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The estimates spawning potential ratio of three dominant demersal fish species landed in Tegal, north coast of Central Java, Indonesia

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Abstract. *Nugroho D, Patria MP, Supriatna J, Adrianto L. 2017. The estimates spawning potential ratio of three dominant demersal fish species landed in Tegal, north coast of Central Java, Indonesia. Biodiversitas 18: 844-849.* Java Sea is one of the important marine waters for fisheries purpose in Indonesia. The rich diversity of marine fish has been exploited for decades. Among them, demersal fish resource was commercially targeted by coastal fishers. The sustainability of demersal fishery is a crucial concern given the substantial economic contribution and its significant dependence of small-scale fishers for their livelihoods. The fishing intensity is considerable growing and tends to become threats their habitats. Three dominant species (*Priacanthus tayenus, Scolopsis taeniopterus* and *Upeneus sulphureus*) were selected in this study. To evaluate the vulnerability of these species to their bio-exploitation level, the spawning potential ratio (SPR) approach were applied. The calculation based on estimated length of first capture (Lc) indicates that SPR those demersal species occurred at less than 20%. These values indicate that existing fishery can be categorized as nearly fully exploited. Across broad range of species, 40% *SPR* is generally accepted as a proxy for Maximum Sustainable Yield (MSY) for recruitment overfishing in less resilience fish population.

Keywords: Demersal dominant species, Java, north coast, spawning potential ratio

INTRODUCTION

The Java Sea is one of the high diverse aquatic living resources in Indonesia. National capture statistics describes that fishing activities in this water contributes as second largest fish landing in the country (DGCF 2015). The typical exploitation mostly consisted of coastal community with small-scale fisheries. Demersal group of fish is one of the major species that has been exploited since decades. Landing record in 2014 was 1.67 million tons or 31% of the national landings. Among eight provincial coastal waters surrounding Java Sea, 93% of these species landed in the north coast of central Java. Previous studies on biological characteristics of dominant species in the north coast of Java have shown that landing is dominated by small size of fish and medium tropic level fisheries, therefore, the exploitation of the demersal fish species is suggested to be at risk (Nugroho et al. 2016).

For fish stocks to persist, successive from generation to generation must be in an average state. This means fishing should not reduce the amount of spawning per recruit below a necessary threshold level for replacement. Brooks et al. (2010) recommend that spawning potential ratio (SPR) utility to apply to stocks with data-limited fisheries. Meanwhile, Hordyik et al. (2015) suggested to support management decision for data-poor fisheries, SPR is length based approach to established biological reference point.

The significant increasing number of Danish seines fleets since the year of 2000 has become a major concern to sustain fish diversity in the Java Sea. The rapid expansion of exploitation has created the need for information on biological status of the demersal fish species as part of developing conservation and management measures. One of the basic goals of fisheries management is to conserve sufficient reproductive potential in stock to allow sustainable exploitation. Sustainability refers to the ability of exploited stock to produce goods and services, including yields at suitable levels in the short term, while maintaining the existing stock's reproductive capacity to continue providing these goods and services into the indefinite future. To achieve this, we use a biological approach which stocks could be managed based on maintaining limit thresholds of Spawning Stock Biomass (SSB) and Spawning Potential Ratio. Three dominant species of Lattice monocle bream (*Scolopsis taenioptera* Cuvier, 1830), Purple-spotted bigeye (*Priacanthus tayenus* Richardson, 1846), and Goatfish (*Upeneus sulphureus* Cuvier, 1829) were used as an indicator of the 'viability' of demersal fish stocks in the Java Sea.

MATERIALS AND METHODS

Study area

The Java Sea has been widely exploited by fleets based from eight provincial coastal fishing ports. Among them, central and east Java are the major contributors. Tegalsari fishing port of Central Java, Indonesia (6°50'58.01" S-109° 7'43.74" E) is one of the highest annual landings for demersal fish, where it also serves as the base for Danish fleets (Figure 1). Sampling was regularly carried out twice a month during August 2014 to July 2015. Specimens were collected from commercial drag wooden demersal Danish seiners (trawl like a fishing gear). The boat size ranges from 10-30 gross tonnage (GT), equipped with a fish net of 18-27 m length of head rope and ¾ inch mesh size cod-end. The catches have mainly consisted of demersal fish, roughly swim up to 5 m above the bottom. Fishing activity was usually done during the daylight.

