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Research Article

Length based spawning potential ratio (LBSPR) of javelin grunter, *Pomadasys kaakan* (Cuvier, 1830) in the Persian Gulf and Oman Sea

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Abstract

Length-Based Spawning Potential Ratio (LB-SPR) model was applied to describe the status of Javelin grunter, *Pomadasys kaakan* in the Persian Gulf and Oman Sea. From April 2002 to March 2019. 45,489 specimens were collected from fish landing sites monthly, and their length (FL) and weight were measured. The results of the present study showed that different gears captured most of the *P. kaakan* before first spawning time. The maximum-recorded length for this species in the study area was 60 cm FL with a mean length of 43.0±4.73 cm. The M/K value corresponds to *P. kaakan* maturation was calculated as 0.53. Based on the LB-SPR assessment model, it could be concluded that these species become vulnerable to fishing at its maturation' size (48 cm). The range of annual SPR of *P. kaakan* was estimated between 0.14 to 0.18 in the Persian Gulf and Oman Sea (Iranian waters), which is even lower than the threshold value of 0.2. Such results suggest that the exploitation of *P. kaakan* occurred above the maximum sustainable limit and has a confounding effect on successful recruitment and juvenile survival of this species. The Spawning Potential Ratio of *P. kaakan* based on time series analysis, as a biological reference point was estimated below 0.2, which means for achieving a higher SPR level and sustainable fisheries, the rate of fishing mortality should be reduced constantly.

Keywords: Length frequency, Sustainability, Spawning Potential Ratio, *Pomadasys kaakan*, Persian Gulf, Oman Sea

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Introduction

The Persian Gulf and Oman Sea fisheries are a combination of industrial and small-scale fisheries with property multispecies and multi gear (Morgan, 2004). The major fishing gears using in the Persian Gulf and Oman Sea are drift gillnet with dissimilar mesh sizes selecting both juveniles and adult fish from demersal and pelagic species, bottom trawl for shrimp and fish, wired traps targeting demersal species, and different hooks and lines (including hand lines, set and drifting longlines, trolling).

The Haemulidae is one of the most abundant fish families along the Persian Gulf and Oman Sea (Asadi and Dehghani, 1996; Al-Husaini *et al.*, 2002; Valinassab *et al.*, 2013), among this family, *P. kaakan* species that is widely found in coastal warm tropical waters considered as one of the most abundant commercial fish in the Persian Gulf and Oman Sea. In 2019, landings of species belonging to Haemulidae family constituted about 1.37% of the total landings in the study area. Over the last two decades, the catch rate for these species group has increased by approximately 60%, which was mainly due to high fishing effort, and high market value of this family. According to Valinassab *et al.* (2013, 2019), the mean CPUA of *P. kaakan* species in different depth layers of the Persian Gulf and Oman Sea has been decreased from 6408.13 kg/nm^2 in 2008 to 1929.24 kg/nm^2 in 2019. Fisheries in the coastal area of the Persian Gulf and Oman Sea are targeting demersal species, as a consequences during the past decade, the catches of some commercially important species substantially decreased (Taghavimotlagh *et al.*, 2014, 2019). According to Morgan (2004), it has been speculated that decline in demersal fish stocks in the Persian Gulf and Oman Sea region is related to nursery habitat destruction as a result of large-scale reclamation and coastal development projects carried out in the various countries and prevalence of illegal, unreported and unregulated (IUU) fishing activities.

The monitoring, control, and surveillance activities in fisheries have been implemented as a part of the code of conduct for responsible fisheries program since 1999 in the studied area (FAO, 1999). Nevertheless, high human population density in the coastal areas, the prevalence of trawl fishing, illegal, unreported, and unregulated (IUU) fishing activities have been progressively forced on fisheries systems in the region (Taghavimotlagh *et al.*, 2021). As a result of fishing pressure, the structure of fish populations and communities is altered, which may change the trophic structure and ecosystem level (Essington *et al.*, 2006).

