The impacts of seasonal water discharge fluctuations on benthic communities on the productivity and the consumption of Tajan Estuary, southern coast of the Caspian Sea

Shapoori M.[1*] and Javanshir A.[2]

1- Islamic Azad University, Savadkooh Branch, Iran

2- Faculty of Natural Resources, University of Tehran, P.O.Box: 4111 Karaj, Iran

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Abstract

In the present study, changes in benthic communities due to seasonal changes in the water of the southern Caspian Basin were investigated. Sampling was conducted monthly, from March 2006 to March 2007, at six selected stations in Tajan River mouth located on south eastern Caspian Sea. Also secondary benthic production consumable for fish and other biota inhabiting the mouth and adjacent areas were estimated. Forcing and limiting factors were also discussed. Benthic communities 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 3.8g AFDWm^{-2} y^{-1}, in the upper part of the mouth, to 78.06g AFDWm^{-2} y^{-1} in the center of the estuary area. Multivariate correlations between environmental variables and the macro benthic biomass highlighted the role of the water level, temperature, organic carbon content and dissolved oxygen which resulted in separation of 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 benthic fauna during drought periods. Only populations of two taxa, *Balanus* sp. (Cirripeda) and *C. plumosus* (Diptera) seemed to be able to recover quickly after the drought crises, which, in turn, could compromise the overall secondary production, which may have negative effects on fish and other superior organisms survival. During summer water renewal, when agricultural activities are intense, nutrient inputs should be regulated in this estuary to reduce the risk of benthic mass mortality and to ensure a sustainable ecosystem.

Keywords: Benthic fauna, Secondary production, Tajan River, Caspian Sea

*Corresponding author's email: marybiot@yahoo.com

Introduction

Temperate coastal estuaries which are influenced by river discharges, are very unpredictable systems characterized by marked seasonal monthly and daily variations of several chemico-physical parameters. Under these conditions, only highly adaptable animal species can have a significant role in the production. 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 & Maltagliati, 2000). Macro benthic communities in estuaries and coastal lagoons may show high secondary production that can be exploited by fish and shorebirds (Wilson, 2002). Therefore, many coastal river estuaries are used worldwide for extensive and semi-intensive fish releasing because of losses in natural fish stocks in the adjacent seas (Barnes, 1999). Some rivers in the southern Caspian Sea have been exploited to release fish, in last decades (from 1970s).

Recently, these rivers have been increasingly subjected to human intervene-tion and greatly affected by eutrophication or mass mortality of fish and other aquatic organisms (Javanshir *et al*., 2008). Tajan River estuary complex, located in the southern basin of the Caspian Sea. The characteristic feature of Tajan Estuary is the hyper eutrophic conditions and dense blooms of diatoms which can result in a drastic depletion of zooplankton, mass mortality of benthic fauna and lack of sea grasses (Sorokin *et al*., 1996; Heijs *et al*., 2000). Due to reduction of 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: (1) to analyses the temporal and spatial fluctuations in the composition and biomass of the macro benthic communities in estuary exploited for fingerling fish releasing; (2) to estimate the annual secondary production; (3) to investigate the environmental factors affecting this production, and (4) to investigate the consumption level of this production by fish or other consumers of the Tajan Estuary.

Materials and methods

The Tajan Estuary is one of the largest estuaries on the south east coast of the Caspian Sea. The climate is mild with a mean air temperature of 16.3°C and total annual precipitation of 700mm. The estuary has a broad shallow bay covering an area of about 2km^2 (Fig. 1), and is located in the most density of population area in North of Iran. Seawater enters the estuary through a deep narrow inlet channel where it is mixed with freshwater of the Tajan River. The river flow fluctuates seasonally with an average monthly discharge varying from 1.5 in summer to 81.3m^3 S^{-1} in winter, which corresponds to a water residence time of 26 and 8 days, respectively (Mahab Ghods, 2006). The exact location of the studied stations is shown in Fig. 1. Six sampling stations were considered. Sampling was carried out by multivariate analysis and clustering method. Stations were selected in relation to distance from the estuary, and also in relation to their communities (plankton & benthos) and physical/chemical parameters. Hence, five stations, named numerically from 1 to 5 were selected (Fig. 1). Station 4, chosen as a control station, was located in the middle of the estuary, away from the influence of industrial discharges.

