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Biological parameters and abundance of the razor clam, (Solen brevis), from the Bushehr area of the Persian Gulf

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Abstract: Biological parameters were estimated for the razor clam (Solen brevis) sampled from the intertidal zone around Bushehr, Iran. Monthly and periodic quadrat sampling along random transects were conducted from October 2008 to September 2009 to estimate abundance and growth parameters. The estimated abundance of S. brevis ranged from 1.50 (August) to 4.20 (October) clams per 0.25 m2 (mean 3.25, SD 1.1), while the estimated growth parameters for L_∞ and K were 120 mm and 0.7, respectively. The mean total length ranged from 80.8 mm (± 10.2) in November to 97.6 mm (± 14.2) in July. Natural mortality (M) and maximum age (Tmax) were estimated at 0.26 per year and 4.6 years, respectively. Expansion of the shrimp culture industry along with petroleum exploration activities are believed to be the major factors responsible for the decrease in population size for S. brevis along the coast of Bushehr.

Keywords: Biological Parameters, Abundance, Clam, Solen brevis, Bushehr, Persian Gulf

1. Introduction

Few studies have been conducted on bivalves from the Persian Gulf. The earliest record identified 17 bivalves' species from the Hormozgan area of Iran (Issel 1865). Later, Martens (1874) identified 119 intertidal species which included the bivalves and gastropods in the Persian Gulf. More recent studies have also focused on shell identification, distribution, growth, and population parameters (Melvill 1940; Biggs 1957; Smyth 1972; Hasan 1994. and Houseinzadeh et al. 2001).

The jacknife razor clam Solen brevis, an edible bivalve known locally as "Melalis", is one of two Solen species common to the eastern Persian Gulf (Hosseinzadeh et al. 2001). Razor clam habitats include stable, fully exposed, surf pounded, broad, flat, uniform, hard and sandy coastal areas (McMillan 1924; Fitch 1953; and Browning 1980). S. brevis is found in the muddy sand substrate, buried vertically at a depth ranging from 5 to 12 cm with in the intertidal zone of Bushehr province. These razor clams are harvested by inserting a sharpened steel rod downward into the siphon-formed hole of the substrate until the clam is impaled, and then slowly pulling upward.

The local abundance and distribution of S. brevis has decreased to the point whereby some formerly inhabited areas are now devoid of the species. Several prominent factors have been attributed to the population decline. Since the introduction of shrimp culturing in the Bushehr area (1996) the demand for razor clams, as a food source for shrimp, has greatly increased. Further, razor clam meat is a preferential bait type used by the hook and line artisanal fleet targeting demersal fishes. It is believed that these two factors have resulted in the overexploitation of S. brevis. In addition, increased activities by oil companies around Bushehr coastal waters have contributed to the destruction of essential razor clam habitat that, in turn, may have impacted the population size. The objectives of the present study were to estimate abundance, growth, mortality, and maximum age parameters of S. brevis found in the Bushehr coastal area. In addition, some environmental factors were also investigated.

2. Materials and Methods

This study was carried out in Bushehr intertidal zone of Iran (from 50° 38′E - 29° 27′N to 52° 41′E – 27° 17N), area where water depth ranges from 0.1 to 2.0 m (Fig. 1). Monthly random sampling transects were conducted in a ziz-zag formation to ensure representative coverage of all shell beds. For each transect, S. brevis were counted and samples collected from two to three quadrats (0.25 m2) during low tide (Fig. 1).

The effects of seasonality were compared by sampling during mpare seasonal differences, samples for the biomass estimation were collected during warm (August, October, November, and December) and cold (January and February) periods. A total of 20-30 quadrats were sampled each month. The mean number of samples was calculated as the sum of individuals from each quadrat (X), divided by the number of quadrats sampled (n). Standard error (SE) and confidence limits ($\alpha = 0.05$) were also calculated.

