

Seasonal variations in abundance and diversity of copepods in Mond River estuary, Bushehr, Persian Gulf

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Abstract. Hedayati A, Pouladi M, Vazirizadeh A, Qadermarzi A, Mehdipour N. 2017. Seasonal variations in abundance and diversity of copepods in Mond River estuary, Bushehr, Persian Gulf. *Biodiversitas* 18: 447-452. The present study was carried out to investigate the abundance and biodiversity of copepods from Mond River (MR) estuary, Bushehr, Persian Gulf during 4 seasons and their relationships with environmental factors. The water samples were collected in mid-season from spring 2012 to winter 2013 for one year period. Copepod samples were collected by using of 140 μ m plankton net with 25 cm mouth diameter and vertical towing in all stations. Copepod assemblages were comprised of 4 orders, 13 families and 10 genera. Orders were included; Calanoida, Cyclopoida, Poecilostomatoida, Harpacticoida and Genera were included: *Cathocalanus*, *Acrocalanus*, *Paracalanus*, *Subeucalanus*, *Centropages*, *Temora*, *Calanopia*, *Labidocera*, *Pontella*, *Acartia*, *Oithona*, *Oncaea*, *Corycaeus*, *Microsetella*, *Microsetella* and *Euterpina*. The order Calanoida with 10 genera was the most diverse and dominant order between Identified orders. The means ($\pm$ SE) of copepods abundance were recorded in spring (5853.4 ± 1826.19 Individual m^{-3}), in summer (6707.6 ± 1930.15 Ind. m^{-3}), in fall (4393.6 ± 1263.37 Ind. m^{-3}) and in winter (3400 ± 763.98 Ind. m^{-3}), respectively. Simpson and Shannon-Wiener biodiversity indices were obtained in spring (0.87 ± 0.11 and 2.86 ± 0.19), in summer (0.89 ± 0.006 and 3.11 ± 0.15), in fall (0.86 ± 0.13 and 2.66 ± 0.2) and in winter (0.83 ± 0.12 and 2.39 ± 0.15), respectively. The copepod assemblages had most amounts of diversity and abundance at station 5 in all seasons. Pearson correlation showed significant correlation between copepod diversity and abundance with salinity, pH and temperature. Results showed that salinity factor was more effective environmental factor on Simpson ($0.01 > P$ and $r=0.783$) and Shannon-Weiner indices ($0.01 > P$ and $r=0.727$), and copepods abundance ($0.01 > P$ and $r=0.664$) in MR estuary.

Keywords: Abundance, copepod, diversity, environmental factor, Mond Estuary

INTRODUCTION

Estuaries form a transfer region between marine environments and rivers and are subject to both marine influences such as waves, tides, and the invasion of saline water and riverine influences, such as currents of fresh water and sediment. The currents of both fresh water and sea water prepare high levels of nutrients in the water column and sediment, making estuaries among the most productive natural habitats (McLusky and Elliott 2004; Lam-Hoai et al. 2006). Zooplankton communities are ideal candidates for the study of the ecosystem reaction to climate variations because their life cycles are short, then assemblages have the potential to respond and reflect event-scale and seasonal variations in environmental situations. Moreover, many zooplankton taxa are known to be indicator species whose presence or absence may illustrate the relative influence of different water types on ecosystem structure. Thus zooplankton may serve as sentinel taxa that reflect changes in marine environments by preparing early indications of a biological response to climate changes (Mackas et al. 2001; Hays et al. 2005; Hooff and Peterson 2006).

Copepods are playing a key role in the food webs in the oceans and are known as secondary producers. They make

the link between phytoplankton and microzooplankton and higher levels of food chains, such as macrozooplankton and planktivorous fishes (Ohman and Hirsch 2001; Kimmel 2011; Calbet et al. 2001; Frangouilis et al. 2004). So far, many researches on zooplankton including copepods have been done in the Persian Gulf waters (Michel and Herring 1984; Al-Khabbaz and Fahmi 1994; Savari et al. 2004; Farhadian and Pouladi 2014, Reazi et al. 2014). Due to the importance of copepods in marine ecosystems and the lack of sufficient information in relation to these planktonic assemblages in Mond estuary, the aim of this study was to identify copepod species and calculation of their diversity and density in different seasons in relation to environmental factors in MR estuary.

