

Research Article

Some Biological Features of Bluefish, *Pomatomus Saltatrix* L. Along the Dhofar Coast of Oman in the Arabian Sea

 Chesalin MV^{1*} and Al-Shajibi SR²
¹Kovalevsky Institute of Marine Biological Research RAS, Russia

²Fisheries Research Center-Dhofar MAFW, Oman

Abstract

The study of biological characteristics of bluefish (*Pomatomus saltatrix*) from the catches of artisanal fishers in the coastal waters of Oman in the Arabian Sea was conducted during 2010 to 2012. The size of 1,040 studied fish ranged from 13.7 cm to 87.5 cm FL (mean 55.9 cm), weight was 30.9 g to 7,825 g (mean 2,724 g). The parameters a and b in the fork length-weight relationship for pooled sexes were 0.0275 and 2.8228, and females were slightly heavier than males of the same length. The bluefish is an active predator and remains of sardines, mullets, other bony fishes, juveniles of cuttlefish and squids were found in the stomachs. The population of *P. saltatrix* spawned between March and August with peak in June to July. During the spawning months, feeding of majority of fish was less active and Condition Factor (CF), Hepatosomatic Index (HSI) and Stomach-Somatic Index (SSI) have lesser values than after spawning during September to February. Males were slightly dominant over females (M:F=1.06:1). The length at first maturity for males and females was approximately 30.0 cm.

Keywords: Pomatomus saltatrix; Size; Length-length; Length-weight relationship; Food; Spawning; Sex ratio; Length at first maturity; Oman; Arabian sea

Introduction

Bluefish, *Pomatomus saltatrix* (Linnaeus, 1766) is the sole species of the Pomatomidae family, order Perciformes [1]. It is a large, schooling, pelagic fish with a worldwide distribution in tropical and temperate waters, except the eastern Pacific [2]. The species has elongated silvery body covered with small round scales, two separated dorsal fins, not deeply forked tail and a large mouth with small, but sharp teeth [3]. In Oman, the species is found along the entire coastline, but more abundant towards the south, particularly in the south region of Dhofar [4].

Bluefish is an important exploited marine fishery resource and have good domestic and export demand in Oman. Traditional fishers target bluefish schools during their migrations along the coast, especially from August to February, pursuing and attacking shoals of sardines, mullets, anchovies or other small fishes. The fish caught mostly with hand lines, gillnets and seine nets. Catches of bluefish in Oman during 2010 to 2013 were about 1,500 to 1,800 tons [5].

Directed fisheries for the bluefish have developed over its entire global range, but in many cases basic biological information is lacking [6]. Bluefish is managed with age-based stock assessments along in the Atlantic Coast of the United States [7-11]. There are some

publications on age, growth and stock assessment of the bluefish in the waters of Australia [12], Brasil [13], South Africa [14] and in the Mediterranean Sea region [15,16].

In spite of commercial importance no information exists on bluefish biology and stock size in Oman, so basic biological information is needed to develop management measures of the species in the area. Preliminary data on biology and population characteristics of bluefish in Oman was published in our abstract of the conference [17].

Material and Methods

Fish samples were collected monthly from traditional fishers in different sites of governorate of Dhofar during two years from March 2010 to February 2012. Each month not less than 40 specimens randomly selected (totally 1,040 fish) were measured for Total (TL), Fork (FL), Standard (SL) and Head (HL) Lengths to the nearest 0.1 mm and weighed for total body wet Weight (W), Gonad Weight (GW), Liver Weight (LW) and Stomach with gut Weight (SW) to the nearest 0.01 g. Mean, minimum, maximum and standard deviation (\pm SD) values were reported. The fullness of the stomachs were defined as: empty (0), poorly fed (1/4 full stomach), moderately fed (1/2 full stomach), actively fed (3/4 full stomach) and full (1). Stomach content was analyzed visually and general food items were identified up to generic/group level. Six stage of maturity were recognized both in males and females by visual observation of gonads: juvenile (I), immature (II), ripening (III), ripe (IV), spawning (V), spent (VI).