Shell length (anterior-posterior axis) was measured to the nearest millimeter using vernier calipers. The values for K, $L\infty$ and t0 were estimated with the Bertalanffy (1938) growth equation.

$$Lt = L\infty \left(1 - e^{-K(t - t°)}\right)$$

Where, Lt is the length at time t, $L\infty$ is the asymptotic length, K is the growth coefficient and t0 is the hypothetical age when the size is zero. The parameters $L\infty$, K, and t0 were estimated using LFDA software (version 5). The growth performance index (Ǿ) was calculated using the formula of Pauly and Munro (1984).

$$Ǿ = \ln K + 2 \ln L\infty$$

Natural mortality (M) was derived using the method described by Taylor (1960) for bivalves.

$$M = 2.996/A0.95$$

Where A0.95 represents the 95th percentile of the asymptotic length. Longevity estimates (Tmax), $L\infty$ and K, were calculated using the inverse of the von Bertalanffy equation (King 2006).

$$Tmax = t0 - (l/k) \ln [1 - (Li/L\infty)]$$

Where Li is arbitrarily considered equal to 99% of the asymptotic length

$$Tmax = t0-(3/K)$$

Over the course of the study, a total of 620 samples were collected for precise measurements of total length (±1 mm) and weight (±0.01 g). Parameters of the relationship between length and weight were calculated by regression analysis.

$$W = a * Lb$$

Small amounts of bottom sediment were taken from cores (15 centimeters depth) in January to calculate the proportion of sand using the method described by Folk (1980). Salinity and water temperature were also measured during high tide of sampling day.

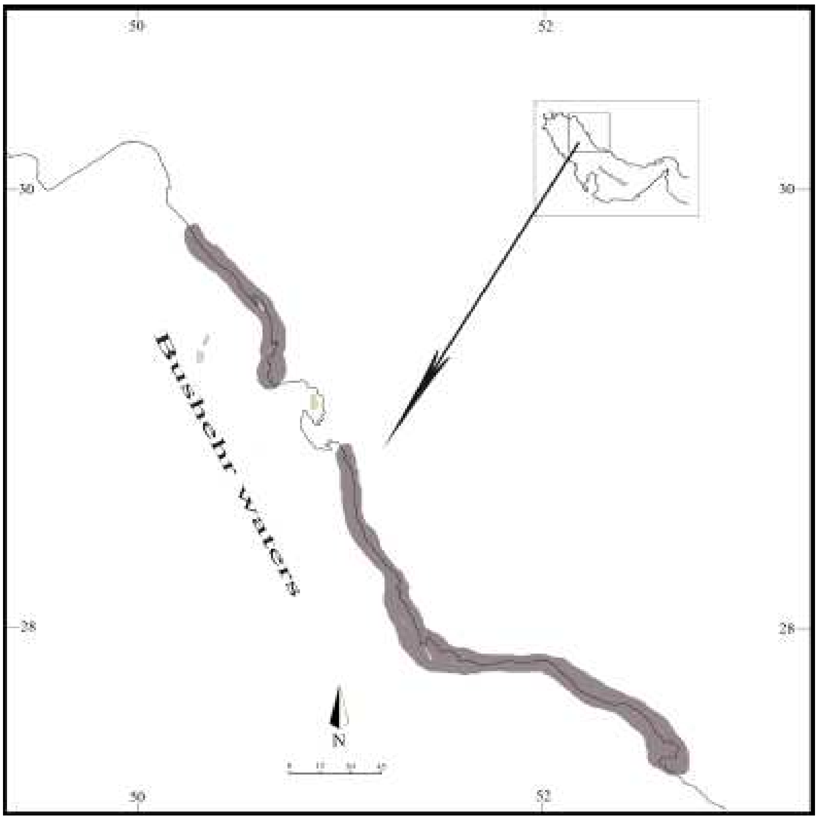

Figure 1. *Sampling area for the razor clam Solen brevis from the Bushehr area of the Persian Gulf (2008-09).*

3. Results

The mean monthly number of S. brevis estimated per quadrat ranged from 1.5 (August) to 4.6 (October). The mean number of individuals per quadrat was 3.25 (SD 1.1, Table 1).

