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IMPACT OF COOLING WATER DISCHARGE ON THE BENTHIC AND PLANKTONIC PELAGIC FAUNA ALONG THE COASTAL WATERS OF QATAR (ARABIAN GULF)

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ABSTRACT

Samples for benthic fauna and zooplankton were collected during winter 2002 and summer 2003 from two coastal sites, opposite to industrial areas located northeast and southeast of Qatar, receiving cooling water discharge. The temperature of cooling water exceeded 40 °C at 50 m distance from the discharge point, while chlorine levels approached 0.5 mg/L. The flow of cooling water drastically impacted the pelagic and benthic fauna in the vicinity of the discharge points. Mollusca is the most tolerant benthic group in the study area, particularly gastropods and bivalves. Bivalves increased gastropods by number near the outfalls. Polychaete species were present near outfall area, with low abundance and dominated by tubed forms. Nereis, capitellids and lumbrinerids are considered the most tolerant species. Most recorded Sponges, and Crustacea are eliminated at temperatures above 37°C. Intertidal species appear to be more tolerant of high temperature than subtidal species. The worst case is faced during summer at seawater temperature exceeding 35 °C which is the lethal threshold for some species. The abundant and persistent zooplankton taxa at impacted points (Copepoda, Mollusca, Polychaeta and to a less extent Chaetognatha) suggest their ability to adapt themselves to the prevailing stress. They showed persistence to more than 0.1 mg/l chlorine and temperature slightly higher than 36.0°C. The main copepod group appearing close to the outfall was harpacticoida dominated by Euterpina acutifrons (16-28%). Calanoids dominated by Paracalanus spp. (8-16%) and cyclopoids dominated by Oithona spp. were abundant (9-18%) away from the outfall. The impact of cooling water is more pronounced on the pelagic rather than the benthic fauna. This may be due to the flowing and buoyant nature of the low density warm cooling water and the physiological nature of the benthic organisms rendering them more resistant.

INTRODUCTION

Cooling water from industrial effluents is discharged at higher temperatures than that of the receiving waters. In tropics there are little fluctuations in sea temperature but in temperate regions, the peak of cooling water discharge is in winter, when the sea temperature is low. Not only that the added heat dissipated more slowly in summer than in cold season but also the summer sea temperature is already near the lethal thermal point of many organisms and with these additions of heat, may easily exceed it.

Cooling of the heated discharge is almost entirely by mixing with the receiving water. The area affected is limited to the plume of hot water and its immediate surroundings. The direction taken by the plume may change with changing tidal currents and so the total area under its influence is greater than what appears. Numerical models were widely used in tracing the plume of the cooling water and predicting its future trends (Sarkkula, 1991).

Chlorine as hypochlorite is used as an antifouling agent for cooling water. The fate of chlorine in the marine environment is determined by temperature, ammonia concentrations and naturally occurring organic substances. Chloramines are toxic substances and their bioaccumulation is lethal. However, chlorination of cooling water and other process water is widely used by all countries and the only attempt is to control its impact by the use of discharge standards.

During the last decade, the coastal waters of Qatar received, due to increased industrial development, huge amounts of cooling water discharge from 2 main industrial cities. Cooling water is usually treated at least intermittently, with chlorine to retard the settlement of organisms in heat exchange systems.

In view of the continuous expansion in industrial cities in general and establishment of new industries in particular, the present study was designed to throw some light on the effect of the increase in temperature and chlorine contents derived from cooling water discharge on the pelagic and benthic fauna communities in certain parts of Qatari coastal waters.

STUDY AREA

Two locations were selected at the northeastern (opposite to Ras Laffan Industrial City, Site A) and southeastern (opposite to Mesaieed Industrial City, Site B) coast of Qatar (Figure 1). A Liquefied Natural Gas facility on the NE coast discharges cooling water to the sea through an open canal. Immediately north and south of the discharge and extending east are small jetties. Several kilometers north of the outfall are the breakwaters of Ras Laffan Port. The cooling water intake for this facility is located inside the port. At site A, about 55,500 m^3 hr^{-1} of seawater, used for heat exchanger cooling, are discharged from this outfall. On the other hand, Mesaieed Industrial City is located southeast of the Qatari peninsula. The industrial complex was commissioned since 1968 harboring Petrochemical, Fertilizer, Chemical, NGL and steel industries. The marine area receives about 241,000 m^3 hr^{-1} of cooling water are discharged from a mixed Petrochemical/Fertilizer/Vinyl industrial complex at site B. Water circulates slowly opposite to the industrial city due to the existence of a coral island to the north which exists over water surface during low tide.

As new industries are coming up in both sites, the amount of cooling water is expected to double in the next 5 years.

CORMIX Model was used to estimate the dilution of the thermal discharge. The surface area of the plume is 203,100 m^2 and its maximum radius is approximately 390 m. However, the corresponding surface plume off Site B has an area of 586,000 m^2 and a maximum radius of 435m.

MATERIAL AND METHODS

Water temperature and free residual chlorine were measured during winter 2002 and summer 2003 from radial sectors perpendicular to the coast at 50, 100, 200, 300, 500, 750, 1000 and 1500 m from the outfall (Figure 1). Temperature was measured using a bucket thermometer graduated to $0.1^{\circ}C$, while Cl_2 was measured immediately using a DR 1890 Hach portable spectrophotometer using the DPD method (APHA, 2002).

From the same locations zooplankton samples were collected vertically using 0.5m mouth, 120µm mesh zooplankton net. Samples were identified to the nearest taxon (Rose, 1933; Newell & Newell, 1977; Yamaji, 1986 and Todd *et al*., 1996 for zooplankton and Jones, 1986; Richmond, 1997 and DuPont & AL-Tamima, 2002 for benthic fauna) and counted to represent Org./m^3 for zooplankton and No./m^2 for benthic fauna.

A quadrate of one meter square was used to collect macro-benthic fauna from the same locations. Samples were collected in triplicates and averaged. Samples were sorted, identified and counted. Fauna diversity was calculated using Shannon-Weaver Diversity Index (1963).

RESULTS AND DISCUSSION

Water temperature off the coast of Qatar normally ranges between 14.1 and 36°C (Sheppard et al., 1992) with a January minimum and July maximum. Variations in temperature readings during winter and summer along the sampled transect for sites A and B appeared in Tables 1 and 2. The temperature gradient between inshore and offshore was more pronounced during winter where the seawater temperature was low. The amplitude reached 7.4°C in site A. On the contrary, during summer and due to the increase in ambient sea water temperature, i.e. 35°C, the gradient of cooling water discharge is lower (Figure 2).