Benthic invertebrate composition, nutrient content and physical parameters, including pH, conductivity, salinity and temperature were measured in each station, near the bottom using electronic probes and a sediment sample was collected to analyze the organic carbon content and granulometry measurements (Edgar, 1990a). Salinity and temperature measurements were obtained using thermo saline meter. Then, a multivariate analysis was utilized to select 6 functioning stations with highest differences among them (in term of Euclidian distance). Sampling was carried out monthly at the same time across the stations. Benthic samples were taken monthly from March 2006 to February 2007, using by Van-Veen grab of 15 X 15cm. Samples were sieved (0.3mm mesh) and preserved using a buffered solution of 4% formaldehyde.

Discrete sampling was carried out on sub-surface (1 m below the surface) by using 5 L Niskin samplers. 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. Net and gross secondary production rates were measured during the entire year of study considering their absolute values differences. Secondary production can be estimated by several methods. Most of the classic methodologies, based on the recognition of cohorts or on size frequency and mass specific growth rate, are expensive and time consuming (Cusson & Bourget, 2005). Although less accurate, a number of empirical models based on equations relating production to biomass and lifespan, maximum individual body weight (Schwinghamer *et al*., 1986) and environmental variables like temperature (Edgar, 1990a; Tumbiolo & Downing, 1994) and depth (Tumbiolo & Downing, 1994) have been proposed. In our study, secondary production of benthic community was calculated based on variations in biomass content of benthic communities.

Univariate and multivariate analyses were used in order to understand the patterns of biomass and secondary productions of macro benthic fauna. 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 of benthic animals (Schwinghamer *et al*., 1986; Edgar, 1990a). Abundance, biomass and number of species, were calculated for each replicate sample and analyzed by two-way analysis of variance (ANOVA) with stations and dates as independent factors. If variances were hetero-geneous even after trans-formation the analyses were run at $\alpha = 0.01$ for significance test (Underwood, 1997). Student-Newman-Kuels (SNK) post-hoc test was also used for multiple comparisons (Underwood, 1997).