Procedures

Data were collected regularly twice a month during August 2014 to July 2015. The sample was measured and observed from selected fleets during the observation. A total of 12,969 specimens were taken for length frequency distribution, among them, 2,038 fish specimens were collected for biological observations (688 *Priacanthus tayenus*, 587 *Scolopsis taenioptera* and 763 *Upeneus sulphureus*) belong to three different families of Priacanthidae, Nemipteridae and Mullidae. The biological characteristics of these species were previously described elsewhere (Nugroho et al. 2016). Fish length was measured in mm, while weight measurement is in grams. To evaluate direct human impact through exploitation to these dominant species, a spawning potential ratio (SPR) and spawning stock biomass estimation were applied as indicators of fishing impact on marine communities.

Data analysis

Data and information on biology and population parameters were described as listed on table 1. Growth pattern of each species follows the von Bertalanffy equation:

$$L_t = L_\infty(1 - e^{-K(t-t_0)}) \qquad (1)$$

Where, L_t is the length at age t, and t_0 is the time at which length is theoretically zero on the modelled growth trajectory (Beverton and Holt 1957). From length-weight relationship, the length-weight regression (a and b) can be obtained. Whole weight-at-age (W_t) is obtained from converting lengths into weights using the equation:

$$W_t = a \cdot L_t{}^b \qquad (2)$$

SPR is used to estimate the percentage of reduction to allow "safe" reference point setting that will prevent recruitment overfishing. Several studies have looked at the optimum percentage over the last decade using meta-analyses, which is fishing mortality at 20% as a limit biological reference points for stocks with average resilience and 30% for stocks with unknown resilience (Mace and Sissenwine 1993; Hoggarth et al. 2006). SPR as the overfishing target and

