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Research Article

Population dynamic of skinnycheek lanternfish *Benthosema pterotum* (Alcock, 1890) in the Oman Sea

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Abstract

Population dynamics of skinnycheek lanternfish, *Benthosema pterotum* (Alcock, 1890), were studied in the Oman Sea from January to December 2019. A total of 2893 individuals were sampled from the commercial catch of bottom trawlers in the Oman Sea. The total length (TL) ranged from 21-60 mm and the average length was 39.4±4.64 mm. More than 84% of the samples were between 33-45 mm TL. The length-weight relationship was obtained TW=0.00008 TL $^{2.38}$ and showed negative allometric growth. The asymptotic length (L_{oo}) and growth coefficient (K) were estimated at 63 mm and 1.6 per year, respectively. In addition, t_{max} and t_0 were calculated at 1.73 and -0.15 year, respectively. The von Bertalanffy growth equation was calculated as L_t=63 (1 – e $^{-1.6(t+0.15)}$). The coefficients of total mortality (Z), instantaneous natural mortality (M), and fishing mortality (F) rates were estimated as 6.65 per year, 2.62 per year, and 4.03 per year, respectively. Size at first capture (L_c) was estimated at 35.67 mm (TL). The current rate of exploitation (*E*) was given as 0.6 and therefore, the values of exploitation ratio were reasonable for the current fishing effort.

Keywords: *Benthosema pterotum*, Growth parameters, Mortality rates, Lanternfish, Oman Sea

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Introduction

Increasing the proportion of conventional fish stocks has reached a state of full exploitation or even over-exploitation, and the search for new fishery resources has been intensified. It was assumed that krill, cephalopods, and mesopelagic fish are the most promising potential resources (Gulland, 1971; Okutani, 1977). A fish species can be called mesopelagic if it spends the day in the mesopelagic zone. They are small and usually found at depths between 100 to 1000 m. mesopelagic fishes play an important trophic role in the open ocean as well as close to steep slopes. Myctophids (lanternfish) account for 75% of mesopelagic fish biomass caught by trawling and the majority of them are larvae and/or juveniles (Moser and Watson, 2006). Myctophids, in particular, display a high diversity that can be used as an indicator of the biogeographic distinctness of a specific area (Wienerroither, 2003). Myctophid distributions are circumglobal and are found in all oceans except the Arctic and estimated global biomass by trawling method is about 550-600 million metric tons (Gjosaeter and Kawaguchi**,** 1980**)**. *Benthosema pterotum* is the most common and numerous myctophids species in the western (Gulf of Oman-Somali region) and the eastern (along the west coast of India) Arabian Sea and is the largest single species stock of fish in the world (Valinassab *et al.*, 2007; Karuppasamy *et al*., 2008a). According to echo sounder records *Benthosema pterotum* aggregates in compact layers especially during the daytime (Karuppasamy *et al*., 2008b). Based on the literature on aging studies, it is found that myctophids are fast-growing (Childress *et al*., 1980; Hosseini-Shekarabi *et al*., 2015), have relatively short life span, and high mortality rates. Growth studies of myctophids based on otolith microstructure were carried out by Gjosaeter *et al*. (1984), Prut'ko (1987), Gartner (1991), and Nishimura *et al*., (1999). Comprehensive data on the life history of any mesopelagic species is scarce. Age and growth are known for some of the more important cold-water species but only tentative information is available on tropical ones. Length distributions have been reported for several mesopelagic fish (*e.g*. Gibbs *et al*., 1971; Krueger, 1972; Goodyear *et al*., 1972; Clarke, 1973; Hosseini-Shekarabi *et al*., 2015). Gjosaeter (1978b) studied aspects of the life history of the two dominant species from the Arabian Sea, *Benthosema pterotum* and *B. fibulatum.*

B. glaciale is one of the best known mesopelagic fish species as far as life history is concerned (Halliday, 1970; Gjosaeter, 1973, 1978). *Notoscopelus kroeyeri* and *Maurolicus muelleri* were studied by Gjosaeter (1978a). Aspects of the life history of Cyclothone have been studied by Badcock and Merrett (1976). The length-weight relationship equation, commercial importance, and bycatch species composition of *Benthosema pterotum* were studied in the Iranian waters of the Oman Sea (Johannesson and Valinassab, 1994; Valinassab *et al*., 2007; Kiaalvandi *et al.*, 2012; Vizvari *et al*., 2017). We analyzed the length frequency data of *Benthosema pterotum* to obtain growth and mortality parameters for better understanding the stock condition in the north western of the Oman Sea.

