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Diversity and distribution of larval and juvenile fish in nearshore waters of the Southeastern Caspian Sea and Gorgan Bay

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Abstract

Occurrence and distribution of larval and juvenile fish was investigated in nearshore waters of the southeastern Caspian Sea including the Gorgan Bay. Samples were collected during seven surveys using a fine mesh beach-seine in five sampling sites from July 2014 to June 2015. A total of 15500 individuals mostly juvenile were captured, representing 18 species from 8 families. Most juveniles belonged to *Liza saliens*, *Atherina caspia*, *Neogobius pallasi* and *Neogobius melanostomus.* The juveniles of *Alburnus chalcoides*, *Vimba persa*, *Syngnathus caspius* and gobies *Neogobius caspius* and *Ponticola syrman* occurred in low number (relative abundance 0.1% - 9.3%). Highest number of juveniles were caught in summer season. The occurrence of larval fish in coastal waters of southern Caspian was recorded for the first time (*Atherina caspia* with minimum length of 12 mm in Caspian and 9.5 mm in Gorgan Bay). In spring, early juveniles of mullet, *Liza aurata*, increased in the Caspian sites but they moved up to deeper waters by the end of the season. Based on results, the density of juvenile fish (specially *Liza saliens*) in Gorgan Bay was several times more than Caspian sites so it could be considered an important nursery ground in the region.

Keywords: Southeastern Caspian, Larval and juvenile fish, Gorgan Bay, Surf zone, Fish diversity, Miankaleh

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Introduction

The Caspian Sea is the largest enclosed water body in the world which longitudinally extends 1200 kilometers so it is affected by the arctic to warm and Mediterranean climate from the north to the south of the sea (Mamaev *et al.*, 2002). A diversified range of habitats from marine to extensive wetlands and also geographical separation has established a unique ecosystem which supports the life of many aquatic species (Mamaev *et al.*, 2002). Fishes are the most important fauna of the Caspian Sea which live in its brackish waters and include endemic, introduced and alien species. Some fish such as mullets and roach have a high commercial value in the region (Afraei Bandpei, 2010; Fazli *et al.,* 2015). Larval and juvenile stages are important parts of fish life cycle because survival in these stages have direct effects on persistence of fish populations (Peguero *et al.*, 2007). Nearshore waters and surf zone could be a potential nursery habitat for juveniles due to suitable shelter and enough prey or food (Mearns, 1979; Lasiak, 1981; Senta and Kinoshita, 1985; Santos and Nash, 1995; Lazzari *et al*., 1999; Layman, 2000; Toft *et al.*, 2004; Fodrie *et al.*, 2009). In the surf zone the action of waves and turbulence forces can cause physiological stress (Paes, 2002), but it may act as a sheltered habitat for fish juveniles which have enough food for growth (Modde and Ross, 1980; Lasiak, 1986; Whitfield, 1989; DeVries, 1990; Jarrin, 2012). The role of coastal wetlands and shallow bays as nursery habitats for larval and juvenile fish have also been demonstrated (Pessanha and Araújo, 2003; Cubedo, 2006; Franco *et al.*, 2006; Keskin and Gaygusuz, 2010).

Many studies have been conducted on fish assemblages and their biology in the southern Caspian but there was little information about juvenile fish and no data on larval occurrence. The aim of this study was to detect and identify larval and juvenile fish and their seasonal appearance and spatial distribution in nearshore habitats of the southeastern Caspian.

Materials and methods

Southeastern Caspian with a climate of moderate winters and warm summers, covers a wide range of habitats including wave exposed sandy shores to vast shallow coastal lagoon such as Gorgan Bay. This Bay (400 km^2 surface area) has a mean depth of 2 meters which is the main part of the Miankaleh protected area, declared as Biospher Reserve in 1976 (Darvishsefat and Tajvidi, 2006). The bottom slope of the Caspian Sea in the area gradually decreases from west to east, so it become very gentle in Miankaleh Peninsula (Firoozfar *et al.*, 2012).

Five sampling sites were selected in the study area based on habitat characteristics (Fig. 1). Among them, two sites (CF: Caspian-Farahabad, CM: Caspian-Miankaleh) were located in the Caspian surf zone and the others (GW: Gorgan-West, GE: Gorgan-East and GZ: Gorgan-Khozini) in the Gorgan Bay. CF site with sandy bed was located close to one of the local fishing sites, 2 kilometers far from Tajan River mouth (with low current flow in recent years). CM site was selected in the Miankaleh peninsula with shallow sandy bed and lower wave action. The beach in this area had natural vegetation which has no agricultural and construction activities but beach seine fisheries were operated in the fall and winter.

GW site in the west of the Gorgan Bay was selected near CM on the other side of Miankaleh narrow peninsula, with a sandy-muddy shallow bed. Other sites (GE and GZ) were selected in the east of Gorgan Bay, both with sandy bottom (rich in small and big shell pieces) but GZ was adjacent to the mouth of Khozini Channel which was connected to the Caspian Sea in the past but sedimentation processes closed it gradually.

Seven sampling surveys were conducted during summer (July, August, and September), fall (December), winter (February) and spring (April and June) from July 2014 to June 2015.

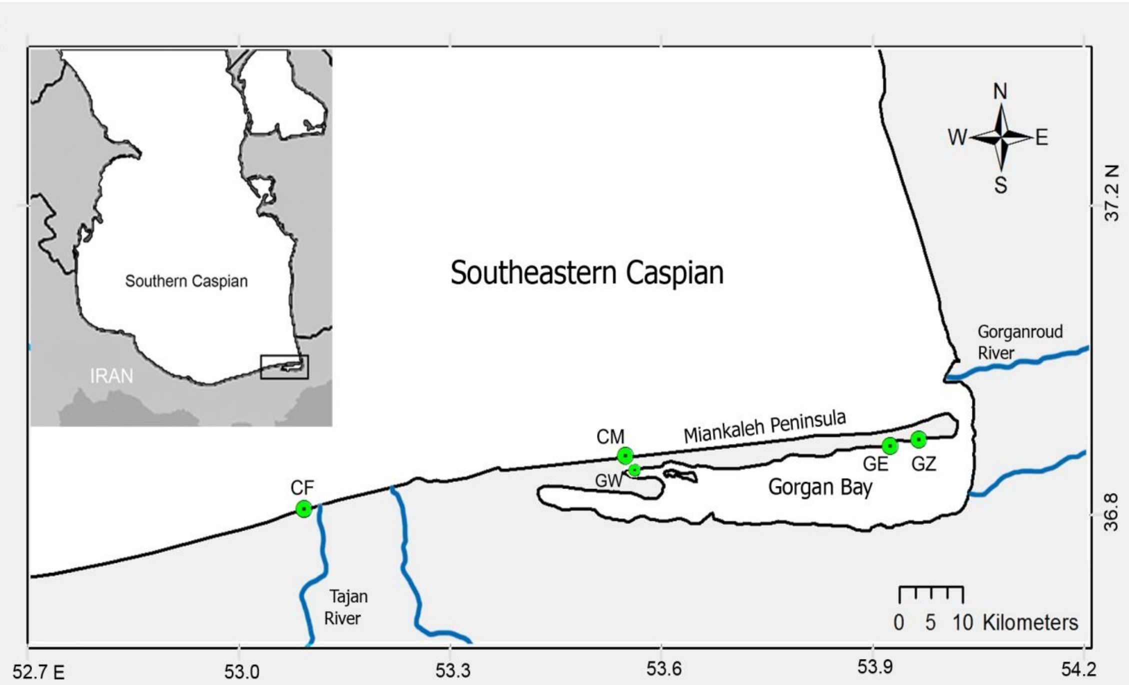

Figure 1: Study area in the Southeastern Caspian Sea and the selected sampling sites (CF: Caspian-Farahabad, CM: Caspian-Miankaleh, GW: Gorgan-West, GE: Gorgan-East and GZ: Gorgan-Khozini).

