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Diversity of Benthic Invertebrates Fauna and Secondary Production in Southern Caspian Sea Basin, Case Study on Tajan River Estuary

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Abstract: Macro benthic invertebrate assemblages were investigated monthly, from March 2006 to March 2007, at six stations in Tajan river estuary, a south eastern Caspian Sea coastal estuary, in order to estimate secondary production consumable for extensive finger fish releasing and to investigate the factors affecting this production. Benthic assemblages comprised 9 taxa, of which *Ballanus* sp., *Chironomus plumosus* and *Cerastoderma lamarki* were the main contributors to both overall biomass and secondary production. Annual secondary production varied from 4.55 g AFDW m^{-2} $year^{-1}$ (Ash Free Dry Weight), in the upper Tajan estuary, to 78.06 g AFDW m^{-2} $year^{-1}$ (Ash Free Dry Weight) in the center of the estuary area. Multivariate correlations between environmental variables and the Macro benthic assemblage biomass highlighted the role of the water level, temperature, sediment organic carbon content and dissolved oxygen in the differentiation of the communities in the estuary. Composition, biomass and secondary annual production of Macro benthic communities were dramatically affected by changes in water residence time and summer drought crises. The isolation of this habitat limits the recovery of other invertebrate benthic assemblages during drought periods. Only populations of two species, *Balanus* sp. and *C. plumosus*, seemed to be able to recover quickly after the drought crises, which, in turn, could compromise the overall secondary production, with negative effects on the released fish survival. During summer water renewal, when agricultural activity is intense and nutrient inputs should be regulated in this estuary to reduce the risk of benthic mass mortality and to ensure a sustainability of this environment.

Key words: Secondary production, benthic invertebrates fauna, population dynamics, Caspian sea, Tajan river

INTRODUCTION

Temperate coastal estuaries which are influenced by river discharges, are very unpredictable systems characterized by marked seasonal and daily variations of several chemical-physical parameters. Under these conditions only highly adaptable invertebrate species can survive and grow. Thus, brackish water benthic assemblages include euryhaline species which prefer a shallow, sheltered environment and opportunistic species with a high tolerance to stress and to disturbance (Cognetti and Maltagliati, 2000). Macro invertebrate benthic communities in estuaries and coastal lagoons may show high secondary production that can be exploited by fish and shorebirds (Wilson, 2002). For this reason many coastal river estuary are used worldwide for extensive and semi-intensive fish releasing because of losses in natural fish stocks in the adjacent seas (Barnes, 1991). Southern Caspian sea rivers have traditionally been exploited for fish releasing in order to repair fish stocks, there is three decades (from 1970s).

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Recently, they have been increasingly subjected to human intervention and greatly affected by eutrophication or mass mortality of fish and other aquatic organisms. Tajan river estuary complex, located north of the Tajan river (Caspian sea south basin region), is characterized by hypereutrophic conditions and dense blooms of diatoms which result in a drastic depletion of zooplankton, mass mortality of benthic fauna and lack of sea grasses (Heijs *et al*., 2000). In spite of their reduced environmental quality, some areas are still exploited for extensive aquaculture in the upper river. Fish are released in deep areas of the river once upon a year often in spring and early summer, allowed to grow during few months and then going on to the sea where, they encounter natural fish stocks. This kind of human intervention does not require an external food supply, a high capital investment or specialized skills. The success of extensive fish releasing depends on the natural primary and secondary productions. Composition, biomass and production of macro benthic assemblages can provide useful information on the sustainability of this kind of interventions. The aims of the present study were to: (1) analyze variations in the composition and biomass of the macro benthic assemblages in a coastal river estuary exploited for finger ling fish releasing; (2) estimate the annual secondary production; (3) investigate factors affecting this production and(4) consumption of this production by fish or other consumers of the Tajan river estuary.

MATERIALS AND METHODS

Study Area

The Tajan estuary is one of the largest estuaries on the south east coast of Caspian Sea. The climate is mild with a mean air temperature of 16.3°C and total annual precipitation of 700 mm. The estuary has a broad shallow bay covering an area of about 2 km^2 (Fig. 1) and is located in the most populated area of North of Iran. Seawater enters the estuary through a deep narrow inlet channel and sea water is mixed with fresh water from the Tajan river. The Tajan river drains an area of 86000 km^2 and the estuary also receives effluent discharges, mainly from urban, industrial and agricultural sources.

