Indian J. Fish., 62(4) : 23-30, 2015

Assessment of stock status of the exploited fishery resources in northern Bay of Bengal using landed catch data

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ABSTRACT

The temporal evolution of fish stocks in the waters of northern Bay of Bengal from 1985 - 2013 was ascertained from commercial marine fish landings. Stocks of major exploited fishery resources were classified based on the trend in landing as "developing", "fully exploited", "overexploited", "collapsed" and "rebuilding". During the early years, most stocks were in "developing" state, but with mechanisation and intense exploitation, stocks gradually became "fully exploited" and then "overexploited". Few stocks "collapsed", after which "rebuilding" occurred but pigface breams remained in a "collapsed" state for many years. No stocks were found in "developing" state and 56.1% of the stocks were found "fully exploited" while 36.8% were "overexploited". Not much difference was observed in the status of pelagic and demersal stocks. The time span a stock remained in a specific category has decreased over the years indicating that stocks are moving faster across categories in recent years. Stock status determined in the present study is consistent with those reported by conventional stock assessment techniques, confirming that stock status plots (SSP) are alternative way of assessing fish stocks when data are limited.

Keywords: Collapsed, Fish stocks, Fully exploited, Northern Bay of Bengal, Overexploited, Rebuilding

Introduction

The Bay of Bengal Large Marine Ecosystem (BOBLME) is highly productive with primary production >300 g cm^{-2} yr^{-1} and chlorophyll a >0.5 mg m^{-3}. The high primary production in the coastal waters of the bay is attributed to the large nutrient input from river run-off; however the central parts of the bay are less productive due to absence of large scale mixing or upwelling (Dwivedi, 1993). Fisheries of the BOBLME are multi-gear and multi-species, targeting a wide range of species, including sardines, anchovies, shads, mackerel, ribbonfish, tuna, snappers, groupers, eels, sharks, shrimps and bivalves (Ghosh *et al.*, 2013; 2014). The northern Bay of Bengal (BOB) is bordered by three maritime states of India *viz*., Andhra Pradesh, Odisha and West Bengal, with a combined coastline of more than 2000 km (974 km for Andhra Pradesh, 480 km for Odisha and 650 km for West Bengal), constituting one fourth of the coastline of India and contributing more than one-fourth to the total marine fish production of the country. There has been a tremendous surge in marine fish production along the northern BOB, increasing from less than a lakh t half a century back to an average of 8 - 10 lakh t in recent years. The advent of mechanisation of fishing craft and introduction of mechanised fishing vessels has brought significant changes in the marine fishing sector of this region.

The high density of trawlers along northern BOB has induced changes in the ecosystem (Vivekanandan *et al*., 2005). Mechanisation of the fishing fleets resulting in increased fishing effort has led to intense exploitation of commercial marine species in recent years, resulting in their biomass changes and in turn threatening their long term sustainability. The number of overexploited stocks is low, but on the rise with most landings recorded from fully exploited stocks (Preston, 2004). Consequently, most marine fish stocks are not as abundant as they were before. The region also faces several other sustainability issues such as pollution and habitat degradation (Ghosh *et al.*, 2013; 2014). Therefore, identification of overexploited and collapsed fish stocks has assumed paramount importance. However, information is lacking on the stock status of major marine resources exploited along the northern BOB. Therefore, it was felt necessary to study the stock status of all commercially important marine fishery resources of the region.

In the northern BOB, owing to the multi-species and multi-gear nature of the fishery, exploitation status

of vast majority of species needs to be assessed for devising suitable fishery management plans. Classical stock assessment tools require reliable estimates of stock biomass, which is difficult to ascertain in multi-species and multi-gear fishery. Moreover, such techniques are extremely data demanding, and hence, are possible only for a small fraction of the commercially important exploited stocks. The alternative is to use assessment tools such as stock status plots (SSP) which are potentially less precise than stock assessments but can give a fair representation of the stock status. Stock status plots depict how fish stocks pass through various developmental phases with its status defined by ratio of landed catch to maximum landed catch obtained from a time series (Froese and Kesner-Reyes, 2002a). Previous studies have analysed global landing data to gain insights into the status of global fisheries, revealing for example, an increase in collapsed stocks and a decline in new stocks (Froese and Kesner-Reyes, 2002b, 2009; Pauly *et al*., 2008; Zeller *et al*., 2009; Kleisner and Pauly, 2011). Their understanding was that landing of commercial fishing vessels constitutes the basis for estimating past and present biomass, which then forms the basis for providing management options. The present study was designed similarly at identifying the status of fish stocks from the waters of northern BOB using commercial landed catch data. This was necessitated owing to limited information available on fishery biology of most species in earlier decades, negating the possibility of using classical stock assessment techniques.

