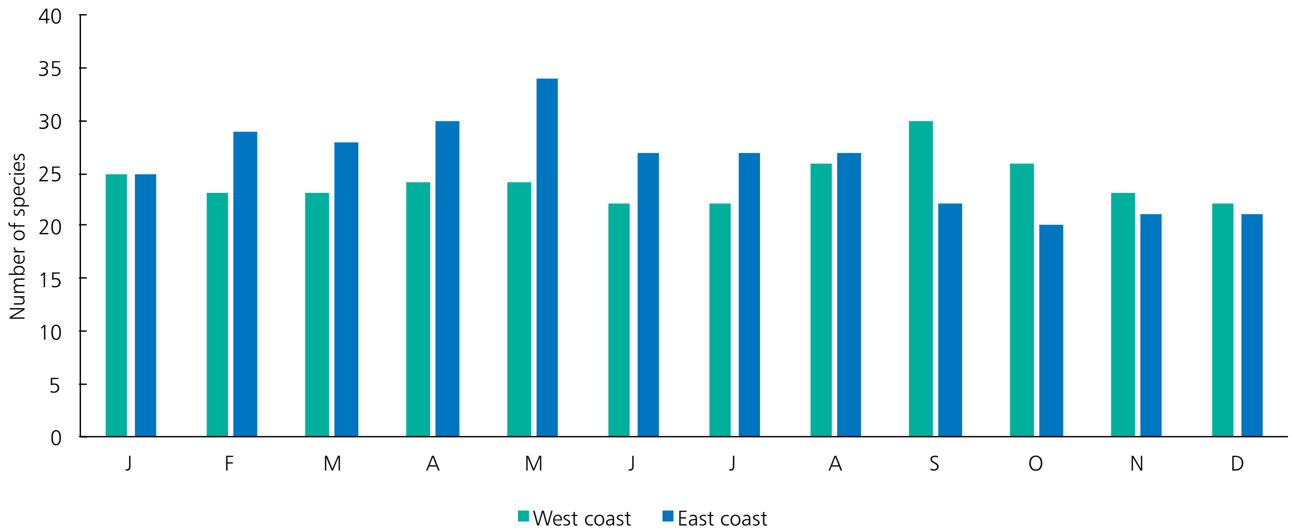


Fig. 2. Number of species spawning in different months along west (n = 43) and east coasts (n = 55) of India (Data source: Vivekanandan *et al.*, 2010)

and reliable methods to find out spawning months. Determining spawning seasonality of marine fishes in India is problematic with the following "drawbacks". The fish samples analysed are collected from landing sites without related information on the fishing grounds from where these fishes were caught. In recent years, particularly, the last ten years, in a single voyage, fishes are caught from different fishing grounds which are at varying distances from the landing sites. These are pooled on the deck of the boat and are landed, masking any site-specific spawning seasonality assessment difficult. In such situations, by the use of information originating only from the landings, the accuracy of information on spatial-seasonal pattern of spawning will be influenced by improper definition of the fishing area. A critical analysis of the two compilations mentioned above indicates that the results on the spawning seasonality were not validated by the authors who originally generated the data. Though the method(s) used by different authors to determine the spawning months has not been stated in the compilation of Vivekanandan *et al.* (2010), it is evident that majority of the studies had determined spawning periodicity based on a visual examination of gonads and classifying it into maturity stages using colour, shape and size of gonads in relation to body cavity. Visual examination lacks precision as it relies upon subjective judgement and very often, visual distinction of stages is not easy. Moreover, in a majority of species, visual classification of maturity stages is confusing as there are vast differences between species. Prior to 1970, most of the studies in India used ova diameter frequency method (Qasim, 1973). As eggs of many sizes and in various stages of development will be present in a single ovary, classifying them into distinct stages from ova diameter measurements may become biased. Visual observation of gonads as well as ova diameter studies were developed for fishes with a definite spawning season as observed in the temperate waters. On the contrary, identifying the spawning timing for tropical fishes has always remained an enigma.