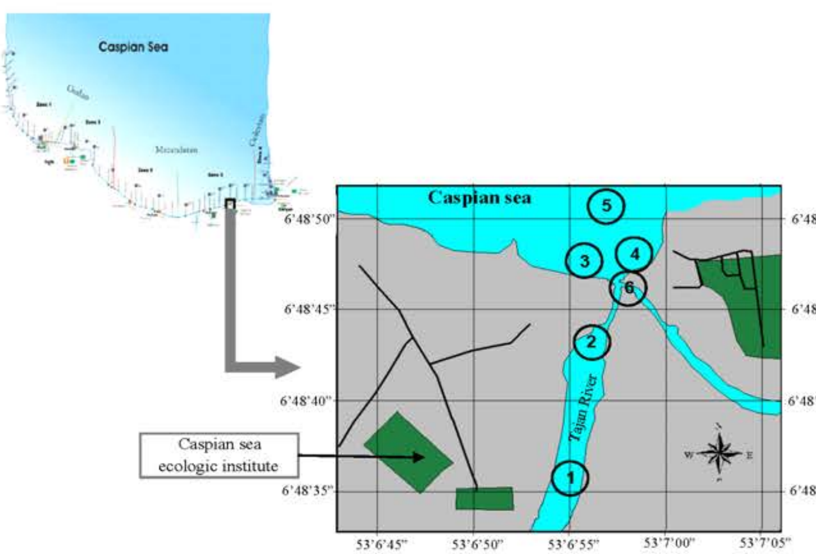

Fig. 1: Map of Tajan River estuary situation. Circles show the six selected stations in the studied area. Stations 1 to 4 and 6 being in the estuarine area, station 5 is located in the plume area in the sea

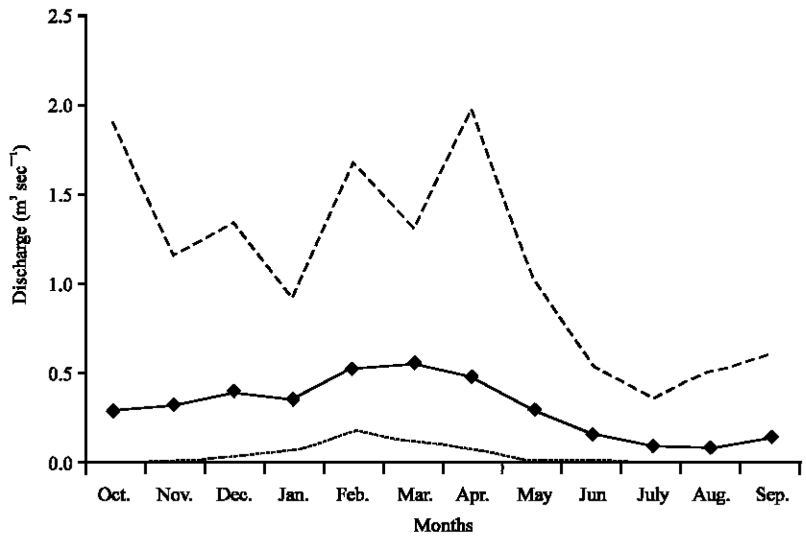

Fig. 2: Comparison among Tajan discharge in m^3 sec^{-1} (------) averages of 48 years maxima (—◆—) during present study and (..........) averages of 48 years minima. This figure suggests that, this study was carried out in a relatively dry year compared to maximum points of discharge value. Also from June to September, river debit was not enough to allow water current inflow to the Caspian Sea

The river flow fluctuates seasonally with an average monthly discharge varying from 1.5 in summer to 81.3 m^3 sec^{-1} in winter (Fig. 2) which corresponds to a water residence time of 26 and 8 days, respectively. The present study was conducted at an area located close to the Caspian Sea Ecologic Institute, in the middle Tajan estuary (Fig. 1). The exact location of the studied stations is shown in this Fig. 1. Six sampling stations were considered, selected after a pre-sampling of 12 stations and selected by multivariate analysis and clustering method, hereafter designed by stations 1 to 6. Stations differed in relation to distance from the estuary and also in relation to their plank tonic communities and physical and chemical parameters.

The location of the sampling stations was chosen in order to study the benthic communities located in a polluted area of the Tajan estuary, the Tajan river, where several industrial plants are located along its coasts. Therefore, station 1 and 2 were located along the Tajan river and station 3 at the same longitude but separated from the river by enlarging the river. Station 4, chosen as a control station, was located in the middle of the estuary, away from the influence of industrial discharges. Station 5 in the sea but influenced by Tajan estuary discharge and station 6 in the estuary of a river closely ending to the estuary's estuary.

Sampling Strategy

In each stations benthic invertebrate composition, nutrient content and physical parameters as pH, conductivity, salinity and temperature were measured. Then utilizing a multivariate analysis, 6 functioning stations were selected where differences among them (in term of Euclidian distance) were maxima. Sampling size and time in these stations remaining constant in the rest of study. Sampling was carried out once per month in the same time for the whole stations. Sampled parameters consisted of biotic and abiotic components of water column (chemical and physical components, invertebrate taxa determination and its composition).

Methods

Benthic samples were taken monthly from March 2006 to February 2007. In each station, four samples were randomly taken; using a modified Van-Veen grab of 15×15 cm. Samples were sieved (0.3 mm mesh) and preserved using a buffered solution of 4% formaldehyde. The sieve mesh size of 0.3 mm was chosen to retain the juveniles of macro benthic species. On each sampling occasion, water depth, water and sediment temperature, salinity (in the Practical Salinity Scale), conductivity, pH and dissolved oxygen were measured near the bottom using electronic probes and a sediment sample was collected to analyze the organic carbon content and granulometry measurements. The animals retained by sieve were identified to the lowest possible taxonomic level and counted. Biomass was measured as Ash Free Dry Weight (AFDW), firstly drying samples in 50°C (48 h) and then ash weight was calculated after ignition at 700°C. The organic content of the sediments was determined as per cent loss of weight on ignition (LOI %: Loss Of Ignition) at 550°C for 8 h after drying at 95°C for 24 h (King *et al*., 1998).

