

Note

Abundance of pelagic chaetognaths in northwestern Persian Gulf

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Abstract: The abundances and species compositions of chaetognaths were investigated on the northwestern coasts of the Persian Gulf in Khuzestan province (2004–2005). Highest mean chaetognath abundance was observed during the summer (324.7 ± 97.6 indiv. m^{-3}), while lowest values occurred during the winter (79.3 ± 18.6 indiv. m^{-3}). Six species were identified, *Sagitta bedfordi*, *S. enflata*, *S. ferox*, *S. hexaptera*, *S. neglecta* and *Krohnitta pacifica*. *Sagitta ferox* was most abundant. It represented 49.7% of total chaetognath numbers. Abundance variation throughout the year cycle seemed to be related to environmental factors. The correlation coefficients between abundance of chaetognaths and the water temperature were significantly positive but there was no significant relation for abundance and salinity. However, salinity values in the Persian Gulf are very high compared with other regions and perhaps pelagic chaetognaths species that inhabit this region are adapted to very high salinities of up to 45.

Key words: abundance, pelagic chaetognaths, Persian Gulf

In oceans and coastal waters, chaetognaths are dominant and constitute a large percentage of zooplankton abundance and biomass (Bigelow & Sears 1939, Grice & Hart 1962). Chaetognaths play a major role in zooplankton communities as one of the main predators and are a useful indicator of water masses (Feigenbaum & Maris 1984, Michel 1995, Castro & Huber 2003, Nagai et al. 2008). These organisms live in various marine habitats from polar to tropical waters and at all depths (Casanova 1999). In addition, their occurrence and distribution can be determined by hydrological conditions (Liang & Vega-Pérez 1994).

There is a lot of information about zooplankton of the Persian Gulf (Michel et al. 1986a, b, Al-Yamani et al. 1998, Khalife-Nilsaz et al. 2002, Falahi et al. 2003, ROPME 2004). However, most previous ecological studies in the Persian Gulf just focused on zooplankton introduction and there has been little attention paid to specific planktonic groups such as chaetognaths. Therefore, the main purpose of this paper is to assess chaetognath abundance fluctuations in the northwestern Persian Gulf (Iran), a marginal sea connected directly to the Indian Ocean, during full seasonal cycle.

Zooplankton samples were collected from the northwestern Persian Gulf (Fig. 1). Monthly sampling was carried out from the Khuzestan coasts (December 2004–November 2005) with a plankton net (300 μm mesh size and 70 cm mouth diameter). Oblique tows were made from near the bottom to the surface.

There was no sampling in July 2005 because of vehicle deficiency. Most of the sampling was conducted in the afternoon and the mean water depth of the stations was 6.6 ± 0.30 m (4 to 12 m). A mechanical flow-meter (HYDRO-BIOS, No. 438 110) was used for measuring the filtered water volume. Along with the biological parameters, surface and bottom temperature and salinity were measured “in situ” at each sampling station by using a standard thermometer (HACH sens ION5, Düsseldorf, Germany) and refractometer (ATAGO, S/Mill- E, Japan). Immediately after net retrieval, zooplankters were preserved in 10 % formalin-sea water solution. Chaetognaths from the collection were sorted out, identified to species level and enumerated by microscopic analysis. Abundance was presented as number per cubic meter (Clesceri et al. 1989). Then the correlation coefficient among environmental factors and chaetognath abundance in different seasons was investigated. Tolerance temperatures and salinity ranges were determined for each species and compared with some prior studies.

During the course of one year, totally, 12,991 individuals were identified (abundance average 295.3 ± 53.0 indiv. m^{-3}). Chaetognath total abundance showed monthly variations. The highest abundance average month-to-month was recorded during June-2005 (430.6 ± 172.6 indiv. m^{-3}), and the lowest during January-2004 (50.0 ± 28.0 indiv. m^{-3} ; Fig. 2). On a seasonal basis, the highest overall mean abundances were found during the summer (324.7 ± 97.6 indiv. m^{-3}), followed by the spring (137.5 ± 50.6 indiv. m^{-3}), the autumn (122.5 ± 43.4 indiv. m^{-3}) and then winter (79.3 ± 18.6 indiv. m^{-3}). A one-way Analysis