Table 1. *Mean number of Solen brevis individuals per 0.25 m2 found in Bushehr study area, (Persian Gulf) during period of October 2008 to September 2009.*

Month	No. of Quadrats	Mean No.individuals per quadrat
Oct 2008	29	4.6
Nov 2008	21	3.4
Dec 2008	20	4.1
Jan 2009	28	3.4
Feb 2009	27	2.5
Aug 2009	30	1.5
Total	155	3.25 (±1.1))

The estimated growth parameters derived from the Von Bertalanffy equation were: $L\infty$ =120 mm, K = 0.7 year -1 and t0 = -0.35 (Fig. 2), while the estimated index for comparing growth performance (Ǿ) was in 0.7 + 2ln120 = 9.2. The relationship of total length and weight determined by exponential regression (Fig. 3) was: W=0.6912 L 2.96.

Mean total length (Fig. 4) ranged from (80.8 mm, SD 10.2, November) to (97.6 mm, SD14.2, July). Maximum estimated age (Tmax) was -0.35 – (3/0.7) = 4.6 year.

The bottom sediment grain sizes (Table 2) consisted of gravel (>2000 μ), sand (2000-62.5 μ), silt (62.5-2.0 μ) and clay (<2.0 μ).

Table 2. *Percentages of bottom sediment particle sizes categorized by weight (μ) in Bushehr, Persian Gulf (2008-09).*

Sediment type	Particle size (μ)	Percent
Clay	<2.0	9.66
Silt	2.0-62.5	28.28
Sand	62.5-2000	61.81
Gravel	>2000	0.15

Water temperatures ranged from13 °C (January) to 38 °C (May, Table 3), while salinity ranged from 38 psu to 42 psu. The mean value of water temperature and salinity were 25.5 °C (SD 7.5) and 39.5 psu (SD 1.1) respectively.

Table 3. *Mean of the salinity (PSU) and temperature (°C) measurements of the Bushehr intertidal zone (Persian Gulf) sampled during the period of October 2008 to September 2009.*

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean	S.D.
Temperature	24	28	17	13	21	18	23	38	28	31	33.5	37.5	25.5	7.5
Salinity	38	38	38	40	40	40	40	41	42	40	42	40	39.5	1.1

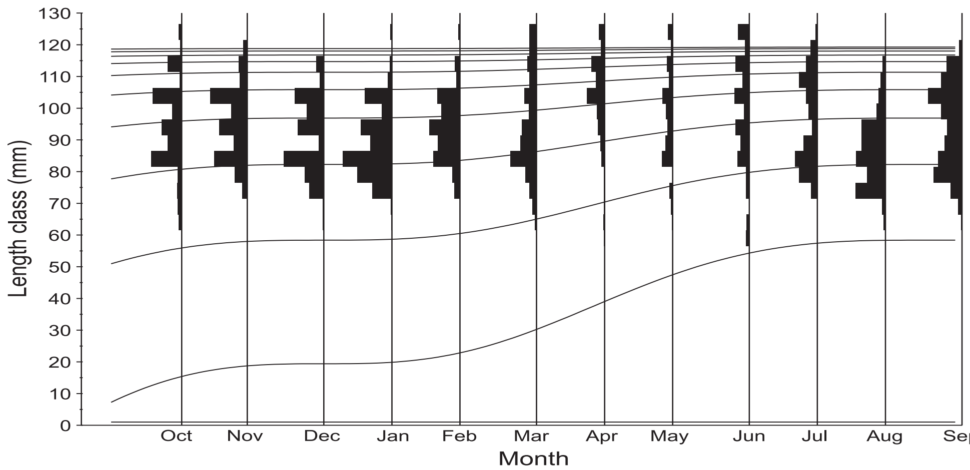

Figure 2. *Length frequency curve for Solen brevis in Bushehr waters, Persian Gulf (2008-09). L∞ = 120mm K=0.7 year -1 t0=-0.35.*