Materials and methods

Region and sampling

Sampling was carried out by fishing vessel 'Zist-Keyhan 5' a stern bottom trawler net (cod-end mesh size 10mm) from January to December 2019. The sampling field was a myctophids fishing ground in the Northwest of the Oman Sea coordinated 57°00E to 58°30E with depths more than 200m and 12 nautical mile distance from the baseline coast (Fig. 1). A total of 240 individuals were collected using random sampling monthly. The lengths and weights of fishes were measured to the nearest 1mm and 0.01 g.

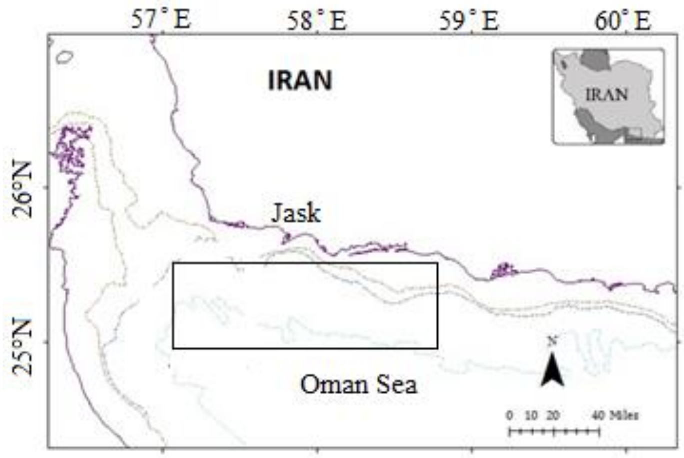

Figure 1: The map of sampling region in the Oman Sea (2019).

Population dynamics

Length-weight relationship

The relationship between total length and total weight was obtained by the power equation below:

$W=a.L^b$

Where W: total body weight (g), L: total length (mm), *a* and *b* are coefficients of the functional regression between W and L (Ricker, 1973).

If calculated *b* from equation power has a significance difference with 3, growth is allometric and otherwise, growth is isometric. The t-student test was used to determine the difference between calculated *b* and 3(Pauly, 1984).

$$t = \frac{s.d(\ln L)}{s.d\ (\ln W)} \times \frac{|b-3|}{\sqrt{1-r^2}} \times \sqrt{n-2}$$

Where, s.d (lnL) is the standard deviation of total lengths, log s.d (lnW) is the standard deviation of total weights log, r is identification coefficient between total length and total weight in equation power, *b* is power in L-W equation, and *n* is the number of samples.

Estimation of growth parameters

Length–frequency data were constructed using 3-mm length intervals (Sturges, 1926). Growth rates were calculated using the von Bertalanffy equation:

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

Where Lt is the length of the fish (mm) at age t (year), L_∞ is the asymptotic length (mm), k is the constant growth rate ($year^{-1}$), and t_0 (year) is the nominal age at which fish length is considered to be zero. The k constant was calculated in the FISAT II software using the ELEFAN I routine (Pauly and David, 1981), which uses the modal displacement of length classes time series to provide an index of growth rates for different age classes. For the calculation of theoretical age at length zeros (t_0) we used the Pauly's empirical formula (Pauly, 1979):

$$\text{Log}(-t_0) = -0.3922 - 0.2752\ \text{Log}(L_\infty) - 1.038\ \text{Log}(K)$$

A comparison of the growth performances of fishes was made, using a growth performance index($\acute{\emptyset}$) (Pauly and Munro, 1984):

$$\acute{\emptyset} = \text{Log}10\, K + 2\, \text{Log}10\, L\infty$$

Estimate of the maximum age of individuals in the populations was calculated from the below equation (Pauly, 1984): $t_{max} = t_0 + (3/K)$

Estimation of mortality

Mortality (95% confidence limit) was calculated from ELEFAN using the length-converted catch curve method (Sparre and Venema, 1992). The output is Z/K: thus, Z can be estimated using the estimated K from the von Bertalanffy growth equation (VBGE):

$$\text{Ln}[N/dt] = a - Zt$$

Natural mortality was estimated from the Pauly empirical equation. According to the schooling behavior of these fishes, the M multiplied by 0.8. (Pauly, 1980).

$$\log(M) = -0.0066 - 0.279\log(L_{oo}) + 0.6543\log(K) + 0.4634\log(T)$$

Where, M is natural mortality per year, K is the intrinsic growth rate per year, T is the annual environmental mean temperature as 21C° (Ebrahimi, *et. al.*, 2005). F is the fishing mortality estimated from the formula:

$$F = Z - M$$

Where, Z is the total mortality rate and $E = F/Z$ where E is the exploitation rate (Sparre and Venema, 1992).