The length frequency data were pooled into groups with 3 cm length intervals. Linear regressions were calculated to determine conversion factors between different lengths ($L_1=a \times L_2+b$). Fork length was used in main estimations.

Length-weight relationships were calculated following the Le Cren's equation [18]: $W=a \times L^b$ for males, females and both sexes combined using a least squares fit, and difference between the slopes of the regressions were compared using ANCOVA test [19].

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***Corresponding author:** Chesalin MV, Kovalevsky Institute of Marine Biological Research RAS, Sevastopol, Russian Federation, Russia, E-mail: mchesalin@ukr.net

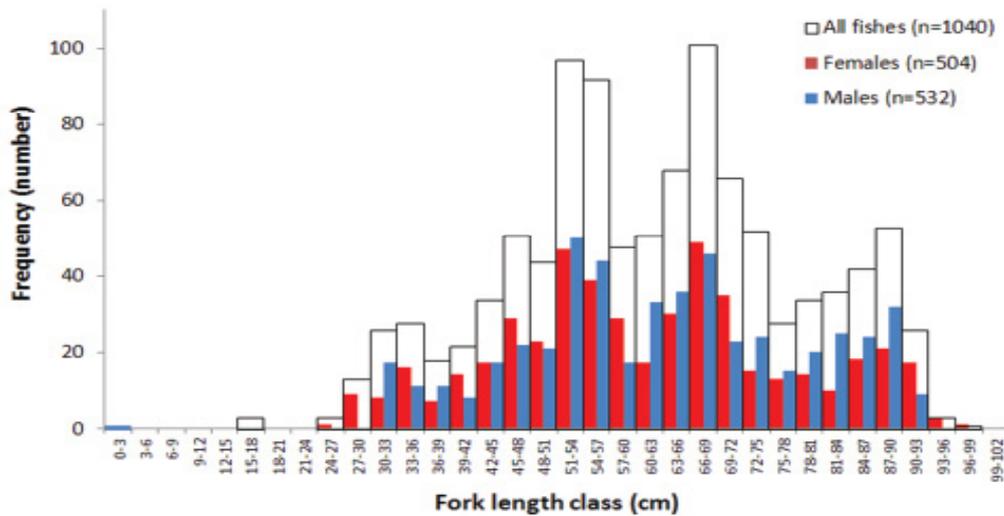


Figure 1: Length frequency distribution of males, females and pooled sexes of *P. saltatrix* in commercial catches in southern region of Oman from March 2010 to February 2012.

The feeding and spawning intensities in relation to months were estimated based on the relative number of empty stomachs and some relative indices:

Stomach-Somatic Index (SSI) $SSI=100 \times SW/W$

Hepatosomatic Index (HSI) $HSI=100 \times HW/W$

Gonadosomatic Index (GSI) $GSI=100 \times GW/W$

where, SW is the Stomach Weight (g), HW is the Liver Weight (g), GW is the wet Gonad Weight (g) and BW is the total wet Fish Weight (g).

Fulton’s Condition Factor (CF) was estimated by following equation:

$$CF = 100 \times \frac{W}{L^3}$$

where, L is corresponding fork length.

The percentage occurrence of different stages of gonads of males and females and monthly variations of Gonadosomatic Index (GSI) during 2010 to 2012 were studied to detect the spawning season of *P. saltatrix*.

The sex ratio (male:female) was calculated monthly and for 5 cm size classes. The sex ratios in the size classes were tested for the expected ratio of 1:1 by Pearson’s chi-square test (χ^2).

To estimate the length at first maturity (L_{m50}) or the length at which 50% of fish attain maturity, individuals were grouped sex-wise into 1 cm size classes and gonads in stages III and above were considered as mature. The cumulative percentages of mature testes and ovaries were used to calculate L_{m50} with the logistic formula [20]:

$$p = 1 + e^{-a(L-L_{m50})}$$

where, P is the proportion of mature females or males in each 1 cm length class, L is the mid-class length, L_{m50} is length at first maturity and a is a constant. Non-linear least-squares fitting with Solver tool incorporated in Excel was used to obtain the best fit of L_{m50} and a.