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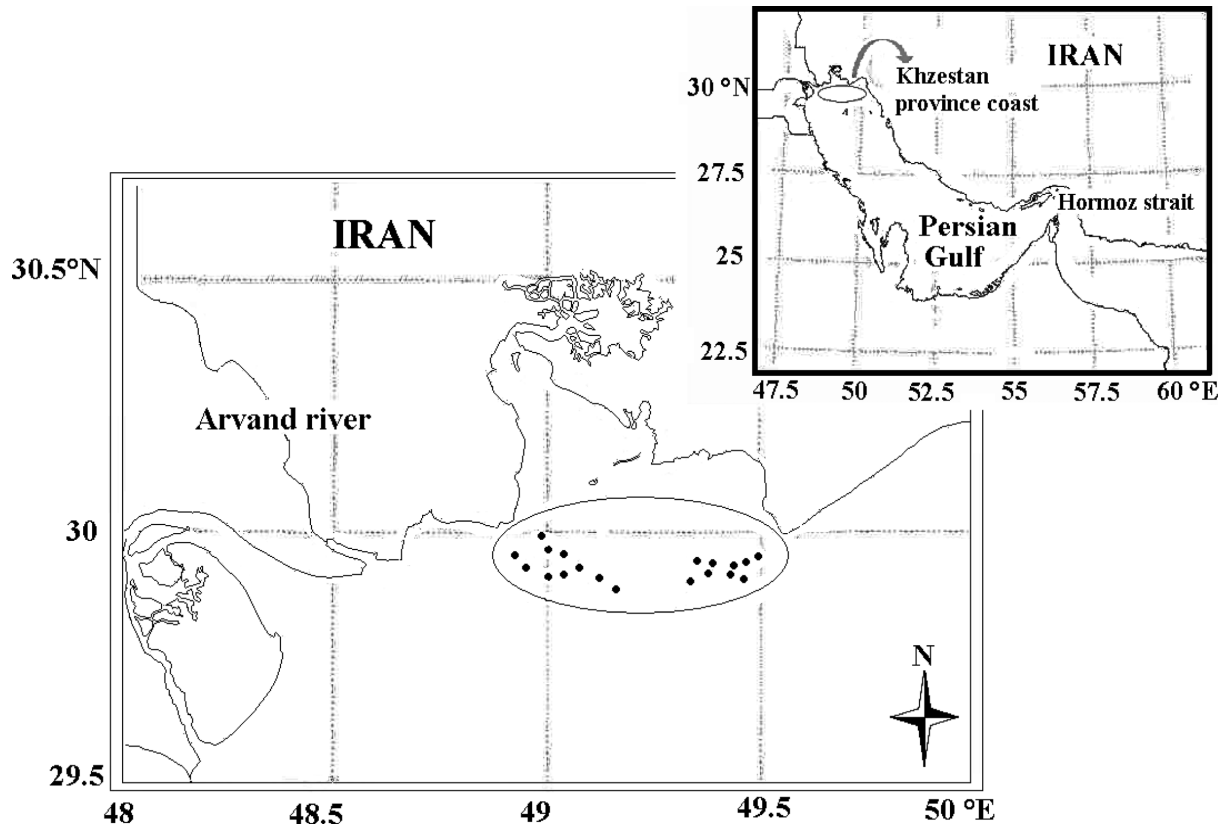


Fig. 1. The sampling site on the northwestern coast of the Persian Gulf in Khuzestan Province.

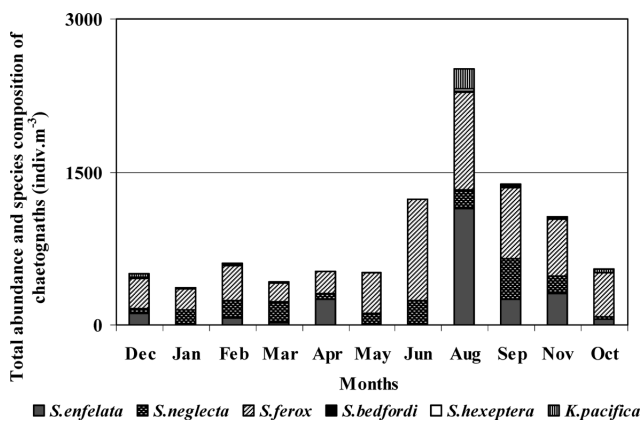


Fig. 2. Seasonal abundance and species composition of pelagic chaetognaths (indiv. m⁻³) along the north-west coast of the Persian Gulf.

of Variance (95% Confidence Interval) showed that seasonal abundances were significantly different between summer and winter.

Six species belonging to two genera of chaetognaths were identified; *Sagitta bedfordi* Doncaster, *S. enflata* Grassi, *S. ferox* Doncaster, *S. hexaptera* d'Orbigny, *S. neglecta* Aida and *Krohnitta pacifica* Aida (Table 1). *Sagitta ferox* was the dominant species and accounted for 49.3% of the total chaetognaths. The other main abundant species were *S. enflata* (17.2%), *S. neglecta* (13.5%) and *K. pacifica* (2.7%), respec-

tively. The other species that contributed to the species composition comprised 17.3% numerically.