Catch probability at length groups

The probability of capture was worked out using FiSAT II software (Gayanilo and Pauly, 1996).

Results

A total of 2893 individuals were sampled and used for population analysis. Total length ranged from 21-60 mm with an average length of 39.4 mm. More than 84% of the samples were between 33-45 mm TL (Fig. 2). Monthly total length changes showed that October and February had the minimum and maximum mean lengths of 35.31 and 43.41 mm, respectively (Table 1).

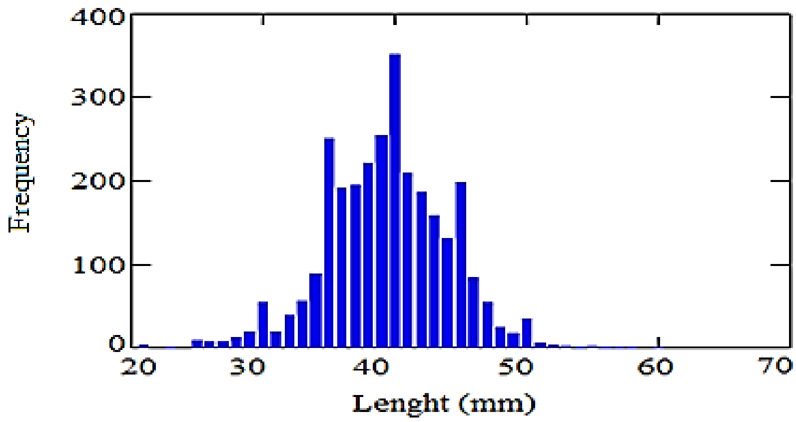

Figure 2: Length–frequency of *Benthosema pterotum* in the Oman Sea (2019).

Table 1: descriptive statistics of *Benthosema pterotum* total length in the Oman Sea (2019).

Month	N	Length range(mm)	Mean (mm)	S.d
Jan	245	25-50	39.65	4.96
Feb	260	32-57	41.43	3.91
Mar	250	21-47	37.28	4.09
Apr	250	21-53	40.31	4.13
May	249	23-51	39.93	4.21
Jun	300	25-50	38.62	4.34
Jul	300	25-50	39.14	4.41
Aug	173	25-52	39.16	5.46
Sep	186	25-46	37.42	4.28
Oct	201	27-45	35.31	4
Nov	250	30-49	40.15	3.29
Dec	229	25-60	41.06	6.19

Population dynamics

Length- weight relationship

The relationship between length (mm) and weight (g) was estimated for 206 specimens (both sexes) as $W= 0.00008L^{2.379}$ (Fig. 3). The calculated t was equal to 10.94 and the number of t table probabilities was 1.96, then there was a significant difference between calculated t and t table probabilities ($p<0.05$), so the growth of this species was identified as allometric.

Growth parameters

The values of L_∞ and K were 63 mm and 1.6 per year, respectively. The values of t_0 and t_{max} were -0.15 and 1.73 year, respectively. The Ǿ value was calculated at 3.8. The result of length-age showed that skinycheek lantern fish has a rapid growth in the first months of life (Figs. 4-5). Von Bertalanffy's plot for this species was as below:

$$L_t = 63 (1 - e^{-1.6(t+0.15)})$$

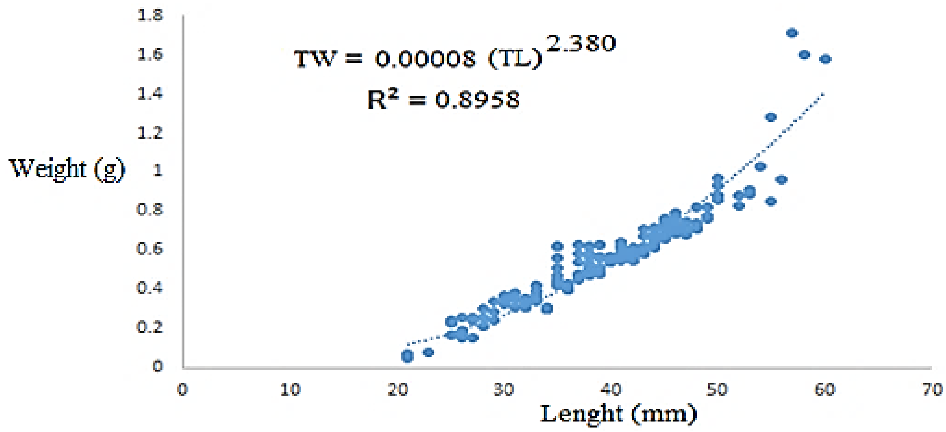

Figure 3: The length-weight relationship plot of *Benthosema pterotum* in the Oman Sea (2019).