Results

Size distribution

The size range of the bluefish, *Pomatomus saltatrix* in studied samples (1,040 ind.) ranged from 13.7 cm to 87.5 cm FL (mean 55.9 ± 14.6 cm (SD)), and weight was 30.9 g to 7,825 g (mean 2,724 ± 1,726 g). Five peaks of modal classes were observed: 27-30, 39-42, 48-51, 60-63 and 78-81 cm (Figure 1). Just three juveniles were found in November 2010 with focal length from 13.7 cm to 15.1 cm. Individuals less than 30 cm represented 5.2%, fish measuring between 30 cm and 70 cm comprised 75.9% and larger 70 cm contributed 18.9% from the total number of studied fish.

Table 1: The linear equations showing relationships between different lengths of *P. saltatrix*.

Equation	R ²
FL=0.9065 TL-0.4944	0.998
FL=1.0893 SL+1.7376	0.997
FL=3.9044 HL-2.0517	0.98
TL=1.1014 FL+0.6438	0.998
TL=1.1982 SL+2.6968	0.996
TL=4.3008 HL-1.6225	0.98
SL=0.8309 TL-2.0201	0.996
SL=0.9163 FL-1.5485	0.997
SL=3.5737 HL-3.3732	0.975

Table 2: The relationships between fork (FL), total (TL) and body weight (W) for males, females and pooled sexes of *P. saltatrix*.

Sex	n	Equation	R ²	Equation	R ²
Male	532	W=0.0302	0.978	W=0.0201	0.979
		FL ^{2.7989}		TL ^{2.8239}	
Female	504	W=0.0285	0.98	W=0.0195	0.981
		FL ^{2.8154}		TL ^{2.8352}	
Pooled sexes	1040	W=0.0275	0.98	W=0.0186	0.981
		FL ^{2.8228}		TL ^{2.8443}	

Table 3: Literature data on weight-length relationship of *P. saltatrix*.

a	b	Size range	n	Region	Author
0.0131	2.934			South Africa, Natal	[28]
0.0135	3.087	2.6-41.2 SL	85	South Africa, estuaries	[31]
0.0281	2.8	FL		USA, Gulf of Mexico	[7]
0.0595	2.509	48.0-75.5 TL	67	Brazil, Central coast	[32]
0.0076	3.051	8.6-25.0 TL	275	Brazil, Rio Grande do Sul	[29]
0.0136	2.899	25.1-67.6 TL	1771		
0.0046	3.19	8.9-39.5 TL	8	Uruguay, Pando estuary	[33]
0.0155	2.798	13.2-21.7 TL (Male)	67	Turkey, Black Sea	[34]
0.0111	2.921	14.3-21.7 TL (Female)	76		
0.0076	3.055	39.2-58.5 TL	59	Croatia, northern Adriatic	[30]

The sizes of the males were in a range of 23.9 cm to 85.3 cm (mean 56.4 cm), females were 23.6 to 87.5 cm (mean 55.5 cm). The largest male was 85.3 cm and weighed 7,825 g, the largest female had 87.5 cm and total weight of 7,500 g. There was no significant difference in size distribution between females and males. Two sample F-test has shown that sample variances do not differ significantly at the specified alpha of 0.05 ($F=1.013, p=0.88$), so for further analysis the pooled data were used.

Length-length relationship

The length-length relationships are important for comparative analysis of biological characteristics of fishes from data of different authors, because some authors use the total length, others the fork length, while taxonomists use the standard length. The body proportions remain constant with fish growth and are expressed by linear regressions with constant coefficients. The calculated regression equations between different lengths (TL, FL, SL, HL) of the bluefish are shown in Table 1. The relationships are very strong and the coefficient of determination (R^2) was higher 0.97 in all cases.