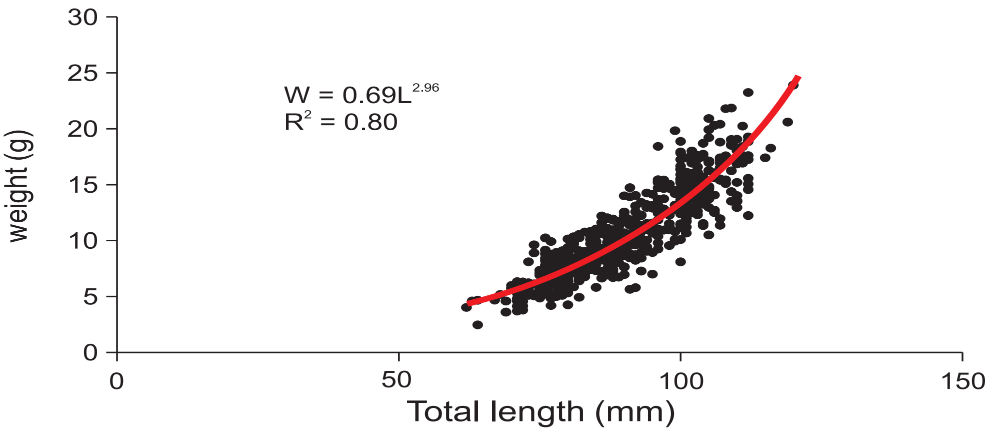

Figure 3. *Relationship of total length and weight of Solen brevis in Bushehr waters, Persian Gulf (2008-09).*

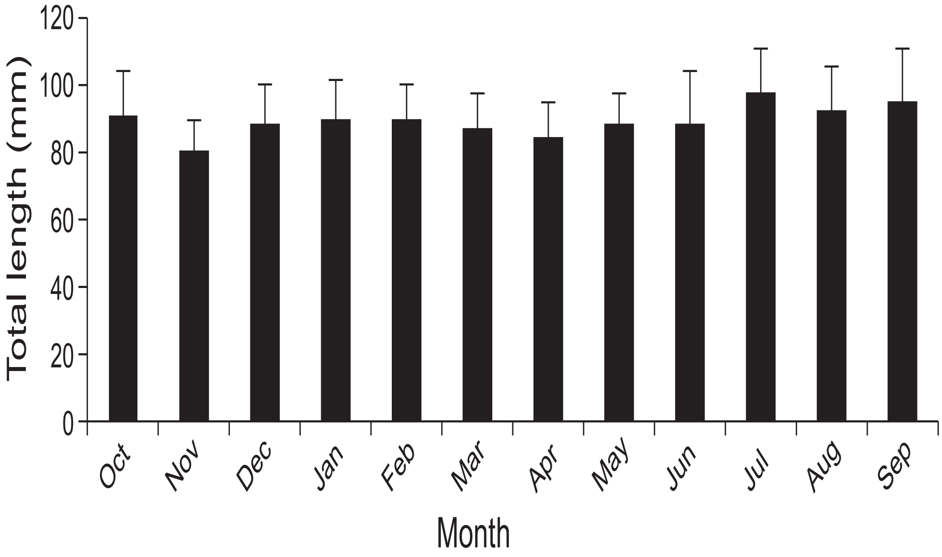

Figure 4. *Average total length of Solen brevis (n = 5390) sampled from Bushehr waters during the period October 2008 to September 2009.*

4. Discussion

The estimates from the present study suggest that the growth rate of the S. brevis increases during the warm months (July-November), and is lowest during the cold season (January-March, Fig. 2). Beginning in August, newly recruited S. brevis exhibited a total length mode of ~70 mm. The length-frequency curve also exhibits two cohorts during most months (Fig. 2). In comparison, the mean reported growth rate of razor clams (S. solecurtus) from the Andaman Sea area was 1.2 mm/month, while the monthly weight gain for ages 6-9 months and 10-37 months were 1.02-1.15 g and 0.07 g, respectively (Veeravaitaya 2007).

Various techniques have been used to estimate the ages of bivalves. Examples include size frequency distribution analysis (Cerrato 1980), mark and recapture experiments (Gaspar et al. 2004), and analyses of oxygen and carbon isotopic composition (Keller et al. 2002). Annuli formation on the bivalve shell surface has also been used to estimate the growth rate of bivalves (Richardson et al. 1990), although it often suffers from the presence of false growth rings (Keller et al. 2002), or recent rings formed to closely together to allow easy distinction (Richardson 2001).