## Conventional methods of assessment of gonadal condition

In this challenging background, it is worth re-visiting the traditional methods of assessment of gonadal condition so that appropriate method(s) could be selected to determine the spawning seasonality. The performance of four conventional methods are given in Table 3.

Like visual observation of gonads, determination of gonado-somatic index (GSI) is another way of finding the spawning season with minimum effort and in conjunction with other methods like the standardized histological methods will give accurate information on spawning season. Use of histological techniques to study gonadal maturation has proven to have greater precision than the other methods listed above. Valuable information on spawning fraction, i.e., the proportion of gonads in spawning condition becomes available but the method is laborious, time consuming and may not be possible to adopt on a routine, species-by-species basis. Hence, a reasonable number of intense analysis using histology

Table 3. Conventional methods of assessment of gonadal condition

| Method | Description | Performance | Confidence level of assessment |
|---|---|---|---|
| Visual examination of gonad | Gives a cost-effective, rapid assessment of maturity stages | Judgement is subjective, accuracy is uncertain; vast differences in the character of maturity stages between species; cannot be considered as a stand-alone method to determine spawning season. | Low |
| Ova diameter measurement | Allows frequency distribution of ova diameter; may be used if the diameter ranges of various stages for the species are already known. | Eggs of many sizes in various stages of development will be present in a single ovary, and classifying them into distinct batches may be biased. | Medium |
| Gonado-somatic Index | Simple means of assessing reproductive cycles. Classification could be successful on dry-weight basis. Necessary to sample individuals of discrete size ranges | Atresia of oocytes and resorption of eggs will not be accounted. If discrete size ranges are not considered, the method assumes that the allometric relationship between gonad and total tissue does not change over the size range, which is not correct. | Medium |
| Histological examination | Maturation can be assessed a few weeks before or after the spawning season accurately. Arguably the most accurate method to assess the gonadal condition. | Laborious, expensive, and limited to providing data on germ cell development. | High |

techniques and covering the whole range of maturity cycle for selected major species can be used to accurately identify the spawning season periodically in conjunction with any two of the first three methods listed in Table 3.

## Measuring spawning frequency

In batch spawning fishes, it is necessary to determine the spawning frequency because the standing stock of advanced oocytes or one-time egg count gives no indication of seasonal/monthly fecundity. New spawning batches are continuously recruited from small unyolked oocytes during the spawning season in batch spawners. In the context of SFB, spawning frequency can be defined as the number of spawning events within a spawning season for the species. Several methods have been suggested for measuring spawning frequency. Histological examination of ovaries with incidence one-day old post-ovulatory follicles in *Engraulis mordax* led to the conclusion that it spawns at least 20 times in one year (Hunter and Leong, 1981). While some attempts have been made to study the frequency of spawning in marine fishes in India (for example, Devaraj, 1986), the classification of maturity stages itself is confusing as it differs from species to species, even closely related.

## Estimating fecundity

For determining the spawning season, it is crucial to estimate the fecundity of fishes in different months and is decisively important in determining the spawning strength and recruitment. In this context, it is worthwhile to consider three terms related to fecundity, namely, Potential Fecundity (PF), Realised Fecundity (RdF) and Relative Fecundity (RF). Potential Fecundity is the term used to describe the maximum number of oocytes commencing to differentiate and develop into mature eggs. However, due to one or other environmental factor like food supply or physiological state of the fish, a fraction of these developing oocytes is resorbed through a phenomenon called atresia. The number of remaining viable oocytes is termed as Realised Fecundity (RdF). The proportion of RdF to the PF changes temporally and from species to species. Relative Fecundity (RF) refers to the number of oocytes in relation to the body size of fish. In general, the RF, estimated as RdF divided by the body size of the fish (in terms of length or weight) differs between months and locations, and increases with the body size of the fish. It has been reported by Devaraj (1986) that the fecundity increases by 65,998 eggs for every 10 mm increase in length in the streaked seerfish *Scomberomorus lineolatus*. Hence, to determine the spawning months, it is important to estimate the RdF of the species during different months considering the size composition prevalent in different months and RF. An understanding of the relationships between reproductive parameters, such as spawning frequency, batch fecundity and spawning duration, with fish length are required to estimate seasonal absolute fecundity for multiple-spawning species with indeterminate fecundity (Fig. 3).