Length-weight relationship

The length-weight relationships calculated for pooled sexes, females and males of *P. saltatrix* are presented in Table 2. The value of 'b' shown negative allometric growth of the species. The coefficient of determination (R^2) in males, females and sexes pooled are highly correlated (>0.97).

Females were slightly heavier than the males of the same length. The regression equations for males and females were tested for equality with ANCOVA and the slopes did not differ significantly between the sexes.

Food composition and seasonal feeding intensity

In the studied samples, the most stomachs of bluefish were empty (43.7% from total number), other contained mainly semi digested matter (27.2%) or remains of sardines, *Sardinella* spp. (27.1%). Also, in the stomach content of *P. saltatrix* were found mullets and unidentified bony fishes (1.8%), juveniles of cuttlefish *Sepia pharaonis* and squid *Sepioteuthis lessoniana* (~0.2%).

During the studied period active, moderate and poor feeding were recorded in *P. saltatrix* based on stomach fullness. Fishes fed more actively from July to December 2010, during April 2011 and from July to October 2011. The empty stomachs occurred in all months, but their higher percentages were recorded during January 2011 and February 2012.

The average monthly values of Condition Factor (CF) ranged from 0.89 to 1.16 (Figure 2A) and values more than 1.0 were observed from September 2010 to April 2011 and from September 2011 to February 2012.

The average monthly values of Stomach-Somatic Index (SSI) were ranged from 2.69 to 6.18 (Figure 2B). The values of SSI were higher from July to September and in November to December 2010 and from July to December 2011.

The monthly values of Hepatosomatic Index (HSI) showed close trend with peaks from August to December (Figure 2C).

Therefore, more active feeding of the bluefish occurs after spawning.

Spawning season

The weight of ovaries varied from 0.1 g to 716.6 g, testes were 0.21 g to 490.1 g. Males and females with ripening gonads (Stage III) were registered from March to June. Fishes with mature and running gonads (Stages IV and V) were occurred from April to August with peak in May to June. Fishes with spent gonads (Stage VI) were recorded from July to November (Figure 3).

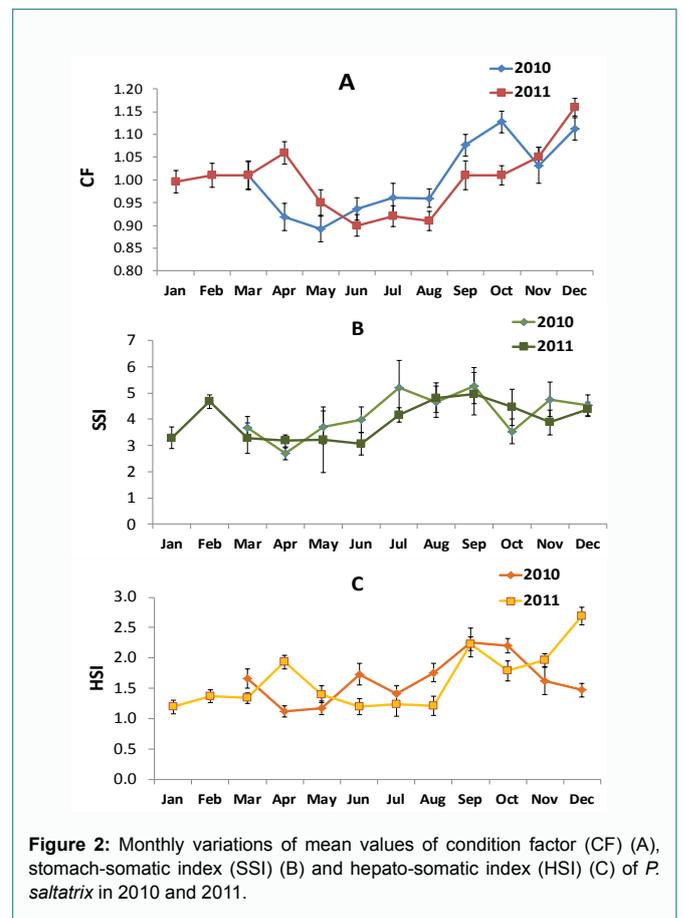


Figure 2: Monthly variations of mean values of condition factor (CF) (A), stomach-somatic index (SSI) (B) and hepato-somatic index (HSI) (C) of *P. saltatrix* in 2010 and 2011.