MATERIALS AND METHODS

Study area

The study area was located in the MR estuary, the southeastern part of Bushehr province, and north of Persian Gulf, Iran. Along MR estuary, five sampling stations were determined based on environmental gradients of flow dynamics and mixing of fresh and coastal waters, depth, tides, river flow and geo-morphological features (Figure 1).

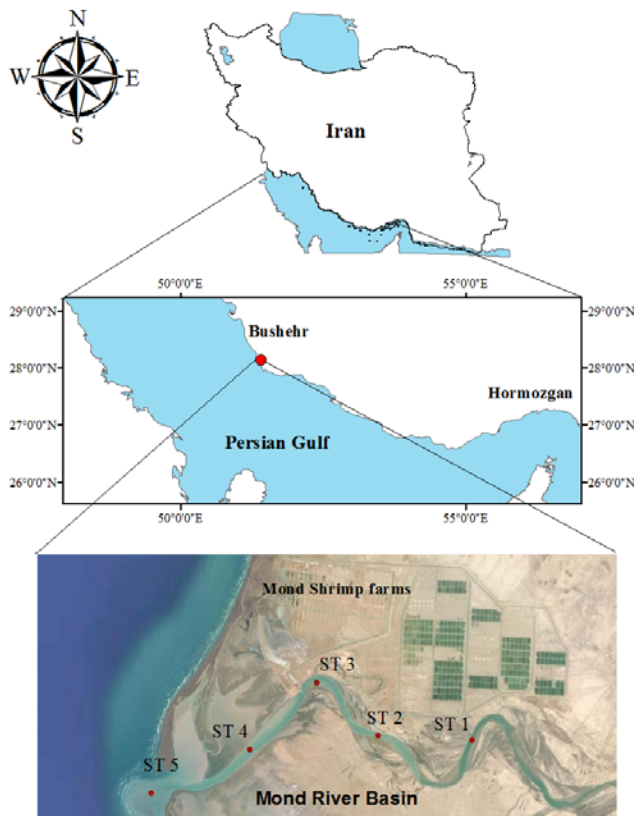


Figure 1. Sampling stations in Mond River estuary, Persian Gulf, Bushehr, Iran

Procedures

Seasonal samplings were carried out in the middle of each season for one year period from May 2012 to February 2013. Water temperature and pH were recorded by Mercury thermometer and pH meter model WTW. Salinity was recorded by using Atago S/Mill refractometer. Dissolved oxygen was measured by YSI 51 Oxygen meter (Model OH, USA) and transparency was obtained by Secchi depth plate. Copepod samples were collected by using of 140 μm plankton net with 25 cm mouth diameter and vertical towing in all stations with three subsamples of each station for measurement of abundance and diversity.

All sampling activities were accomplished in high tide times. For determination of copepod abundance, 3 subsamples from each sample with volume of 10 mL were prepared and were poured in Bagarov's chamber. Counting and identification of copepod communities were done by using of laboratory loop (Olympus, SZ6045, Japan) with magnification of 6 and invert microscope (model CETI, making Belgium) with magnification of 40 and seawater and brackish water zooplankton keys (Fernando 2002; Conway et al. 2006; Ali et al. 2009). The following formula was used to calculate the abundance of copepod (Omori and Ikeda 1984):

$$D = (N / V_1) \times V_2 / V \quad (1)$$

D: Copepod abundance, N: Number of individuals in the sample, V_1 : Volume of the sample used for counting

(mL), V_2 : The exact size of the original sample (mL), V: Volume of water filtered by plankton net (m^3)

The Shannon-Wiener diversity index (H') (Shannon and Weaver 1948) and Simpson diversity index (D) (Simpson 1949) were used for species diversity as following:

$$H' = - \sum_{i=1}^S (P_i) (\ln P_i) \quad (2)$$

$$D = 1 / \sum_{i=1}^S (P_i)^2$$

P_i : the relative abundance of the i^{th} taxon, S: total number of taxa

One-way ANOVA was performed to test significant seasonal differences in copepod abundance, diversity and water quality factors. Data were presented as means $\pm$ standard error of means. All data met the parametric test assumptions (normal distribution, homogeneity of variance, independence and randomness of the data). Data was transformed by Arcsin-square root to ensure a normal distribution (Zar 1984). All statistical analysis was carried out by using SPSS version 18.0 and diversity indices were calculated by using Ecological Methodology, version 6.0 (Krebs 1999).