Daily river flow data for Tajan River were provided by Study Bureau of Mahab Ghods of Islamic Republic of Iran. Salinity and temperature measurements were obtained using thermosaline meter (WTW Tetracon 325 Japan). Discrete sampling was carried out on sub-surface (1 m below the surface) by using 5 L Niskin water samplers, fitted with non-toxic silicone tubing. Samples for the identification of benthic species composition were preserved on board with an acid lugol solution. Benthic species were identified and counted by microscopic examination on an 100×loop (Zeiss). Net and gross secondary production rates were measured during the entire year of study considering their absolute values differences. The experimental design was based on the measurement production of benthos content in samples based on biomass (AFDW) variations upon months. Benthos fluctuations during months and among stations was calculated, considering differences between two successive values in total biomass in g m^{-2}; when values are additive, it was translated to a production compared to last sampling (here one month ago) and when there was a decrease of this value (here on month later) it is suggested that a consumption of this production compared to last month. The origin of consumption could be of different kinds. It can be consumed in place by other benthic invertebrates or birds feeding activity or be derived from the place by currents or only it was decomposed by bacterial recycling. However, in present study these compartment are not studied per case and effect of all of them is expressed in term of secondary production consumption (net or gross). Secondary production can be estimated by several methods. Most of the classical methodologies, based on the recognition of cohorts or on size frequency and mass specific growth rate, are expensive and time consuming (Cusson and Bourget, 2005).

Although less accurate, a number of empirical models based on equations relating production to biomass and lifespan, maximum individual body weight and environmental variables like temperature (Tumbiolo and Downing, 1994) and depth (Tumbiolo and Downing, 1994) have been proposed. In present study, but in this study, secondary production of benthic community was calculated based on variations in biomass content of benthic communities. Descending values suggested that there was a decrease in produced live measured materials, thus it was estimated that, loss in benthic values could be a result of consumption where the origin is not clearly understood.

Data Analysis

To better understand the patterns of biomass and secondary production, macro benthic invertebrate assemblages were analyzed using univariate and multivariate analysis. Faunal biomass, as Ash-Free Dry Weight (AFDW), was estimated from the number of specimens of each taxon. Although there is a risk of this method introducing an error into the biomass estimate, it has been widely applied in studies aimed to assess the secondary production of a whole community. Abundance, biomass and number of Species (S), were calculated for each replicate sample and analyzed by two way Analysis of Variance (ANOVA) with stations and dates as fixed factors. Cochran's C test was used to check the assumption of homogeneity of variances and, when necessary, appropriate transformations were applied to the data. If variances were heterogeneous even after transformation the analysis were run at $\alpha = 0.01$ for significance test. Student Newman Kuels (SNK) post-hoc test was used for multiple comparisons.

RESULTS

Sediment and Water Variables

Results of sediment granulometry (size classifying) (Table 1) of overall stations from 1 to 6 and in 4 seasons indicate that water discharge and depth of station 6 situated in the estuary of auxiliary stream to the Tajan river estuary is less but water velocity is more than the main Tajan river. This condition results that station 6 to have more instable sediments and erosion could be more important than the main river, here thin sediments could be washed from this station and exported to the Tajan river estuary. Size studies of station 6 show that important fractions of sediments are composed from thick materials as sand (near to 93). Because of permanent erosion mainly in winter and spring TOM (Total Organic Matter) content of station 6 was less than other studied stations. Although there was not any important variety among seasons in whole stations but cruds of winter washed main part of thin sediments which was exported to the sea. Considering what mentioned above, TOM (Total Organic Matter) content in the main river (Stations from 1 to 5) during the studied year was more than station 6. This pattern conduct to characterize station 6 as sandy, stations 1 as clay and other stations situated relative to the estuary having silt texture. Organic materials of sandy bottoms are simply washed and transported by river flow, because of important porosity between grains.

Table 1: Result of sediment granulometry (grain size) and TOM of sampling stations in studied area, Tajan estuary

	Clay (%)	Silt (%)	Sand (%)	TOM (%) of organic matter in sediment (average of season)
Station 1				
Spring	56.0	32.0	12.0	1.2
Summer	50.0	34.0	16.0	1.1
Fall	54.0	34.0	12.0	1.3
Winter	48.0	38.0	14.0	1.2
Station 2				
Spring	44.0	42.0	14.0	1.7
Summer	46.0	41.0	13.0	2.0
Fall	42.0	45.0	13.0	1.5
Winter	44.0	44.0	12.0	1.3
Station 3				
Spring	44.0	42.0	14.0	1.7
Summer	43.0	44.0	13.0	2.0
Fall	43.0	44.0	13.0	1.5
Winter	43.5	43.0	13.5	1.3
Station 4				
Spring	44.0	44.0	12.0	1.7
Summer	43.0	43.0	14.0	2.0
Fall	44.0	42.0	14.0	1.5
Winter	45.0	43.0	12.0	1.3
Station 5				
Spring	41.0	44.0	15.0	0.8
Summer	40.0	42.0	18.0	0.6
Fall	40.0	41.0	19.0	0.9
Winter	39.0	43.0	18.0	0.8
Station 6				
Spring	2.0	3.0	95.0	0.2
Summer	2.0	4.0	94.0	0.2
Fall	3.0	5.0	92.0	0.1
Winter	4.0	6.0	90.0	0.3