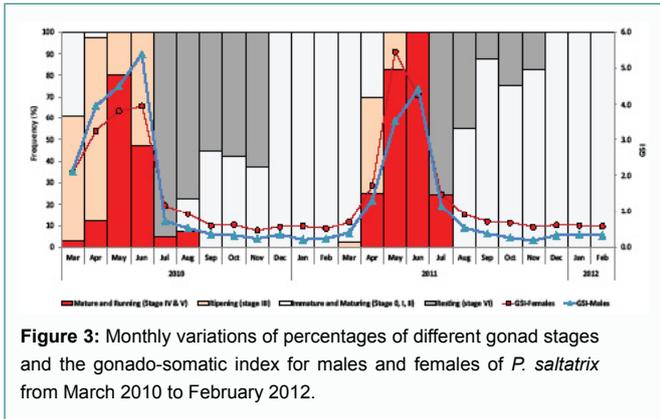


Figure 3: Monthly variations of percentages of different gonad stages and the gonado-somatic index for males and females of *P. saltatrix* from March 2010 to February 2012.

The minimum and maximum mean GSI values recorded during 2010 for males were 0.24 (November, 2010) and 5.40 (June, 2010) and corresponding values for females were 0.46 (November, 2010) and 3.95 (June, 2010). The maximum Gonadosomatic Index (GSI) values for males and females were observed in May and June. The similar trend was found in 2011, the maximum GSI value for males was registered in May 2011 and for females in June 2011. The lower GSI values as for males and females were recorded from September 2010 to March 2011 and from September 2011 to February 2012. The high GSI values indicated reproductive months of *P. saltatrix* from March to July. The drop of GSI values testifies the peak of spawning season of the bluefish in June and July.

The data on GSI values and the occurrence of fish with ripe, spawning and spent gonads indicate that spawning season of *P. saltatrix* along the southern Oman coast lasts about six months from March to August with peak in June to July.

Sex ratio

The pooled sex ratio of bluefish in the Dhofar region during 2010 to 2012 was 0.94:1 (48.6% females and 51.4% males). Males dominated numerically in most months and during spring-summer spawning season, while females were more abundant in winter time (October to January).

The male:female ratio was estimated for different 5 cm size classes for samples pooled in 2010 to 2012. The sex-ratios were different in the majority size classes, but respective chi-values were found significant only in classes of 40 cm to 75 cm, 70 cm to 75 cm and 80 cm to 85 cm FL. Overall, the obtained value of χ^2 at $p=0.05$ was less than the critical value: $20.71 < 22.36$, then the null hypothesis is not rejected and the sex ratio in size classes of bluefish is not significantly different, so the distribution of males and females is homogeneous in the population.

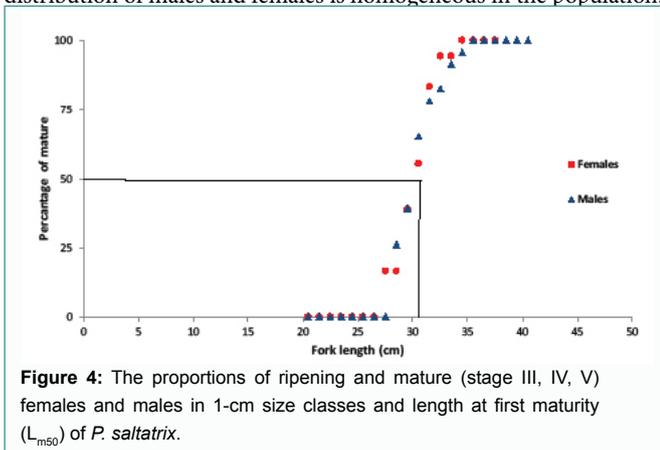


Figure 4: The proportions of ripening and mature (stage III, IV, V) females and males in 1-cm size classes and length at first maturity (L_{m50}) of *P. saltatrix*.