Samples were collected using a 20 m beach-seine with 2 mm mesh size and 2.5 m height. One end of the seine was held at about 5 meters distance from the shore line in water while the other end was manually extended perpendicular to the shore and then pulled in a semi-circular direction to the beach. Three seine hauls were done at each Caspian station but due to more abundant fish, two hauls were conducted in the Gorgan Bay (in GW, one haul in winter and early spring because of decreasing depth and muddy bed). The maximum

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depth of sampling in the Caspian surf zone and Gorgan Bay was 0.5 and 1.2 m, respectively. The sampling times were chosen on the basis of fish reproduction data and seasonal occurrence (early, mid and end of summer; late fall; mid winter; early and end-spring).

All specimens were fixed in 4% formalin solution in sea water for subsequent analysis. Water temperature was measured by a thermometer, salinity and pH were determined using WTW instrument. In the laboratory, preserved samples were sorted and identified according to Naderi and Abdoli (2004) and the size (total length) of each individual was measured to the nearest 0.5 mm. Larval and early juvenile fish were identified according to morphological characteristics (Makeyeva *et al*., 2011; Ben Khemis *et al*., 2013). Diversity index of Shannon-Wiener ($H^{\prime}$) was determined using the formula $H^{\prime}=- [\sum Pi \ln Pi]$ where Pi is the proportion of each species in the sample; lnPi = natural logarithm of this proportion (Krebs, 1989). Margalef's species richness (Margalef, 1968) and evenness index of Pielou (1966) was calculated for all sampling sites using Excel software.

Shapiro-Wilk test was conducted for testing the normality of data. Due to normality distribution of data after transformation, Principle Component Analysis (PCA) performed on the basis of species abundance, measured factors and sampling times (Husson, *et al*., 2017). In order to reduce the effect of scattering data, the species with relative abundance of more than 1% were chosen. All analyses were conducted using R program (version 3.3.1.).

Results

A total of 15500 larval, juvenile and adult fish were captured, representing 18 species from 8 families (Tables 1-4). The larval stages of fish were caught in the Southern Caspian and Gorgan Bay for the first time. Annually the most abundant juveniles were *Liza saliens*, *Atherina caspia* and *Neogobius pallasi* (Tables 1, 2, 3, 4).

Water temperature displayed considerable changes during seasons (Fig. 2), ranging from 32 ºC in summer to 10.5-12 ºC in winter (charactristics of temperate areas). Salinity had low variations between 10.2-11.2 g L^{-1} in the Caspian sites but there were more temporal changes in Gorgan-West (11.2-18.7 g L^{-1}) and Gorgan-East (11.8-15.4 g L^{-1}). The pH was recorded between the range of 8.57±0.16 (±SD) and 8.55±0.23 in the Caspian and Gorgan sites.

The first survey was conducted in early summer 2014 and we found the smallest juveniles of *Liza saliens* at lengths of 12-13 mm (in larval-juvenile metamorphosing stage). Their average size was 38.6 and 28.6 mm in CF and CM sites, respectively (Table 2). in CF, *Rutilus kutum* juveniles were dominant (68.1% relative abundance). In CM site *Atherina caspia*, *Rutilus kutum,* and

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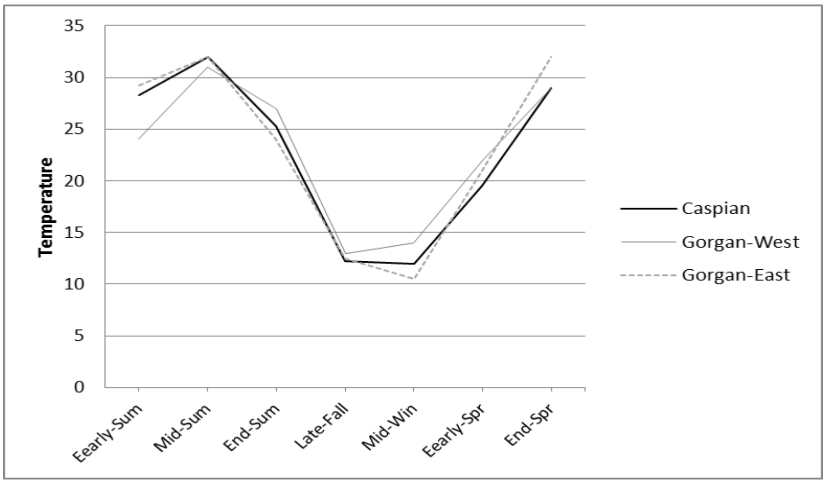

Figure 2: Temporal variations of water temperature (°C) in Caspian, Gorgan-west and Gorgan-east sampling sites in summer (sum), fall, winter (win) and spring (spr).

Neogobius pallasi were dominant. Larval stages of *Atherina caspia* at lengths (TL) of 10-22 mm reported for the first time in Gorgan Bay (Table 4). Early juveniles of *N. Pallasi* (*N. fluviatilis*) were also reported in GW and early juveniles of *L. saliens* (size range 16.5-67.5 mm) and *A. caspia* (22-40 mm) dominated the beach seine catches in the eastern sites (GE and GZ). The juvenile stage of a rare species, tubenose goby (*Proterorhinus marmoratus*) was also caught in GE.

Table 1: Annual frequency of fish species in the Caspian sites (CF and CK) as mean catch per seine haul (C/S) with percent frequency (N%) and size range (min-max) of specimens. Life stages (L-stage) determined as larvae (L), Metamorphosis (MS), Juvenile (J) and Adult (A).

Family	Species	CF					CM				
		C/S	N%	Min	Max	L-Stage	C/S	N%	Min	Max	L-Stage
Atherinidae	*Atherina caspia*	21.3	3.6%	30	131	J,A	219.7	31.2%	12	114	L,J,A
Clupeidae	*Clupeonella caspia*						0.3	0.05%	26	26	J
Cyprinidae	*Alburnus chalcoides*	54.7	9.3%	35	160	J,A	4	0.6%	50	98	J
	Carassius auratus	1.3	0.2%	60.5	93	A					
	Hemiculter leucisculus	3	0.5%	85	148	A					
	Rutilus kutum	168.3	28.7%	30	92.5	J	33	4.7%	36	84.5	J
	Vimba persa	14	2.4%	52.5	88	J					
Gasterostidae	*Gasterosteus aculeatus*	9.7	1.6%	53	65.5	A	0.3	0.05%	65	65	A
Gobiidae	*Neogobius caspius*	11	1.9%	48	83	J,A	4	0.6%	51	98	J,A
	Neogobius melanostomus						1.7	0.2%	41.5	67	J,A
	Neogobius pallasi	58.3	9.9%	36	106	J,A	106.3	15.1%	29.5	97	J,A
	Ponticola syrman	0.7	0.1%	52	56	J	0.7	0.1%	51	67	J
Mugilidae	*Liza aurata*	70.3	12.0%	29	62	J	76	10.8%	24	58	J
	Liza Saliens	174.3	29.7%	12.5	181	MS, J	255.7	36.3%	12	178	MS, J
Syngnathidae	*Syngnathus caspius*	0.3	0.1%	144	144	A	2	0.3%	83	159	A
	Totals	587.3	100%				703.7	100%			

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Table 2: Temporal frequency of more abundant species in Caspian sites (CF and CM) as mean catch per seine (C/S) in summer (sum), fall, winter (win) and spring (spr) with relative abundance (N%) and mean (± Standard Deviation) total length (TL) of specimens. Life stages (L-stage) determined as larvae (L), Metamorphosis (MS), Juvenile (J) and Adult (A).