Fish stock assessment is the scientific approach used to advise fisheries managers to avoid stock depletion and to optimize catches (yields). Conventional stock assessment models, however, require large amounts of data, including a time-series of historical catch and effort data, which do not exist for many exploited species (Dowling *et al.,* 2019; Halim *et al.,* 2019). Hence there have been developments in methods of assessment which could utilize available data to advise on those stocks where conventional assessment methods practically are not able; the data-limited stocks (Lart, 2019). Therefore, a suite of reference points based on relatively easily collectible data, like catch, CPUE, and length distributions of the catches have been developed.

The Iranian Fisheries Organization has been taken an effective effort to collect length frequency data of some commercial species, therefore by collected length-frequency data of *P. kaakan* during past decades, Length-Based Spawning Potential Ratio (LB-SPR) model was applied to describe the stock status of this species and give possible management advice to fishery managers for sustainable exploitation of this resource.

Materials and methods

Sampling

Iranian coastal areas of the Persian Gulf and Oman Sea cover approximately 251,000 km^2 extending from the intertidal zone to the 50-m isobaths contour (Fig. 1).

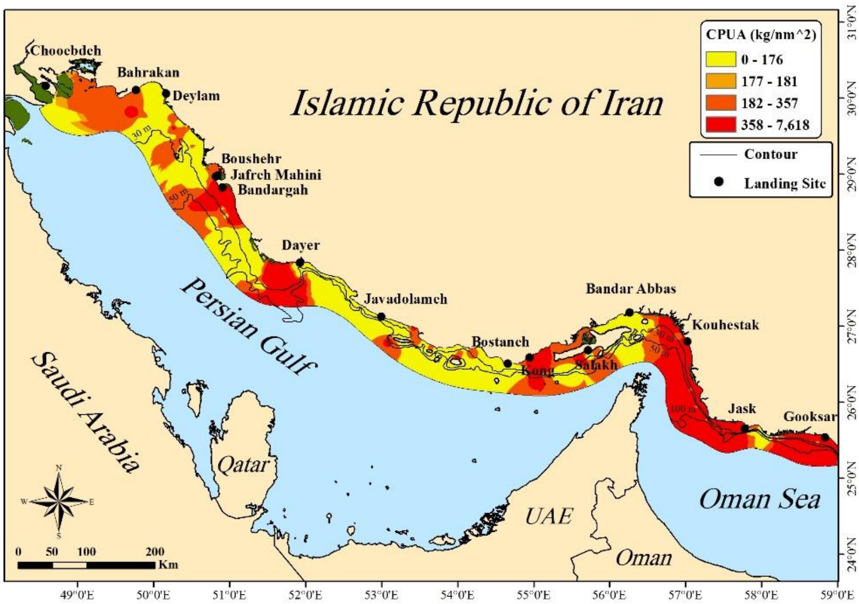

Figure 1: Map of the study area, showing the Landing sites (where data collected) and distribution of the Haemulids species in the Northern part of the Persian Gulf and Oman Sea (2017-18).

The Haemulidae family has a broad geographic distribution in tropical and subtropical waters around the world, Figure 1 illustrated the catch per unit area (CPUA) and distribution of the Haemulidae family in the coastal area of the Persian Gulf and Oman Sea (Valinassab *et al.,* 2019). To conduct the present study a total of 45,489 specimens of *P. kaakan*, have been collected monthly during the past 17 years, from April 2002 to March 2019 from the Iranian coastal waters of the Persian Gulf and Oman Sea, However, only the data for 2019, were used to estimate growth parameters, fishing mortalities, and maturation stages. Samples have been collected from different fishing methods including drift gillnet, trap (locally called Gargor), and trawl.

According to the sampling design, the fork length and weight of each specimen have been measured to the nearest 1 cm and 0.1 g and gonad weight (GW) with an accuracy of 0.01 g. Altogether, 435 specimens were determined by macroscopic examination of the gonads in the laboratory. The maturity stages of females were assigned macroscopically (Nikolsky and Birkett, 1963).

Life history estimation

Running the model based on different gear types would violate the assumption that the length data was representative of the exploited stock (Prince *et al.*, 2015a), therefore, the data collected from different gears were combined.