The impact of cooling water changes with tidal stages. During neap tide periods, the increase of temperature is more pronounced because water mixing is limited while during spring tides when high water elevation cause dilution and consequently less pronounced increase of temperature. Due to its higher temperature, the cooling water is buoyant. Thus its impact is concentrated in the vicinity of the discharge (see figure 3) favoring some species that are tolerant of elevated temperatures and reducing populations of others which are near their upper temperature tolerance in summer months.

The percent probability of temperature increase exceeding 3°C at the surface is 100% at the discharge point decreasing to 65% at 150m, 15% at 300m and 0% at 450m; while for the bottom it is 68% at the discharge point decreasing to 5% and 0% at 150 and 300m, respectively, at Ras Laffan (Edinger Ass., 2000).

Impact of cooling water on benthic fauna

The water flow in the cooling water discharge plume is likely to change the nature of bottom substratum and thus influence the distribution of fauna off the outfall. During **Summer**, benthic fauna disappeared in the vicinity of the discharge at Site A where temperature reached 38°C (Figure 4). The number of fauna increased gradually during summer from 13 orgs./m^2 at 100m from the discharge point to 385 orgs./m^2 at 1500m (temperature difference 1.9°C). Mollusca (29-34%), Polychaeta (26%) and Nematoda (18-25%) and to less extent Crustacea (14-17%) showed high resistance and withstand temperatures >36.0°C (Figure 4). Meanwhile, Porifera, Cnidaria, Ectoprocta, Echinodermata and Tunicata nearly disappeared to a distance of 200m from cooling water discharge. Between 1000-1500m from discharge, where ambient temperature is approached i.e. 35.4°C, Mollusca (21-33%), Crustacea (21-35%) and Echinodermata (5-19%) dominated the benthic community with a minor appearance of Porifera and Tunicata (Figure 4).

On the other hand, the extent of impact of cooling water was more pronounced on the fauna of Site B during summer where organisms disappeared to a distance of 100m from the outfall (Table 2) at temperature exceeding 39°C and chlorine between 0.18 and 0.20 mg/l. Between 200 and 500 m the density of benthic fauna was poor (6 – 30 orgs./m^2), and dominated by Mollusca (50-60%) (Figure 5) where water temperature approaches 36.0°C and chlorine level is 0.05 mg/l. Crustacea (18-36%), Echinodermata (13-34%), Porifera (6-10%) and tunicates (5-10%) dominated between 750m and 1500m (Figure 5) where temperature fluctuate narrowly between 35 and 35.8°C and chlorine between 0.02 and 0.04 mg/l.

In Winter, benthic fauna appeared along all sampled stations of Site A (Table 1). Mollusca (41-58%) and Polychaeta (12-25%) were the predominant taxa near the outfall extending to 500m distance (Figure 4), where the temperature gradient decline from 27.9 to 24.1°C and the corresponding chlorine from 0.23 to 0.03 mg/l. Crustacea (27-30%) and Echinoderms (6-15%) dominated between 1000-1500 (Figure 4) where the water temperature approached (21.9-20.5°C) and chlorine disappeared from the water column.

Between 500-1000m a clear peak of nematods (40%) existed. Porifera (1-5%) and tunicates (4-8%) disappeared near the outfall and existed between 500-1500m and 750-1000m distance contours, respectively (Figure 4).

At site B, though Mollusca and Polychaeta disappeared from near the outfall to 100m distance during winter (Figure 5), both taxa predominate the survey sector between 200 and 1500m ranging between 33 and 76% (Mollusca) and 12-34% (Polychaeta). Crustacea and Nematoda appeared significantly between 500-750m from the outfall while Porifera (reaching 18%) and tunicates (5-6%) exist offshore (between 1000-1500m).

The density of benthic fauna was clearly lower at Site B compared to Site A (Tables 1 and 2). This decline is mainly related to the history of establishment of the Industrial cities i.e. early 70’s for Site B compared to early 90’s for Site A. The quantity and quality of cooling water reaching site B is larger containing several pollutants like hydrocarbons and ammonia. The exposure of Site B to discharges rather than cooling water from close-by industries, dredging activities on the northern peripheries could be additional factors.

The thermal plume is often considered as having three component effects, namely near-field, mid-field and far-field. In the near-field zone, usually very close to the outfall, mixing is minimal and is generally as a result of shear turbulence at the edge of the discharge plume. In the mid-field, the plume may still be a cohesive, having definable entity though the rate of temperature decay and mixing are rapid. In the far-field temperatures, there are areas of ambient water intermingled with discrete patches of the slightly warmer effluent water. During the present study, the near-and mid-field are within the mixing zone as defined through the EIA studies for both sites while the far-field is considered outside of the mixing zone. This classification leads to the significant variations appearing in the benthic communities.

Aquatic species living in subtropical ecosystem zones are especially sensitive to changes in water temperature and quality, as these biota are living close to their upper thermal limits. This is of particular concern to organisms in the Arabian Gulf as temperature in the Gulf varied widely according to season. Generally, studies of temperature effects on tropical organisms indicate that temperatures around 35°C are critical or lethal. AL-Ansi et al. (2002) through laboratory experiments, observed that fish from the Gulf can't withstand or tolerate the increase of temperature over 35°C for 24 hrs where any increase in water temperature lead to difficulty in breathing, cessation of feeding, uncontrolled swimming and reduction in activity. Hence, species in the Gulf are close to their thermal lethal limits and naturally stressed by their environment prior to any additional anthropogenic impacts. These effects are particularly exacerbated in shallow waters, where temperature changes are most extreme. This is also where the most productive and sensitive marine communities are found.

The non-mobile species such as corals, soft sediments biota are potentially at risk from the thermal discharge, as it is expected that mobile species will move away from areas with elevated temperatures. Benthic ecosystems in the area would appear to have already been affected due to impacts of the existing discharge, although a further increase in discharge volume may extend the impact zone further into the coastal environment.