Family/ Species	CF C/S	CF N%	CF TL (mm) Mean ±SD	CM C/S	CM N%	CM TL (mm) Mean ±SD	L-Stage
Atherinidae							
Atherina caspia							
Early-Sum 2014	0.3	0.2%	-	31.3	42.3%	80.6 ± 19.3	J, A
Mid-Sum 2014	0.3	0.5%	-	0.3	0.6%	-	L, A
End-Sum 2014	1.7	2.4%	95.1 ± 4.1	0.3	0.8%	-	J, A
Late-Fall 2014	3.3	9.3%	77.9 ± 19.2	68.0	93.2%	60.8 ± 15.1	L,J,A
Mid-Win 2015	10	17.4%	65.9 ± 19.1	13.3	9.3%	56.4 ± 15.0	J,A
Early-Spr 2015	3.7	3.3%	96.2 ± 24.2	54.0	28.1%	71.1 ± 9.6	A
End-Spr 2015	2	2.2%	35.6 ± 6.4	52.3	41.6%	35.8 ± 17.1	L, J, A
Cyprinidae							
Rutilus kutum							
Early-Sum 2014	104.7	68.1%	40.0 ± 4.8	19.7	26.6%	43.0 ± 3.9	J
Mid-Sum 2014	2.3	3.4%	63.6 ± 14.7	4.3	8.0%	44.9 ± 5.5	J
End-Sum 2014	5.7	8.0%	73.1 ± 9.7	4.3	10.7%	75.5 ± 5.8	J
Early-Spr 2015	1	0.9%	68.0 ± 4.6	-	-	-	-
End-Spr 2015	54.7	60.5%	46.5 ± 3.8	4.7	3.7%	57.9 ± 5.4	J
Gobiidae							
Neogobius pallasi							
Early-Sum 2014	3.3	2.2%	77.1 ± 8.4	15.3	20.7%	68.4 ± 8.2	J, A
Mid-Sum 2014	2.7	3.9%	75.4 ± 8.8	-	-	-	A
End-Sum 2014	3	4.2%	65.3 ± 12.0	4.0	9.8%	67.0 ± 12.0	J,A
Late-Fall 2014	-	-	-	0.7	0.9%	56.3 ± 1.1	J,A
Mid-Win 2015	8.3	14.5%	80.7 ± 12.6	0.3	0.2%	-	A
Early-Spr 2015	16.3	14.6%	78.5 ± 12.2	54.3	28.3%	60.6 ± 14.6	J,A
End-Spr 2015	24.7	27.3%	71.2 ± 9.2	31.7	25.2%	66.4 ± 8.6	J,A
Mugilidae							
Liza aurata							
Mid-Win 2015	11	19.2%	50.7 ± 5.1	1	0.7%	47.2 ± 2.6	J
Early-Spr 2015	59.3	53.1%	43.9 ± 7.9	75	39.1%	37.4 ± 6.9	J
Liza Saliens							
Early-Sum 2014	26	16.9%	38.6 ± 38.2	4.3	5.9%	28.6 ± 13.7	MS, J
Mid-Sum 2014	51.7	76.0%	46.9 ± 20.2	49.7	91.4%	55.6 ± 22.7	MS, J
End-Sum 2014	45	63.7%	48.2 ± 10.3	31	76.2%	41.5 ± 11.8	J
Late-Fall 2014	11.3	31.5%	64.6 ± 11.6	3.3	4.6%	62.1 ± 28.7	J
Mid-Win 2015	24	41.9%	58.6 ± 8.5	129.3	89.8%	63.4 ± 7.0	J
Early-Spr 2015	13	11.6%	66.4 ± 8.0	4.3	2.3%	77.4 ± 14.3	J
End-Spr 2015	3.3	3.7%	90.5 ± 25.1	33.7	26.8%	38.4 ± 30.5	J

Table 3: Annual frequency of fish species in Gorgan Bay sites (GW, GE and GZ) as mean catch per seine haul (C/S) with percent frequency (N%) and size range (min-max) of specimens. Life stages (L-stage) determined as larvae (L), Metamorphosing Stage (MS), Juvenile (J) and Adult (A).

Family	Species	GW C/S	GW N%	GW Min	GW Max	GW L-Stage	GE C/S	GE N%	GE Min	GE Max	GE L-Stage	GZ C/S	GZ N%	GZ Min	GZ Max	GZ L-Stage
Atherinidae	*Atherina caspia*	563.5	40.4%	10	113	L,J,A	118	7.7%	22	70	L, J, A	408.5	13.4%	13.5	108	L,J,A
Clupeidae	*Clupeonella caspia*	17	1.2%	41	127	J,A										
Cyprinidae	*Alburnus chalcoides*											0.5	0.1%	38	38	J
	Rutilus kutum						2	0.1%	46	60	J					
Gasterostidae	*Gasterosteus aculeatus*											0.5	0.1%	26	26	J
Gobiidae	*Knipowitschia caucasica*	21	1.5%	22.5	39	A	17	1.1%	26	41	A	47	1.5%	17.5	52	A
	Neogobius caspius											1	0.4%	80	80	A
	Neogobius melanostomus	90	6.4%	13	87	J.A						221	7.2%	19	83	J,A
	Neogobius pallasi	154	11%	11	123	J.A	5.5	0.4%	29	85	J,A	142	4.7%	20.5	108	J,A
	Ponticola syrman	8	0.6%	61.5	94	J	0.5	0.5%	71	71	J	3.5	0.1%	64.5	69	J
	Proterorhinus marmoratus						2	0.1%	29.5	45	J	2.5	0.1%	36	57.5	J
Mugilidae	*Liza aurata*						10.5	0.7%	31	57	J	49	1.6%	26.5	51	J
	Liza Saliens	267.5	19%	12	112	MS, J	1351.5	88%	15	113	J	2155.5	71%	12	136	MS, J
Poeciliidae	*Gambusia holbrooki*	265.5	19%	20.5	44	J,A	30	1.9%	19	36	J,A	15.5	0.5%	11.5	37	J.A
Syngnathidae	*Syngnathus caspius*	10	0.7%	41	90	J.A	2.5	0.2%	66	104	A	3.5	0.1%	55	116	J,A
	Total	1397	100%				1540	100%				3050	100%			

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Table 4: Temporal frequency of more abundant species in Gorgan Bay sites (GW, GE and GZ) as mean catch per seine (C/S) in summer (sum), fall, winter (win) and spring (spr) with relative abundance (N%) and mean (± Standard Deviation) total length (TL) of specimens. Life stages (L-stage) determined as larvae (L), Metamorphosis (MS), Juvenile (J) and Adult (A).