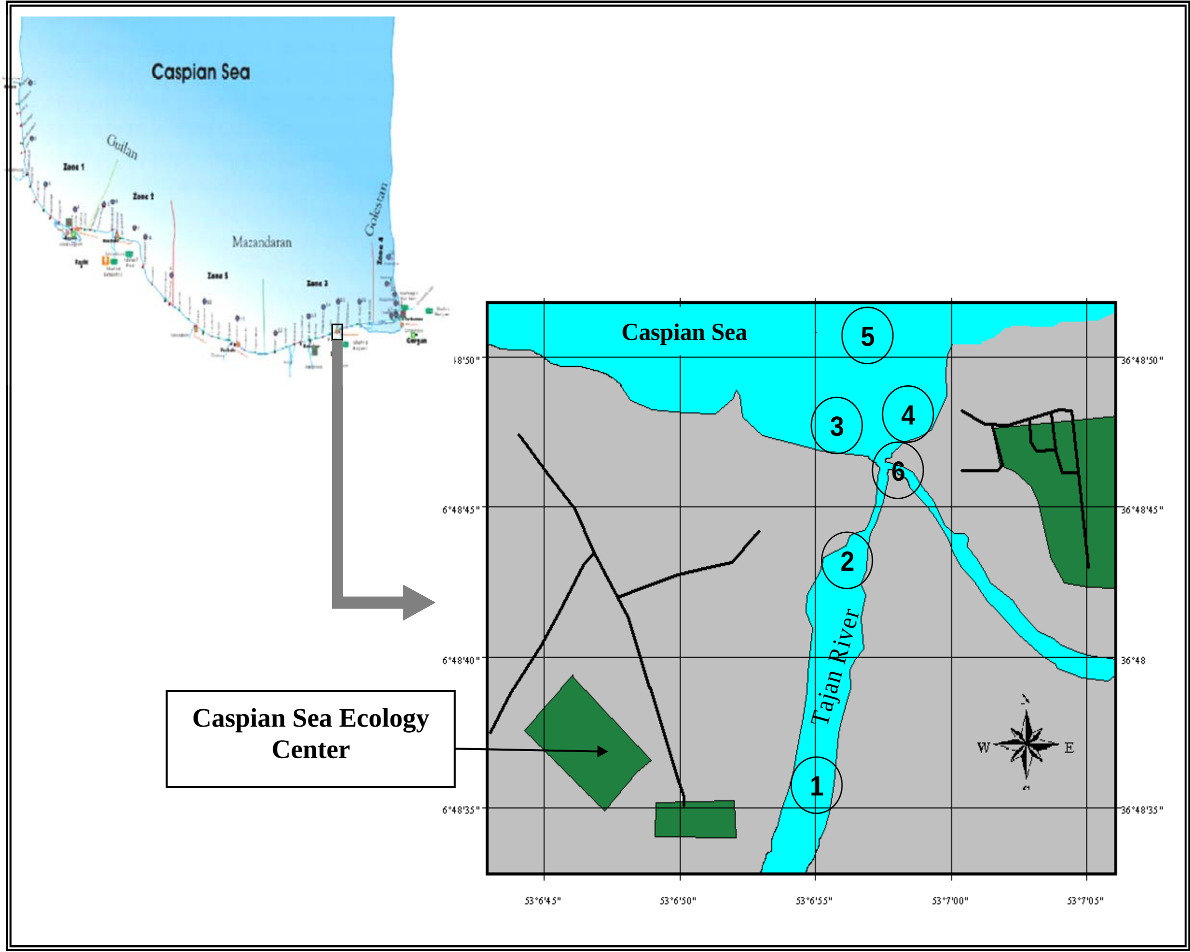

Figure 1: The location of Tajan River Estuary. Circles show the six selected stations in the studied area

Results

Results of sediment granulometry (Table 1) of overall stations from 1 to 6 and in 4 seasons indicated that water discharge and depth of station 6 situated in the estuary of auxiliary stream to the Tajan Estuary is less but water velocity is more than the main Tajan River resulting in station 6 having more instable sediments and erosion be more important than the main river, thus thin sediments are washed from this station and exported to the Tajan River Estuary. Grain size in station 6 showed that important fractions of sediments are composed from thick materials as sand (near to 93%).

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.

Variations of benthic biomass, led to concretise benthic gross production and its consumption in 6 stations of study area. Stations could be classified base on their gross secondary production into three classes (Figs 2, 3, 4):

- Stations 1 and 6 where flowing rivers led to low annual secondary benthic production of 3.8g.m^{-2}. year^{-1} and 24.0g.m^{-2}. year^{-1} for station 1 and 6 respectively (Fig. 3).
- Second category consists of stations 2, 3 and 4 where benthic production during the year exceeds its consump-tion (Fig 2). In station 2, consumption values of 13.46g.m^{-2}.30days^{-1} begin in spring which is compensated by high production till 29.4g.m^{-2}.30days^{-1} in the end of spring.
- Station 5 represents 3rd category with relatively mild lack of production in spring and early summer but consumption is compensated by benthic production up to 6.40g.$^{m-2}$.30day^{s-1} and 12.66g.$^{m-2}$.30 day^{s-1} in early autumn and the end of winter, respectively.

These changes may be related essentially to temperature and salinity which covariates in the study area, both of them as main result of river discharge to the mouth. 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 3.51-12.5‰ throughout the year. Salinity values were higher during summer months and were reduced by increased rainfall and river input. For water column, station 1 had significantly ($p < 0.001$) lower salinity than other stations.

Net production and consumptions varied in studied stations. 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%, respectively. In total, efficiencies of these stations were near to 60%. This estuary has an annual production of 393.8g.m^{-2}. year^{-1} compare to a consumption of 117.4g.m^{-2}. year^{-1}, where net production efficiency is 70% (276.4g.m^{-2}. year^{-1}) which may be transported to the sea. Station 2 in the estuary of Tajan River is dominant by its 78.0g.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 was the most production efficient, compared to other studied stations.