Maximum age estimates reported for razor clam vary by location, increasing sharply from five years for Pismo Beach, California (Weymouth et al. 1931), to 9-11 years for the Pacific Northwest (McMillan 1924), and 18-19 years for Alaska (Nickerson 1975). In contrast, the maximum age of S. brevis in the present study was lower (4.6 years).

Weymouth et al. (1925) reported that razor clam shells turn translucent prior to spawning. After spawning, the shells lose their translucence and become dark again. In the present study the larger specimens of S. brevis had dark shells. Further, the length–frequency data indicated that large, older clams were predominant in the summer months, while the smallest clams appeared in November. Although our sampling did not include spring months, these two factors suggest that S. brevis spawning in the Bushehr area may occur during this period. In support, the congener S. roseomaculatus is known to spawn in the Persian Gulf during the spring and summer months, peaking in June (Houseinzadeh 2004).

A prominent source of natural mortality for S. brevis in the Bushehr area is predation by fishes of the family Sparidae, specifically Acanthopagrus berda and Sparidentex hasta (Niamaimandi 1991). Seabirds may also prey on the Bushehr population of S. brevis. Although this has not been substantiated, avian predation on razor clams has been documented elsewhere. For example, McMillan (1924) estimated that >20,000 seabirds preyed on newly recruited razor clams along Copalis Beach Washington. Also, Tegelberg and Magoon (1969) observed great numbers of shorebirds feeding on razor clams throughout the period of dense set. In the Bushehr study area, recruitment occurs in August (Fig. 2), which is also the period of lowest biomass. Other reports have indicated the highest natural mortality rate for razor clams (99%) occurs in the initial eight months of age, and the lowest (1%) for those grouped >3 years of age (McMillan, 1924; Nikerson, 1975 and ; Link, 1980).

In the present study most of the substrates inhabited by S. brevis on Bushehr beaches are flat. More than 50% of the bottom sediments are sand with the grain size 2-0.625 mm in diameter. The lowest percentage (0.00015%) of particles greater than 2 mm consisted of gravel. The percentage of the total organic matter in the study area was less than 1 percent. A low percentage of organic material in razor clam habitat has also been reported by others (McMillan, 1924). Hirschhorn (1962) described a flat beach-face slope along the coast of Oregon, with small sand grain size (0.2 mm). In a survey of Alaskan razor clam beaches, Nickerson (1975) reported a uniform substrate with an average grain size of 0.16-0.19 mm, and suggested that productive beaches have a low clay fraction. The densities of these

Alaskan razor clams were highest on beaches having the lowest percentages (0.0005% to 0.85%) of particles less than 0.005 mm. In comparison, the average sediment grain size for S. Solecurtus habitat in the Andaman Sea was 0.125 mm (Veeravaitaya, 2007).

Water temperature in the Bushehr study area varied monthly, ranging from 13 °C to 38 °C (Table 3). Exposure to high temperatures has been linked to razor clam mortality in laboratory studies. Sayce and Tufts (1971) reported that mortality began around 21°C, but varied according to absolute temperature and period of exposure. For example, mortality at 21°C occurred after 4 h, at 27 °C after 3 h, at 28 °C after 2 h, and at 29 °C after 1 h. Weymouth et al (1925) noted that spawning of razor clams on Washington beaches occurred at 13 °C, while Bourne and Quayle (1970) suggested that spawning might be linked to factors associated with upwelling, tidal cycle, and food availability. Although fluctuations in salinity levels were minimal in the Bushehr study area, other studies suggest that salinity may be a prominent factor affecting the growth and mortality of razor clams. McMillan (1924) reported that clams were killed when salinity was reduced along Washington beaches after heavy rainfall, and Tegelberg (1964) reported that decreased salinity slowed the growth rate of razor clams.

Overexploitation by Bushehr fishers targeting razor clams for bait or cultured shrimp food is believed to be the main factor associated with the decrease of the razor clam population. Environmental degradation resulting from increased petroleum exploration and extraction activities may also have contributed to the decrease, although this is not understood well and warrants further investigation.

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