Family/ Species	GW			GE			GZ			L-Stage
	C/S	N%	TL (mm) Mean ±SD	C/S	N%	TL (mm) Mean ±SD	C/S	N%	TL (mm) Mean ±SD	
Atherinidae										
Atherina caspia										
Early-Sum 2014	48	31.9%	46.3 ± 22.1	4	3.8%	28.9 ± 6.9	36	14.9%	24.2 ± 7.4	L,J,A
Mid-Sum 2014	186.5	64.2%	43.4 ± 20.1	31	5.2%	40.2 ± 7.8	16	2.0%	39.7 ± 25.5	L,J,A
End-Sum 2014	9	2.1%	47.4 ± 10.7	30.5	16.5%	42.1 ± 6.8	17	1.9%	58.1 ± 12.0	J,A
Late-Fall 2014	2	1.9%	20.3 ± 3.3	33	7.1%	33.1 ± 6.9	16.5	5.5%	39.2 ± 7.8	L,J,A
Mid-Win 2015	-	-	-	4.5	8.6%	35.6 ± 13.3	117.5	83.9%	34.3 ± 3.8	J,A
Early-Spr 2015	244	84.4%	71.1 ± 9.9	15	12.2%	41.7 ± 5.5	204.5	37.5%	76.9 ± 10.7	J,A
End-Spr 2015	74	84.3%	61.9 ± 13.9	-	-	-	1	0.8%	17.8 ± 6.0	L,J,A
Gobiidae										
Knipowitschia caucasica										
Early-Sum 2014	-	-	-	1.5	1.4%	30.0 ± 6.1	9	3.7%	24.4 ± 2.5	A
Mid-Sum 2014	1.5	0.5%	24.0 ± 1.7	-	-	-	4	0.5%	24.9 ± 3.7	A
End-Sum 2014	4.5	1.0%	26.1 ± 2.3	-	-	-	3	0.3%	26.0 ± 1.8	A
Late-Fall 2014	-	-	-	1	0.2%	31.5 ± 1.4	22.5	7.5%	36.5 ± 7.3	A
Mid-Win 2015	1	2.4%	37.0 ± 0.0	10.5	20.0%	36.7 ± 2.3	8	5.7%	34.6 ± 1.6	A
Early-Spr 2015	14	4.8%	32.8 ± 3.4	4	3.3%	35.1 ± 4.3	1	0.1%	37.0 ± 0.0	A
Neogobius melanostomus										
Early-Sum 2014	2	1.3%	79.5 ± 9.0	-	-	-	3.5	1.4%	60.1 ± 7.1	J,A
Mid-Sum 2014	18	6.2%	26.0 ± 5.6	-	-	-	77.5	9.7%	43.8 ± 16.8	J,A
End-Sum 2014	66	15.2%	29.7 ± 5.0	-	-	-	139	15.4%	38.4 ± 7.3	J,A
Early-Spr 2015	4	1.4%	55.0 ± 5.2	-	-	-	1	0.2%	53.0 ± 21.2	J,A
Neogobius pallasi										
Early-Sum 2014	90.5	60.1%	32.7 ± 27.6	2	1.9%	53.6 ± 6.2	3	1.2%	73.2 ± 4.9	J, A
Mid-Sum 2014	29	10.0%	30.1 ± 15.2	-	-	-	26.5	3.3%	35.0 ± 14.2	J,A
End-Sum 2014	12.5	2.9%	30.2 ± 5.8	1.5	0.8%	70.0 ± 13.5	43.5	4.8%	62.0 ± 14.5	J,A
Late-Fall 2014	-	-	-	-	-	-	0.5	0.2%	64.0 ± 0.0	A
Early-Spr 2015	13	4.5%	76.3 ± 17.1	2	1.6%	37.3 ± 12.7	68.5	12.5%	46.6 ± 19.5	J,A
End-Spr 2015	9	11.7%	70.6 ± 15.0	-	-	-	-	-	-	J,A
Mugilidae										
Liza aurata										
Early-Spr 2015	-	-	-	10.5	8.6%	42.5 ± 7.0	49	9.0%	37.9 ± 6.2	J
Liza Saliens										
Early-Sum 2014	1.5	1.0%	37.0 ± 6.1	93	88.2%	32.1 ± 12.5	184	76.0%	21.9 ± 6.4	J
Mid-Sum 2014	32.5	11.2%	59.7 ± 11.2	552.5	92.9%	33.9 ± 12.8	672.5	84.1%	29.6 ± 10.4	J
End-Sum 2014	78.5	18.1%	58.2 ± 14.0	134	72.6%	38.3 ± 13.2	685	75.9%	33.4 ± 10.9	MS, J
Late-Fall 2014	101.5	96.2%	40.1 ± 8.9	431	92.7%	41.7 ± 11.5	260.5	86.7%	28.5 ± 6.3	J
Mid-Win 2015	39	95.1%	53.4 ± 5.7	35.5	67.6%	30.3 ± 1.7	14.5	10.4%	41.3 ± 13.0	J
Early-Spr 2015	14	4.8%	66.6 ± 22.7	91	74.3%	62.3 ± 13.9	221.5	40.6%	53.0 ± 17.8	MS, J
End-Spr 2015	0.5	0.9%	94.0 ± 0.0	14.5	100%	56.2 ± 25.7	117.5	99.2%	21.9 ± 8.9	J

The next sampling in mid-summer displayed significant increase of *Liza saliens* juveniles in Gorgan Bay, especially in GZ and GE (84.1% and 92.9%). Juveniles of *Neogobius melanostomus* were abundant in GZ (9.7%, min TL: 19 mm) and GW (6.2%, min TL: 13 mm).

At the end of summer, the juveniles of *L. saliens* still had high density in Gorgan Bay but abundance of *A. boyeri* decreased.

Reduction of fish juveniles recorded in late-fall (except for *L. saliens* in Gorgan Bay).

Mid-winter sampling was characterized by the first occurrence of *Liza aurata* in CF site (about 20% of total catch with average TL = 51 mm), while we caught the high number of *Liza saliens* in CM amongst the sampling surveys in this site (Table 2).

The early-spring sampling represented *Liza aurata* as the most abundant species in CM (size range 24-58 mm) and CF (29-62 mm) which was also captured in the eastern sites of Gorgan Bay in less numbers. The goby, *N. pallasi* again appeared in sampling sites especially CM and GZ.

At the end of spring, the species composition characterized by disappearance of *L. aurata*, significant abundance of *R. kutum* and occurence of *Hemiculter leucisculus*, an alien species (Mousavi-Sabet *et al*., 2013), but the capture of larval *Atherina caspia* in site CM was the first record of fish larvae in waters of the southern Caspian. Totally 40 larvae of *A. caspia* were caught at lengths of 12-22 mm (21 June 2015, site position: 36°52'35.65''N, 53°33'0.60''E).

The species *Alburnus chalcoides*, *Vimba persa*, *Clupeonella caspia*, *Hemiculter leucisculus*, *Gasterosteus aculeatus*, *Syngnathus caspius* and gobies *Neogobius caspius*, and *Ponticola syrman* occurred in low numbers. The goby *Knipowitschia caucasica* and *Gambusia holbrooki* only captured in Gorgan Bay.

PCA was conducted for selected species and revealed that dimension 1 and dimension 2 were responsible for 30.86% and 22.28% of the total variation, respectively (Fig. 4). In the base of coordination with dimension1, salinity was a more effective hydrological measurement (0.5) and comparing fish groups in stations CF (-1.49), CM (-0.9), were different from GE (0.03), GW (0.89), and GZ (1.47) in the base of coordination with dimension1 and there was more variability of GW (Fig. 5). PCA ordination was also performed for the seven sampling times (Fig. 6). In terms of ordination space, early-spring is somewhat separate from the other times, extending mainly in Dimension 2. The variability from early to end of summer is high and there is considerable correlation between mid and end of summer.