Fishes exhibiting multiple spawning have either of the three types of oocyte development in the ovary, which need to be considered for determining the spawning strength (Table 4). Among these, indeterminate seasonal fecundity is the most common among tropical fishes.

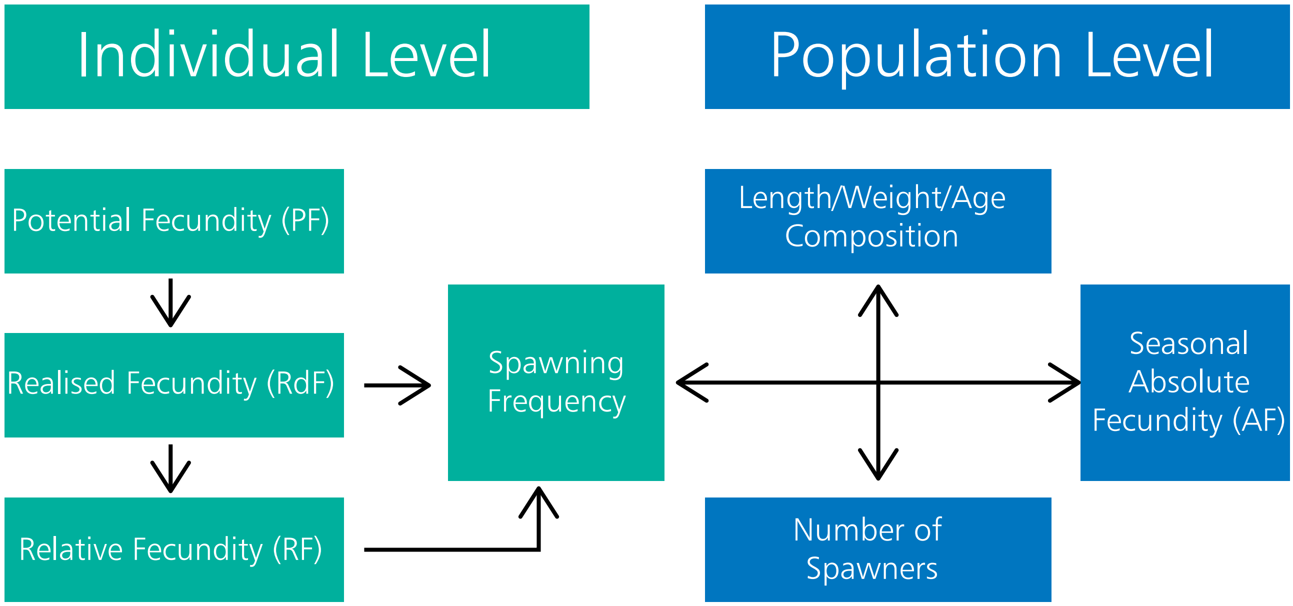


Fig. 3. Flow chart for determining seasonal spawning strength of fish species

## Egg Production Model

Assessment of the spawning biomass of marine fishes based on ichthyoplankton data and annual egg production method was described by Saville (1964), and later a model was developed by Lo (1985). By downscaling this annual model to monthly fish landings data and incorporating the proportion of mature spawning female, the following equation could be adopted for estimating the SSB on a monthly basis:

$$P = B*R*F (E/W)$$

Where, P = Egg production at a given month; B = Spawning biomass; R = Proportion of female; F = Proportion of mature spawning female; E = Average monthly fecundity; W = Average monthly female weight.

While modern egg production models demand on-board fishing and ichthyoplankton surveys which are expensive, the modified method narrated above is simple to follow and can be applied to data collected from the commercial catches. It is an extension of the estimates on gonadal maturity, fecundity and spawning frequency.