The cooling water impact not only affects the density and distribution of benthic fauna but also extends to the composition of the different communities. For Site A, **Mollusca** was dominated by *Tellina valtonis, Dosina histrio, Corbula sulculosa, Cardiolucina sernperiana, Pinctada radiata, Luna tayloriana, Sunetta effosa, Arca plicata, Diodora rupplii, Mitrella blanda, Littorina intermedia, Cerithidea cingulata, Rhinoclavis* *kochi, Glycymeris stritularis, Chlamys livida, Acrosterigma lacunose, Ervillia purpurea, Gafrarium divericotum,* and *Pirinelli concia.* **Polychaeta** was dominated by *Perinereis cultrifera , Syllis gracilis, Cirriformia tentaculata, Marphysa macintoshi, Eunice indica, Lysidice collaris, Nereis pelagica, Scoloplos chevalieri, Capitella capitata,* and *Terebella sp.,* while **Crustacea** was dominated mainly by the amphipod *Cymadusa filosa,* and isopod *Gnathia sp.* in addition to *Synalpheus quinquedens, Petrolisths rufescens, Mysid kempi, Xantho hydrophilus, Pilumnopeus longicornis, Cumacea sp. and Etisus sp.* **Echinoderms** *were dominated by Ophiothela danae, Ophiothrix savignyi, Echinodiscus auritus, Holothuria rigida, Logunum reperessum, Clypeaster humilis,* and *Diadema sp.,* while most of the **Porifera** were *Haliclona sp., Cliona vastifera, Dysidea sp., Suberites sp.,* while *Acropora sp., Favites sp., Pacillopora sp.* and *Turbinaria sp.* were the dominant **Cindaria**. *Bugula neritina* and *Membranipora sp.* were the dominant **Ectoprocta**.

For Site B, *Atys cylindrica, Potamides conicus, Turbonilla sp., Mitrella blanda, Pirinelli concia, Cerithium scabridum, Retusa sp.,* and *Epitonium sp.* (Gastropoda) and *Dentalium octangulatum* (Scaphopoda) and *Ervillia purpurea, Cardiolucina sernperiana, Corbula sulculosa, Pillucina angela, Fulvia fragile, Tellina vernalis, Modiolus sirahensis, Circe intermedia, Sunetta effosa, Turitella fultoni, Dosinia contracta, Lucina sp.,* and *Parvicardium sp.* (Bivalvia) were the common **Mollusca**. **Polychaeta** was dominated by *Branchiosyllis spongicola, Syllis gracilis, Scoloplos chevalieri, Nephtys ciliata, Eunice indica, Nereis pelagica, Capitella capitata,* and *Exogone sp.,* while **Crustacea** was only represented by the gammarid, *Ampelisca brevicornis* and *Perioculodes sp.* The **Echinoderm** community was also poor (diversity wise) as represented by *Astropecten indicus* only. Similarly **Nematod** was represented by *Spadella sp.* **Porifera** was more diversified and dominated by *Haliclona sp., Dysidea sp., Xestospongia sp.,* and *Spongia sp.*

According to Sheppard et al. (1992) tropical marine animals are generally unable to withstand a temperature increase of more than 2-3°C. Most sponges, and crustacea are eliminated at temperatures above 37°C. Intertidal species appear to be more tolerant of high temperature than subtidal species

Only few species were common between the two sampled sites. More than 80% of the recorded organisms were previously recorded along the Qatari coast (SARC, 1997; SARC, 1999). However, both surveys covered wider areas and thus recorded more bivalves and gastropods while more polycheata and crustacean were observed in the present study. A comparison with a similar sector sampled north to Doha City (Smaisma Area, Figure 1) apart from any onshore activity showed: (a) higher diversity indices (av. 3.40; range 3.26-3.52), (b) higher density of organisms (average 563 org./m^2; range 481-590 orgs./m^2), (c) regular onshore-offshore benthic fauna distribution (d) predominance of Mollusca, Crustacea and Porifera at ambient sea water temperatures recorded in both seasons and complete absence of chlorine in water (Nour El-Din, unpublished data).

The average species diversity index for Site B (1.2) was significantly lower ($p<0.02$) than the diversity index for Site A (2.08). Diversity of species increases at both sites in the seaward direction indicating a clear impact of cooling water on species diversity near the outfall.

Since all sampled Sites for both sectors are at nearly similar depth range lying on sand bottom and similar salinity range (42-44 psu), any differences seen are likely to be due to discharge from outfall.

The bivalve Molluscs, *Corbula sulculosa,* and *Cardiolucina sernperiana* as well as the Polychaeta *Scoloplos chevalieri* are ubiquitous and worth considering for future contaminants monitoring, especially in the absence of *Pinctada radiata* the most widely used bioindicator along the gulf.

Irrespective of the outfall, the standing stock of the benthic fauna observed in winter season is higher than that of summer (Tables 1 and 2). However, the correlation coefficients between temperature, chlorine and total number of benthic individuals showed a clear negative relationship in both sectors during both seasons. Higher significant relation was observed during winter at both sites (r^2=0.8416, p<0.003 at Site B and r^2=0.7644, p<0.010 for Site A) where the gradient in temperature is more significant than during summer (r^2=0.4633; p<0.18 for Site B and 0.3651; p< 0.27 for Site A). The elevated summer temperature is the factor controlling the distribution of benthic fauna.

Mollusca are the most tolerant species in the study area with gastropods and bivalves present at most of surveyed sites. Bivalves tend to increase over gastropods near the outfalls. Polychaete species were generally present near outfall area, most of which were tubed varieties although their abundance was low. *Nereis pelagica*, *Lumbrineris gracilis* and *Capitella capitata.* are considered from the present study to be the most tolerant species. Sensitive organisms like corals, sponges and some crustacean were absent or reduced from the majority of these sites and appear (corals and sponges) in small colonies or distant from the outfalls.

The temperature of the cooling water discharge plume during summer is normally above the lethal threshold for most species. Mobile species are expected to avoid the hot plume reducing direct mortality. The buoyancy of the plume impacted communities in the immediate vicinity of discharge and is considered minor. Some species are tolerant of elevated temperatures while others show population reduction where species are near their upper temperature tolerance in summer.

Table 1. Temperature (°C), Chlorine (mg/l), Total zooplankton (Orgs./m^3) and Total Benthic Fauna (Orgs./m^2) at different distances from cooling water outfall for Site A during winter 2002 and summer 2003.