Diversity indices (Shannon-Wiener, Margalef's richness and Evenness) were calculated in each sampling time (Fig. 3). The indices showed variations between seasons. Amongst the sites, CF had higher mean values and there was a declining trend of indices toward Gorgan Bay.

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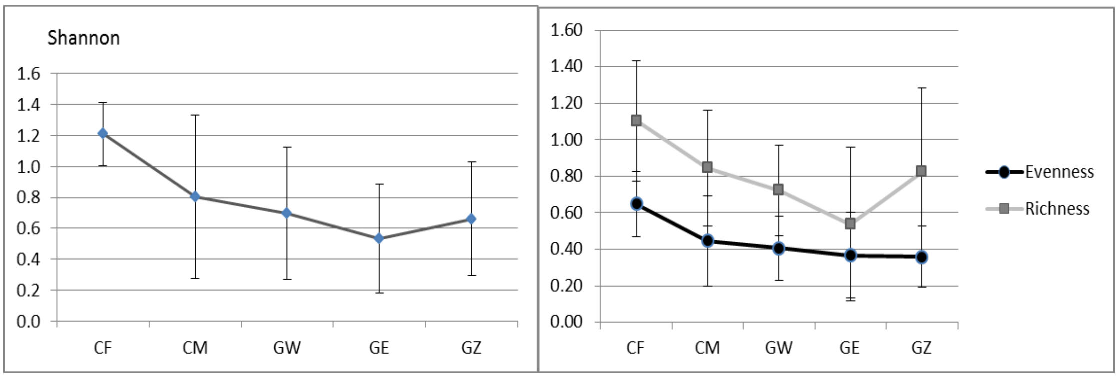

Figure 3: Variations of fish community indices (mean ± SD) for each site (CF, CM, GW, GE, GZ) during the whole sampling periods.

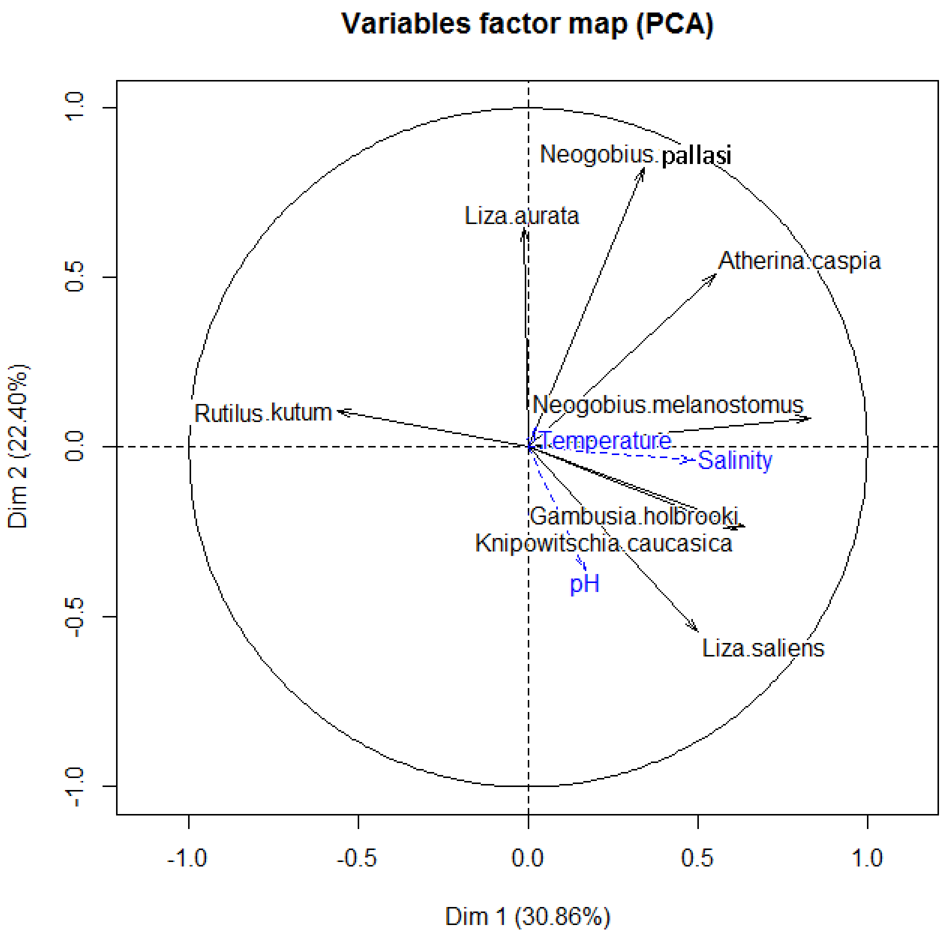

Figure 4: PCA ordination of three environmental variables and abundance of the studied species.

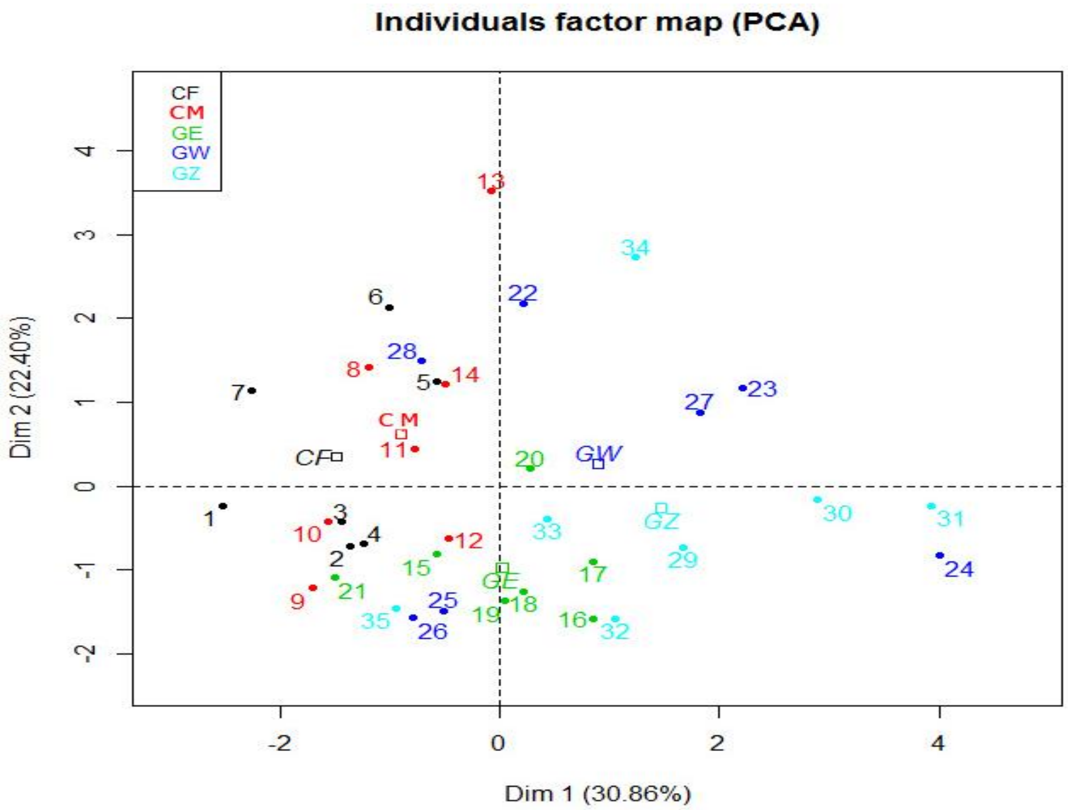

Figure 5: Principal component analysis of sampling sites shows separation between the Caspian (CF, CM) and Gorgan (GW, GE, GZ) sites.