Materials and methods

"Stock", in the present study, is defined as of one species, genus or family in northern BOB for which the first and the last reported landings are at least 15 years apart and that there are at least 5 years of consecutive landings and for which the accumulated landing is at least 5000 t (modified from the definition stated by Pauly, 2008). By considering each species/group to be a single stock, it was ensured that we are studying the behaviour of established stocks that has been fished over a large period of time. Hence, species/groups occurring rarely in the landings were not taken and only those species/groups which formed a regular fishery were selected. The species-wise marine fish landings data of Andhra Pradesh, Odisha and West Bengal for the period from 1985 to 2013 was obtained from the National Marine Living Resources Data Centre (NMLRDC) of ICAR-Central Marine Fisheries Research Institute (ICAR-CMFRI). The annual estimates of landings were made by ICAR-CMFRI following the stratified multi-stage random sampling design (Srinath *et al*., 2005). Species names were specified only for groups that represented single species fishery. Higher taxonomic groups and pooled groupings representing a variety of species with divergent fishery and biology were avoided to eliminate intra-group masking of stock status (Kleisner *et al*., 2013). Implicit in the present landing based study is the assumption that with expansion and development of fishery, fishing mortality increased with time (Kleisner *et al*., 2013). Altogether 57 species/groups were included in the analyses. Species/groups were classified to determine their stock status in any given year, into one of the stages *viz*., developing, fully exploited, overexploited, collapsed and rebuilding using the criteria given in Table 1 (Froese and Kesner-Reyes, 2002a; Froese *et al*., 2012; Kleisner *et al*., 2013). The categories "undeveloped" and "developing" used originally by Froese and Kesner-Reyes (2002a) were combined to a single category "developing" as suggested by Kleisner *et al*. (2013). Two SSPs were created; one based on the numbers of stock by status and the other based on the percentage of landed catch by stock status over time (stock status catch plots). The numbers of stock by status graph depicted the percentage number of stocks that were considered overexploited or collapsed whereas the landed catch by stock status graph depicted the percentage of landed catches that originated from overexploited or collapsed stocks (Kleisner *et al*., 2013). For estimating stock transition time between categories from 1986 to 2013, the percentage of stocks in each year that remained in their respective categories for <7 years and the average number of years within this subset that a stock in each status group remained was computed. As study period was for 28 years, to obtain four equal periods, 7 years was used as threshold for each period.

Table 1. Criteria used to assign exploitation stages based on landed catches (C) relative to the maximum landed catch recorded in the time series (C_{max})

Status of fishery	Criterion applied
Developing	Year Before Year of C_{max} and $C/C_{max} < 0.5$
Fully exploited	Year Before / After Year of C_{max} and $C/C_{max} > 0.5$
Overexploited	Year After Year of C_{max} and C/C_{max} 0.1 – 0.5
Collapsed	Year After Year of C_{max} and $C/C_{max} < 0.1$
Rebuilding	Years between collapsed and first subsequent fully exploited
Final year rules	
Developing	If C_{max} occurs in the final year, increase C_{max} by 50% and set its year of occurrence as final year plus one

Results and discussion

Stock status

SSP reveals that with years passing by, the number of stocks in "developing" category decreased and by 2013, no stocks were found to be in "developing" category. Consequently, the number of stocks in "fully exploited",