## Data required for identifying spawning season

The data required for finding out the spawning season of fishes, as mentioned above is indicated as a flow chart (Fig. 4). Until right type of accurate information are available, there will be uncertainty in identifying the spawning season. However, in multispecies fisheries, it is not possible to collect the entire set of data for all the species. Hence, species may be selected for the analysis

Table 4. Different types of multiple spawning in fishes

| Type | Description | Prescribed analysis |
|---|---|---|
| Indeterminate seasonal fecundity | New spawning batches of oocytes are recruited from small unyolked oocytes continuously during the spawning season. Presence of unsynchronised, unlimited number of developing oocytes. | Rate of egg production to be determined from spawning frequency and batch fecundity. |
| Determinate seasonal fecundity | Oocytes destined for spawning in a season are identifiable at the beginning of the season. Presence of synchronous development of a fixed number of oocytes. | Fecundity to be estimated for the entire spawning season until all the oocytes spawn; spawning frequency need not be determined. |
| Determinate fecundity, but all oocytes do not spawn in a season | Un-utilised oocytes exist at the end of season | Fecundity to be estimated for the entire spawning season and the unspawned oocytes to be determined at the end of season; spawning frequency need not be determined. |

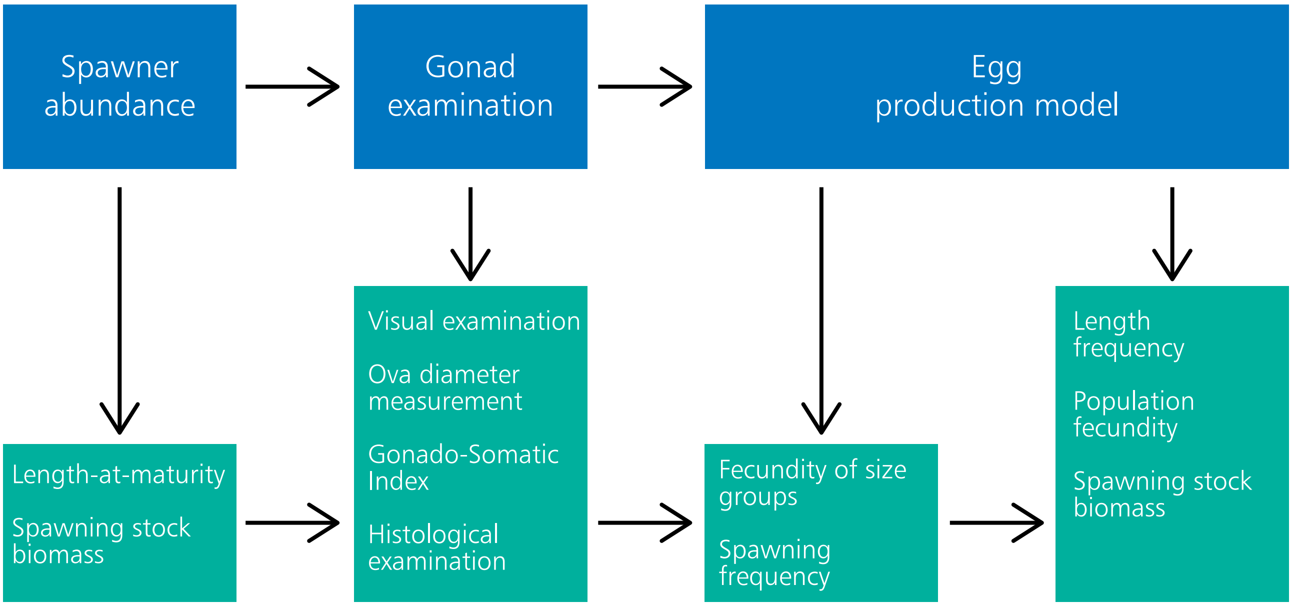


Fig. 4. Sequential flow of data required for determining the spawning season of multiple spawners

based on their abundance levels as per landings data and economic value. This is a time-consuming and expensive exercise, but would provide strong scientific insights with certainty, on the spawning seasonality of fishes that is essential for creating/improving effective strategies to link scientific advice to management decisions on timing and duration of SFB.