Table 2: Salinity (S%), pH, water temperature (T°C), Total Suspended Substances (TSS) mg L^{-1}, $N\text{-}NO_3$, $N\text{-}NO_2$ and ammonium for water column of six stations in the Tajan estuary. Values are averages from monthly sampling throughout one year

Station	S%	pH	T°C	TSS	$N\text{-}NO_3$	$N\text{-}NO_2$	$N\text{-}NH_4$
1	3.51	7.99	27.76	3142.90	5.40	1.20	20.25
2	9.37	8.12	27.16	5780.98	7.60	0.00	17.07
3	9.03	8.27	27.30	8864.01	1.70	0.00	20.55
4	8.23	8.22	28.24	7552.37	3.30	0.00	22.40
5	12.50	7.13	26.24	11274.81	20.00	0.00	24.22
6	4.52	8.34	25.83	3878.50	12.30	0.00	21.55
Standard errors	1.36	0.18	0.37	1262.04	2.77	0.20	0.98

Thus this kind of substrate has less fractions of TOM. Although thin particles of clay are more stable than silt ones, but clay permeability to organic materials is less than silt which contains more organic materials. The general pattern of the Tajan river flow rates recorded during the 2006 annual discharge (Fig. 2) followed a seasonal variation characterized by maximal values in fall and winter (seasonally averages; 1.45 and 1.30 m^3 sec^{-1}, respectively) and minimal values during summer (average of the season; 0.48 m^3 sec^{-1}). Many high discharges were observed during spring season in this study with an average of 1.16 m^3 sec^{-1}. Low discharge during summer led to high residence time beyond the lack of nutrient inflow from upper Tajan river.

Physical and Chemical Variables

Water temperatures ranged between 25.83°C in station 6 and 28.24°C in station 4 and no significant differences were found between stations (Table 2). Salinity ranged between 3.51 and 12.5% throughout the year. Salinity values were higher during summer months and were reduced by increased rainfall and river input. For whole water column, station 1 had significantly ($p<0.001$) lower salinity than other stations, because it is the closest station to the Tajan River; pH values were constant throughout the year with an average value of 8.01±0.45. TSS was relatively constant throughout the year and annual means ranged between 3142.96 and 11274.81 mg L^{-1} TSS values were significantly ($p<0.05$) higher for station 5 and significantly ($p<0.01$) lower for station 1 and 6.

The studied period corresponded to a dry year and the Tajan annual river flow value was less than half of the average of the last 30 years. River flow fluctuated greatly during the study period with a maximum value in November (81.3 m^3 sec^{-1}) and a minimum in August (1.5 m^3 sec^{-1}). These values correspond, approximately, to water residence times in the upper estuary of 8 and 26 days, respectively. With the exceptions of June, October and November, water residence times were considerably higher than average values (Fig. 2).

Benthic Invertebrates Gross Production

Fluctuation of benthic biomass leads to concretise benthic gross production and its consumption in 6 stations of study area. Stations could be categorised by their gross secondary production into three classes (Fig. 3, 5):

- Station 1 and 6 where flowing behaviour of rivers leads to low annual secondary benthic production of 3.8 and 24.0 g m^{-2} $year^{-1}$, respectively (Fig. 4). Station 1 situated in the upper part of Tajan estuary receiving inflow of Tajan river, is exposed to high concentrations of nutrients and low water residence time which seems to be the main cause of low production. This station receives major part of vegetative material in the form of detritus DOM (Detritus Organic Materials) but not phytoplankton production of its proper station. Station 6 situated near to the sea estuary of estuary is charged by draining waters of agricultural wastes and pollutants, thus low concentration of phytoplankton production necessary to benthic growth and production. This station probably play the role of nutrient supply to the Tajan estuary and by this way participate to its high primary and secondary productions. Also its sand size bottom substrata seem to contribute to its low accumulation of benthic communities

