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The effect of marine fish cage culture on benthic communities using BOPA index in Ghazale Creek (Persian Gulf)

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Abstract

The present work has been carried out to investigate the probable effects of fish cage culture on benthic communities as a pollution and stress indicator and to evaluate the biotic health condition using BOPA index, in Ghazale Creek (Khowre-Mussa - Persian Gulf). Monthly sampling from 4 stations was carried out from June 2007 to March 2008 (during nine months). Stations were selected from under the cage to 400 m distant (as control site) in Ghazale Creek. Three samples were taken at each station for macrobenthos and one for sediment grain size and total organic matter (TOM), using a 0.0125 m^2 van veen grab. Also physical-chemical parameters sampling from three stations was done (during nine months). Stations were under cage station, 50 m and 400 m far from cages in Ghazale Creek.The percentage of total organic matter (TOM) in sediment ranged from 6.11 to 23.26 and the range of silty-clay percentage was from 4.76 to 97.47. The dominant macrobenthos groups were *Polychaets* (60.62%), *Mulluska* (19.67%), *Crustacea* (16.49%). Macrobenthic abundance, biomass and diversity index values in the under cage station were less than that in the control station. Comparing the results of BOPA with the guidelines shows that all stations had bad environmental conditions. The under cage station was more polluted than the control station. The range of physical-chemical parameters in water were: DO (6.5-11.43) ppm, BOD (1.5-10.9) ppm, Salinity (43-45.6) ppt, NO_2^- (0.006-0.29) ppb, NO_3^- (3.98-32.2) ppm, Turbidity (14-70) NTU temperature (11.8-32.5) °C.

Keywords: Marine fish, Cage culture, Macrobenthos community, BOPA index, Physical-chemical parameters, Ghazale Creek, Persian Gulf

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Introduction

The environmental impacts of aquaculture activities are one of the most important challenges facing developing countries. It needs a careful plan for monitoring and environmental evaluation. Fish cage farms release large amounts of effluents including; nutrients, waste food and feces, and by-products such as medications and pesticides. These effluents have impacted the local environment, depending on the amounts of released waste, the time-scale over which the releases take place, and the assimilation capacity and flushing ability of the recipient water body (Gowen and Bradbury, 1987; Ackefors and Enell, 1994; Wu, 1995; Axler et al., 1996; Kelly et al., 1996). This may cause organic enrichment of the sediments below the cages (Gowen and Bradbury, 1987; Findlay et al., 1995), thereby affecting the benthic community regarding macrofaunal succession with large differences in the spatial extend of the impacts (Stewart, 1997; Mazzola et al., 1999; Pergent et al., 1999; Delgado et al., 1999; McGhie et al., 2000; Naylor et al., 2000; Nordvarg and Johansson, 2002). Because of the role of benthic organisms in sediment-water interface and their relatively long and sedentary life, they are considered as potentially powerful indicators for marine ecosystem health (Pearson and Rosenberg, 1978; Dauer et al., 2000). The relationship between macrofaunal assemblages and the effect of contaminants on them have been described extensively in the literature, (Pearson and Rosenberg, 1978; Warwick et al., 1990; Simboura et al., 1995; Estacio et al., 1997; Ellingsen, 2002; Morrisey et al., 2003; Guerra-Garcia and Garcia-Gomez, 2004).