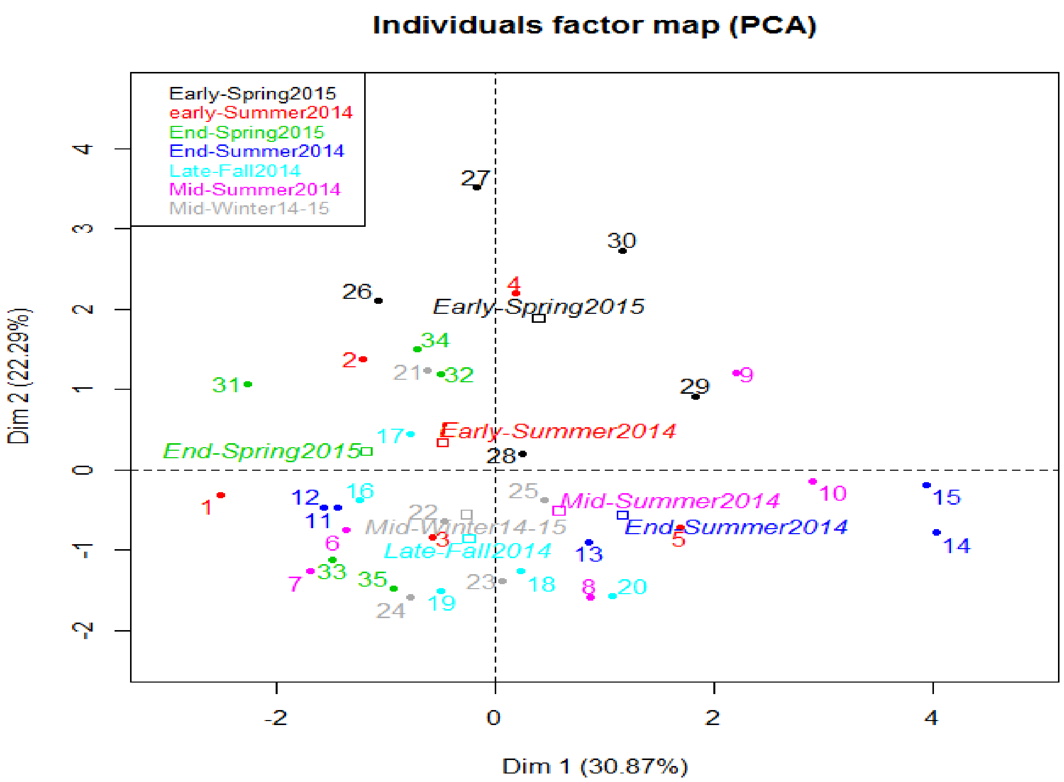

Figure 6: Principal Component Analysis of seven sampling times indicating the particle composition correlations.

Discussion

Based on results of the present study, shallow nearshore waters were occupied by a great proportion of juvenile fish and a few small sized species which is similar to general pattern in other seas and water bodies (Moreno and Castro, 1995; Uzars *et al*., 2003; Bouriga *et al*., 2009; Keskin and Gaygusuz, 2010; Del Favero and Dias, 2013; Altin *et al.*, 2015; Esposito *et al*., 2015). Larvae and early juveniles of several fish species were caught and reported in the Southeastern Caspian. According to results in Tables 1 and 3, the annual catch of juvenile fish in the Gorgan Bay was several times more than that of the Caspian sites which demonstrated the role of Gorgan Bay as an important nursery ground in the region.

Although the stocks of mullet *L. saliens* encountered significant decrease in recent decades (Fazli *et al*., 2013), a large number of juveniles were observed throughout the year especially in Gorgan Bay. The early juveniles of this species had a high abundance in GZ site (adjacent to Khozini Channel) during the summer and fall (Table 4), so it seems the presence of a channel provides better conditions for juveniles. A similar situation has been reported in channel systems of salt marsh regions in Venice Lagoon (Franco *et al.*, 2006) and also Neretva river estuary in Croatia (Bartulović *et al*., 2009). The juvenile abundance of other mullets, *L. aurata*, increased from winter to early spring in the Caspian sites (when *L. saliens* significantly declined at this time) and then they left nearshore waters up to the end of season (Table 2). This occurrence pattern also exists in the Mediterranean Sea, typically in the northern Sicilian coast with high abundance of *L. aurata* juveniles in early May (Esposito *et al*., 2015). The sand smelt *A. caspia* as a resident fish in nearshore waters occurred throughout the year in the study area. It has been considered as a distinct species from *A. boyeri* (Tarasov, 2001; Naseka and Bogutskaya, 2009). The results (Tables 1, 3) display that *A. caspia* has more density in the eastern half of the study area specially in the spawning season which probably indicates that this small fish prefers more calm and shallow waters and coastal lagoons. The Gobidae family had wide distribution in the study area but early juveniles of *N. pallasi* and *N. melanostomus* were caught mainly in the Gorgan Bay in summer (Table 4) so it seems the Bay is a more suitable habitat for the life and growth of these gobies.

The composition of the most abundant fish groups in Gorgan Bay (*L. saliens*, *A. boyeri* and gobied fish) is similar to that in Mar Menor Lagoon in Spain (one of the largest coastal lagoons in Mediterranean Sea) where dominant fish are *L. saliens*, *A. boyeri* and gobids (Verdiell Cubedo, *et al.*, 2004; Verdiell-Cubedo *et al*., 2012). Meanwhile, it shows the successful tolerance of euryhaline species like *Liza saliens* and *A. boyeri* for survival and growth in brackish waters of Gorgan Bay (salinity,11-19 g L^{-1}) as well as hypersaline waters of Mar Menor with salinity of 39-45 g L^{-1}. Generally, the families Mugiliidae, Atherinidae and Gobiidae have already been demonstrated as dominant fish groups in warm temperate and semi tropical coastal lagoons (Potter *et al*., 1990; Elliott and Dewailly, 1995; Costa *et al*., 2002; Malavasi *et al.*, 2004) which are in accordance with our results.

The juveniles of *N. pallasi* were caught in all sites but they were mainly found in large numbers in the eastern sites especially the Gorgan Bay. The species *N. melanostomus* and *K. caucasica* were residents of Gorgan Bay Although low number of *N. melanostomus* was caught in the eastern Caspian site (CM). *Gambusia holbrooki* (as an introduced fish for malaria control in past decades) was reported in all sites of the Gorgan Bay. This species also has a wide distribution in other habitats of the region such as wetlands, reservoirs, slow current rivers and dams (Fattahi *et al*., 2013). A few specimens of three-spined stickleback (*G. aculeatus*) were caught especially in the CF site. The occurrence of this alien species was first reported by Coad and Abdoli (1993).

According to results, most juveniles belonged to those species which reproduce in the sea or lagoonal habitats. Indeed there was low abundance of juvenile anadromous fish such as *V. persa* and *A. chalcoides* and this is attributed to the destruction of riverine habitats making them unsuitable for spawning and also illegal fishing of adult fish in rivers of the area (Falahatkar *et al*., 2015). However the high abundance of juvenile *R. kutum* in the early summer (Table 2) was due to the artificial breeding and release the juveniles as part of the restocking programs (Abdolhay *et al.*, 2011) .