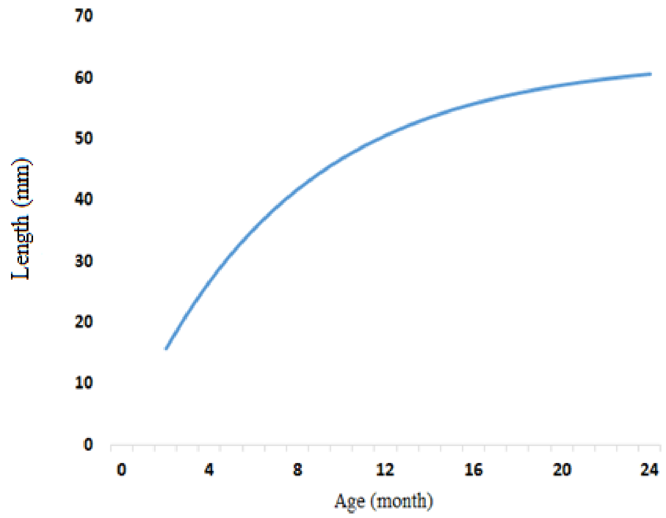

Figure 4: The length-age plot of *Benthosema pterotum* in the Oman Sea (2019).

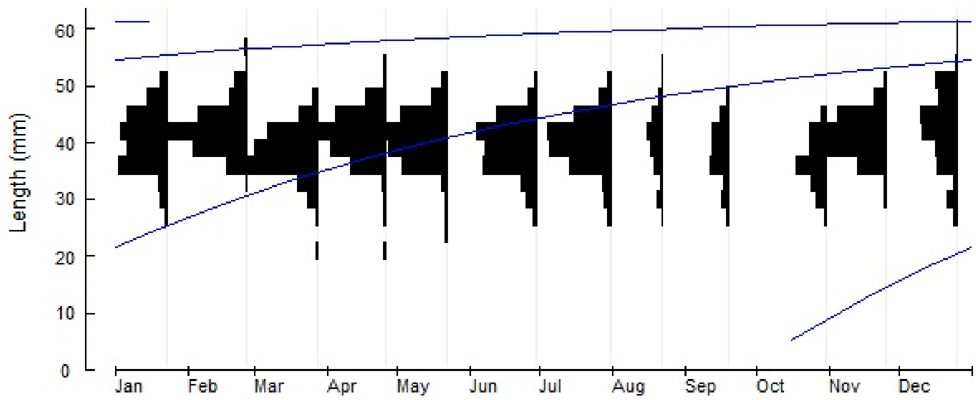

Figure 5: The growth curve plot of *Benthosema pterotum* in the Oman Sea (2019).

Mortality

Total mortality (Z) (95% confidence limit), calculated from the length converted catch curves, was 6.65 per year, the fishing mortality (F), was 4.03 per year and natural mortality (M) was estimated at 2.62 per year. The exploitation ratio (E=F/Z) was 0.60.

Catch probability at length groups

The capture probabilities curve at values L_{25}, L_{50} and L_{75} were estimated 33.26, 35.67, and 37.15 mm, respectively (Fig. 6).

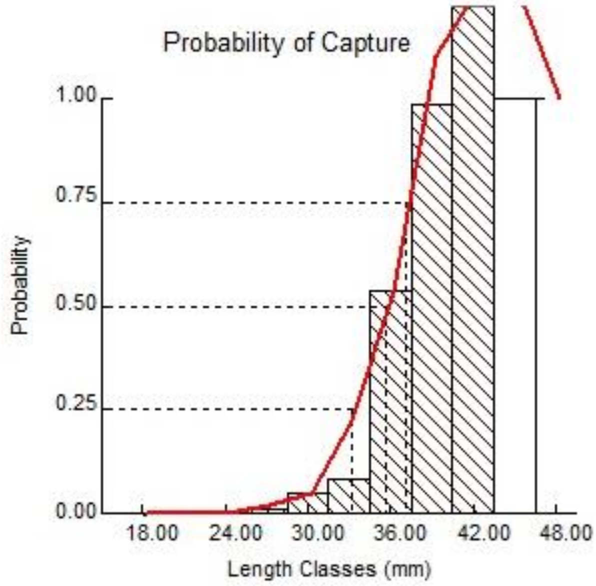

Figure 6: The capture probabilities curve of *Benthosema pterotum* in the Oman Sea (2019).