Season	**Distance From outfall (m)**	**Intake Temp. (°C)**	**Off outfall Temp.(°C)**	**Off outfall Cl$_2$ (mg/l)**	**Total Zoopl. (Orgs./m^3)**	**Total Benthic Fauna/m^2**
Winter 2002	50	20.6	27.9	0.23	305	20
	100		26.8	0.17	2,086	120
	200		25.2	0.10	2,200	130
	300		25.0	0.07	4,416	160
	500		24.1	0.03	4,070	168
	750		23.0	0.01	6,030	210
	1000		21.9	0.00	8,216	360
	1500		20.5	0.00	7,970	460
Summer 2003	50	35.5	38.0	0.46	ND	ND
	100		37.3	0.30	ND	13
	200		37.0	0.28	ND	22
	300		36.9	0.24	49	36
	500		35.9	0.10	210	186
	750		35.3	0.05	460	145
	1000		35.4	0.01	347	290
	1500		35.4	0.00	580	385

Table 2. Temperature (°C), Chlorine (mg/l), Total zooplankton (Orgs./m^3) and Total Benthic Fauna (Orgs./m^2) at different distances from cooling water outfall for Site B during winter 2002 and summer 2003.

Season	Distance From outfall (m)	Intake Temp. (°C)	Off outfall Temp.(°C)	Off outfall Cl_2 (mg/l)	Total Zoopl. (Orgs./m^3)	Total Benthic Fauna/m^2
Winter 2002	50	21.0	27.5	0.07	179	ND
	100		27.3	0.07	1,060	ND
	200		26.5	0.05	2,250	13
	300		26.4	0.05	2,110	22
	500		24.7	0.02	2,415	48
	750		23.2	0.03	4,180	121
	1000		22.3	0.00	4,640	143
	1500		21.3	0.00	5,010	179
Summer 2003	50	35.5	40.3	0.20	ND	ND
	100		39.3	0.18	ND	ND
	200		38.7	0.06	ND	8
	300		37.8	0.06	ND	6
	500		36.0	0.05	186	30
	750		35.8	0.04	191	86
	1000		35.3	0.03	234	113
	1500		35.0	0.02	281	150

Impact of cooling water on pelagic fauna (zooplankton)

Copepods are the predominant zooplankton group along the coastal waters of Qatar, constituting more than 74% of the total zooplankton population (Nour El-din & El-Khayat, 2001). In the present survey, they constituted between 51 and 72%. Zooplankton disappeared completely from water samples off the outfall points of sites A and B during summer (Figures 6 & 7). The disappearance was more pronounced off Mesaieed outfall (Site B) extending to 300m distance from the outfall (Table 2) where temperatures fluctuated between 40.3°C at 50m and 37.8°C at 300m. Generally, zooplankton density was low during summer rarely exceeding 500 orgs./m^3. This matches the seasonal trend in distribution observed by previous studies (Dorgham & Hussien, 1991; Hussien, 1992; Ghobashy et al., 1994; Nour El-Din & Ghobashy, 1999). Even away from discharge points, temperatures are >35°C which are most probably beyond the threshold of survival of such fragile species especially that warm water is buoyant and spreads on the surface.

The cooling water discharge at both sites clearly impacted the spatial distribution of zooplankton population especially at Site B (Table 2). The number of organisms increased gradually offshore reaching 5,010 orgs./ m^3 at Site B and 7,970 orgs./m^3 at Site A at 1500m distance from discharge. The impact is more pronounced during winter.

The main copepod group appearing close to the outfall was harpacticoides dominated by *Euterpina acutifrons* (>20%). However, Calanoids dominated by *Paracalanus parvus and P. aculeatus* (>12%) and Cyclopoids dominated by *Oithona nana, O. plumifera and O. setigera* were abundant (>15%) away from the outfall. *Acartia clausi*, *Calanopia elliptica*, *Centropages typicus*, *Clausocalanus arcuicornis*, *Paracalanus parvus* , and *Temora longicornis* as well as *Labidocera kroyeri* are the common Calanoidae in the samples showing more than 5% abundance each, while *Oncaea spp*. was the second abundant Cyclopoid in the study area

(<11%). The harpacticoids: *Macrosetella gracilis, Microstella rosea,* and *Clytemenestra scutellata* were less frequent.

Ostracoda and Cladocera appeared in all samples dominated by *Conchoecia abtusata and Cypridina spp.* (Ostracoda) and *Penilia avirostris* and *Evadne spinifera* (Cladocera). Other crustacean groups like cirriped larvae, amphipods, isopods and decapods constituted normally <5% of the community showing no clear distribution trend along the sampled sectors with the exception of the predominance of amphipods and isopods near the outfall. Bivalves and gastropods veligers (Mollusca) contributed between 4-8% of the zooplankton community and existed with high percentages near the outfalls (Figures 6 and 7). However, other zooplankton groups like Coelentrates represented by Medusae dominated by Anthomedusae, Leptomedusae and Trachymedusae and Siphonophores dominated by *Lenzia* appeared only at the 1000m and 1500m distance lines from the outfalls in both sites showing their avoidance of high temperature and chlorine while Annelida (Polychaete larvae) and Chaetognatha represented by *Sagitta elegans, Sagitta maxima* and *Sagitta enflata* contributed also to <5% and appeared close to outfalls during winter. Meanwhile, *Oikopleura parva* and *Salpa fusiformis* dominating Larvacea and Thaliacea, respectively, as well as Echinoderm larvae which existed at offshore sites.

The impact of temperature on the zooplankton standing crop was more pronounced than that of chlorine opposite to the cooling water discharge points for sites A and B (Tables 1 and 2) especially during winter season. High temperature and chlorine not only lowered the density of zooplankton groups but also reduced species diversity near the outfalls where they prevent the survival of certain species. Low diversity indices <0.7 and 0.5 were observed near outfalls compared with >2.1 and 2.8 at the 1500m distance line of Sites A and B, respectively.

The persistent taxa at impacted points (Copepoda, Mollusca, Polychaeta and to a less extent Chaetognatha) suggest their ability to adapt themselves to the prevailing stress. They showed tolerance to chlorine concentration ranging from 0.07 to 0.24 mg/l chlorine and withstands temperatures slightly higher than 36.0°C.

Commons *et al.* (1996) defined two types of exposure of an aquatic species to an effluent plume: (a) Eularian exposure assuming that the organism is fixed in space at a given location and is exposed to the effluent plume as it passes over and (b) Largrangion exposure where the organism travels with the plume and is exposed to a wide range of the effluent. The latter matches with the present case where planktonic species have a limited ability to escape the effluent plume.