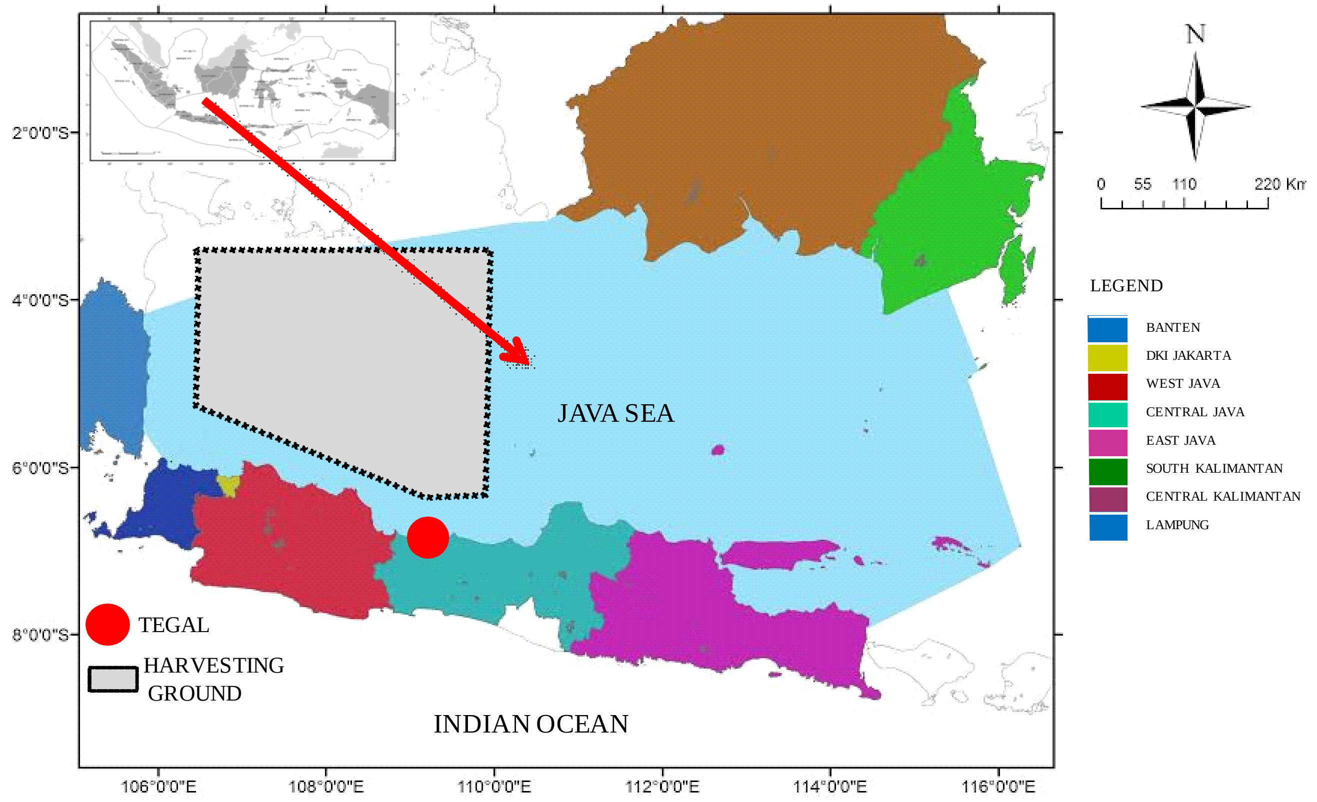

Figure 1. Site location and fishing ground of demersal Danish seine based in Tegal, Central Java, Indonesia

threshold can be derived from different levels of length at first capture (L_c) and F, by dividing spawning stock biomass under exploitation (SSB_F) by pristine spawning stock biomass ($SSB_F = 0$).

$$SPR = \frac{SSB_F}{SSB_{F=0}} \quad (3)$$

Biomass is calculated at each time-age class, while spawning stock biomass is simply the sum of all biomass above the age at maturity. Spawning stock biomass is calculated as:

$$SSB = \sum_{t=t_m}^{t_\lambda} \overline{N}_t \cdot \overline{W}_t \quad (4)$$

Where W_t is the average weight-at-age of species caught. Spawning stock biomass is calculated at pristine levels (B_0) and under various management scenarios (L_c, F). Natural mortality (*M*), the Von Bertalanffy Growth parameters (k, L_∞. t_0), parameters of Length-weight regression (a, b), and Length of the first maturity (L_{50}) are parameters required to estimate SPR (Ault et al. 2008; Prince et al. 2014; Hordyk et al. 2015). Some data used in this research (*i.e,* Population parameters of *P tayenus, S. taenioptera* and *U. sulphureus* were taken from bio-exploitation status analysis of three dominant demersal species in the Java Sea (Table 1). A classical analytical process using spreadsheet were applied for all parameters estimations.

RESULT AND DISCUSSION

Annual trend of landing of demersal fish species

The best available data to perform the annual trend of the landing of three interest species was derived from the available national capture fisheries during 1980 to 2014. Since fish landing records aren't detailed by species, therefore, data represented by a group of each species is used. Ignoring unreported data on this fishery, the annual trend on the landing of the three groups of species shows increasing trend since 2007 and rose significantly since 2012 (Figure 2). This indicates that removal of fish due to fishing proportionally increased particularly in the past two consecutive years. The landing volume increased proportionally with significant increment demersal Danish seine numbers operating in the Java Sea. Demersal Danish seine units increased from 1,300 in 1980 to around 13,000 units in 2014 (Nugroho and Atmadja 2014). This increasing numbers of fleets is also correlated with spatial shifting on fishing ground, from north coast of Java to southwestern part of Kalimantan during the year 2000 to 2010 (Atmaja and Nugroho 2012).

Size frequency distribution

Size distribution figures of three dominant demersal species (Figure 3) show length frequency distribution of fork length accumulated on a yearly basis. Fish sampled ranged from 7.5-30.0 cmFl for *P. tayenus* 9.0-26 cmFl for *S. taeniopterus* and 5.5-16.0 cmFl for *U. sulphureus* respectively. The figures also indicate mean length of each species were approximately 11.2, 18.9 and 17.1 cmFl. Combining annual trend of catch data (Figure 2) with the size distribution of three dominant species (Figure 3) indicates that the exploitation of the demersal fish biodiversity was dominated by a group of small fish (with estimated maximum size of less than 30 cm).