Sagitta ferox was most abundant during the summer (826.2 ± 130.9 indiv. m⁻³) followed by the spring (535.3 ± 232.1 indiv. m⁻³), the autumn (497.8 ± 63.6 indiv. m⁻³) and then winter (252.8 ± 37.9 indiv. m⁻³). This epipelagic species occurred in every sample and was the most abundant percentage-wise during all seasons.

Sagitta enflata was the second most abundant species, only after *S. ferox* along the Khuzestan coast. This species was most abundant during the summer (695.7 ± 440.7 indiv. m⁻³) and spring (180.2 ± 128.4 indiv. m⁻³).

Sagitta neglecta was the third most abundant species. This species is endemic to Indian Ocean waters (Tokioka 1959, Conway et al. 2003) and was observed numerically abundant during the summer (293.5 ± 103.7 indiv. m⁻³) and winter (143.0 ± 34.3 indiv. m⁻³).

Krohnitta pacifica a eurythermal euryhaline species, is common in the Persian Gulf area (Michel et al. 1986b, Conway et al. 2003). Our results showed that this species was most abundant during summer (106.5 ± 95.3 indiv. m⁻³). The remaining two species, *S. bedfordi* and *S. hexaptera* were less abundant year round. Probably, they were carried beyond the strait of Hormoz by oceanic currents.

The annual fluctuations of water temperature and salinity were measured monthly (Fig. 3). Due to the shallowness of the Persian Gulf and the effect of the northwesterly winds, mixing occurs between deep and surface waters (Al-Yamani et al.

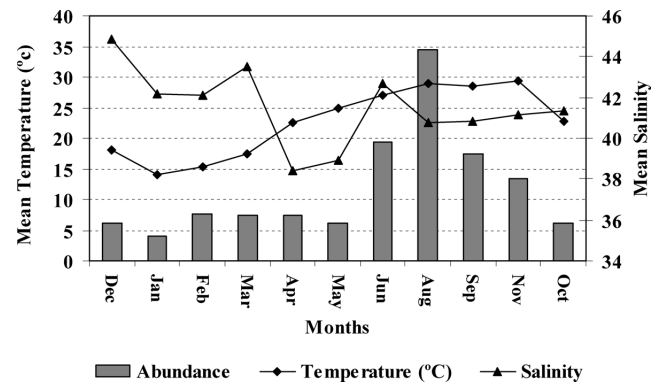
Table 1. Mean abundance (indiv. m⁻³) and relative abundance (%) of chaetognath species during different seasons.

Species	Winter		Spring		Summer		Autumn	
	Abundance	%	Abundance	%	Abundance	%	Abundance	%
<i>Sagitta bedfordi</i>	4.8±3.4	1.0	0	0	11.5±3	0.6	4.1±2.4	0.6
<i>Sagitta enfelata</i>	32.1±20.1	7.0	87.9±79.9	11.6	695.7±440.7	35.8	159.7±76.9	22.7
<i>Sagitta ferox</i>	238.9±49.9	51.8	535.3±232.1	70.7	826.2±130.9	42.5	43.0±77.1	61.1
<i>Sagitta hexoptera</i>	0	0	0	0	11.5±2.8	0.6	0	0
<i>Sagitta neglecta</i>	175.4±15.7	38.1	132.7±54.2	17.5	293.5±103.7	15.1	80.7±45.5	11.5
<i>Krohnitta pacifica</i>	9.8±1.8	2.1	1±0.6	0.1	106.5±95.3	5.5	29.5±8.0	4.2

Table 2. The correlation coefficients between water temperature (°C), salinity, season and abundance of chaetognaths.

		Salinity	Water Temperature	Seasons
	Pearson Correlation	-0.109	0.690*	0.631*
Abundance (indiv. m ⁻³)	Sig. (2-tailed)	0.748	0.018	0.037
	N	11	11	11

*significant at the 0.05 level (2-tailed)

**Fig. 3.** The effect of temperature and salinity on the annual abundance of chaetognaths.**Table 3.** Temperature (°C) and Salinity values over the distributional ranges for chaetognatha species.