"overexploited", "collapsed" and "rebuilding" categories gradually increased over the years. In 2013, 56.1% of the stocks were "fully exploited", 36.8% "overexploited", 3.5% "collapsed" and 3.5% were "rebuilding". Most of the pelagic and demersal finfish stocks were "fully exploited" and bulk of the rest "overexploited" (Fig. 1); whereas shellfish stocks were equally "fully exploited" and "overexploited". The numbers of stock by status and the landed catch by stock status graphs are depicted in Fig. 2. "Fully exploited" stocks appeared in the fishery from as early as 1986 onwards while "overexploited" stocks appeared from 1989 onwards. The highest number (46) of stocks in "fully exploited" state was observed in 2011 and the highest number (26) of stocks in "overexploited" state was observed in 2012. Stock specific status of pelagic, demersal and shellfish resources are presented in Fig. 3, 4 and 5. The first "overexploited" stock was that of skates. The first "collapsed" fishery observed in 1993 was that of *Scomberomorus lineolatus*. It remained "collapsed" for a year, after which "rebuilding" started. Pigface bream (*Lethrinus* spp.) fishery "collapsed" in 1997, and again in 2000, 2003, 2007, 2009 and 2011. In between, it remained "overexploited". Shad fishery had "collapsed" in 2001 and 2003 and *Sardinella longiceps* "collapsed" in 2002 and 2004. Fishery for shads and *Sardinella longiceps* after "collapse" entered "rebuilding" phase. However, *S. longiceps* was again "overexploited" by 2010. Soles and threadfins (*Polynemus* spp.) "collapsed" in 2013. In 1994, 88.1% of the landings were from stocks in "developing" state, while 11.8% of the landings were from stocks in "fully exploited" state. By 2004, landings from stocks in "fully exploited" state increased to 43.1% and landings from stocks in "developing" state decreased to 55.7%. Towards end of the study period, by 2013, 70.8% of landings were from stocks in "fully exploited" state and 26.9% of the landings were from stocks in "overexploited" state. The proportion of landings emanating from "collapsed" and "rebuilding" stocks was found to be less throughout the study duration.

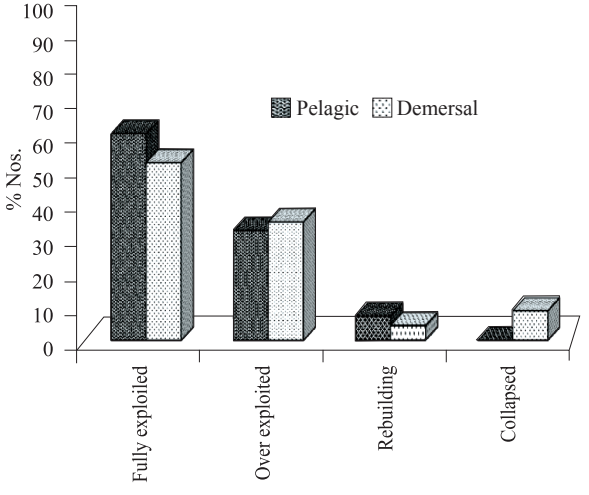

Fig. 1. Present status (2013) by numbers (%) of pelagic and demersal stocks of northern Bay of Bengal

The introduction of multiday fishing in 1980 for 4 months during October-January; followed by introduction of voyage fishing of 8-15 days duration by large mechanised trawlers for six months during October-March and single-day fishing for rest of the months has had an impact on the status of fish stocks in the waters along northern BOB. From 1990 onwards, voyage fishing extended to 9 months and from 1995, it was conducted throughout the year (Rajkumar *et al*., 2005). Mechanised vessels operating gillnets and indigenous crafts using outboard engines also started operation from the late 1990s (Rajkumar *et al*., 2005); as a result of which, by 2013, most of the stocks were "fully exploited", "overexploited" and a few "collapsed" (Fig. 6). In general, not much difference was observed in the state of stocks of pelagic and demersal