Many marine species have 24-98hr LC 50 values for chlorine of less than 1 mg/L (Irving & Solbé, 1980). A review of chlorine toxicity to marine species showed 96 hr LC 50 of 0.09 mg/L for Juvenile plaice and Dover Sole and sublethal effects at even lower concentrations, for example LC 50 of 0.01 mg/L for inhibition of photosynthesis by phytoplankton (Irving & Solbé, 1980). The toxicity of chlorine is conditioned by the level of salinity, temperature and other variables like dissolved oxygen. Early life stages (eggs and larvae) of meroplanktonic zooplankton will be affected as they are more sensitive to chlorine and chlorinated organics than adults and also have little or no ability to avoid the plume.

It is observed from the present study that the cooling water discharge showed more pronounced impact on the pelagic rather than the benthic fauna. This may be due to the flowing nature of the low density warm cooling water plume. The physiological nature of the benthic organisms renders them more resistant to stress (Sheppard *et al.*, 1992) than zooplankton.

In view of the future expansion in natural gas related industries, especially at Site A, located NE of Qatar, and the expected increase in cooling water discharge by 2005, a continuous monitoring program is advisable for following up the degradation in biological habitats around the outfalls and thus several alternative scenarios for outfalls designs and locations should be discussed and considered during Environmental Impact Assessment studies for mega-projects.

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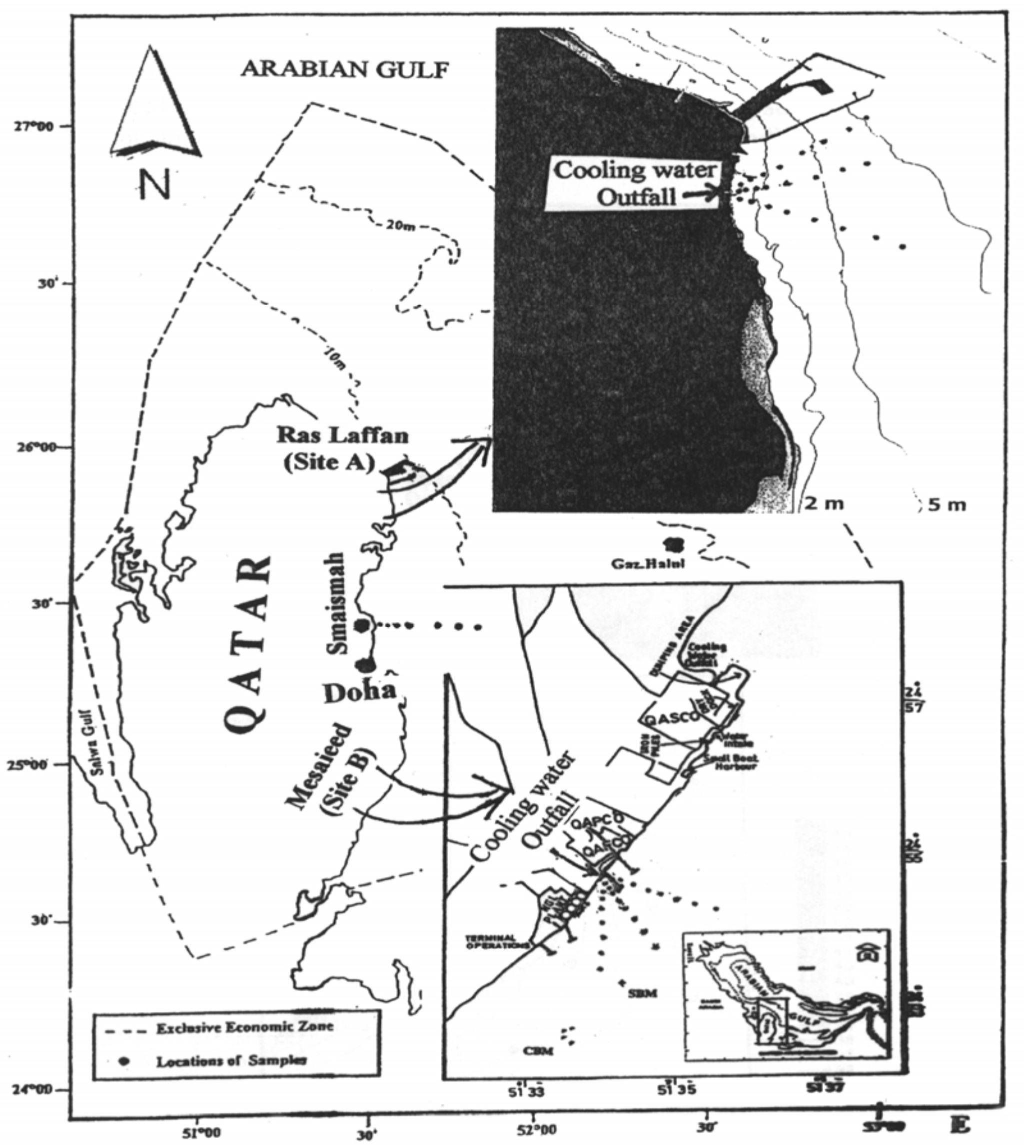

Fig.1 : The coastal water of Qater showing the cooling water outfalls and Sampling sites