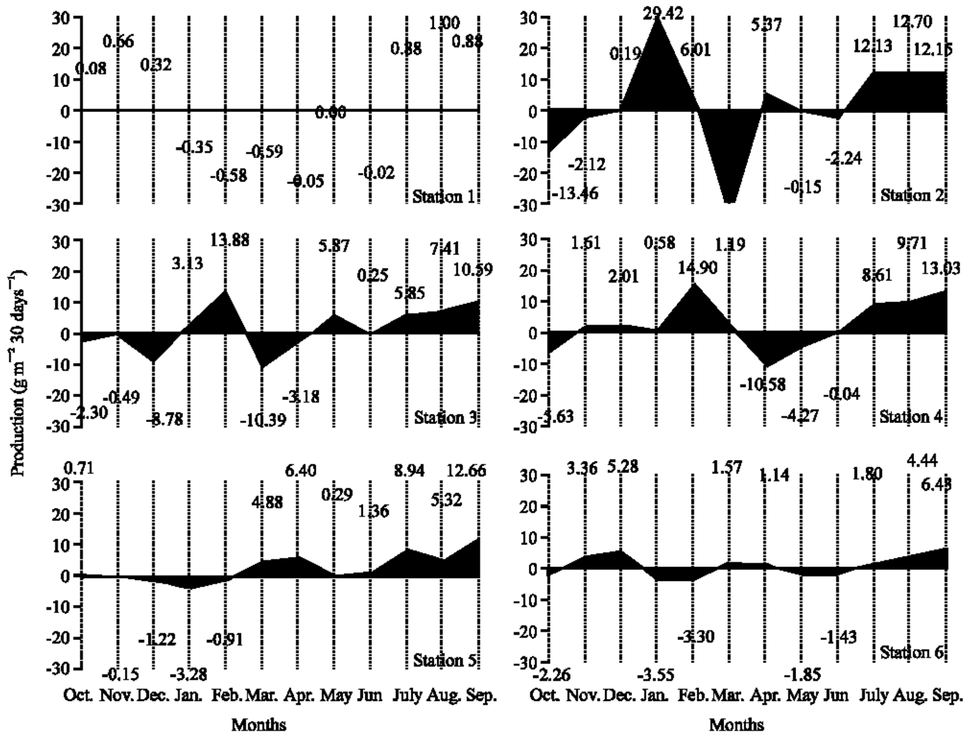

Fig. 3: Fluctuation of benthic secondary production and consumption in stations of studied area. Tajan estuary

- Second category consists of station 2, 3 and 4 where benthic production during the year exceeds its consumption (Fig. 3). In station 2 consumption values of 13.46 g m^{-2} 30 days^{-1} begin in spring which will be compensated by high production to 29.4 g m^{-2} 30 days^{-1} in the end of spring. This production decreases abruptly in early summer, because of dramatic decrease of water flow in this period. Production continues until fall and winter months probably related to lack of consumers (fish and macro invertebrates). Two marked consumption peaks in early spring and end of fall can be related to Anadromous fish migration in order to their natural reproduction which takes place in the river. Two stations of 3 and 4 did not so suffered from losses in water discharge during summer months. Considering the lather stations situated in the estuary of Tajan river and being influenced more by sea currents and waves than the river, they can support loss of water inlet from river thus stay independent from river dryness in summer months. Both of them exhibit decreased values of production (consumed) in early spring and at the end of fall, which probably due to Caspian Sea fish recruitment during these two periods
- Station 5 represent 3rd category with relatively mild lack of production in spring and early summer but consumption is compensated by benthic production up to 6.40 and 12.66 g m^{-2} 30 days^{-1} in early fall and the end of winter, respectively. Considering the location of this station in the sea and being at the front of Tajan estuary, where, sediment are so instable, benthic production may be replaced by zooplankton production stimulated by phytoplankton front existing during spring and early summer

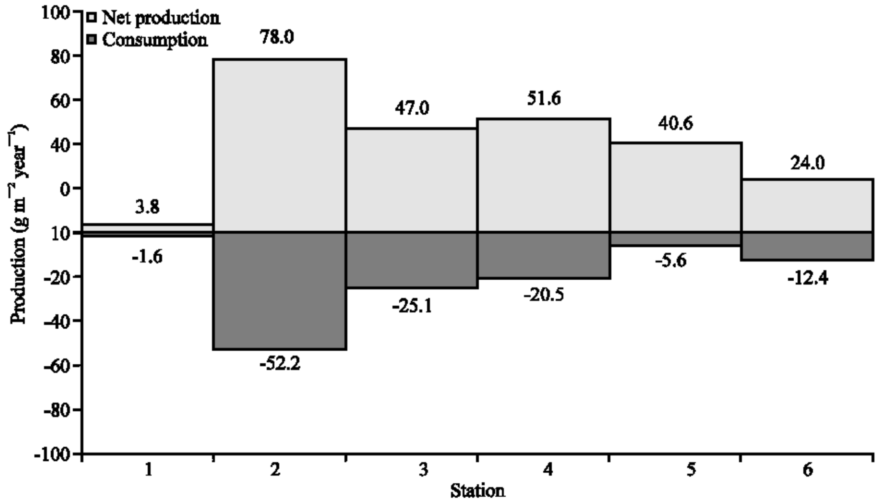

Fig. 4: Comparing net production and consumptions in stations of studied area, Tajan river