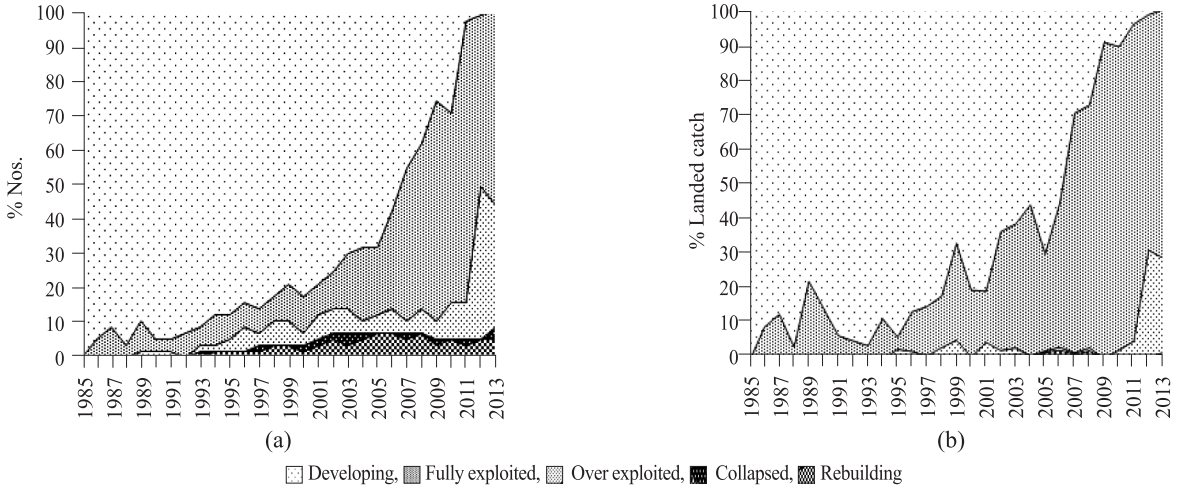

Fig. 2. Stock status plots by numbers (a) and landed catch (b) of marine fishes of northern Bay of Bengal during 1985 - 2013

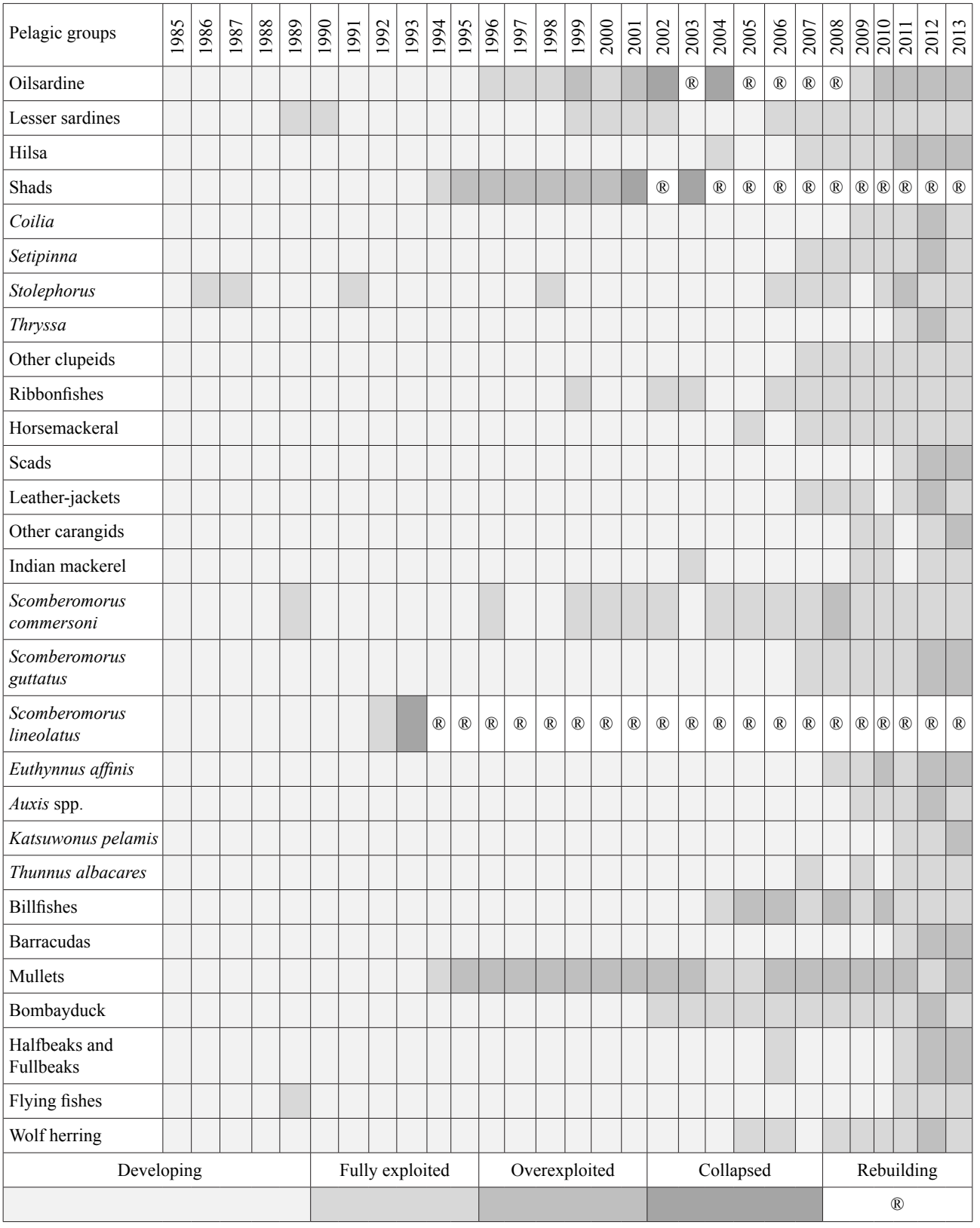

Fig. 3. Stock specific status of pelagic resources landed along northern Bay of Bengal during 1985 - 2013