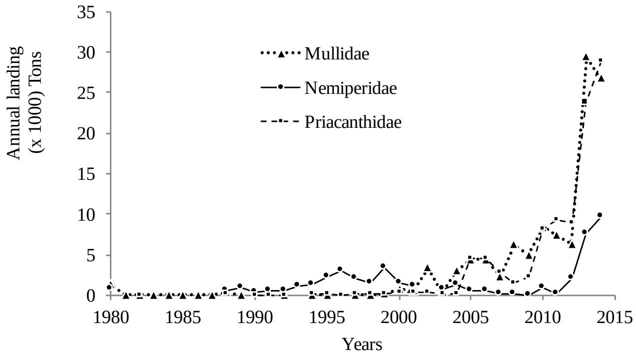

Figure 2. Annual landing of three major group of fish families in Java Sea 1980-2014 (DGF 1980-1999; DGCF 2000-2015)

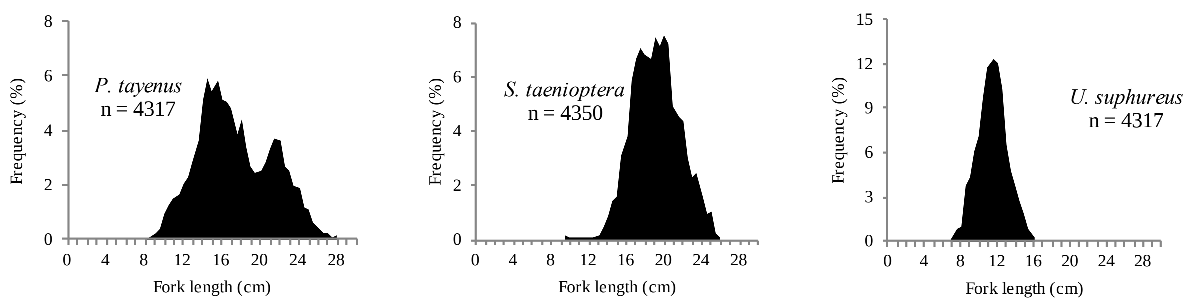

Figure 3. Size distribution of three dominant species (*P. tayenus, S. taenioptera, U. sulphureus*)

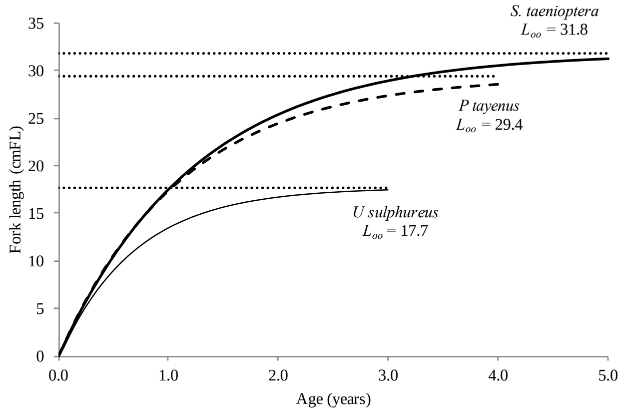

Figure 4. Growth curve of (*P. tayenus, S. taenioptera,* and *U. sulphureus*)

Estimated age at length

The individual growth rate in a population is a critical parameter for understanding the life history of a species and to develop management plans for wild fish populations. Although growth studies based on modal progression analysis have yielded indirect measurements, there are some disadvantages to this approach. This approach, however, has been widely used particularly in tropical waters (Pauly 1983 in Haddon 2011). Estimation of L_{oo} and K is derived from Gulland and Holt plot approach (King 2007). The growth curve is shown in Figure 4 and the parameters were indicated in Table 1.

The estimates growth coefficient (K) and length infinitive ($L\infty$) of three dominant species are 0.89 (*P. tayenus*), 0.799 (*S. taenioptera*) and 1.4388 (*U. Sulphureus*) with each length infinitive ($L\infty$) of 29.4, 31.8 and 17.0. These parameters indicate that all three-major species belonged to fast growing small size (< 30 cm) species.

Estimate Spawning potential ratio (SPR)

The population parameters are the main parameters to estimate SPR. The size of maturity is estimated by the size class, where the second essential data input is when 50% of the stock become mature (L_{50}). This condition needs to be set when the technique is first applied to stock due to limited available data. Through the calculation of the Spawning Potential Ratio (SPR), the present status of the *demersal* fisheries can be determined. The population parameters used for this approach were listed in Table 1.

Applying the equation (3) and (4), the calculated SPR of each species based on the value of the length of the first capture (Lc) of 176 mm for *P tayenus*, 187 mm for *S. taenioptera* and 113 mm for *U. sulphureus*. The preliminary result sets as a precautionary approach to evaluating the stock status. All values resulted equivalent with the SPR of less than 20% (Figure 5) in which 17.5% for *P. tayenus*, 13.2% (*S. taenioptera*) and 11% (*U. sulphureus*). Goodyear (1993) suggests threshold level for the SPR should probably not to be set much below 20% (limited reference point) without considerable justification, and that 30% (target reference point) might be a more reasonable first choice.