The comparison of the Gorgan Bay with the Gomishan Wetland (another important lagoon in the region) shows differences in fish abundance and species composition. In Gomishan which is a 2000 ha protected coastal wetland with a mean depth of 1 m, the most abundant species was *A. caspia* (62% relative abundance in spring) followed by *G. holbrooki* (63% in fall), but *L. saliens* had relative abundance of 25% in the winter sampling (Patimar *et al*., 2009) compared to 60-100% in the Gorgan Bay, so the relative abundance of *L. saliens* in the Bay was the highest in southeastern Caspian.

The lower mean values of diversity indices in the Gorgan Bay (Fig. 3) could be attributed to seasonal fluctuations in fish abundance and also to the lack of anadromous fish, but higher richness value in GZ could indicate the attraction of more species around the Khozini Channel probably in search of food and refuge. PCA analysis (Fig. 4) demonstrated more correlations of salinity with species that occurred in Gorgan Bay (with more salinity) such as *N. melanostomus*, *K. caucasica*, and *G. holbrooki*, so it may refer to the degree of species residency in Gorgan Bay. Further studies are needed to assess the effects of salinity changes on fish distribution in the bay. In PCA of sampling sites (Fig. 5) the distinction between the Caspian and Gorgan sites was noticeable, representing a different pattern of fish

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assemblages in the lagoonal habit of the Gorgan Bay.

In PCA of sampling seasons (Fig. 6) a clockwise movement around the axis reflects the regular seasonal changes in this temperate region and the separation of early spring from other sampling times could be attributed to a shift in the fish assemblage pattern in nearshore waters of the area such as the appearance of the mullet, *L. aurata*.

This study identified the spatial distribution and composition of larval and juvenile fish in nearshore waters of the southeastern Caspian and showed the importance of the Gorgan Bay as a nursery ground for migratory and resident fish such as mullets and gobies.

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References

Abdolhay, H.A., Daud, S.K., Ghilkolahi, S.R., Pourkazemi, M., Siraj, S.S. and Satar, M.A., 2011. Fingerling production and stock enhancement of Mahisefid (*Rutilus frisii kutum*) lessons for others in the south of Caspian Sea. *Reviews in Fish Biology and Fisheries*, 21(**2**), 247-257.

Afraei Bandpei, M.A., 2010. Population dynamics of Caspian Kutum, *Rutilus frisii kutum* (Cyprinidae) in southern Caspian Sea, Iran. PhD Thesis, University of Sains Malaysia. 207 P.

Altin, A., Ayyildiz, H., Kale, S. and Alver, C., 2015. Length-weight relationships of forty-nine fish species from shallow waters of Gökçeada Island, northern Aegean Sea Turkey. *Turkish Journal of Zoology*, 39(**5**), 971-975 .

Bartulović, V., Matić-Skoko, S., Lučić, D., Conides, A., Jasprica, N., Joksimović, A. and Glamuzina, B., 2009. Recruitment and feeding of juvenile leaping grey mullet, *Liza saliens* (Risso, 1810) in the Neretva River estuary (south-eastern Adriatic, Croatia). *Acta Adriatica*, 50(**1**), 91-103 .

Ben Khemis, I., Gisbert, E., Alcaraz, C., Zouiten, D., Besbes, R., Zouiten, A. and Cahu, C., 2013. Allometric growth patterns and development in larvae and juveniles of thick-lipped grey mullet *Chelon labrosus* reared in mesocosm conditions. *Aquaculture Research*, 44(**12**), 1872-1888 .

Bouriga, N., Selmi, S., Aurelle, D., Barthelemy, R., Quignard, J.-P. Trabelsi, M. and Faure, E., 2009. Lagoonal sand smelts (*Atherina lagunaea*, Teleostei, Atherinidae) inhabit marine shallow waters of the coasts of Djerba Island (Tunisia) *Bulletin de l'Institut National des*

Sciences et Technologies de la Mer de Salammbô, 36, 65-72.

Coad, B. and Abdoli, A., 1993. Exotic fish species in the freshwaters of Iran. *Zoology in the Middle East*, 9, 65-80 .

Costa, M.J., Cabral, H.N., Drake, P., Economou, A.N., Fernandez Delgado, L., Gordo, L., Marchand, J. and Thiel, R., 2002. Recruitment and production of commercial species in estuaries. In: Elliott, M., Hemingway, K.L. (Eds.), Fishes in Estuaries. Blackwell Science, Oxford, 54–123 .

Cubedo, D.V., 2006. Dinámica espacio-temporal de la Familia Mugilidae en las áreas someras del Mar Menor (SE, Murcia): estados alevines y juveniles: Universidad de Murcia, Departamento de Zoología y Antropología Física.

Darvishsefat, A.A. and Tajvidi, M., 2006. Atlas of protected areas of Iran. Tehran: University of Tehran.

Del Favero, J.M. and Dias, J.F., 2013. Spatio-temporal variation in surf zone fish communities at Ilha do Cardoso State Park, São Paulo, Brazil/Variación espacio temporal de la ictiofauna del Parque Estatal Ilha do Cardoso, São Paulo, Brasil. *Latin American Journal of Aquatic Research*, 41(**2**), 239

DeVries, D.R., 1990. Habitat use by bluegill in laboratory pools: where is the refuge when macrophytes are sparse and alternative prey are present? *Environmental Biology of Fishes*, 29(**1**), 27-34 .

Dmitriev, A.N., 1964. Mullet in the Iranian waters of Caspian. *Priroda*, 12, 74-75

Elliott, M. and Dewailly, F., 1995. The structure and components of European estuarine fish assemblages. Neth. *Aquatic Ecology*, 29, 397–417 .

Esposito, V., Castriota, L., Battaglia, P., Consoli, P., Romeo, T., Scotti, G. and Andaloro, F., 2015. Fish community in a surf zone of the northern Sicilian coast (Mediterranean Sea): diversity and functional guild composition. *Mediterranean Marine Science*, 16(**3**), 502-512 .

Falahatkar, B., Amlashi, A.S., Eagderi, S. and Mousavi-Sabet, H., 2015. Review on the Caspian Shemaya, *Alburnus chalcoides* (Güldenstädt, 1772). *International Journal of Aquatic Biology*, 3(**5**), 323.

Fattahi, N., Patimar, R., Ghorbani, R., Farhangi, M. and Bahalkeh, A., 2013. Investigation on some growth characteristics of Gambusia *Gambusia holbrooki* (Girard, 1859) in some aquatic ecosystems of Golestan Province, Northern Iran. *Journal of Applied Ichthyological Research*, 1(**1**), 53-66 .

Fazli, H., Daryanabard, G.R., Abdolmaleki, S. and Bandani, G.A., 2013. Stock status assessment of sharpnose mullet (*Liza saliens*) by using overfishing indicators in southern part of the Caspian Sea (1991-2011). *Journal of Aquatics Exploitation and breeding*, 2(**1**), 55-68.

Fazli, H., Daryanabard, G., Bandani, G. and Pourgholami, A., 2015. Population dynamics of bony fish in the Iranian waters of the Caspian Sea. Iranian Fisheries Science Research Institute (IFSRI). Final report. 96 P.

Firoozfar, A., Bromhead, E.N., Dykes, A.P. and Neshaei, M.A.L., 2012. Southern Caspian Sea coasts, morphology, sediment characteristics, and sea level change. *In Proceedings of the Annual International Conference on Soils, Sediments, Water and Energy*. Vol. 17 , Article 12.

Fodrie, F.J., Levin, L.A. and Lucas, A.J., 2009. Use of population fitness to evaluate the nursery function of juvenile habitats. *Marine Ecology Progress Series*, 385, 39-49 .