RESULTS AND DISCUSSION

The copepod communities in Mond River estuary were comprised of 4 orders, 13 families and 10 genera (Table 1). Genera were including: *Cathocalanus*, *Acrocalanus*, *Paracalanus*, *Subeucalanus*, *Centropages*, *Temora*, *Calanopia*, *Labidocera*, *Pontella*, *Acartia*, *Oithona*, *Oncaea*, *Corycaeus*, *Microsetella*, *Microsetella* and *Euterpina*. Among the identified copepods, *Acartia fossae* (587 ± 295 Individual m^{-3}), *Acartia* sp. (467 ± 266 Ind. m^{-3}) and copepod nauplii (1000 ± 303 Ind. m^{-3}) in spring, *Acartia* sp. (547 ± 289 Ind. m^{-3}) and *Acartia ohtsukai* (426 ± 182 Ind. m^{-3}) and copepodite (453 ± 148 Ind. m^{-3}) in summer, *Acartia fossae* (400 ± 193 Ind. m^{-3}), *Acartia* sp. (307 ± 185 Ind. m^{-3}) and copepod nauplii (626 ± 185 Ind. m^{-3}) in fall, *Labidocera* sp. (346 ± 154 Ind. m^{-3}), *Acartia fossae* (333 ± 216 Ind. m^{-3}) and copepod nauplii (426 ± 116 Ind. m^{-3}) in winter had the highest abundance, respectively. During sampling period; *Temora discaudata*, *Calanopia elliptica*, *Acartia fossae*, *Acartia* sp. and *Oithona brevicornis* had the most presence and *Centropages orsinii* and *Pontella* sp. showed the least presence in the estuary environment (Table 1).

Most population abundance of copepods were observed in station 5 in the mouth of estuary in all seasons that were (12733 ± 1930 Ind. m^{-3}) in spring, (14067 ± 3154 Ind. m^{-3}) in summer, (9467 ± 1268 Ind. m^{-3}) in fall and (6267 ± 1314 Ind. m^{-3}) in winter, respectively (Figures 2). Among Copepods, calanoids were the dominant assemblages in MR estuary. Cyclopoid and calanoid copepods are dominant holoplanktonic zooplankton in some estuaries. They are main grazers of microzooplankton and phytoplankton and they play the role of prey for zooplanktivorous fishes and invertebrates (Benfield 2013). Similar situation has been

reported in other estuaries (Primo et al. 2009; Hwang et al. 2010; Xuelu et al. 2011; Farhadian and Pouladi 2014). Also copepods nauplii as a wide variety of species were observed in Mond River estuary, which occurred in appreciable amounts. Copepods nauplii, copepodites and adult stages of smaller copepods are important grazers and essential food sources for critical fish larval stages and are considered to be an important component of the marine trophic web (Webber and Roff 1995).

Change of species composition and community structure can be explained numerically with species diversity (Kulshreshta et al. 1989). The diversity of zooplankton species in aquatic ecosystems is linked to its abundance. High diversity might indicate larger food chain, inter-specific interaction and stability among the estuarine zooplankton community (Varadharajan and Soundarapandian 2013). Highest amounts of copepods Simpson and Shannon-Weiner diversity were obtained in station 5 that were (0.91 ± 0.003) and (3.52 ± 0.092) in spring, (0.91 ± 0.02) and (3.63 ± 0.28) in summer, (0.9 ± 0.01) and (3.36 ± 0.14) in fall, (0.88 ± 0.009) and (2.96 ± 0.14) in winter, respectively (Figures 3 and 4). In comparison the seasons were studied, summer with the average abundance (6707 ± 1930) an average Simpson (0.89 ± 0.006) and Shannon-Weiner (3.11 ± 0.15) had highest amounts and winter with average abundance (3400 ± 763) an average Simpson (0.83 ± 0.12) and Shannon-Weiner (2.39 ± 0.15) had lowest amounts, respectively (Table 2).