TropFishR (Mildenberger *et al.*, 2017), an R package ver. 3.5.1 for tropical fisheries analysis was used to estimate growth and mortality parameters. TropFishR has enhanced functions of the FAO-ICLARM Stock Assessment Tools , FISAT II (Gayanilo *et al.*, 2005). The bootstrapped ELEFAN with Simulated annealing (ELEFAN_SA) function was used for estimation growth parameters, L∞ and K of the von Bertalanffy equation (Mildenberger *et al.*, 2017) as follows (Sparre and Venema, 1992):

$$L_t = L_\infty^{\,(1 - e^{-k\,(t - t0)})}$$

Where L_t is the length at time t, L∞ the asymptotic size, k the instantaneous growth coefficient and t_0 the hypothetical time at which length is equal to zero. The instantaneous total mortality coefficient (Z) was estimated using Powell-Wetherall method ($\bar{L}$)=a+b Ĺ, where the $\bar{L}$ is the mean length and Ĺ is the lowest length class of the samples. The ratio of total mortality to Von Bertalanffy growth coefficient Z/K could be calculated from, Z/K= -1-a/b equation. This method allows estimation of L∞ and Z/K from a sample representing a steady-state population, as can be approximated by pooling a time series of length-frequency data (Pauly, 1990). Natural mortality (M) is one of the essential parameters of life history. The rate of natural mortality (M) was estimated according to the empirical equation as "Pauly_Linf" function (Pauly, 1990). Following the calculation of Z and M, fishing mortality (F) was estimated using the functions: Z= F + M.

The size of maturity schedule specified in terms of L50% and L95%, the size at which 50% and 95% of a population mature (Hordyk *et al.*, 2015b; Prince *et al.*, 2015b).

The size at first sexual maturity (is denoted as ‘Lm50’) at which 50% of all fish sampled are at the relevant maturity stage (III, IV, and V) was calculated using following equation:

$$P = \frac{1}{1+e^{-(a+b*L)}}$$

Where P is the percentage of mature individuals as a function of size class (FL) (Pope *et al*., 2010).

Spawning potential ratio (SPR)

Spawning Potential Ratio (SPR) is one of the biological reference points, which estimates the proportion of the unfished reproductive potential left at any given level of fishing pressure. SPR 20% is called as limit reference point and SPR 40% as a target reference point (Bunnell and Miller, 2005; Kilduff *et al.,* 2009; Hordyk *et al.,* 2015a). Estimating SPR needs parameters of life history. The SPR was defined as:

$$\text{SPR}=\frac{\sum(1-LX)^{(M/K)[(F/M)+1])}L_x^b}{\sum(1-L_X)^{M/K}L_x^b},$$

Where, Lx is fork length; M is natural mortality; k is growth rate; F is fishing mortality, and b is exponent usually close to 3. Estimating SPR with those functions need the simple assumptions of asymptotic or logistic selectivity and no variation in length at age. F/M ratio can be estimated from the length composition of the catch (Hordyk *et al.*, 2015b). The relationship between F/M and SPR is asymptotic and determined by the selectivity parameters.

The LB-SPR model uses maximum likelihood methods to estimate simultaneously the selectivity ogive, which is assumed a logistic curve defined by the selectivity-at-length parameters SL50 and SL95, and the relative fishing mortality (F/M), which are used to calculate the SPR. The LB-SPR analyses were completed using the LB-SPR R package (Carruthers and Hordyk, 2018).

Results

The data of length and weight measurements, which have been collected through catch monitoring scheme in the Persian Gulf and Oman Sea were used to apply LB-SPR, to examine the status of *P. kaakan* in the region. The growth parameters and fishing mortalities estimated for *P. kaakan* presented in Table 1. Size at 50% and 95% maturity were estimated to be 48 and 65 cm respectively. Life history ratios (M/K and Lm/L∞) were calculated as 1.2 and 0.64. The relative size at first maturity was estimated: Lm50= 48 cm. From all the parameters SPR then estimated ranged between 14-18.

Table 1: Estimation of growth parameters and mortality rates used as an input to assess *P. kaakan* in the Persian Gulf and Oman Sea.