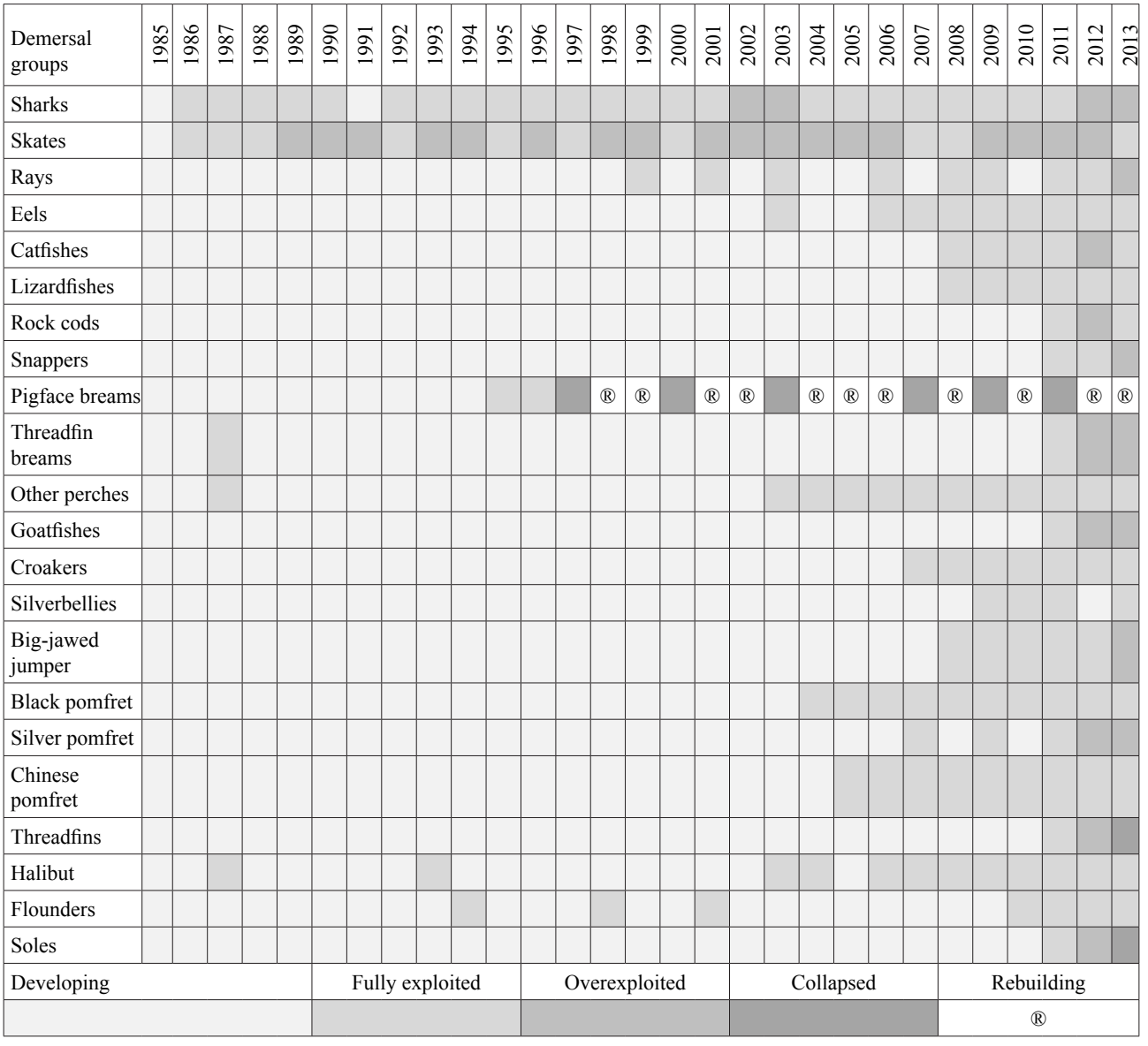

Fig. 4. Stock specific status of demersal resources landed along northern Bay of Bengal during 1985 - 2013