Spatial distribution of species in 6 studied stations indicated that freshwater species, such as *C. plumosus*, *Simulium* sp. and *Hydropsyche* sp. were found only in upper mouth stations of 1, 2 and 6. *Simulium* sp. being characteristic of medium quality indicated that the quality of station 6 adjacent directly to the Tajan estuary, depends to the estuary itself and not by the current water of the stream. *C. lamarki* which is a brakish-marine species was present in all stations except station 1 in upper estuary which is far from the sea (Table 3). This species benefiting from high concentrations of phytoplankton materials for its filter feeding needs, ascend near to upper estuary and is omnipresent in estuarine and marine stations. However, *Nereis diversicolor*, 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. This absence may be not due to high salinities of this station but it is so sensible to lack of habitat as it has a sessile life.

Results of the total macro benthic fauna secondary net production are better explained by analyzing the whole fauna. Table 4 demonstrates, production and consumption of each station related to its dominant species. In 1 station the annual benthic production and consumption were $4.55 g.m^{-2}. year^{-1}$ and $1.5 g.m^{-2}. year^{-1}$, respectively. *Chironomus plumosus* was the dominant species in 1 station. 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 $78.6 g.m^{-2}. year^{-1}$ and $52.26 g.m^{-2}. year^{-1,}$ respectively. Only at the beginning of summer, chironomid were representative, since, river discharge decreased to its lowest values or this species tolerate high variation of water temperature.

Two stations 3 and 4, located near to the sea where production/consumption efficiencies were higher in our study, were also dominated by filter feeder communities of *C. lamarki*. Exceptionally, at the end of summer, *Dreissena polymorpha* was the dominant community in both stations. After summer their dominant status was replaced by *C. lamarki*. In station 5, which was entirely situated in the sea in front of estuary, *C. lamarki* was dominant for the entire year. 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 24.02g.m^{-2}. year^{-1} compared to 12.39g.m^{-2}. year^{-1}.

Table 1: Result of sediment granulometry (grain size) and TOM of sampling stations in the studied area Tajan Estuary, 2006-2007

	Station	Season	Clay %	Silt %	Sand %	TOM % of organic matter in sediment (average of season)
	1	Spring	56.0	32.0	12.0	1.2
	1	Summer	50.0	34.0	16.0	1.1
	1	Autumn	54.0	34.0	12.0	1.3
	1	Winter	48.0	38.0	14.0	1.2
Average			52.0	34.5	13.5	
	2	Spring	44.0	42.0	14.0	1.7
	2	Summer	46.0	41.0	13.0	2.0
	2	Autumn	42.0	45.0	13.0	1.5
	2	Winter	44.0	44.0	12.0	1.3
Average			44	43.0	13.0	
	3	Spring	44.0	42.0	14.0	1.7
	3	Summer	43.0	44.0	13.0	2.0
	3	Autumn	43.0	44.0	13.0	1.5
	3	Winter	43.5	43.0	13.5	1.3
Average			43.3	43.2	13.3	
	4	Spring	44.0	44.0	12.0	1.7
	4	Summer	43.0	43.0	14.0	2.0
	4	Autumn	44.0	42.0	14.0	1.5
	4	Winter	45.0	43.0	12.0	1.3
Average			44.0	43.0	13.0	
	5	Spring	41.0	44.0	15.0	0.8
	5	Summer	40.0	42.0	18.0	0.6
	5	Autumn	40.0	41.0	19.0	0.9
	5	Winter	39.0	43.0	18.0	0.8
		Average	40.0	42.5	17.5	
	6	Spring	2.0	3.0	95.0	0.2
	6	Summer	2.0	4.0	94.0	0.2
	6	Autumn	3.0	5.0	92.0	0.1
	6	Winter	4.0	6.0	90.0	0.3
Average			2.75	4.5	92.75	