L∞ = 75 cm	CV∞ = 0.1	W_{max} = 3800 g
Lm50 = 48	M = 0.4 - 0.7	F/M = 1.5
Lm 95 = 65	K = 0.34 per year SPR = 14-18%	M/K= 1.42

Length-frequency distributions by year with their corresponding LB-SPR model fits with a modal length of 40-50 cm are presented in Figure 2. *P. kaakan* is long-lived species and it is clear from length frequency distribution that gears are selective. Figure 3 demonstrates the trend of mean size (FL) of *P. kaakan* catches by different gears, the sizes of fish harvested with wired trap and trawling ranged from 12 to over 60 cm, whereas drift gillnet caught fish ranged between 20 and 58 cm.

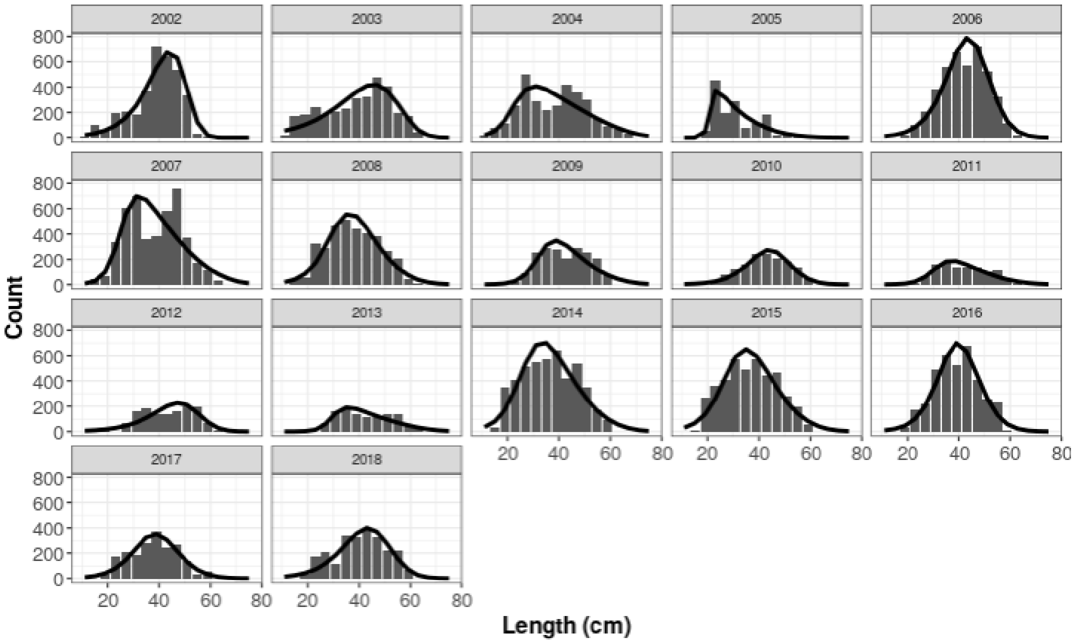

Figure 2: Length frequency distributions for *P. kaakan* with curves fitted by LB- SPR assessment.