Length at first maturity

The smallest female of *P. saltatrix* with ripening (Stage III) and mature ovary (Stage IV) was 26.6 cm FL and the smallest male with ripening testis (Stage III) had 27.1 cm FL. The portions of ripening and mature females and males (Stages III to V) were calculated and the cumulative percent of mature ones was used to calculate length at first maturity (L_{m50}) (Figure 4).

The logistic function describing the cumulative distribution of the percentage of ripening and spawning fish were:

$$\text{Females (n=138)} \quad P=1+e^{-1.13(\text{FL}-30.02)}$$

$$\text{Males (n=153)} \quad P=1+e^{-1.79(\text{FL}-30.04)}$$

So, the length at first maturity of *P. saltatrix* is estimated as 30.02 cm FL for females and 30.04 cm FL for males.

Discussion

The maximum sizes of bluefish observed in this study was 87.5 cm FL (96.6 TL) and 7,825 g. This length is within the range in the Atlantic Ocean off the US coast reported by Lassiter [21] of 81.2 cm, 88 cm [22], 88 cm [9], 95 cm [23]. However, these sizes are considerably less than the maximum known length of bluefish of about 130 cm TL reported for the Omani waters by [24] and weight of 14.4 kg registered by International Game Fish Association in World record game fishes [25]. The maximum known length of the bluefish in the Black Sea is 71 cm TL [26,27] documented maximum length of 67.2 cm near Brazil coast.

The parameters a and b in length-weight relationship of *P. saltatrix* in the present study were calculated for pooled sexes as 0.0275 and 2.8228, and females were found slightly heavier than males of the same length. These data is in agreement with earlier estimations on the LWR of the bluefish from the South Africa [28], northern Gulf of Mexico [7], adult fish from the southern Brazil coast [29] and northern Adriatic [30] (Table 3). Considerable differences in LWR parameters were observed when authors measured only small fish as in the Black Sea [34] or estuarine of South Africa [31].

The bluefish *P. saltatrix* is an active predator and in Omani waters feeds on other fish and cephalopods. It is known that this species eat also crustaceans (shrimp, crabs, amphipods) and benthic gastropods [35,36]. The most active feeding of bluefish in Oman was observed from July to February after spawning.

The spawning of bluefish in the Arabian Sea was found to occur between March and August with peak in June to July. The similar spawning period was reported for the species in the Mediterranean Sea (March to August) [37] and the Black Sea (June to September) [38]. In southern hemisphere, *P. saltatrix* spawns in autumn-winter months: in South Africa from September to December [28], in Australia in August to November [39]. Interesting that near US coast, spawning of bluefish has two peaks and was reported as spring (March to May), so autumn (September to November) [6]. That is demonstrating the potential of an extended bluefish spawning season. Bluefish are characterized as multiple spawners with indeterminate fecundity which spawns continuously during their spring migration [10].

Sex ratio of *P. saltatrix* in Omani waters estimated close to 1.06:1 with slightly prevalence of males in the larger size classes (>50 cm FL). The similar sex ratio was found for all age groups in Atlantic coast of US [40], although Lassiter [21] reported a ratio of two females per male in North Carolina, and Ceyhan et al. [15] found that females

dominated in all age groups with ratio 1.4 females per one male in the Marmara Sea.

The length at first maturity for females and males in our investigation was 30.0 cm FL. Wilk [41] reported about 50% of 1-year-old fish were mature and full maturity was attained by age 2. Salerno et al. [9] found the L_{m50} as 33.9 cm and 33.4 cm FL for males and females respectively, and observed proportions at age showed that bluefish maturation occurs between 1 and 2 years for both sexes. Known L_{m50} values also 24 cm to 25 cm FL in South Africa [28], 30 cm TL in eastern Australia waters [39] and 38 cm FL near Senegal [42].

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