Table 1. Comparison of copepods presence (*) during different seasons in Mond River estuary

Order	Identified copepod	Spring	Summer	Fall	Winter
Calanoida	<i>Cathocalanus pauper</i>	*	*		
	<i>Acrocalanus longicornis</i>	*	*	*	
	<i>Paracalanus</i> sp.		*		*
	<i>Paracalanus indicus</i>	*		*	
	<i>Subeucalanus flemingeri</i>	*	*	*	*
	<i>Centropages orsinii</i>		*		
	<i>Temora discaudata</i>	*	*	*	*
	<i>Temora Turbinata</i>	*	*	*	*
	<i>Calanopia elliptica</i>	*	*	*	*
	<i>Labidocera</i> sp.	*			*
	<i>Labidocera minuta</i>		*	*	
	<i>Pontella</i> sp.		*		
	<i>Acartia fossae</i>	*	*	*	*
	<i>Acartia</i> sp.	*	*	*	*
Cyclopoida	<i>Acartia ohtsukai</i>		*	*	
	<i>Oithona attenuata</i>	*	*	*	
	<i>Oithona brevicornis</i>	*	*	*	*
	<i>Oithona</i> sp.	*	*		
Poecilostomatoida	<i>Oncaea</i> sp.	*			*
	<i>Corycaeus</i> sp.	*	*	*	
	<i>Corycaeus agilis</i>			*	*
Harpacticoida	<i>Microsetella</i> sp.	*	*		
	<i>Macrosetella</i> sp.	*	*	*	
	<i>Euterpina</i> sp.		*		*
Others	Copepodite larvae	*	*	*	*
	Nauplii larvae	*	*	*	*

Seasonal average of temperature and dissolved oxygen were 23.92°C and 8.28 mg L^{-1} in spring; 33.4°C and 6.87 mg L^{-1} in summer; 19.54°C and 7.39 mg L^{-1} in fall, and 14.8°C and 9.46 mg L^{-1} in winter, respectively. Seasonal average of water transparency, salinity and pH were 43.6 cm , 28.2 ppt and 8.2 in spring; 44.8 cm , 38.8 ppt and 8.1 in summer; 46 cm , 35.8 ppt and 8.1 in fall and 49.8 cm , 25.2 ppt and 8.15 in winter, respectively (Table 3).

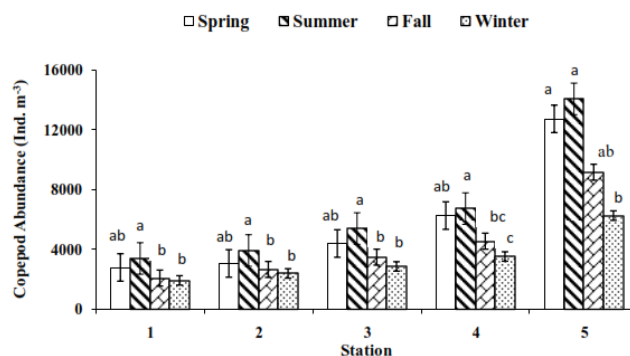


Figure 2. Seasonal abundance (Mean $\pm$ SE) of copepods at different stations in Mond River estuary ($0.05 > P$)

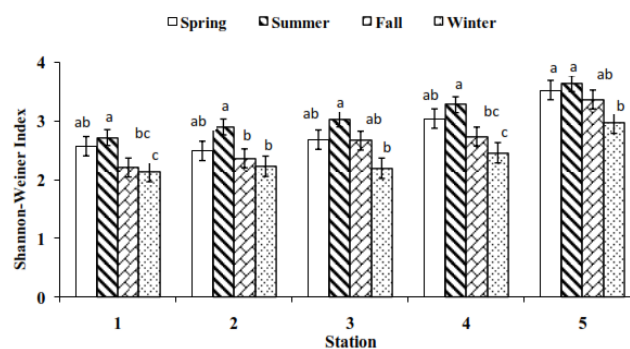


Figure 3. Shannon-Weiner diversity (Mean $\pm$ SE) of copepods at different stations in Mond River estuary ($0.05 > P$)