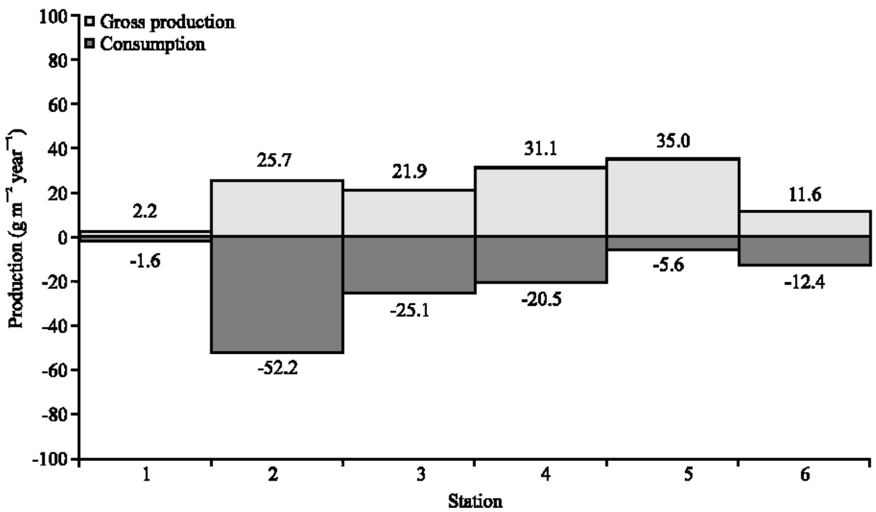

Fig. 5: Fluctuation of benthic biomass leads to concretise benthic gross production and its consumption in stations of studied area

Production and Consumption along Stations

Comparing net production and consumptions in studied stations, show variation of both of values. In stations 1 to 6, efficiencies of benthic net production compared to benthic consumption (in term of g m^{-2} year^{-1}) were 58, 40, 47, 60, 87 and 49 %. In total efficiencies of these stations were near to 60 %. This estuary has an annual production of 393.8 g m^{-2} year^{-1} compared to a consumption of 117.4 g m^{-2} year^{-1}, where, net production efficiency is 70% (276.4 g m^{-2} year^{-1}) which may be transported to the sea. Station 2 in the estuary of Tajan river is dominant by its 78.0 g m^{-2} year^{-1} benthic net production as an annual yield. But this 40% of this important benthic production is consumed in this station (52.2 g m^{-2} year^{-1}). Station 5 having mild production have been the most production efficiency, compared to other studied stations. This station situated in front of the estuary could profit from phytoplankton front formed in this region. Instable sediments under action of waves can reduce consumers of benthic materials produced (Fig. 4).

Invertebrate Composition

Dispersion of species in 6 studied station show that fresh water specific species like *C. plumosus* and *Simulium* sp. and *Hydropsyche* sp. were found only in river-situated stations of 1, 2 and 6. *Simulium* sp. being characteristic of medium quality waters indicates that the quality of station 6 adjacent directly to the Tajan estuary, is predominate by the estuary itself and not by the water current of the stream. *C. lamarki* which is a brakish-marine species was present in all stations except station 1 in upper estuary (Table 3).

This species benefiting from high concentrations of phytoplankton materials for its filter feeding behaviour, ascend near to upper estuary and is omnipresent in estuarine and marine stations. However *Nereis diversicolor*, which is an exotic species and transported to Caspian sea by Russian program of species introduction to the Caspian sea as early as 1940s, was found only in absolute marine station (5) and not in marine places affected by estuarine waters with salinity variability. Presence of *Balanus* sp. in stations 3 and 4 and its absence in station 5 which was marine station in present studies, suggest that its absence in station 5 was not due to high salinities of this station but its is so sensible to lack of habitat as it has a sessile life.

Results of the total macro benthic invertebrate secondary net production are better explained by analyzing the whole assemblages. Table 4 demonstrates, production and consumption of each station related to its dominant species. Considering station 1 in the upper Tajan estuary, where, water residence time is lowest compared to other stations. In this station the annual benthic production and consumption were 4.55 and 1.5 g m^{-2} $year^{-1}$, respectively. Regarding the dominant species *Chironomus plumosus* which is characteristic of polluted waters with low quality, this point could suffer from high trophic inputs. However organic materials in this station were lower than other studied points and important part of POM (Particulate Organic Materials) are transported due to river flow and sandy bottom of the river. Approaching to the river estuary in station 2 Chironomid dominance is replaced by filter feeding communities of *Cerastoderma lamarki* specimens where, benthic production and consumption were 78.6 and 52.26 g m^{-2} $year^{-1}$, respectively. Only at the beginning of summer, Chironomids were representative, since, river discharge decreased to its lowest values or this species tolerate high variation of water temperature. Two stations of 3 and 4 located near to the sea where production/consumption efficiencies were higher in present study are also dominated by filter feeder communities of *C. lamarki*. By exception, at the end of summer dominant species in both of them was communities of *Dreissena polymorpha*. After summer their dominant state was replaced by *C. lamarki*. In station 5 which is entirely situated in the sea in front of estuary, *C. lamarki* was dominant for the entire year. Present observation indicating dominant species fluctuations in this small estuary of south Caspian basin showed that benthic communities are

Table 3: Tajan river benthic invertebrate composition in studied station

	Station					
Species	1	2	3	4	5	6
Chironomus plumosus	*	*				*
Hydropsyche sp.	*					
Simulium sp.	*					
Parhypania sp.		*	*		*	
Cerostoderma lamarki		*	*	*	*	*
Hypaniola sp.		*	*	*	*	
Dressena polymorpha			*	*		*
Balanus sp.			*	*		
Nereis diversicolor					*	