Discussion

In the present study, the range of total length was recorded from 21 to 60 mm. The mean length and weight of this species were reported 37.8 mm and 0.43 g with ranges from 10-58 mm and 0.03-0.94 g, respectively in the Oman Sea (Johannesson and Valinassab, 1994). They recorded the average of length as 42.7 mm which coincides with the spawning period. The maximum length of *B. pterotum* was reported 56 mm in eastern Arabian Sea (Karuppasamy *et al.* 2008a), while we obtained a maximum length of 60 mm. The power length-weight relationship helped us to estimate weight by using length. Usually, the *b* values in this equation ranged between 2 to 4 (Weatherley, 1972). Vizvari *et al* (2017) obtained length-weight relationship for this species in the Oman Sea and reported allometric growth for juveniles and isometric growth for adults; moreover, they suggested when the total length was more than 46 mm the value of *b* increased significantly. Our results showed an allometric growth for this species. *A* and *b* values of length-weight power equation were reported as 0.0000059 and 3.05, respectively (Johannesson and Valinassab, 1994). In the present study *b* value was obtained as 2.38. Differences in *a* and *b* values can be related to environmental condition changes, physiology of fishes, evolution of gonads, time and method of sampling and sex (Pitcher, 2002). The K and L_∞ values for non-tropical mesopelagic fishes were reported from 0.11-1.05 per year and 49 –119 mm (Gjosaeter and Kawaguchi, 1980). Based on a new method of age determination, values of the growth curve were calculated, K from 1.8 to 5.62 per year and (L∞) values from 68 to 77 mm (Gjosaeter and Blindheim, 1978). In the present study, K was obtained 1.6 per year and L∞ was estimated 63 mm (TL). The K and L∞ were obtained 1.81 per year and 68 mm in the Arabian Sea, respectively (Gjosaeter, 1978). Indeed, the rapid growth at the first stages of life in aquatic animals is a kind of strategy versus preying by larger animals (Begg and Sellin, 1998), therefore, the rapid growth of *Benthosema pterotum* at the first stages of their life cycle can be explained by this strategy and furthermore reaches as early as possible to sexual maturity. Generally, it seems that mesopelagic fish from cold waters are slow growing although growth may be rapid during the first part of life. Warm-water mesopelagic fish commonly have a fast growth and most of them probably reach maximum size in one year or less. Some species (*e.g. Naurolicus muelleri* and *Diaphus suborbital*) seem to have a fast growth until sexual maturity is reached and a very slow growth later (Go *et al.,* 1977; Gjosaeter, 1978). It seems most of the temporal myctophids and Gonostomatids have a one-year lifespan (Clarke, 1973). The different *K* values in various species refer to different inhabiting ecosystems. The growth curve does not show that species in deep waters have many seasonal changes, because these species contrary to the species in shallow waters are affected by hydrographic changes such as temperature and availability of food (Kawaguchi and Mauchline, 1982). The results showed a fast growth in the early stages of life for *Benthosema pterotum* although the growth rate reduced after 7 months, which is similar to growth patterns in most myctophids (Smoker and Pearcy, 1970; Filin, 1997). The t_0 values for two species of mesopelagic fish *Benthosema glaciale* (West Norway, fjords) and *Notoscopelus kroeyeri* (North-east Atlantic) were reported to -0.64 and -0.17 year, respectively (Gjosaeter, 1978). The negative value of t_0 conforms the rapid growth in the early stages of life (Walford, 1946). The reason for different growth parameters in various studies can be related to sampling methods and gears and using various methods for data analysis (Pillai *et al.*, 1993). Differences in growth parameters can be related to length classification to a high extent (Dudley *et al*., 1992). In the present study t_{max} calculated was approximately 19 months. The maximum age of *B. pterotum* was calculated at 349 days for 51.5mm total length (Hosseini-Shekarabi *et al*., 2015). Fishes that have a short age often are small and are preyed on by other predators. The total mortality (Z) rates were reported for *B. fibulatum* and *B. glaciale* 0.51 and 0.74 per year, respectively (Gjosaeter, 1973; Vipin *et al.,* 2018). Both species *B. glaciale* and *B. fibulatum* live in sub-tropical waters while *Benthosema pterotum* is a tropical species. The capture length for *B. fibulatum* was reported to 84.62 mm, which reaches this length approximately at 2 years old (Vipin *et al.*, 2018). The results of the present paper recorded the length of capture as 35.67 mm for *B. pterotum* that will reach 6 months old. The current rate of exploitation (*E*) was given as 0.6, the values of the exploitation ratio were reasonable for the current fishing effort.

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