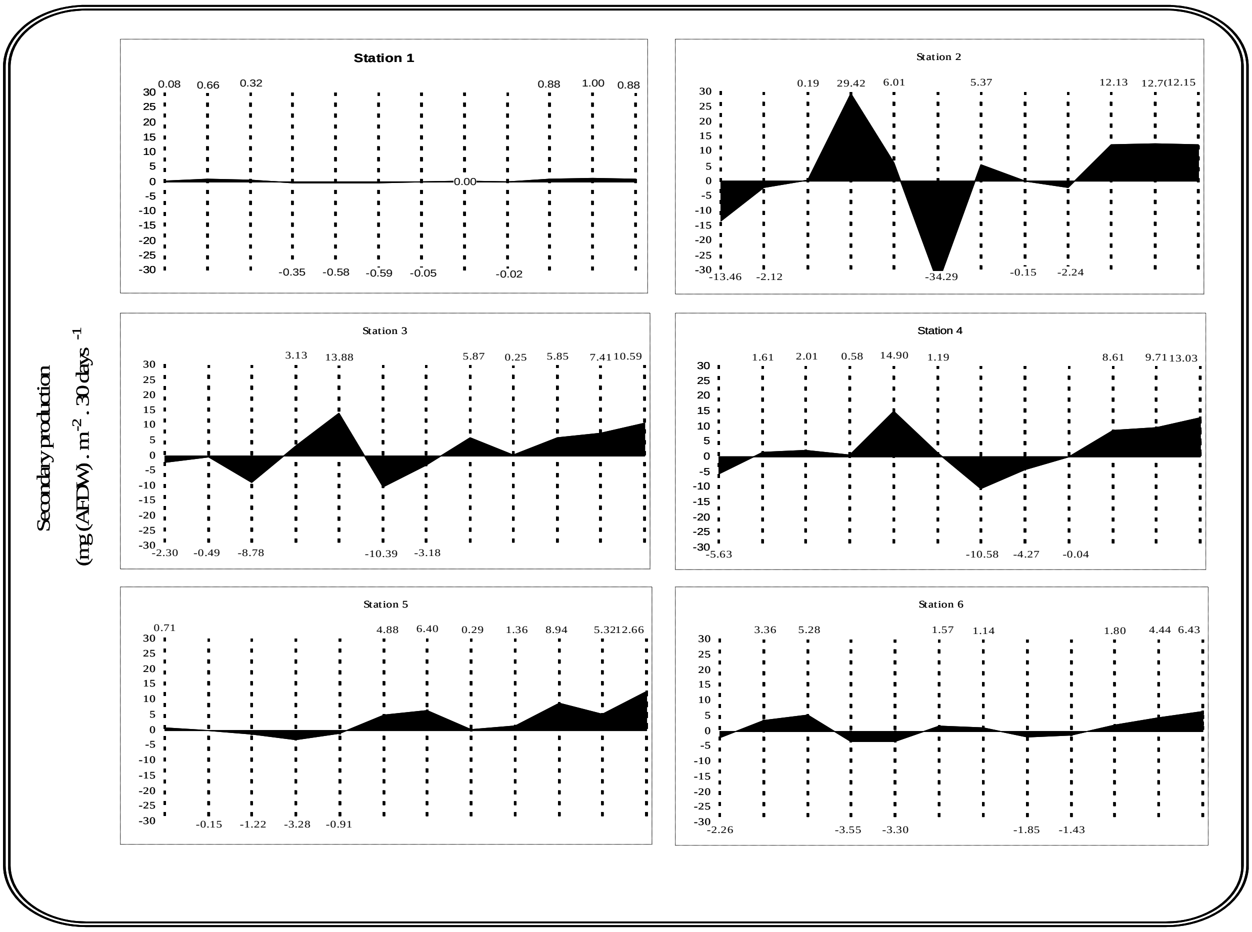

Figure 2: Fluctuation of benthic secondary production and consumption in stations of studied area, Tajan Estuary, 2006 - 2007