Some consideration to define long-term management objectives is values of the fishing level, which allow larger catches in size to ensure conservation of the stocks. The figure shows that the harvesting of all three-fish species is relatively low and below the carrying capacity of the environment or limited reference point (red lines). This strongly relates to the increasing annual amount of landed fish which were at an age before they reached the first maturity. It is important to note as a preliminary assessment which the applied SPR model suggests extremely high exploitation rates occurred in this typical multi-species fishery.

Table 1. Population parameters of *P tayenus, S. taenioptera* and *U. sulphureus*

Parameters	Species		
	P. tayenus	***S. taeniopterus***	***U. sulphureus***
The average length at first mature (L_{50})	194	168	129
The average length at last mature (L_{95})	275	300	170
Intercept (a) on length-weight relationship	3e-05	6e-05	7e-05
Slope (b) on length-weight relationship	2.8335	2.7381	2.7312
Estimate length infinity $L\infty$ (mm)	294	318	177
Estimate length at first capture (Lc) (mm)	176	187	113
Estimate growth rates (K) /yr	0.8952	0.799	1.4388
Theoretical age at zero length (t_0)	-0.76	-0.83	-0.809
Estimate age at first recruitment t_r (year)	0.3	0.45	0.3
Estimate age at first capture ($t_{c)}$ (year)	1	1.6	0.7
Estimated maximum age t_{max} (year)	3.35	3.75	1.78
Estimated natural mortality (M)	1.38	1.25	2.45
Estimated total mortality (Z)	3.23	4.19	5.37
Estimated F/M	1.34	2.35	1.19

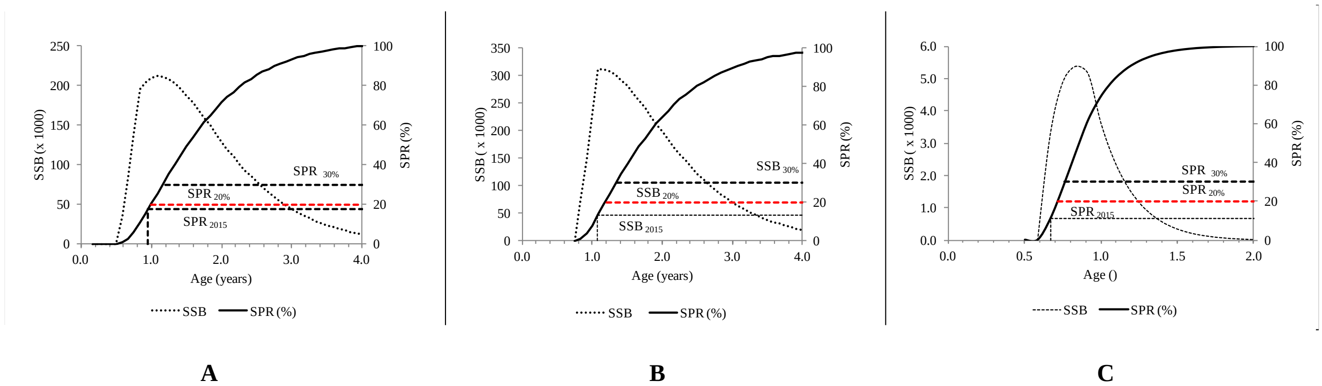

Figure 5. Estimated spawning potential ratio of three dominant species: A= *P. tayenus*, B = *S. taenioptera*, and C = *U. Sulphureus*
Remarks: SPR 30% = target reference point; SPR 20% = limited reference point; SSB = spawning stock biomass estimation; SPR = spawning potential ratio