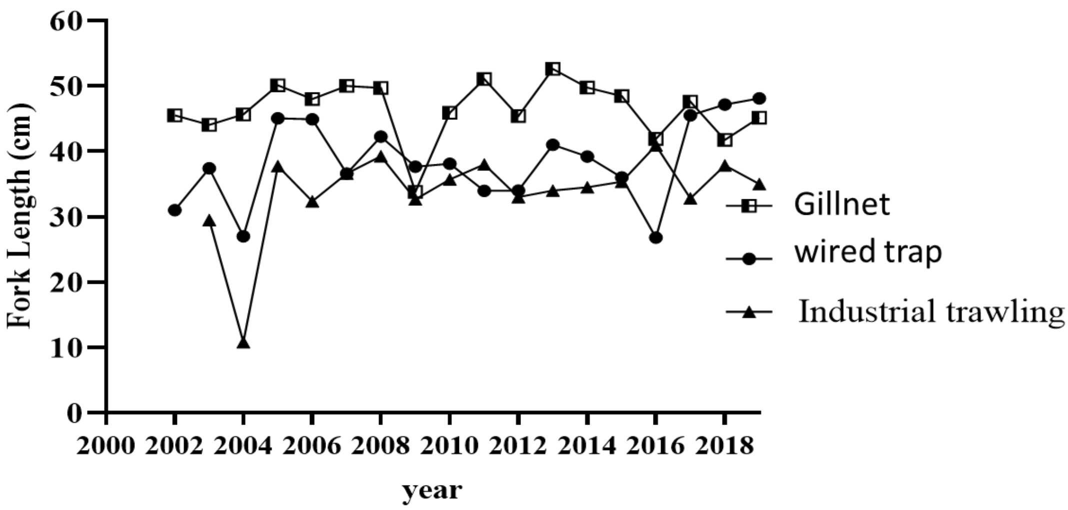

Figure 3: The mean size (FL) of *P. kaakan* taken by different gears.

Figure 4a, shows, that most of the *P. kaakan* is caught before the first sexual maturation and spawning. Furthermore, displayed the expected size structure of the catch and the expected unfished size structure of the vulnerable *P. kaakan* population (Fig 4a). Red bars represent the current scenario and indicate the frequency of observed length with a modeled spawning potential ratio below 20%. Green bars indicate the simulated target length-frequency distribution of a population with a 40% spawning potential ratio. The current harvest pattern results in a lower spawning potential ratio than the ecological target of 40%. Maturity and selectivity curve modeled based on *P. kaakan* length-based data from seventeen years data was shown in Fig 4b. Analysis of length frequency of *P. kaakan* for 17 years, indicated most of this species have been harvested before the size of its first maturity. In addition, Figures 4c-d demonstrated that most of the fishes were caught before they reach their spawning time.