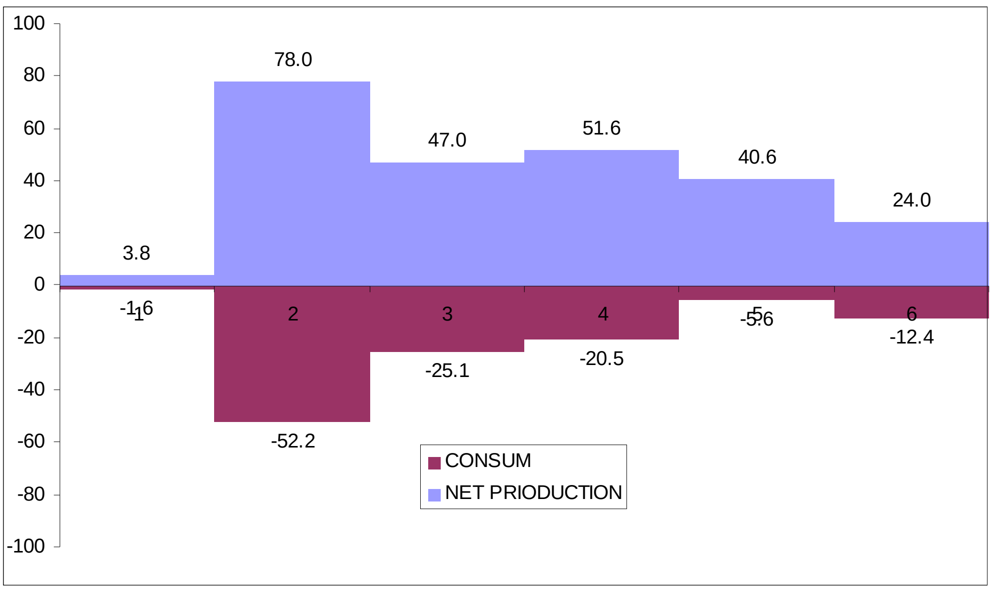

Figure 3: Comparison between net production and consumptions in stations of studied area, Tajan Estuary, 2006 -2007

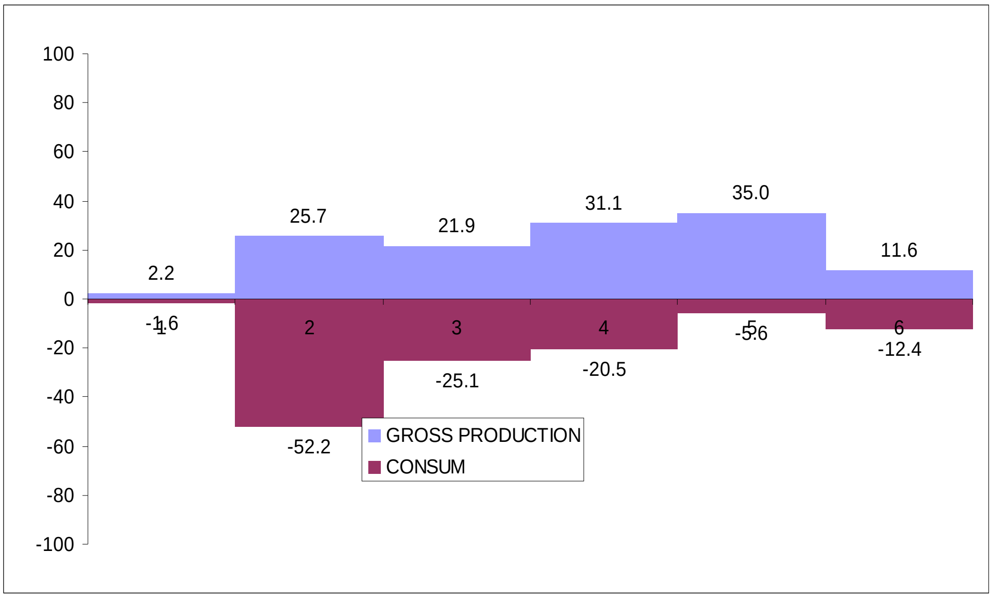

Figure 4: Fluctuation of benthic biomass leads to concretize benthic gross production and its consumption in Tajan Estuary, 2006 -2007

Table 2: Abiotic parameters (Annual average) for water column of sampling stations in the Tajan Estuary, 2006- 2007