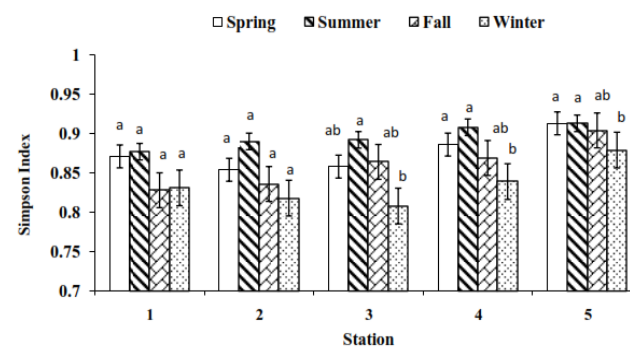


Figure 4. Simpson diversity (Mean $\pm$ SE) of copepods at different stations in Mond River estuary ($0.05 > P$)

Table 2. Mean ($\pm$ SE) of copepods abundance and diversity indices in different seasons in Mond River estuary (0.05> P)

Index	Spring	Summer	Fall	Winter
Abundance	5853.4 $\pm$ 1826.19 ^a	6707.6 $\pm$ 1930.15 ^a	4393.6 $\pm$ 1263.37 ^a	3400 $\pm$ 763.98 ^a
Simpson	0.87 $\pm$ 0.11 ^{ab}	0.89 $\pm$ 0.006 ^a	0.86 $\pm$ 0.13 ^{bc}	0.83 $\pm$ 0.12 ^c
Shannon-Weiner	2.86 $\pm$ 0.19 ^{ab}	3.11 $\pm$ 0.15 ^a	2.66 $\pm$ 0.2 ^{ab}	2.39 $\pm$ 0.15 ^b

Table 3. Mean ($\pm$ SE) of water quality factors in different seasons in Mond River estuary (0.05> P)

Parameters	Spring	Summer	Fall	Winter
Salinity (ppt)	28.2 $\pm$ 4.21 ^{bc}	38.8 $\pm$ 1.68 ^a	35.8 $\pm$ 1.53 ^{ab}	25.2 $\pm$ 4.19 ^c
Dissolved Oxygen (mg L ⁻¹)	8.28 $\pm$ 0.15 ^b	6.87 $\pm$ 0.22 ^c	7.39 $\pm$ 0.11 ^c	9.46 $\pm$ 0.38 ^a
pH	8.2 $\pm$ 0.025 ^a	8.1 $\pm$ 0.013 ^b	8.1 $\pm$ 0.06 ^b	8.15 $\pm$ 0.045 ^{ab}
Temperature (°C)	23.92 $\pm$ 0.16 ^b	33.4 $\pm$ 0.5 ^a	19.54 $\pm$ 0.2 ^c	14.8 $\pm$ 0.33 ^d
Transparency (cm)	43.6 $\pm$ 0.68 ^b	44.8 $\pm$ 1.16 ^b	46 $\pm$ 1.05 ^b	49.8 $\pm$ 1.5 ^a

Note: Values with different letters indicate significant mean differences

Table 4. Pearson correlation between some of water properties with abundance and biodiversity indices in Mond River estuary, Persian Gulf, Iran

	Correlation	Abundance	Simpson Index	Shannon-Weiner Index
Salinity	Pearson Correlation	0.664**	0.783**	0.727**
	Sig. (2-Tailed)	<u>0.001</u>	<u>0.001</u>	<u>0.001</u>
Dissolved Oxygen	Pearson Correlation	-0.056	-0.243	-0.370
	Sig. (2-Tailed)	<u>0.816</u>	<u>0.302</u>	<u>0.108</u>
pH	Pearson Correlation	0.541*	0.453*	0.322
	Sig. (2-Tailed)	<u>0.014</u>	<u>0.045</u>	<u>0.166</u>
Temperature	Pearson Correlation	0.452*	0.652**	0.734**
	Sig. (2-Tailed)	<u>0.045</u>	<u>0.002</u>	<u>0.001</u>
Transparency	Pearson Correlation	0.182	0.019	-0.156
	Sig. (2-Tailed)	<u>0.441</u>	<u>0.936</u>	<u>0.512</u>

Note: * Correlation is significant at the 0.05 level, ** Correlation is significant at the 0.01 level. Data in parentheses are significant level

Correlation between water parameters with copepods abundance and diversity indices are presented in (Table 4). The results showed that there were positive correlation between copepods abundance and salinity (0.01> P and $r=0.664$); Simpson diversity and salinity (0.01> P and $r=0.783$); Shannon-Wiener diversity and salinity (0.01> P and $r=0.727$); copepods abundance and pH (0.05> P and $r=0.541$); Simpson diversity and pH (0.05> P and $r=0.453$); copepod abundance and Temperature (0.05> P and $r=0.452$); Simpson diversity and Temperature (0.01> P and $r=0.652$); Shannon-Wiener diversity and Temperature (0.01> P and $r=0.734$) (Table 4).