Many types of indices have been developed to evaluate the benthic community condition and marine habitat quality. Some of these indices are based on the classification of species (or groups) in several ecological communities representing specific sensitivity levels to disturbance. BOPA is one of the most frequently used indices, in which the taxonomic effort is reduced. The main advantages of this index, as well as the reduced taxonomic knowledge, are its independence of sampling protocols, its use of mesh sieves and of the surface unit chosen to express abundances (Pinto et al., 2009). This index is negatively correlated with amphipods, which are a particularly sensitive zoological group, not only to significant increases in organic matter but also to increases in other kinds of pollution including metals and hydrocarbons (Dauvin and Ruellet, 2007). On the other hand, polychaete group contains both sensitive and tolerant species and they are found along the whole gradient from pristine to heavily disturbed areas (Olsgard et al., 2003). The presence or absence of specific polychaetes in marine sediments provides an excellent indication of the condition or health of the benthic environment (Pocklington and Wells, 1992). Therefore the opportunistic polychaete/amphipod ratio is studied as an indicator to estimate the effects of marine fish cages on sediment quality. This is why we used BOPA index developed by Dauvin and Ruellet (2007), to evaluate the pollution effects on marine ecosystem by macrobenthic community. Aquaculture is one of the human activities, in Mussa creek in south of Khuzestan province, which impacted the marine ecosystem. Dehghan madiseh, 2008 and Dostshenas, 2009 used the benthic index for evaluation of biotic health in Mussa Creek. Their studies showed the decrease in environmental quality. The main objective of this study is to compare the frequency, diversity, biomass and physical-chemical parameters of benthic communities in the below cages area, as an under stress place, with a distant place, as an unstressed place (or less stressed area).

Materials and methods

Ghazaleh creek is located at 19°, 13′ E and 30°, 27′ N in north-west of the Persian Gulf. The samples were collected monthly from June 2007 to March 2008. Four stations were selected in Ghazaleh Creek as follows: below the cages, 50, 150 and 400 (control station) meters far from cages. Three samples were taken at each station for macrobenthos and one for sediment grain size and total organic matter using a 0.0125 m2 Van Veen grab. Figure 1 shows the location of Ghazale Creek in the Persian Gulf. Marine fish cages which were established in Ghazaleh Creek, since 1992, contained nine cages with 2*2*3 m^3 and 5*5*5 m^3 dimension. For macrobenthos study, the sediments were immediately transported to the laboratory and separated by passing through a 0.5 mm mesh size sieve and then the benthic organisms were collected from the sieve.