Station	(ppt) S‰	pH	T°C	TSS mg. L^{-1}	(ppm) N-NO3	(ppm) N-NO2	(ppm) N-NH4
1	3.51	7.99	27.76	3142.90	5.4	1.20	20.25
2	9.37	8.12	27.16	5780.98	7.6	0.00	17.07
3	9.03	8.27	27.30	8864.01	1.7	0.00	20.55
4	8.23	8.22	28.24	7552.37	3.3	0.00	22.40
5	12.50	7.13	26.24	11274.81	20.0	0.00	24.22
6	4.52	8.34	25.83	3878.50	12.3	0.00	21.55

Table 3: Benthic composition in studied stations, Tajan Estuary, 2006-2007

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

*** indicates presence of the taxon. Evidently presence or absence indicates preference of specimens to marine and river environment.**

Table 4: Dominant species, monthly production and consumption of sampling stations in Tajan Estuary 2006-2007

Station	Month of the year	Dominant species	Net Production	Consumption
1	1	C.p	0.8	0
1	2	C.p	0.66	0
1	3	C.p	0.33	0
1	4	C.p	0	0.35
1	5	C.p	0	0.58
1	6	C.p	0	0.5
1	7	C.p	0	0.05
1	8	C.p	0	0
1	9	C.p	0	0.02
1	10	C.p	0.88	0
1	11	C.p	1	0
1	12	C.p	0.88	0
3	1	C.l	0	2.3
3	2	C.l	0	0.49
3	3	C.l	0	8.78
3	4	C.l	3.13	0
3	5	C.l	13.88	0
3	6	D.p	0	10.39
3	7	C.l	0	3.18
3	8	C.l	5.78	0
3	9	C.l	0.25	0
3	10	C.l	5.85	0
3	11	C.l	7.41	0
3	12	C.l	10.59	0
5	1	C.l	0.71	0
5	2	C.l	0	0.15
5	3	C.l	0	1.22
5	4	C.l	0	3.28
5	5	C.l	0	0.91
5	6	C.l	4.88	0
5	7	C.l	6.4	0
5	8	C.l	0.29	0
5	9	C.l	1.36	0
5	10	C.l	8.94	0
5	11	C.l	5.32	0
5	12	C.l	12.66	0
2	1	C.l	0	13.46
2	2	C.l	0	2.12
2	3	C.l	0.19	0
2	4	C.p	29.42	0

Table 4 continue:

Station	Month of the year	Dominant Species	Net Production	Consumption
2	5	C.l	6.01	0
2	6	C.l	0	34.29
2	7	C.l	5.37	0
2	8	C.l	0	0.15
2	9	C.l	0	2.24
2	10	C.l	12.13	0
2	11	C.l	12.79	0
2	12	C.l	12.15	0
4	1	C.l	0	5.63
4	2	C.l	1.61	0
4	3	C.l	2.01	0
4	4	C.l	0.58	0
4	5	C.l	14.9	0
4	6	D.p	1.19	0
4	7	C.l	0	10.58
4	8	C.l	0	4.27
4	9	C.l	0	0.04
4	10	C.l	8.61	0
4	11	C.l	9.71	0
4	12	C.l	13.3	0
6	1	C.l	0	2.26
6	2	C.l	3.36	0
6	3	C.l	5.28	0
6	4	D.p	0	3.55
6	5	C.l	0	3.3
6	6	C.l	1.57	0
6	7	D.p	1.14	0
6	8	D.p	0	1.85
6	9	D.p	0	1.43
6	10	D.p	1.8	0
6	11	D.p	4.44	0
6	12	D.p	6.43	0

Abbreviations: C.p: ***Chironomus plumosus*****, C.l:** ***Cerastoderma lamarki*****, D.p:** ***Dreissena polymorpha*****.**

Discussion

In the studied area, the wide availability of organic matter in the sediment, added to low water inputs thus 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 agricultural wastes, feces and nutrients. This can leads to intensify of 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 lagoon, there was an accumulation of free sulphide in the rhizomes of the macrophytes sea grass, during late summer as a result of an imbalance between sulphate reduction rates and sulphide reoxidation rates. As well as directly inhibiting sea grass 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 lagoo complex (Sorokin *et al*., 1996).