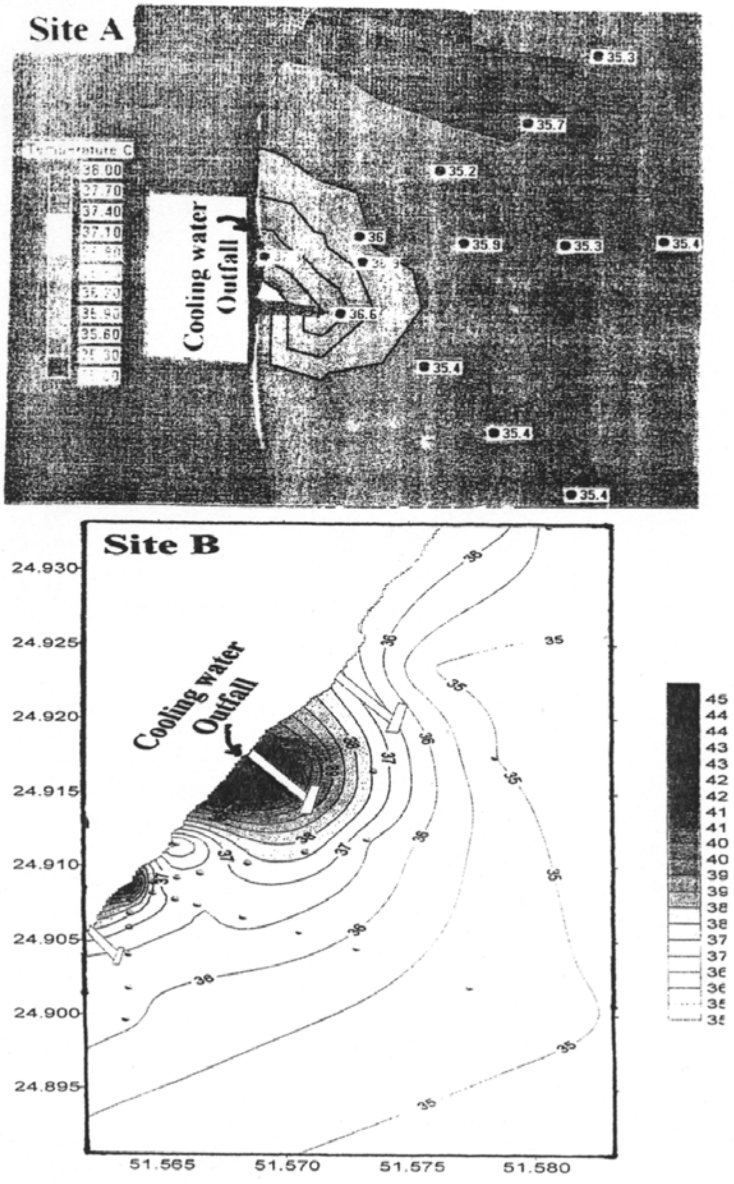

Fig. 2: Temperature variation along the sampled sites during summer season.

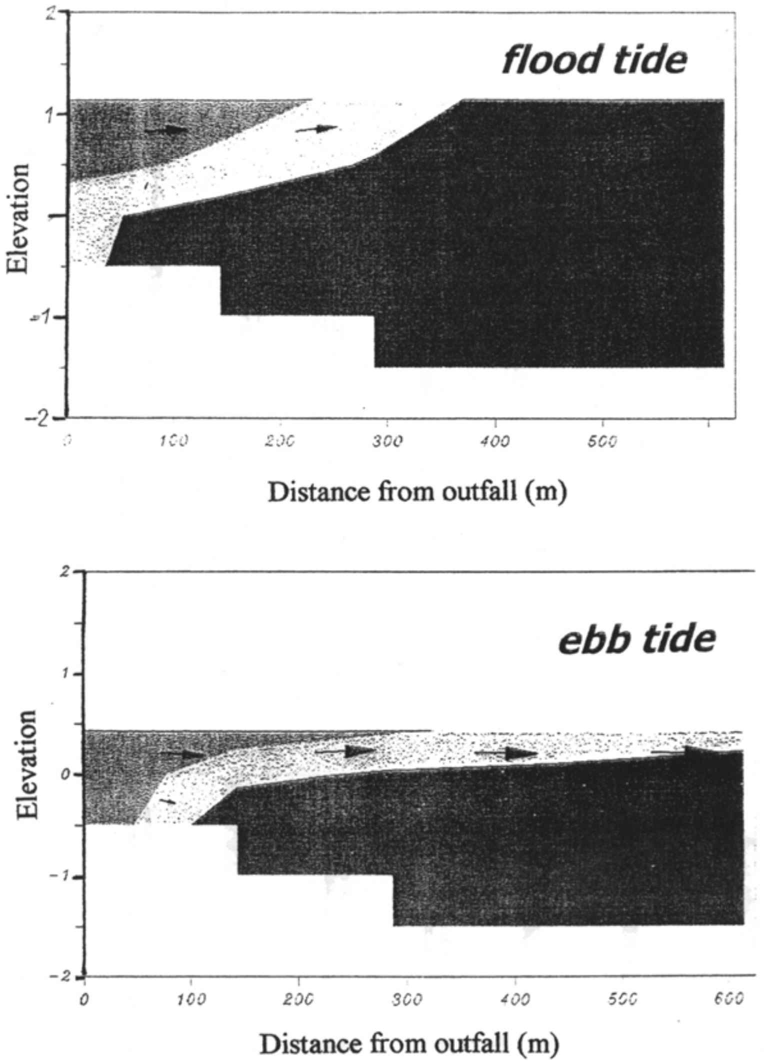

Figure 3. Vertical profiles for water flow from cooling water outfalls during flood and ebb tide.