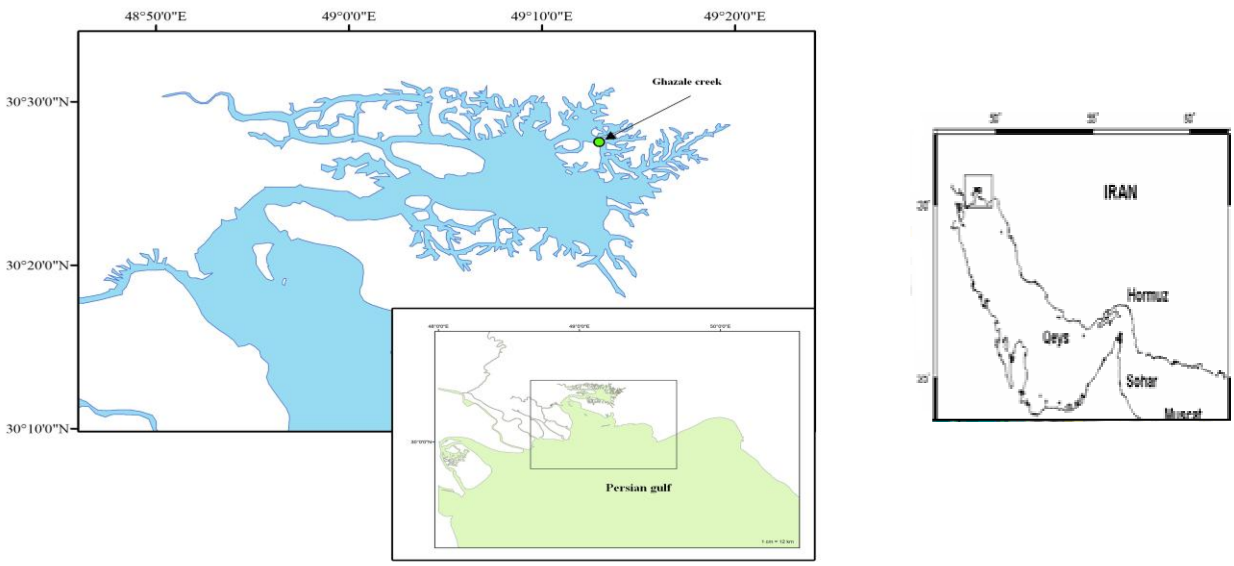

Figure 1: Location of Ghazale creek in north west of the Persian Gulf

Macrobenthos were separated to the lowest species level and individuals of all species were counted using benthic identification keys, such as: Barnes, 1987; Jones, 1986; Hutchings, 1984; Carpenter and Niem, 1998; Sterrer, 1986. The identifications were done using a binocular microscope. Macrofauna`s weights were taken as dry weight (Holme and Mcintyre, 1984). Sediment grain size and total organic matter (TOM) were also measured using Holme and Mcintyre (1984) method. The

Benthic Opportunistic Polychaetes Amphipods (BOPA) values were calculated according to equation 1 :

$$BOPAindex = \log(\frac{fp}{fA+1}) + 1 \quad \textbf{(1)}$$

where f_P is the opportunistic polychaete frequency (ratio of the total number of opportunistic polychaete individuals to the total number of individuals in the sample); f_A is the amphipod frequency (ratio of the total number of amphipod individuals excluding the opportunistic Jassa amphipods to the total number of individuals in the sample), and $f_P + f_A < 1$. The two ''+1'' terms in the equation are needed in order (1) to allow the division operation to be completed even when f_A is null, and (2) to prevent the eventuality that a log of zero (which does not exist) would need to be calculated if f_P is null. The BOPA index is null only when there are no opportunistic polychaetes, indicating an area with a very low amount of organic matter. The index is low when the environment is good, with few opportunistic species; and it increases as increasing organic matter degrades the environment, this variation has been shown in table 1 (Dauvine and Ruellet, 2007). Its value can vary between 0 (when $f_P = 0$) and log 2 (when $f_A = 0$) because:

f_P =[0; 1] and f_A =[0; 1]

$$(f_{A+1}) = [1;2] \longrightarrow \frac{f_P}{f_A+1} = [0;1] \longrightarrow \left(\frac{f_P}{f_A+1} + 1\right) = [1;2]$$

BOPA index =[0; log 2]

Table 1: Theoretical variations of BOPA index and Shannon-Wiener (H ´)

WFD	Pollution classification	BOPA	H ´
High	Unpolluted/normal	0.00≤BOPA≤0.062	>4.6
Good	Slightly polluted	0.045<BOPA≤0.197	4.1-4.6
Moderate	Moderately polluted	0.139<BOPA≤0.284	3.1- 4.0
Poor	Heavily polluted	0.193<BOPA≤0.301	1.6-3.0
Bad	Extremely polluted	0.267<BOPA≤0.301	*<1.5*

We used the IV and V ecological groups given by Borja, 2000 as opportunistic polychaetes. BOPA values for each station were examined using a two-factor analysis of variance (ANOVA) with distance and month as constant factors, using Excel and Minitab version 15, and biological indexes were calculated from bio-tools.

Results

The results show that the mean percentage of silty-clay fraction ranged from 4.76 to 97.47 and the mean percentage of total organic matter (TOM) ranged from 6.17 to 23.26 in different stations. There are significant differences in silty-clay values, and no-significant differences in TOM values ($p<0.05$) among the stations.

A total of 21 groups of macrobentic animals were identified. The percentage of the most abundant macrobenthos groups and their biomass are shown in figures 2 and 3. The maximum of mean frequency and macrobenthic biomass values were found at control station and the minimum of the values were found at the under cage station (Figure 3). No significant differences in macrobenthos frequency were found among stations ($p>0.05$).