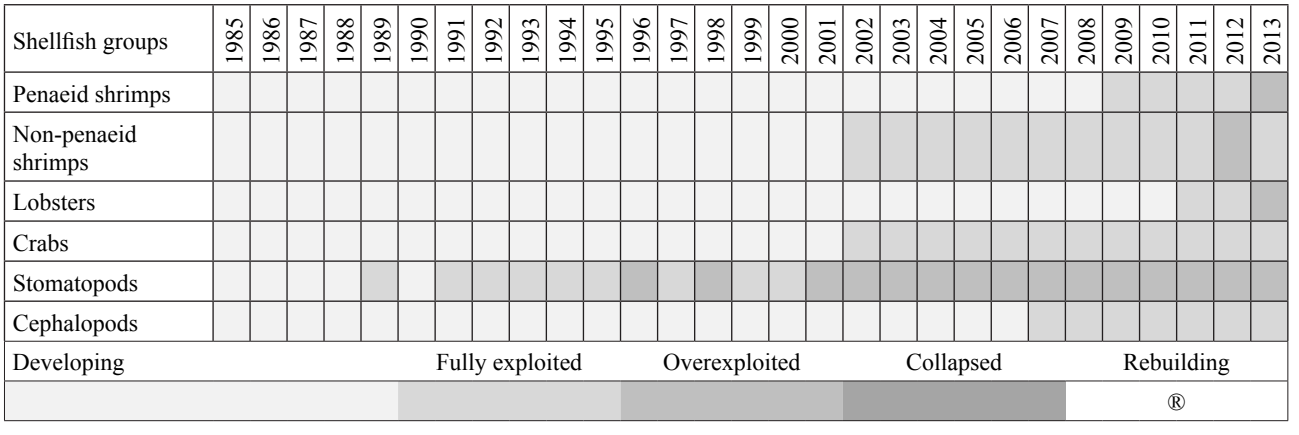

Fig. 5. Stock specific status of shellfish resources landed along northern Bay of Bengal during 1985 - 2013

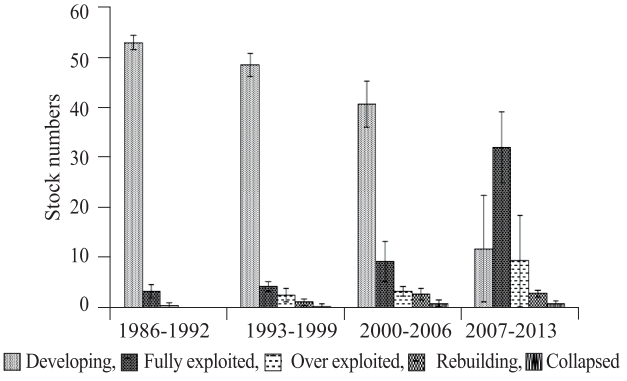

Fig. 6. Stock numbers (Mean±SD) in various categories during 1986 - 2013

fishes. Most of the demersal and pelagic stocks after "collapse" were found to be "rebuilding". Similar views were expressed by Ghosh *et al.* (2013; 2014), on the stock structure of lesser sardines and ribbonfishes from northern BOB using classical stock assessment techniques. According to them, the stocks of both lesser sardines and ribbonfishes were overexploited. They suggested limiting the fishing fleet size and increasing the mesh size of gears. The same advisory holds well from the present study, and it reaffirms the accuracy and authenticity of landing based stock assessment of marine fisheries on a larger time frame.

"Collapsed" stocks

Pigface breams (*Lethrinus* spp.) inhabit rocky grounds and coral reef areas in the adult phase, while juveniles prefer seagrass beds and occur mostly in nearshore areas, river mouths and estuaries. There is targeted fishery in known fishing grounds using hooks and lines, and as they are protogynous hermaphrodites, it leads to skewed sex ratio and ultimately to recruitment overfishing (Young and Martin, 1982). Habitat degradation of juveniles and growth overfishing in nursery areas has also resulted in the collapse of pigface bream stocks. Similarly, Froese and Kesner-Reyes (2002a) observed low resilience to fishing for coral reef associated fishes.