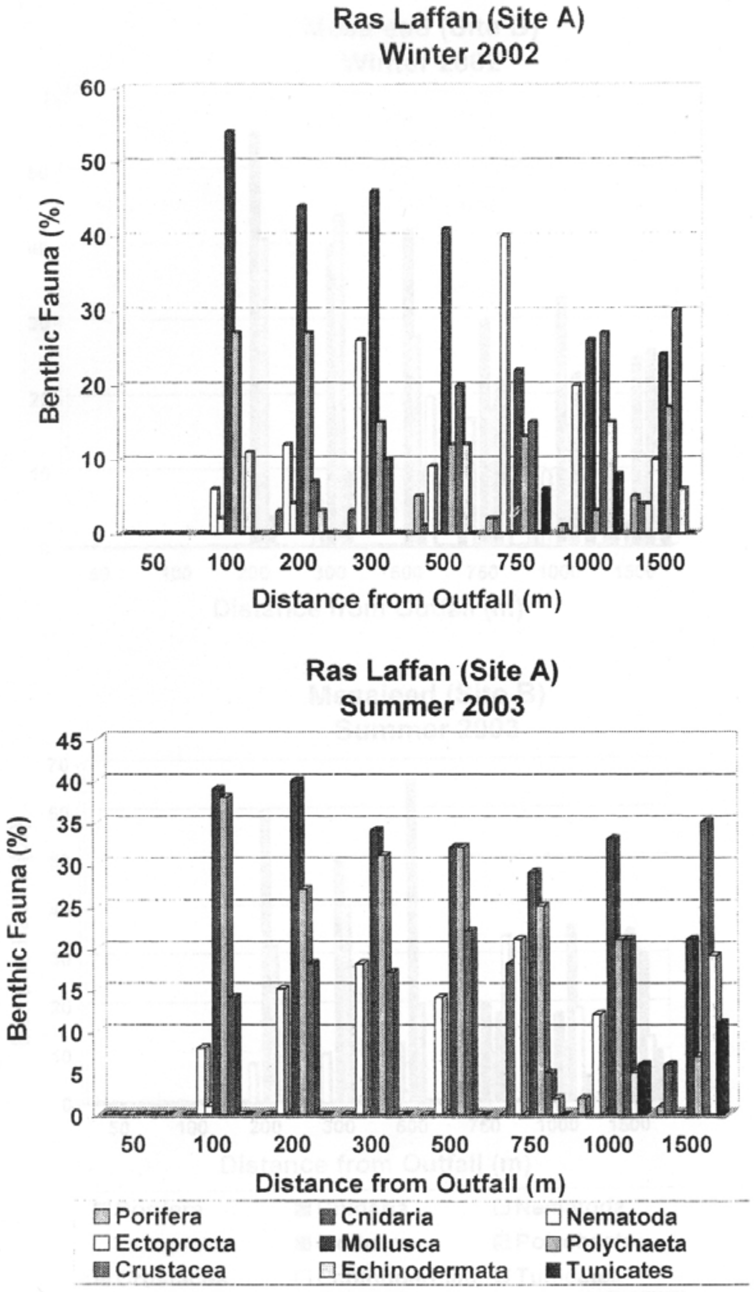

Figure 4. Variations in benthic fauna (%) opposite to the cooling water discharge for Site (A) during winter 2002 and summer 2003.

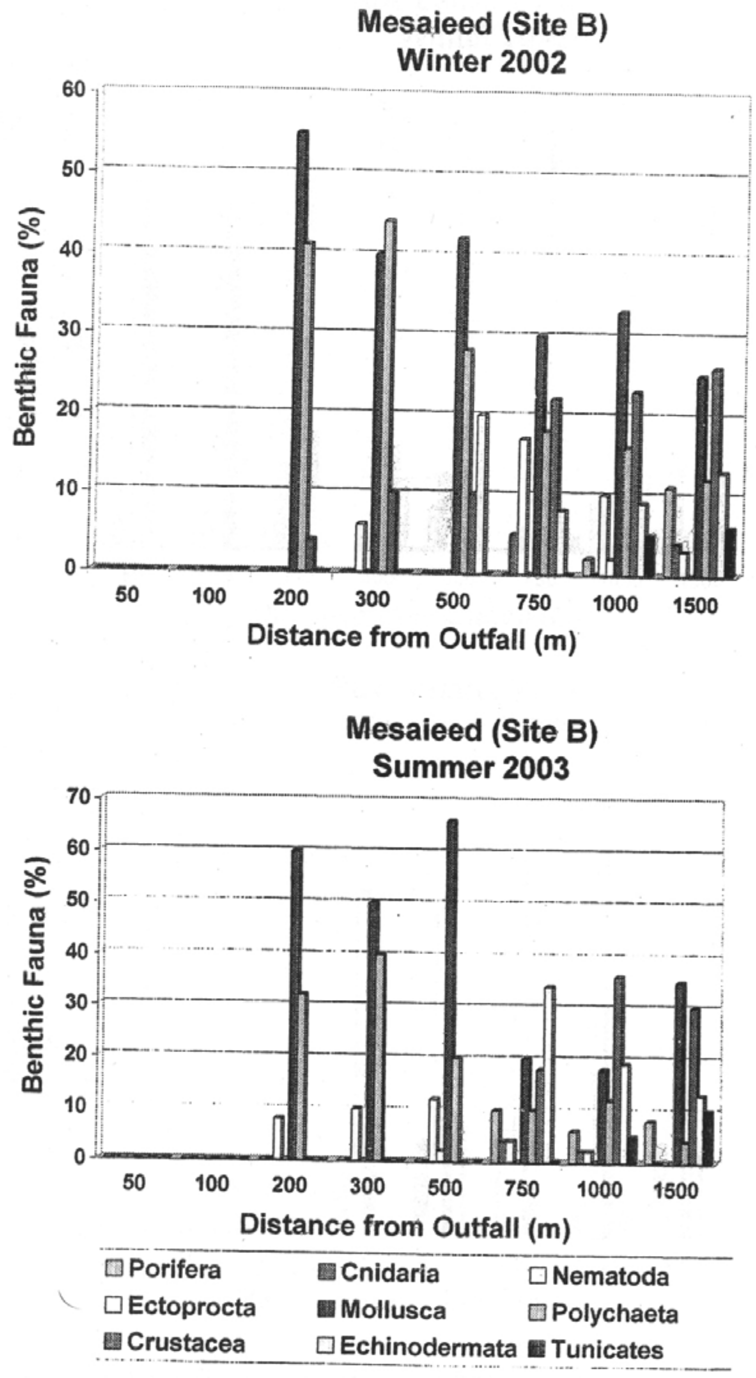

Figure 5. **Variations in benthic fauna (%) opposite to the cooling water discharge for Site (B) during winter 2002 and summer 2003.**