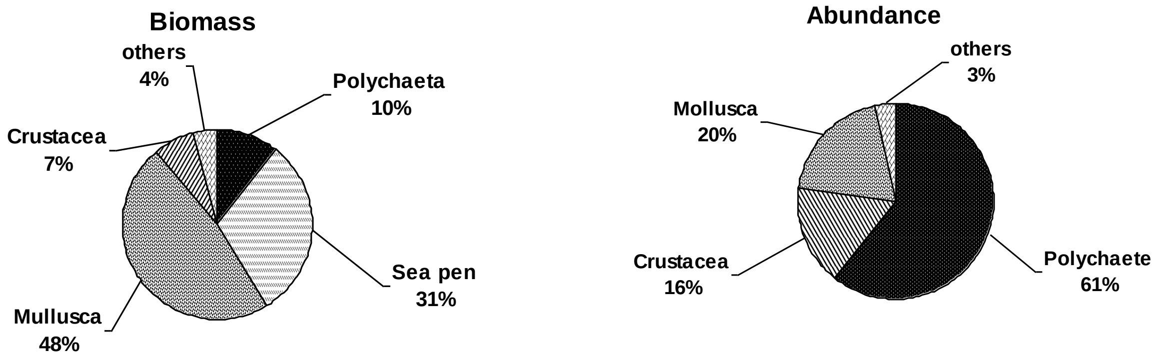

Figure 2: The faunal groups` composition (%) of identified macrobenthos based on mean abundance and biomass in Ghazaleh creek

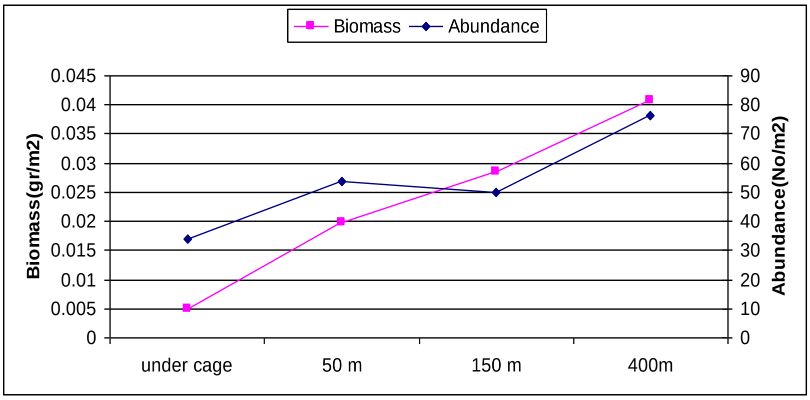

Figure 3: Mean values of abundance and biomass at sampling station in Ghazaleh Creek

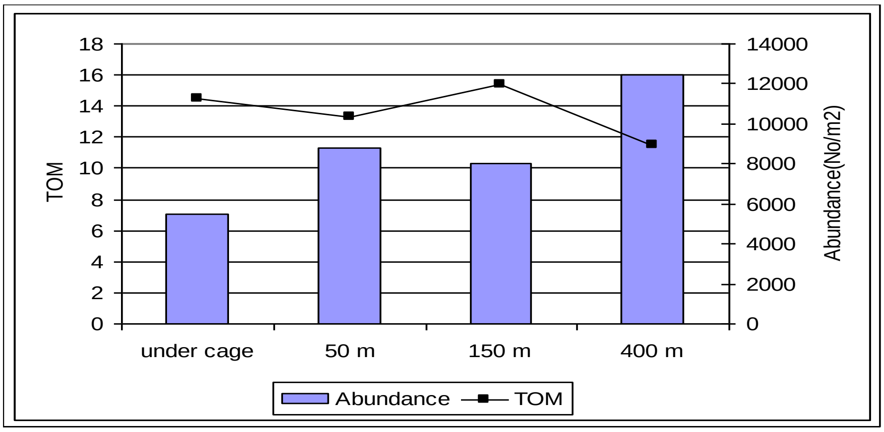

Figure 4: Comparison between the percentage of TOM and macrobenthic abundance values in Ghazale Creek

Negative significant relationships were observed between total organic matter and Macrobenthos frequency (r =-0.25) (figure 4).The results of calculated biotic index at sampling station are represented in table 2. The BOPA value at the under cage station was more than that for other stations (Figure 5) The ANOVA results showed no significant differences in BOPA values among stations. Physico-chemical parameters show Nitrite, Turbidity, DO and BOD_5, in the under cage station are more than the 400 m distant station (figure 6). The one-way analysis (ANOVA) results showed no significant difference in physical-chemical water parameters among stations ($p>0.05$) but monthly differences were significant for temperature, salinity and BOD_5 ($p<0.05$).