Generally, Copepods productions are related to range of biological parameters such as egg productions, successful egg blossoming, survival and growth of nauplii, the copepodite stages, the median age, adult sex ratio and access to food and non-biological factors such as temperature, salinity, dissolved oxygen, the acidity and other parameters. Their reproductive cycles, growth, reproduction and survival rates are all important factors that affecting fish resources (Harris et al. 2000; Roman et al. 2005; Knuckey et al. 2005; Prabhakar et al. 2011).

Salinity was positively correlated with the copepods abundance, Shannon-Weiner and Simpson diversity indices (0.01> P). The salinity in Bushehr coastal waters is affected by the general trend of salinity variation in Persian Gulf which is depended on the current entering from Indian Ocean and Oman Sea in to Persian Gulf, and mixing of low saline freshwater of Mond and Helleh Rivers with high saline seawater (Kamp and Sadrinasab 2006; Aein Jamshid et al. 2014). Salinity is the most important factor influencing the community structure of zooplankton assemblages in tropical estuaries. Development of a salinity gradient from the upstream areas to the sea in estuaries is mainly due to the strength of diurnal tidal current and the volume of freshwater flow from the upstream (Nasser et al. 1998; Mishara and Panigrahy 1999; Lee et al. 2006; Hwang et al. 2010). The greatest numbers of species occur in more saline waters, and species diversity tends to decrease with decreasing salinity. Distribution of major groups of zooplankton populations is governed by various behavioral and physiological adaptations of the plankton population to ever changing hydrographical conditions (Mann 2000).

The pH was in alkaline range and showed positive correlation with copepods abundance and diversity ($0.05 > P$). MR basin has formed of alluvial and alkaline soils therefore it is expected to have alkaline water. Alkaline pH makes soluble carbon compounds such as calcium carbonate and bicarbonate usable for photosynthesis production and increasing the amount of chlorophyll *a* (Day et al. 1989). Natural plankton biomass increases within the pH range from 8 to 9 (Pedersen and Hansen 2003). The pH varies with aquatic acid-base balance. High pH may enhance the toxicity of some chemical compounds in the aquatic environment, thereby negatively affecting the health, feeding, and survival of marine copepods. However, little is known about the effects of pH on the physical ecology of marine plankton (Pedersen and Hansen 2003; Liu 2004; Li et al. 2008).

Many studies have reported that temperature is an important physical factor affecting plankton distribution. It can directly or indirectly impact the distribution of zooplankton, including copepod (Nakata et al. 2004; Bigler et al. 2006; Pipan et al. 2006). The results showed that there was a positive correlation between diversity ($0.01 > P$) and density ($0.05 > P$) of copepods with temperature which is corresponded with increasing the density of copepods in summer and decreasing of them in winter. In many ecosystems, the abundance of copepods is greatly affected by factors such as temperature and the amount of food in the water that it has a significant impact on the regulation of egg production and its growth (Niehoff 2007). The cold season results showed a decline in copepod population. Yahia et al (2004) study showed that with decreasing in temperature in cold months and subsequently lower food reserves, the abundance of copepods nauplii were reduced, which represent a reduction in egg productions and the number of adults in the cold season. Typically, with increasing of sunlight intensity in summer, the rate of photosynthesis and subsequently phytoplankton production rises that could lead to an increase in the diversity and density of herbivorous creatures (Madhu et al. 2007). Other studies in other parts of the Persian Gulf and the Indian Ocean have reported similar results (Michel and Herring 1984; Abdel-Aziz et al. 2007; Pouladi et al. 2014).

To conclude, this study revealed that the most diversity and abundance of copepod assemblages were at 5 stations in the mouth area of the estuary during all seasons and showed a positive correlation with salinity, pH and Temperature. Since few studies have been done in the estuaries of Persian Gulf, therefore, it is recommended to consider other planktonic assemblages for better perception of plankton roles in food webs in estuaries.

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