Apart from pigface breams, other "collapsed" stocks were able to recover themselves. Shads and *S. longiceps* remained "collapsed" for a couple of years; after which "rebuilding" commenced because of high recruitment turnover with low spawning stock biomass (Devaraj and Vivekanandan, 1999). Similarly, Mohamed *et al.* (2010) reported that for most tropical short-lived species, short term fluctuations are not very significant, even if it is caused by excessive fishing pressure and with reduction in fishing pressure, optimum environmental conditions and lack of predatory pressure, the situation is reversed very soon naturally. Likewise Worm *et al.* (2006) stated that enhanced recovery in fish stocks is possible in areas with high diversity, because fishers can switch more readily among target species, potentially providing overexploited taxa with a chance to recover.

Threadfins and soles "collapsed" in 2013. The distribution of threadfins is restricted to coastal waters and estuaries. They spawn in sea and juveniles actively recruit to estuaries and ascend toward freshwater rivers. There is targeted fishing of these threadfin shoals by artisanal fishermen dating back to several decades which has resulted in the declining nature of this stock. Mackinson *et al.* (1997) reported that small shoaling stocks are at greater risk of collapse because high levels of fishing effort continues to be expended even at low abundance levels. This phenomenon, known as "hyperstability" is common in shoaling fishes, as their low abundance is not reflected in their catches. Intense trawling coupled with degradation of benthic habitat and the consequent non-availability of their preferred food items would have adversely affected the stock of soles. Soles are known to be distributed in accordance to sediment type and particle size and any change caused by terrestrial run-offs would impact the sole fishery (Niekerk and Lamberth, 2013).

Stock transition time

During the study period, the percentage of stocks that remained in a specific category for <7 years increased from 17.54% during 1986-1992 to 73.68% during 2007-2013. The increase is more pronounced in the "developing" category. From this we can infer that in recent years, there have been accelerations in transition times between categories. The average number of years that a stock remained within each category also decreased from 6.61 and 6.33 years during 1986-1992 and 1993-1999 to 5.42 and 4.21 years during 2000-2006 and 2007-2013 respectively. Thus there has been a decline in transition time over the years. Presently, stocks appear to change more quickly as compared to earlier times, as reported by Garcia and Newton (1997), Froese and Kesner-Reyes (2002a) and Kleisner *et al.* (2013). They observed that the transition time required for a stock to move into the succeeding category has declined over the years.

Classical stock assessment techniques of exploited stocks involving the estimation of biomass are often considered as authoritative for indicating their status. However, such stock assessments require extensive data, spanning back to several decades, which are not available for the vast majority of exploited stocks, and therefore, are undertaken only for a small proportion of the commercially exploited species. Thus, stock assessment becomes fundamentally biased in that they represent high value and resilient stocks that have been

fished extensively for decades (Kleisner *et al*., 2013). The present methodology of assessing stock status based on landings has been proven on a global scale (Froese and Kesner-Reyes, 2002a, 2009; Pauly *et al*., 2008; Zeller *et al*., 2009; Kleisner and Pauly, 2011; Froese *et al*., 2012; Kleisner *et al*., 2013) and as found in the present study, holds good for assessing the state of marine fisheries of northern BOB. However, misinterpretations do occur, when inferring the stock status from landed catch. A classical example is the case where landings become low or negligible when a targeted species become non-targeted because of its low demand or profitability, or because of social factors or management measures. Fish behaviour *viz*., "hyperstability" (as in pelagics that form shoals) and "hyperdepletion" (as in crustaceans that live in hideouts) can lead to misconceptions. Similarly, shift in climate regimes resulting in changes in landing composition, or high fuel prices altering fishing patterns can also lead to faulty conclusion. In such cases, it becomes difficult to attribute a change in landing to a corresponding decrease or increase in biomass (Kleisner *et al*., 2013). The gradual increase in mechanisation and fleet size as well as capacity over the years from 1985 to 2013 has taken a toll on the health of marine fishes, with all fishes now either in "fully exploited" or "overexploited" state and few stocks in "collapsed" state. It is the need of the hour to restrict fleet size and capacity, coupled with strict implementation of "Marine Fisheries Regulation Act", or else majority of the fish stocks would collapse in future. However, more research and insight are required, while linking stock status to the evolution of fishing technology that has taken place over the decades. The fishery for pigface breams needs careful monitoring and proper plans have to be put in place, including establishment of marine protected areas (MPAs) for conservation and rejuvenation.

Acknowledgements

The authors express their gratitude to the Director, ICAR-Central Marine Fisheries Research Institute, Kochi, Kerala, India.

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Date of Receipt : 26.05.2014
Date of Acceptance : 31.07.2015