## Fishing effort and capacity control

Another important objective of SFB is control of fishing effort. Reduction of the fishing duration and fishing mortality by limiting the amount of fishing, would supposedly increase stock size. However, it is difficult to predict the response of fishing mortality based on the amount of effort control since it depends on how fishers respond to the specific regulations set forth. For example, if fishing mortality and effort are high in a fishery and a closed season is established, fishers may respond with greater effort by using more gear and/or boats when the season is open. When opened after the closure, the fishery provides the communities with an opportunity to boost fish catch to meet elevated social and economic demands.

In India, the number of fishing boats and efficiency are consistently increasing, with smaller non-motorised boats being replaced by motorised and mechanised boats. The census carried out by ICAR-CMFRI during different periods shows that not only the number of fishing boats has increased, but the composition of fishing fleet has changed over the years, from 15.0% mechanised boats in 1992-93 to 36.5% in 2010 (Table 5). The gross tonnage of fishing fleet and the summed up horsepower of engines in the fleet would have increased substantially, for which data are not available. It is overwhelmingly important to estimate the capacity of fishing fleet and complement the data with fishing effort.

Moreover, the number of existing boats, particularly the mechanised and motorised boats is double the number

Table 5. Change in the composition of fishing fleet over the years in India

| Year | Non-motorised | Motorised | Mechanised |
|---|---|---|---|
| 1992-93 | 74.0 | 11.0 | 15.0 |
| 1994-95 | 70.9 | 11.8 | 17.4 |
| 2003 | 64.8 | 15.9 | 19.2 |
| 2005 | 44.0 | 31.5 | 24.5 |
| 2010 | 26.6 | 36.9 | 36.5 |

(Source: Census Reports, ICAR-CMFRI)

of the estimated optimum fishing fleet (DAHDF, 2011), indicating overcapacity of the fleet. Excess capacity is, in general, associated with open access fisheries. These factors have the potential to jeopardise the objective of SFB. Hence, it is important to realise that SFB will not be effective as a stand-alone management measure to reduce fishing effort and thereby fishing mortality. The problems in using input controls alone to regulate fisheries are associated with problems of determining how much effort is actually represented by each fishing unit. Even discrete fleets within a fishery are characterized by considerable variation in the size of vessel, nature of gear and technical and technological aids used. However, SFB could complement other stronger measures to control fishing effort such as cap on the number of boats, and gear and catch restrictions. Otherwise, SFB amounts to just postponing fish capture by two months. Unless effective measures for capacity controls are concurrently implemented, the period of closed season for building the stock size could become longer. Gulland (1974) stated that there is little theoretical justification for seasonal closures unless the fishing effort is controlled by other effective methods. If the fishing effort or capacity is not restricted, achieving the targets such as reduced fishing mortality and increased stock size becomes redundant.

## Conclusion

Authoritative scientific input and monitoring is required to fix the period and duration of seasonal fishing ban and to assess its performance. Considering that protecting fish spawners is the major objective of enforcing seasonal fish ban in marine fisheries in India, this overview emphasises the need for generating accurate data on a monthly basis on the gonadal condition, spawning frequency and egg production of important species to enable identification of right months and duration of fishing closure. To assess whether the ban has addressed the intended objectives, continuous monitoring of recruitment and spawning stock biomass is required.Closure of fishing for a specific duration every year is expected to reduce/control pressure on fish stocks. This would be reflected in the form of reduction in annual fishing effort, but the right type of data required is time-series on changes in annual fishing capacity, if any. The positive outcome of ban, that needs to be assessed, is reduction in fishing mortality and improvement in yield-per-recruit. To generate the above-mentioned data, conventional methods that are being used by fishery biologists for the past many years have been suggested in this overview. However, painstaking effort has to be made to collect the data to gain a firm grasp of the dynamics of fisheries and the bases underlying the importance and problems of their management.

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CMFRI

Indian Council of Agricultural Research
**Central Marine Fisheries Research Institute**

Post Box No.1603, Ernakulam North P.O., Kochi-682 018, Kerala, India.
Phone: +91 484 2394357, 2394867 Fax: +91 484 2394909
E-mail: director.cmfri@icar.gov.in **www.cmfri.org.in**