Table 2: Biological index in stations at Ghazale Creek

Shannon-Wiener(H´)	Evenness	Simpson's Dominance	Richness	station
1.75	0.74	0.30	21	under cage
2.16	0.84	0.20	18	50 m
2.06	0.85	0.24	16	150 m
2.66	0.85	0.11	26	400 m

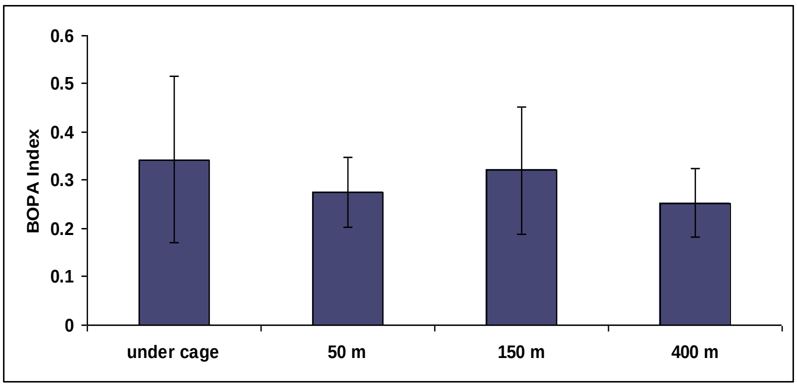

Figure 5: Mean of BOPA values in different stations

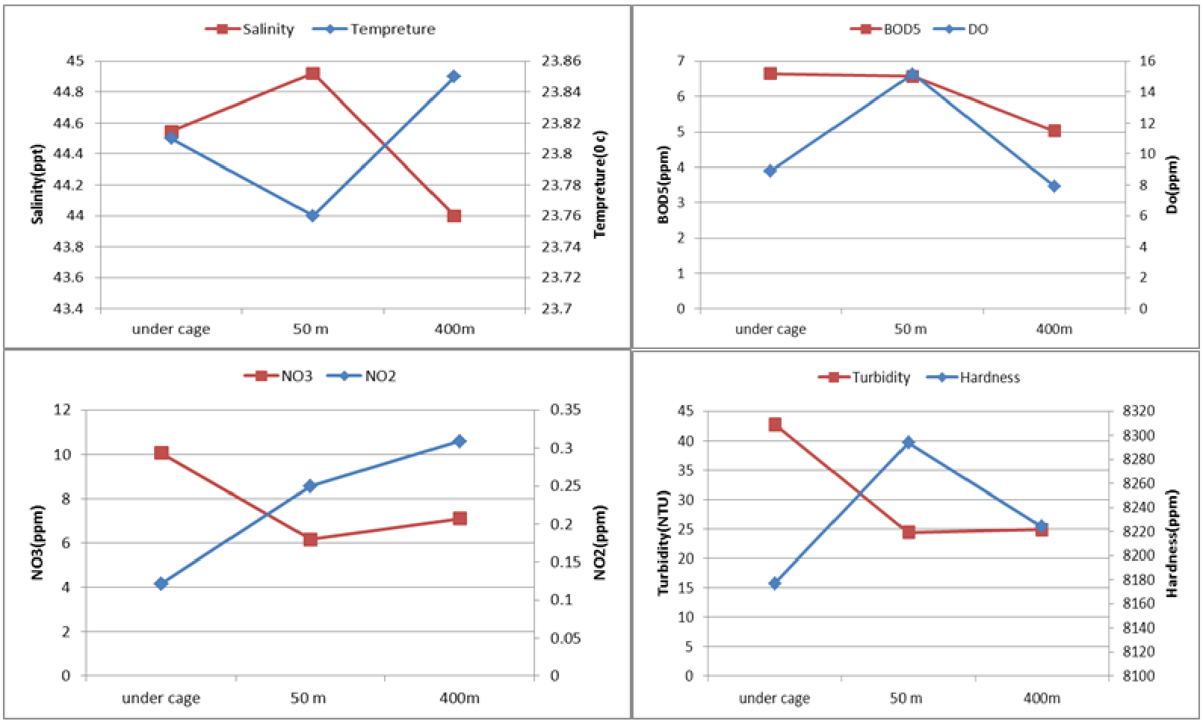

Figure 6: Mean values of physical-chemical parameters in sampling stations in Ghazaleh Creek

Discussion

According to grain size analysis and TOM content, it is clear that Ghazale Creek is characterized by a soft muddy bottom. The amounts of TOM showed no significant differences between studied stations, so we can`t relate this factor to the role of marine fish cages on sediment. Polychates were the dominant and abundant group in studied stations. The mean of macrobenthos abundance and biomass in the under cage station was less than the 400 m distant station, but there are no significant differences between stations. Also there are weak correlations between macrobenthos abundance and total organic matter that can show organic matter has an effect on macrobenthos community.

No-significant differences were observed in physical-chemical parameter values among stations, which shows these factors didn't have any sever effect on our data, but significant differences between months in salinity, temperature and BOD5 were observed, which show there are seasonal variations in macrobenthic communities in this area. According to previous studies in Khuzestan coastal waters such as Nilsaz et al., 2005, these temporal variations could have occured due to obvious seasonal changes in physical-chemical and biological parameters in this area.

The BOPA index is easier to use than other indices because the need for taxonomic knowledge is reduced. It is only necessary to recognize amphipods and a reduced listof opportunistic polychaetes and distinguish the Jassa amphipods from the others. According to the October 2005 inventory made available by