Stars indicate presence of genera (even if in one sampling time)

Table 4: Dominant species, monthly production and consumption of 6 studied stations with annual sum of these values. Abbreviations indicate as: C.p : *Chironomus plumosus*, C.l : *Cerastoderma lamarki*, D.p : *Dreissena polymorpha*

	Dominant species	Net production	Consumption		Dominant species	Net production	Consumption
Station 1				**Station 2**			
1	C.p	0.80		1	C.l		13.46
2	C.p	0.66		2	C.l		2.12
3	C.p	0.33		3	C.l	0.19	
4	C.p		0.35	4	C.p	29.42	
5	C.p		0.58	5	C.l	6.01	
6	C.p		0.50	6	C.l		34.29
7	C.p		0.05	7	C.l	5.37	
8	C.p	0.00		8	C.l		0.15
9	C.p		0.02	9	C.l		2.24
10	C.p	0.88		10	C.l	12.13	
11	C.p	1.00		11	C.l	12.79	
12	C.p	0.88		12	C.l	12.15	
Sum		4.55	1.50	Sum		78.06	52.26
Station 3				**Station 4**			
1	C.l		2.30	1	C.l		5.63
2	C.l		0.49	2	C.l	1.61	
3	C.l		8.78	3	C.l	2.01	
4	C.l	3.13		4	C.l	0.58	
5	C.l	13.88		5	C.l	14.90	
6	D.p		10.39	6	D.p	1.19	
7	C.l		3.18	7	C.l		10.58
8	C.l	5.78		8	C.l		4.27
9	C.l	0.25		9	C.l		0.04
10	C.l	5.85		10	C.l	8.61	
11	C.l	7.41		11	C.l	9.71	
12	C.l	10.59		12	C.l	13.30	
Sum		46.89	25.14	Sum		51.91	20.52
Station 5				**Station 6**			
1	C.l	0.71		1	C.l		2.26
2	C.l		0.15	2	C.l	3.36	
3	C.l		1.22	3	C.l	5.28	
4	C.l		3.28	4	D.p		3.55
5	C.l		0.91	5	C.l		3.30
6	C.l	4.88		6	C.l	1.57	
7	C.l	6.40		7	D.p	1.14	
8	C.l	0.29		8	D.p		1.85
9	C.l	1.36		9	D.p		1.43
10	C.l	8.94		10	D.p	1.8	
11	C.l	5.32		11	D.p	4.44	
12	C.l	12.66		12	D.p	6.43	
Sum		40.56	5.56	Sum		24.02	12.39

not entirely dependent to their substratum and this study proves that seasonality can play an important role in benthic population dynamics. Station 6 which inlets directly to the little estuary showed the medium state between river and estuary where filter feeders were dominant during spring with relatively important fresh water inputs. In the rest of the year *D. polymorpha* was dominant species. The annual benthic production and consumption of this station were 24.02 g m^{-2} $year^{-1}$ compared to 12.39 g m^{-2} $year^{-1}$. Considering evolution of dominant species in estuarine stations (3, 4, 5 and 6) one can observe that during fall and winter settled dominant species tend to increase their production (as a result of enhancing biomass values). While, in river situated points as, 1 and 2 where, benthic communities are much more influenced by water input from river and low residence time doesn`t allow to have a local production. Production and consumption values remained relatively constant during months. In these stations important consumptions were happened during dry months of summer.