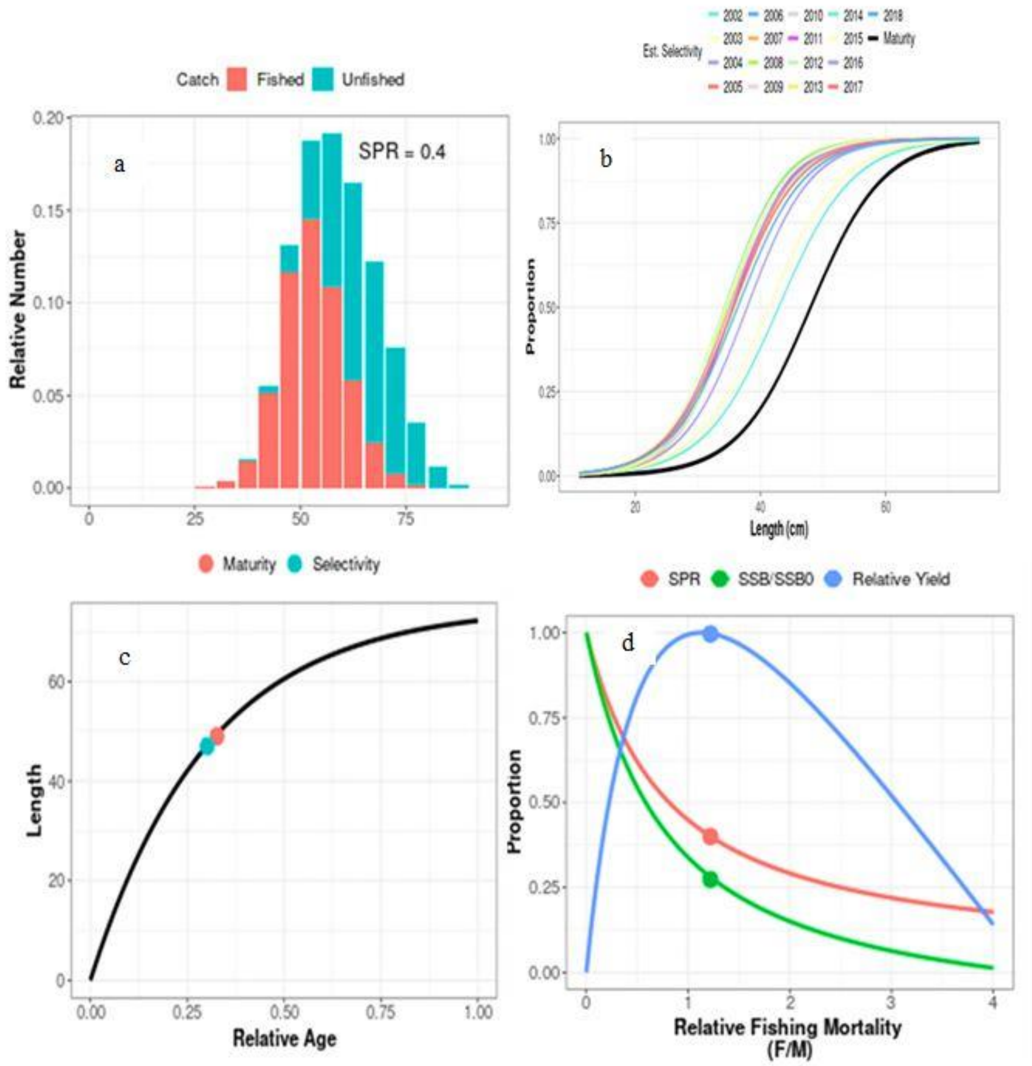

Figure 4: Output from the length-based SPR assessment software for *P. kaakan*. a) the expected (equilibrium) size structure of the catch and the expected unfished size structure of the vulnerable population, b) the maturity and selectivity-at-length curves, c) the growth curve with relative age, and d) the SPR and relative yield curves as a function of relative fishing mortality.

The M/k value for *P. kaakan* was M/k >0.53, which means all specimens, are mature with the length composition consisting of widely varying age and near asymptotic size. Current fishing pressure was F/M=1.5, it is more than slightly upper the level likely to produce the maximum sustainable yield.

The specific estimated parameters SL50, SL95, F/M ratio, and SPR by year are presented in Figure 5. The estimated value of SPR based on length-frequency by year was lower than 20%.

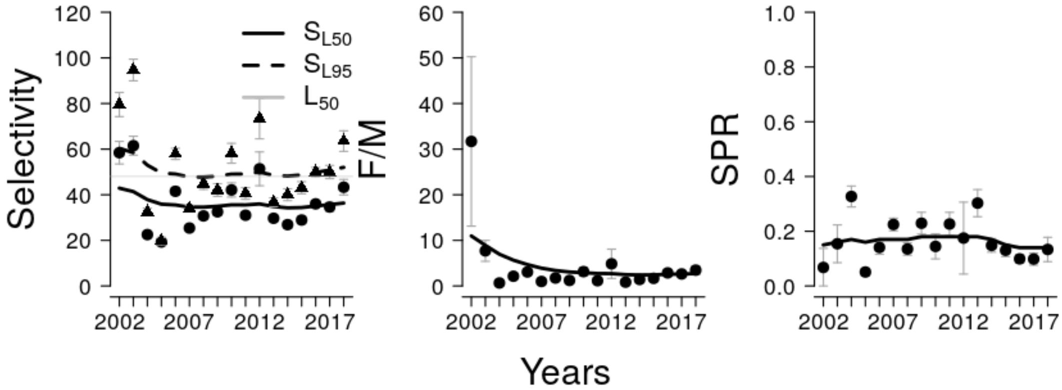

Figure 5: Visual display of estimated quantities (SPR, S50, S95, and F/M). The black line corresponds to the smoother line to the estimated points.

Discussion

The present study makes use of the first application of the LB-SPR approach advanced by Hordyk *et al.* (2015b) to develop an assessment of SPR in a small-scale and data-poor fishery with prominence on the *P. kaakan* as an economic importance to fisheries in the Persian Gulf and Oman Sea. Given the high diversity of fisheries resources and their economic importance for the livelihood of the people living in the coastal areas of the Persian Gulf and Oman Sea, this technique provides insights on the species vulnerability to exploitation and status of a small-scale fishery.