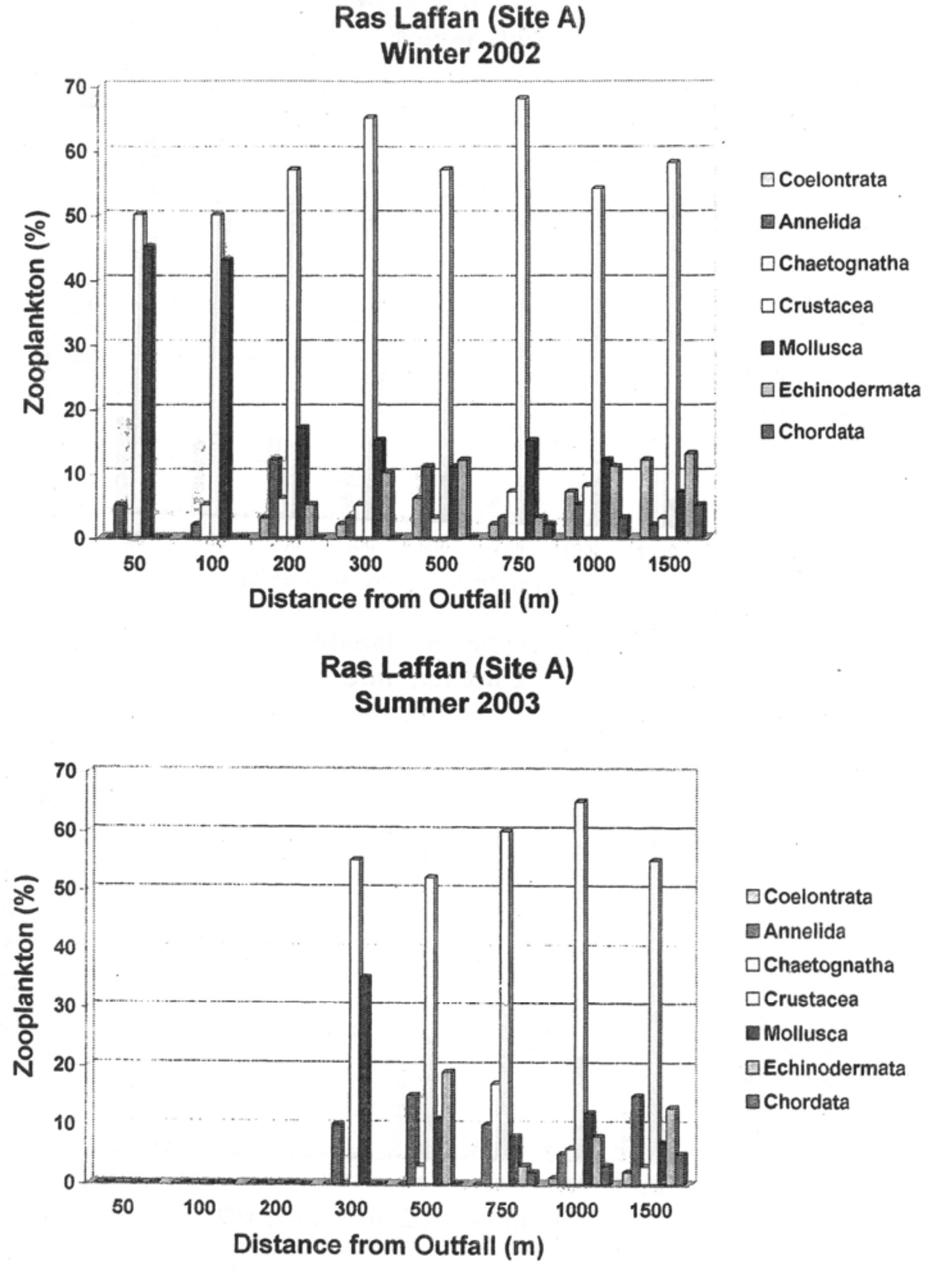

Figure 6. Variations in zooplankton (%) opposite to the cooling water discharge for Site (A) during winter 2002 and summer 2003.

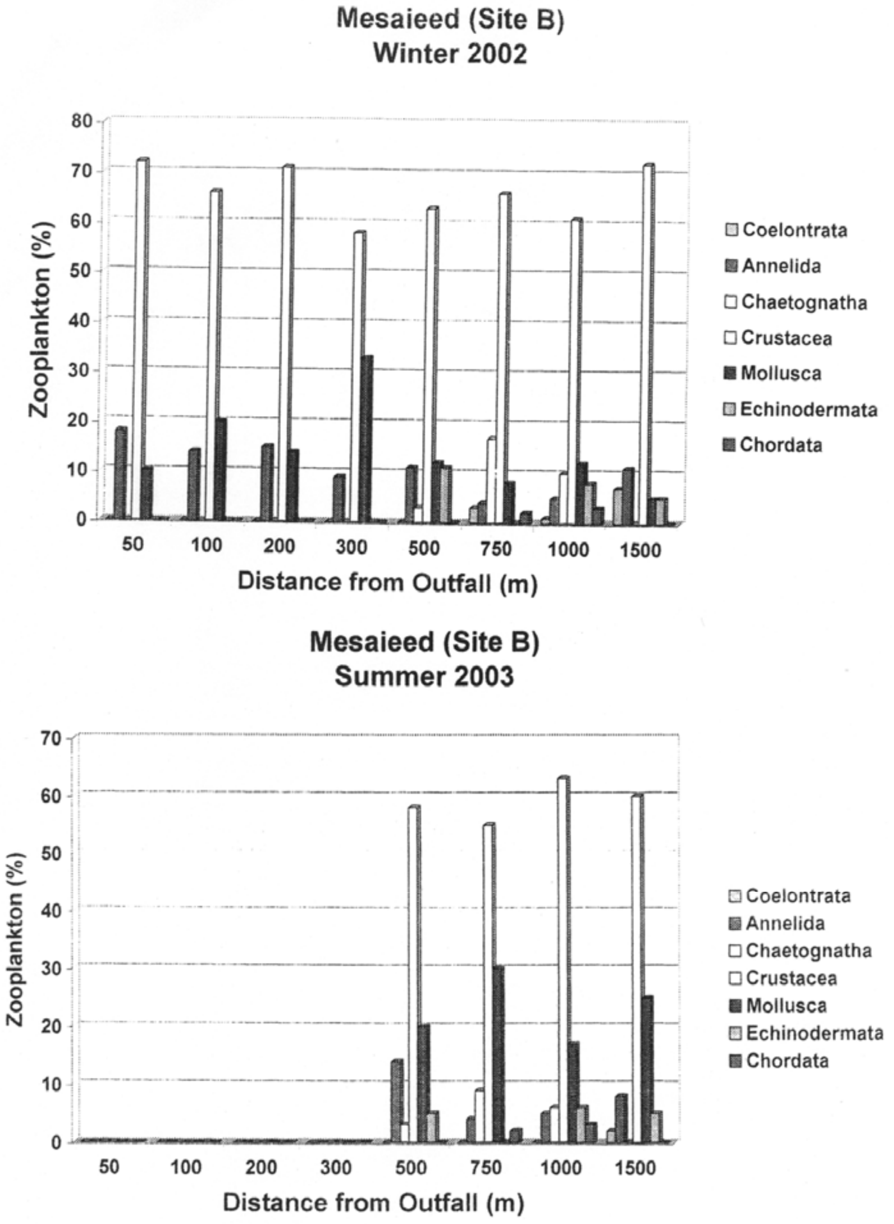

Figure 7. Variations in zooplankton (%) opposite to the cooling water discharge for Site (B) during winter 2002 and summer 2003.