Franco, A., Franzoi, P., Malavasi, S., Riccato, F., Torricelli, P. and Mainardi, D., 2006. Use of shallow water habitats by fish assemblages in a Mediterranean coastal lagoon. *Estuarine, Coastal and Shelf Science*, 66(**1**), 67-83 .

Husson, F., Josse, J., Le, S. and Mazet, J., 2017. Multivariate exploratory data analysis and data mining. URL http://factominer.free.fr. 96 P.

Jarrin, J.R.M., 2012. Sandy beach surf zones: What is their role in the early life history of juvenile chinook slmon (*Oncorhynchus tshawytscha*)? Oregon State University.

Keskin, Ç. and Gaygusuz, Ö., 2010. Length-weight relationships of fishes in shallow waters of Erdek Bay (Sea of Marmara, Turkey). *IUFS Journal of Biology*, 69(**2**), 87-94 .

Krebs, C.J., 1989. Ecological methodology, Harper Collins Publishers. Inc., New York. 654 P.

Lasiak, T.A., 1981. Nursery grounds of juvenile teleosts: evidence from the surf zone of King's Beach, Port Elizabeth. *South African Journal of Science*, 77(**9**), 388-390 .

Lasiak, T.A., 1986. Juveniles, food and the surf zone habitat: implications for teleost nursery areas. *African Zoology*, 21(**1**), 51-56 .

Layman, C., 2000. Fish assemblage structure of the shallow ocean surf-zone on the eastern shore of Virginia Barrier Islands. *Estuarine, Coastal and Shelf Science*, 51(**2**), 201-213 .

Lazzari, M.A., Sherman, S., Brown, C.S., King, J., Joule, B.J., Chenoweth, S.B. and Langton, R. W., 1999. Seasonal and annual variations in abundance and species composition of two nearshore fish communities in Maine. *Estuaries and Coasts*, 22(**3**), 636-647 .

Makeyeva, A.P., Pavlov, D.S. and Pavlov, D.A.E., 2011. Atlas of larvae and juveniles of freshwater fishes of Russia: KMK ScientificPress, Moscow, Russia. 383 P.

Malavasi, S., Fiorin, R., Franco, A., Franzoi, P., Granzotto, A., Riccato, F. and Mainardi, D., 2004. Fish assemblages of Venice Lagoon shallow waters: an analysis based on species, families and functional guilds. *Journal of Marine Systems*, 51(**1**), 19-31.

Mamaev, V., Gugele, B., Strobel, B., Taylor, P., Ritter, M. and Jaoshvili, S., 2002. The Caspian Sea. European Environment Agency. Available at: http://www.eea.europa.eu/publications/report_2002_0524_154909/regional-seas-around-europe/CaspianSea.pdf/

Margalef, R., 1968. Perspectives in ecological theory. Chicago: University of Chicago Press. 111 P.

Mearns, A.J., 1979. Abundance, composition, and recruitment of nearshore fish assemblages on the southern California mainland shelf. *California Cooperative Oceanic Fisheries Investigations Report*, 20, 111-119 .

Modde, T. and Ross, S., 1980. Seasonality of fishes occupying a surf zone habitat in the northern Gulf of Mexico. *Fishery Bulletin*, 78(**4**), 911-922 .

Moreno, T. and Castro, J.J., 1995. Community structure of the juvenile of coastal pelagic fish species in the Canary Islands waters. *Scientia Marina*, 59(**3-4**), 405-413.

Mousavi-Sabet, H., Habibi, A. and Bagherpur, O., 2013. Studies on length-weight and length-length relationships, relative condition factor and fulton's condition factor of *Hemiculter leucisculus* (Pisces: Cyprinidae) from the Southwestern Caspian Sea Basin. *Our Nature*, 11(**1**), 25-30.

Naderi Jolodar, M. and Abdoli, A., 2004. Fish species atlas of south Caspian Sea Basin (Iranian Waters): Iranian Fisheries Research Organization. 90 P. (in Persian).

Naseka, A. and Bogutskaya, N., 2009. Fishes of the Caspian Sea: zoogeography and updated check-list. *Zoosystematica Rossica*, 18(**2**), 295-317.

Paes, E., 2002. Nécton marinho. *Biologia marinha*. Ed. Interciência, RJ, pp. 180-193 .

Patimar, R., Abdoli, A., Hasanzade Kiabi, B., Allahyari, S. and Naderi Jelowdar, M., 2009. Fish species diversity of the coastal areas in Gomishan Wetland. 16(1-a). *Journal of Agricultural Sciences and Natural Resources*, 16 (Special Issue 1-a), 89-98 (in Persian).

Peguero, M., Sánchez-Velasco, L., Lavín, M. and Marinone, G., 2007. Larval fish assemblages, environment and circulation in a Semienclosed Sea (Gulf Of California). *Estuarine*, *Coastal and Shelf Science*, *79*(**2**), 277-288.

Pessanha, A.L.M. and Araújo, F.G., 2003. Spatial, temporal and diel variations of fish assemblages at two sandy beaches in the Sepetiba Bay, Rio de Janeiro, Brazil. *Estuarine, Coastal and Shelf Science*, 57(**5**), 817-828 .

Pielou, E., 1966. Species diversity and pattern diversity in the study of ecological succession. *Journal Theoretical Biology*, 13, 131-144.

Potter, I.C., Beckley, L.E., Whitfield, A.K. and Lenanton, R.C., 1990. Comparison between the roles played by estuaries in the life cycles of fishes in temperate western Australia and southern Africa.

[DOR: 20.1001.1.15622916.2019.18.2.11.8]

Environmental Biology of Fishes, 28, 143– 178 .

Santos, R.S. and Nash, R.D., 1995. Seasonal changes in a sandy beach fish assemblage at Porto Pim, Faial, Azores. *Estuarine, Coastal and Shelf Science*, 41(**5**), 579-591 .

Senta, T. and Kinoshita, I., 1985. Larval and juvenile fishes occurring in surf zones of western Japan. *Transactions of the American Fisheries Society*, 114(**4**), 609-618 .

Tarasov, A.G., 2001. Hypersaline ecosystems: oil- and gas-sources. Edel-M Publ., Moscow, 111 P. (in Russian).

Toft, J., Simenstad, C., Cordell, J. and Stamatiou, L., 2004. Fish distribution, abundance, and behavior at nearshore habitats along City of Seattle marine shorelines, with an emphasis on juvenile salmonids. University of Washington, School of Aquatic and Fisheries Sciences, Seattle. 51 pp.

Uzars, D., Ustups, D., Müller–Karulis, B. and Urtans, E., 2003. Size structure and feeding ecology of fish communities in the surf zone of the Eastern Baltic. In *ICES Annual Science Conference. Tallinn, Estonia*,18 P.

Verdiell-Cubedo, D., Andreu, A., Egea, A., Oliva Paterna, F. and Torralva, M., 2004. Dinámica espacio-temporal de la familia Mugilidae en las áreas someras del Mar Menor (SE Murcia): Estados alevines y juveniles. Paper presented at the Actas del III Congreso de la Naturaleza de Murcia, 117-123.

Verdiell-Cubedo, D., Torralva, M., Ruiz-Navarro, A. and Oliva-Paterna, F.J., 2012. Fish assemblages in different littoral habitat types of a hypersaline coastal lagoon (Mar Menor, Mediterranean Sea). *Italian Journal of Zoology*, 80(**1**), 104-116.

Whitfield, A.K., 1989. Ichthyoplankton in a southern African surf zone: nursery area for the postlarvae of estuarine associated fish species? *Estuarine, Coastal and Shelf Science*, 29(**6**), 533-547.