the AZTI research (www.azti.es) team, the list of opportunistic polychaetes contains two families (*Capitellidae* and *Cirratulidae*), nine genus (*Cossura*, *Laeonereis*, *Ophryotrocha, Paraprionospio, Polycirrus, Polydora, Prionospio, Pseudopolydora and Rhaphidrilus*) and 21 species (*Chloeia rosea, C. venusta, Dipolydora caulleryi, D. coeca, D. flava, D. giardi, D.qua-drilobata, D.socialis, Ficopomatus enigmaticus, Glycera alba, Leitoscoloplos mammosus, Malacoceros fuliginosus, Neanthes caudata, N. irrorata, Parougiacaeca, Pholoeinor-nata, Phyllodoce* (*Anaitides*) *groenlandica, Schistomeringos rudolphii, Scolelepis tridentata, Sigambra parva* and *S.tentaculata*). We used a modified BOPA index (Dauvin and Ruellet, 2007) to classify the areas affected by cages. The results indicated that (See Table 2) all of the stations were classified as having a ‘‘bad” status. It indicates that the ecological status of all stations is in bad condition, and among them the under cage station showed the worst status, and the control station showed the better status. But the maximum amount of Shannon-Wiener (H´) index was 2.66 in the 400m distant station and the minimum one was 1.75 in the under cage station (See Table1). According to table 2 the amounts of Shannon-Wiener (H´) index show that this area has a moderate ecological status. Nabavi, 1999 and Dehghan madiseh, 2008 state Ghazale creek and the environmental quality of Khowre-Mussa can be considered as a moderate pollution area, similar to the result of the present study. Due to Hydrodynamic nature and high tidal currents in the studied area (as natural stress) severe fluctuations on benthic community are observed in unstable sediments. Cage culture activities can affect macrobenthos diversity as a result of organic matter loading, but we believe that despite these facts, other factors such as anthropogenic activities in our study area could act as a main cause of reducing biodiversity.

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