DISCUSSION

In Tajan river estuary, the wide availability of organic matter in the sediment, coupled with low water exchange and high temperatures during the summer may promote dystrophic crises. In addition, the water inlet of the adjacent small stream, issued from agricultural activity, is very likely to be enriched by remains of fertilizers, faeces and nutrients (Sorokin *et al*., 1999). This leads to an increase in primary and secondary production and may contribute to the establishment of dystrophic conditions (Sorokin *et al*., 1999). Azzoni *et al*. (2001) showed that, in this kind of lagoons, there was an accumulation of free sulphide in the rhizosphere of aquatic plants during late summer as a result of an imbalance between sulphate reduction rates and sulphide reoxidation rates. As well as directly inhibiting macrophyte growth, dystrophic events undoubtedly have a lethal effect on macro benthic fauna. Consequently, decreases in macro benthic abundance and biomass might be related not only to the oxygen depletion, but also to the high production of toxic free sulphide, as has already been documented in the Comacchio lagoon complex. The macro benthic assemblage structure and composition and the environmental conditions found in Tajan river estuary, were very similar to those found in a shallow lagoon in the Bay of Cadiz. However the number of species was relatively low compared to the assemblages described in the other estuaries such as Valli di Comacchio estuary and other brackish water ones (Mistri, 2002) and same estuaries in northern Adriatic lagoons. After the late summer crisis, the macro benthic assemblages had an appearance of greater homogeneity among the stations as a consequence of an overall reduction in abundance and biomass. This aspect is likely to be most relevant for species that have limited dispersion due to a short pelagic phase or direct development such as *Cerastoderma lamarki*, *Chironomus plumosus* and *Dreissena polymorpha*. The degree of isolation could also explain the local diminution of *Cerastoderma lamarki* after the dystrophic event. On the other hand, *Ballanus* sp. and *Chironomus plumosus* appeared to recover quite quickly after the dystrophic crises. *Ballanus* sp. communities were able to overcome the dystrophic crises due both to their ability to remain at the air/water interface and their continuous breeding strategy (Barnes, 1999). The larvae of *C. plumosus* are periodically restored at each reproduction cycle since adults fly from neighbouring aquatic habitats. Although the dryness crises affect the community structure, however the secondary production in Tajan river estuary appeared very high. Secondary macrobenthic production is sustained by a small number of species. *Dreissena polymorpha*., larvae of *Chironomus plumosus* and *Cerastoderma lamarki* emerged as the most important species in terms of both biomass and production. They represented dominant species in all of our studied stations. The somatic productivity is traditionally expressed by the production-to-biomass ratio (P/B ratio). The estimated P/B ratio of *C. plumosus*, was in the range 9.1-11.9 year^{-1} and is in good accordance with the mean value of 12.7 year^{-1}, obtained in Cadiz Bay (Spain), with the size-frequency method. The P/B ratio of *Ballanus* sp., in Tajan river estuary ranged from 6.1 to 7.8 year^{-1}. These values was slightly higher than the ratios found in literature for the same species obtained by cohort or size frequency analysis, which appeared highly variable ranging from 1.8 to 6.1 year^{-1} according to the study stations (Drake and Arias, 1995; Lillebo *et al*., 1999).

Most of this kind studies were carried out in the northern European tidal flats, where habitat characteristics and lower temperatures can limit the productivity of the *Ballanus* sp. In our study, the P/B ratios for *Cerastoderma lamarki* vary according to the sampling stations from 2.3 to 3.9 year^{-1}. In spite of the high mortality observed at the time of the dryness crisis, the annual turnover of *C. lamarki* was in good accordance with the value of 3.2 year^{-1}, calculated using the Tumbiolo and Downing (1994) method, from the Sacca di Goro, another coastal lagoon (Mistri *et al*., 2001). Present results based on variations of benthic biomass showed that this estuary export the sum of 245.99 g m^{-2} year^{-1} of benthic production to the south Caspian Sea basin. 117.37 g m^{-2} year^{-1} is consumed locally in the estuary by estuarine proper animals or removed by Caspian Sea euryhaline fishes living in the near shore of the bay.

Although the assemblage composition and environmental conditions found in Tajan river estuary were very similar to those found by, a direct comparison of the estimated secondary production is impossible due to the different methods applied. As (Mistri *et al*., 2001) conceded, their estimation of macro benthic production using methods widely underestimates the production of the multivoltine chironomids, which fall in the range 0.3 to 5 mm. Many studies have demonstrated that vegetated bottoms support higher secondary production compared to the surrounding unvegetated bottoms (Edgar *et al*., 1994; Dolbeth *et al*., 2003, 2005). However, total biomass was dramatically affected by dryness crises, especially in low deep areas. Macro benthic secondary production in Tajan river estuary supported a large biomass of predators, largely reared finger ling fish species, issued from stock restoration organized by Iranian fisheries organization, in particular *Acipenseridae species* and Caspian Roach (Rutillus firissi Kutum) released into the estuary each spring. The reduction of biomass may reduce the secondary production and lead to negative effects on the growth of the commercial fish, beginning with those like Caspian Roach, *Rutilus rutilus* (frissi kutum), *Huso huso*, *Acipenser persicus*, *A. guldenstadtii* and *A. stellatus*, which mainly feed on benthic macroinvertebrates during their juvenile life stage (Pita *et al*., 2002) and are released in huge quantities from spring to early summer by Iranian fisheries organization. In Tajan river estuary, it was found that they mainly feed on nereid polychaetes, bivalves like juveniles of *Cerastoderma lamark*, amphipods like *Gammarus* sp., larvae of *Chironomus plumosus* and on the *Ballanus* sp. However, results from this study show that biomass community structures and secondary macro benthic production are negatively affected by the drought events. Management of these kinds of coastal lagoons focuses mainly on fish releasing but often the importance of the benthic assemblages is neglected. Monitoring programs generally take into account only a few environmental variables, like dissolved oxygen concentration and water temperature, apart from the health of the benthic community structure.

Since it is very difficult to operate directly on the oxygen concentration and water temperature in the field, the management practices should try to prevent the dry periods by limiting nutrient inputs and by ensuring an adequate water renewal. Moreover, it is very important to remember that any severe alteration of the macro benthic secondary production will inevitably be reflected, through the food chain, up to the higher trophic levels, i.e., the released fish. Although empirical methods for secondary production estimation are less accurate than the direct methods, especially when the assemblages are not in steady state, they are widely applicable and can provide a reliable and practical tool for monitoring and management purposes. There are thus grounds for suggesting that monitoring programs of the fish releasing managed for stock restoration should also include the macro benthic assemblage composition in terms of biomass.

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