Discussion

A fundamental goal on sustaining biodiversity as part of conservation biology is to ensure the long-time survival of species in its nature environment (Meffe and Carol 1997; Primack 2006). The growth coefficient of *Upeneus sulphureus* was higher than previously studied (0.78) by Martosubroto (1982), while Badrudin (1978) K at 2.04 and Marzuki et al. (1987) estimate K at 1.76. The K of *Priacanthus tayenus* is also different compared to Prihatiningsih et al. 2013 with a value of 0.91. This different value probably occurred due to uncertainties on the model prediction of length based aging estimation (Pope et al. 2010). Total mortality is derived from the catch-curve model, where the length-based structure is converted to age. If either fishing or natural mortality can be estimated, then the remaining unknown mortality can be determined by subtraction from total mortality. Once fishing mortality and natural mortality have been identified, it can be used to describe the fishing impact towards the stock (Beddington and Kirkwood 2005). Several research findings on the similar fishing situation have pointed out that commercial fisheries reduced target populations, and affected life-history parameters, such as growth rate and age at maturity. Moreover, in extreme circumstances, resulted diminishing local species (Casey and Myers 1998; Pauly et al. 1998). The low SPR for all three species indicates the ability of spawning stock to support their abundance in nature was under their biological capacity to produce the adult groups in their population structures.

Based on the biological parameters estimated for the fishes of the study area, there was a clear indication of r strategist species, characterized by high growth rates (K) and high natural mortality (M), and strongly related to early sexual maturation and low longevity. These parameters could categorize as rapid replacement of generations (Camargo et al. 2015). The relationship between spawning potential and age of the species suggests life-history uncertainty surrounding the status of the stocks, causing overfishing to go incognito until stocks have finally collapsed. To avoid collapsed fishery, increasing the probability size of the first capture of this fishery should be applied to achieve 40% SPR as target reference point. This TRP were emphasized to rebuild predator species or higher trophic level stocks in that has been diminished. This is required to avoid loss capacity on supporting their spawning biomass. In relation to this issue, there are several ministerial regulations on controlling the fishery, e.g. through minimum mesh size available. However, this regulation does not seem to be effective due to low compliance occurred in the area. Even fishing communities want to invest and change their fishing strategies by shifting forward to the fishing ground beyond its provincial jurisdiction. Another strategy is by getting the vessels sail longer by equipping more advanced technology (e.g. frozen fish hold to storage large number of fish). Fishing vessels sized less than 24 m LOA can operate for more than 30 days at sea, under the condition of a minimum catch 10 tons per trip. Fisher's resistance and reluctance due to low awareness of stock status and high demand on market supply play a significant role on this low value of SPR. The extremely low values of the spawning biomass or the fishing level, which might seriously affect the self-rebuilding of the stocks. These fishing level values of catch and biomass are designated as biological reference points (BRP). The target reference points (TRP) are BRP defined as the level of fishing mortality or of the biomass, which permits a long-term sustainable exploitation of the stocks, with the best possible catch. For this reason, these points are also designated as reference points for management (Cadima 2003).

Global biological diversity is rapidly declining as consequence of human activities (Sutherland et al. 2009), and small unassessed fisheries are in substantially worse condition and continue to decline (Costello et al. 2012). Therefore, rebuilding the biodiversity through an effective implementation of conservation and management measures is essential for small-scale fisheries. This is mainly to sustain food and livelihoods for households, particularly in developing countries where other options are often limited for the coastal community. One of major goals of fishery management is conserving resource base. This means that the productivity of the population in term of recruitment overfishing should be prevented. States of the art of biodiversity bottom fish to its long-term exploitation in the tropical waters were still needed to be observed so far. The biological indication on declining fish stocks should become one of the principal concerns of fisheries management in the area. Moreover, the conservation and sustainable use of marine resources are two main highlighted goals on sustaining this demersal fishery. This water requires crucial concern given the substantial economic contribution and significant dependence of small-scale fishers for their livelihoods.

Saving in some fish caught is not directly related to improvement in static SPR. Theoretically, large number of fish would be saved by increasing average size at first capture from 17.6 to 19.5 cm FL for *P. tayenus*, 18.7 to 21.4 cm FL for *S. taenioptera* and 11.3 to 12.5 cm FL for *U. sulphureus*. Applying size limit on saving small fish seems to provide relatively small gains in static SPR. Conversely, limiting catch limit would theoretically produce greater gain than the increasing minimum size limit. Saving more fish in the sea imply less pressure and greater gain for the stocks. This is because the probability of survival mature fish is higher for fish that already survived from the impact of fishing and it would reduce fish mortality, mainly to matured fish to accomplish greater mature biomass. Declining population sizes of several commercially exploited fish species have led to concerns about threats of extinction. However, the extent to which marine fish is threatened by extinction is still debatable, as it is often assumed that the subject in question is naturally resilient to extinction due to high fecundity, wide distribution and high natural variability in abundance (Butterworth 2000).

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