Significantly, around 20% of SPR fish population can still stabilize under fishing pressure, but are unable to rebuild over time, as there is only enough spawning potential to replace the existing adults, but not enough to grow the population, as well as, this level of SPR is called the ‘replacement level’ because it is sufficient to replace existing adults. Below 20% SPR, it is expected long-term declines in population to occur because the fishes are not allowed to fulfill enough of their potential for reproduction, before being caught, to replace themselves (Prince, 2017).

The current results suggest that relative fishing mortality (F/M=1.5) for this species is intense and should be lowered to achieve a level of stability. As Hordyk *et al*. (2015a) pointed out , the relative effort at levels of F/M>1 would lead to a sharp decrease in SPR, relative yield and the spawning stock biomass (SSB) for all the species. The relevance of the ratio F/M=1.5 and decreasing of mean size (FL) from 52.9 cm in 2014 to 48.0 cm in 2017 is also an indication of fishing pressure on this stock. Therefore, implementing size-based regulation in place could prevent the landings of under-sized fish.

The length-frequency distribution of the *P. kaakan* showed little variation over the sampling period, which is related to nonselective fishing gears in some years of sampling, the size structure of the catch was skewed toward smaller size classes (FL<20 cm) with a higher proportion of immature individuals L50=47 cm (FL) . This seems to be a clear indication of likely unsustainable fishing mostly targeting juveniles. This finding concurs with results from other studies in the Persian Gulf, which concluded that overfishing is affecting almost half of all bony fish species and threatened extinction of 8.2 percent of the bony fish which is twice that of the world average (Buchanan *et al.,* 2019).

Size-related measures (e.g., mean length or weight; length compositions) have long been used as indicators of response to population decline (Beverton and Holt, 1959; Cope and Punt, 2009). Wired trap , trawl and drift-gillnet are the main methods of catching some of the overexploited species living close to the seafloor in the Persian Gulf and Oman Sea and involved for being non-selective, since they catch a wide range of length, including non-target fish (Hicks and McClanahan, 2012). Based on Figure 3, the fish fork length caught by traps and trawls ranged from 12 to over 60 cm, whereas drift gillnet caught fish ranged from 20 to 58 cm. The size frequency distribution of different gears shows that 34% of the catch was above length at first maturity for drift gillnet, 24% for wire trap and 10% for trawl. These findings suggest that in general, *P. kaakan* stock is caught after recruitment in the fishing ground and the proportion of large-sized (>60 cm) “mega-spawners” is low in the catch composition.

However, Hommik *et al.* (2020) point out that the estimates of SPR were interpreted concerning good state reference points and expert knowledge of each respective fishery. The threshold value of SPR noted by Goodyear (1993) of SPR=0.20 is considered to be the limit reference point above which stocks maintain acceptable productivity and SPR=0.40 is widely recognized as an MSY proxy under national fisheries law (Mace, 1994). The range of annual SPR, of *P. kaakan* estimated to be between 0.14 to 0.18 in the Persian Gulf and Oman Sea (Iranian waters), which is even lower than the threshold value noted by Goodyear (1993). Such results suggest that the exploitation of *P. kaakan* occurred above the maximum sustainable limit and has a confounding effect on successful recruitment and juvenile survival of this species in the Persian Gulf and Oman Sea. The mean length of the *P. kaakan* estimated by Fakhri *et al.* (2011) with our findings showed a difference which might be related to sampling method . The result of M/K value (1.42) is in accordant with (Al-Husaini *et al.*, 2002; Fakhri *et al.*, 2011), both studies were based on total length. Fakhri *et al.* (2011) concluded that this species moderately exploited, our finding implies that this species during the past years after 2012 are under fishing pressure, which resulted in altering the structure of its community.

In conclusion, SPR as one of the biological reference points can be used to determine the stock status for many species in the Persian Gulf and Oman Sea. The value of the Spawning Potential Ratio (SPR) of *P. kaakan* in the study area for the last two decades estimated to be less than 20% (limit reference point) which dictated that the fishing pressure for this species should be decreased. The results also indicated that high number of juveniles of *P. kaakan* have been caught by multi-gears before sexual maturity in the Persian Gulf and Oman Sea.

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