The macro benthic fauna 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 (Arias & Drake, 1994). However, the number of species was relatively low compared to the fauna described in the other estuaries such as Valli di Comacchio estuary and other brackish waters (Mistri, 2002) and same estuaries in northern Adriatic lagoons (Ceccherelli *et al*., 1994; Mistri *et al*., 2001a,b). 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* (Sprung, 1994b), *Chironomus plumosus* (Oyenekan, 1983) and *Dreissena polymorpha* (Bartels-Hardege & Zeeck, 1990).

The degree of isolation could also explain the local diminution of *Cerastoderma lamarki* after the dystrophic event. *Ballanus* sp. and *Chironomus plumosus* appeared to recover 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 (Drake & Arias, 1995a). 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 estimated P/B ratio of *C. plumosus*, was in the range 9.1 to $11.9y^{-1}$, and is in good accordance with the mean value of $12.7y^{-1}$, obtained in Cadiz Bay (Spain), with the size-frequency method (Drake & Arias, 1995a). The P/B ratio of *Ballanus* sp., in Tajan estuary ranged from 6.1 to $7.8y^{-1}$. These values was slightly higher than the ratios found in literature for the same species obtained by cohort or size frequency analyses, which appeared highly variable ranging from 1.8 to $6.1y^{-1}$ according to the study stations (Siegismund, 1982; Britton, 1985; Bachelet & Yacine-Kassab, 1987; Drake & Arias, 1995b; Sola, 1996; Lillebo *et al*., 1999).

Most of these 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 3.9y^{-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 3.2y^{-1}, calculated using the Tumbiolo and Downing (1994) method, from the Sacca di Goro, another coastal lagoon (Mistri *et al*., 2001a). Our results based on variations of benthic biomass showed that this estuary export the sum of 245.99g.m^{-2}. $year^{-1}$ of benthic production to the south Caspian Sea basin. 117.37g.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 macrobenthic composition and environmental conditions in Tajan Estuary were very similar to those found by Arias and Drake (1994), a direct comparison of the estimated secondary production is impossible due to the different methods applied. As Arias and Drake (1994) conceded, their estimation of macro benthic production using Edgar's (1990a) methods widely underestimates the production of the multivoltine chironomids as well as the contributions of juveniles of certain species, which could include ballenid species, which fall in the range 0.3 to 5mm (Bachelet & Yacine-Kassab, 1987). Secondary net production estimated in Tajan Estuary is higher than that estimated in the Sacca di Goro coastal lagoon, using Tumbiolo and Downing's (1994) method (50e75 gAFDMm^{-2} y^{-1}; Mistri *et al*., 2001a). Although Tumbiolo and Downing's method seems to produce underestimation (Dolbeth *et al*., 2005), the lower secondary production estimated in the Sacca di Goro might also be related to hypertrophic conditions and an absence of sea grass meadows. Many studies have demonstrated that vegetated bottoms support higher secondary production compared to the surrounding unvegetated bottoms (Edgar, 1990b; Edgar *et al*., 1994; Sprung, 1994a; Dolbeth *et al*., 2003). 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 fingerling fish species, issued from stock restoration organized by Iranian Fisheries Organization, in particular Acipenserid species, 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 white kutum, *Rutilus rutilus* (frissi kutum), *Huso huso*, *Acipenser persicus*, *A. guldenstadtii* and *A. stellatus*, which mainly feed on benthic macroinvertebrates (Ferrari and Chieregato, 1981; Khodorevskaya *et al*., .1997; Pita *et al*., 2002) and are released in huge quantities from spring to early summer by Iranian

Fisheries Organization. Although these fishes are able to adapt their diet (Ferrari & Chieregato, 1981; Pita *et al*., 2002), in Tajan 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. (Khodorevskaya *et al*., 1997; Javanshir *et al*., 2007). However, results showed that biomass community structures and secondary macro benthic production are negatively affected by the drought events. Management of these kinds of coastal ecosystems focuses mainly on fish releasing but often the importance of the benthic fauna 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. 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 (Mistri *et al*., 2001b). 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 and the direct estimation of secondary production.

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