Geographical Area/Species		<i>S. enfelata</i>	<i>S. ferox</i>	<i>S. neglecta</i>	<i>K. pacifica</i>	Reference
Persian Gulf	Salinity	38.4–44.85	38.4–44.85	38.4–44.85	38.4–44.85	present study
	Temperature	14.0–29.4	14.0–29.4	14.0–29.4	14.0–29.4	
Red Sea	Salinity	40.46–40.86	—	—	—	Furnestine (1958)
	Temperature	21.5–24.9	—	—	—	
Bay of Bengal	Salinity	26.0–34.0	22.94–34.34	26.0–34.0	23.72–33.62	Rao & Ganapati (1958)
	Temperature	23.3–29.6	25.3–29.6	23.3–29.6	23.6–28.1	
Eastern tropical Pacific	Salinity	32.64–34.89	32.64–34.80	32.64–34.79	32.64–34.89	Sund (1961)
	Temperature	5.4–28.2	15.1–27.3	19.8–28.2	13.0–28.2	

2004). So, only surface water temperature and salinity was discussed, because there was only a minor difference between the surface and bottom readings. Water temperature and salinity varied respectively from 14.1 to 29.4°C (mean 22.7±1.7°C) and 38.4 to 44.9 (mean 41.5±0.6). Temperature and salinity tolerance ranges for several species comparing the present and some prior studies in the Bay of Bengal, Red Sea and the Eastern tropical Pacific (Furnestine 1958, Rao & Ganapati 1958, Sund 1961) are showing in Table 3.

All the six chaetognath species recorded herein have been previously reported from Kuwaiti waters in the southwestern

Persian Gulf (Michel et al. 1986 a, b, Al-Yamani et al. 1998, Al-Yamani et al. 2004). The seasonal abundance fluctuations were similar to those found in prior study but the species composition was relatively different. Probably, the abundances and species compositions were related to water circulation and shallowness of the water column in the Persian Gulf area. *Sagitta ferox*, the most abundant chaetognath along the Khuzestan coast is a common neritic community indicator. In addition, it is abundant in the Arabian Sea and the north of the Indian Ocean (Nair et al. 2002, Bisby et al. 2005). Adults of *S. ferox* with mature gonads were present abundantly in most

samples, suggesting reproduction and recruitment occurs in the northwestern Persian Gulf. This numerically dominant species was nearly three times as abundant as the next abundant species, *S. enflata*. However, *S. ferox* was absent in Kuwaiti waters and instead *S. enflata* was reported as the most numerically dominant species there (Michel et al. 1986b). Nair et al. (2002) recorded that in the surface stratum, *S. ferox* was a dominant species in the northern Indian Ocean and was more abundant during the night. Perhaps, a zooplankton rich surface stratum of Indian Ocean water entering through the strait of Hormoz brings this epipelagic and oceanic current indicator species in to the north of the Persian Gulf. However, Kuwait Bay and its coastal areas are not influenced by the counter-clockwise current circulation of the Persian Gulf because of the deviation effect of the Arvand river currents (Michel et al. 1986b).

Sagitta enflata was the second most numerically abundant chaetognath in the northwestern Persian Gulf. It is an oceanic species in the Gulf currents, commonly is more numerous towards the edge of the shelf than in the open sea and reaches areas well inside the bay (McLelland 1989, Pierrot-Bults 1991, Hernández et al. 2005). Therefore, *S. enflata* is more abundant in Kuwait Bay than along the Khuzestan coasts. *Sagitta neglecta* was recorded as the third most abundant chaetognath species with a year round presence in the northwestern Persian Gulf; Michel et al. (1986b) mentioned a similar finding for Kuwaiti offshore stations.

The present results show that seasonal variations in chaetognath abundance were related with environmental factors. The correlation coefficients between the abundance of chaetognaths and the water temperature were significantly positive ($p < 0.01$) but there was no significant relation for abundance and salinity (Table 2).

All numerically abundant species were present throughout most of the year and tolerated an extensive range of temperatures and salinities. A comparison of temperature tolerance ranges for different chaetognath species showed a high tolerance range for most of the recorded species. In the northwestern Persian Gulf, *S. enflata* tolerated a more extensive range compared to those species that exist in the Red Sea (Furnest 1958) and the Bay of Bengal (Rao & Ganapati 1958). However, species from the Eastern tropical Pacific were tolerant of a more extensive temperature range (Sund 1961). Distribution results for *S. neglecta*, *S. ferox* and *K. pacifica* showed that their tolerance of temperature ranges in the northwestern Persian Gulf was higher than all other region. However, regarding salinity tolerance chaetognaths in the Bay of Bengal were tolerant of a more extensive range of salinities (Rao & Ganapati 1958). However, the highest salinity value occurred in the Persian Gulf compared to other regions and perhaps pelagic chaetognaths species that inhabit this region are adapted to very high salinities up to 45.

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