Distribution and abundance of zooplankton in relation to petroleum hydrocarbon content along the coast of Kollam (Quilon), south west coast of India

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Abstract: In the present study, we examine status, impact and trends in prevailing situation of coastal ecosystem of Chavara, Neendakara, Tangasseri and Paravur zones of Kollam coast in terms of zooplankton density and petroleum hydrocarbon content (PHC). Zooplankton samples and water samples were collected during the period May 2003 to June 2004. The numerical count of zooplankton made and PHC content estimated. Paravur offshore recorded the maximum zooplankton count (1390 no./m³) and Tangasseri nearshore the lowest (700.5 no./m³). The petroleum hydrocarbon content was highest at Tangasseri nearshore (21.95 µg/l) and lowest at Paravur offshore (9.40µg/l). We also observe statistically significant negative correlation between zooplankton density and PHC for a few organisms. The overall impact appears minor, yet, coastal ocean monitoring imperative for sustainable development.

Key words: Zooplankton, Kollam coast, Petroleum hydrocarbon content, Marine oil pollution

Introduction

Petroleum hydrocarbon content in aquatic environment can cause deleterious effects on biota, effects which are not visible and may come to light after a long period of time. Holoplankton as well as meroplanktonic organisms are sensitive to exposure to hydrocarbons. (Nair, 2001). Lethal concentrations of oil (96hr LC₅₀) ranges from 0.5 to 10mg/l (NIO, 1995). However, in general the eggs and planktonic larval stages of pelagic as well as benthic organisms are sensitive to low oil concentrations of 10-100µg/l (Nair, 2001). Plankton and especially the neuston living on the top few centimeters of the sea might be supposed to be particularly at risk because it is exposed to the highest concentration of water soluble constituents leaching from floating oil. The sub lethal effects of petroleum encountered in zooplankton vary widely and include alterations in feeding, growth, reproduction, fecundity, reduction in larval life span, reduction in brood size and number of young ones produced, inhibition of molting in larval crustaceans, inhibition of yolk utilization, occurrence of abnormal intermediate larval stages, morphogenic abnormalities and alternations in swimming activity and food perception. (NIO, 1995).

The zooplankton abundance and distribution from eutrophic as well as oligotrophic waters have been reported earlier (Paulinose and Aravindakshan, 1977; Trainter and George, 1972; Haq et al., 1973; Smith, 1982; Wickstead, 1961; Chua and Chong, 1975; Rezai et al., 2000; Rezai et al., 2003; Madhupratap et al., 1977; Madhupratap, 1983; Madhupratap et al., 1983; Madhupratap et al., 1993; Al-yamini et al., 1993; Price et al., 1993; Khalli and El-Rahman, 1997; Goswami 1983). Coastal areas of the Arabian Sea are major areas of upwelling (Currie et al., 1973) and this area sustains the maximum abundance of zooplankton. The abundance of zooplankton in the south west coast of India has been reported earlier (Madhupratap et al., 1992; Asha et al., 2002). That the west coast is more productive and tolerant groups responded differently at different stations to various physico chemical parameters has been observed (Nair et al., 1978).

Neendakara, which is one of the major fishing harbours in Kerala, harbours more than three thousand fishing vessels. Petroleum hydrocarbon content at Neendakara has been reported by many investigators. The boats fitted with outboard engines which are being extensively used for fishing in Neendakara are the sources of high PHC content (Robin et al., 2002). The possibility can not be excluded that the fairly substantial amounts of oil that reach the sea are responsible for the expansion of impoverisher, altered coastal environment and disappearance of sensitive types of organisms (Santher et al., 2000). Unnithan et al. (1981) reported tar like deposits appear to be derived from oil spills and oil tanker washings from fourteen beaches of Kerala.

Zooplankton can accumulate petroleum hydrocarbon and concentrate both aliphatic and aromatic hydrocarbons. Moreover, the metabolites are resistant to depuration. The retention of oil may create long term consequences (Nair, 2001). Due to these facts, the studies on the relation of zooplankton distribution and abundance to petroleum hydrocarbon content along the coast of Kollam assume key importance and significance.

Materials and Methods

Kollam, on the south west coast of India, located between 8º45' and 9º28' N latitude and 76º28' and 77º17' E longitude has a coastline length of 41 km.

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During the study period June 2003 to May 2004 (the study period being divided into three seasons, June to September (monsoon), October to January (post monsoon), February to May (pre monsoon)), marine water sampling was done from a mechanized canoe on a monthly basis during the first week of every month from eight sampling stations of the four sites of the Kollam coast, Chavara nearshore S₁, Chavara offshore S₂, Neendakara nearshore S₃, Neendakara offshore S₄, Tangasseri nearshore S₅, Tangasseri offshore S₆, Paravur nearshore S₇, and Paravur offshore S₈ (Fig. 1).

The atmospheric temperature and relative humidity were noted and given in Table 1. At each station, zooplankton samples were collected by filtering 25 litre two times of surface seawater using plastic container, through plankton nets (mesh size 30 μm and 150 μm) and preserved with 4% neutral formalin solution. The volume of each sample was concentrated to 100 ml and sub samples of 2 ml were transferred into a counting cell and each zooplankton was counted separately using a research binocular microscope under high magnification. The density of zooplankton organisms was calculated as their total number per cubic meter. For the estimation of petroleum hydrocarbon content, seawater samples were collected in wide mouthed 2.5 litre glass bottles and estimations were done by Partition Gravimetric method (APHA, 1998).

Results and Discussion

A total number of 28 zooplanktons were identified along the study area. The distribution of zooplankton of Kollam coast (annual average) is depicted in Table 2. The mean numerical counts of different zooplankton community indicate that a regular trend in the distribution is not discernible. The data revealed that even though the overall zooplankton no/m³ were more at the offshore area, relative abundance was observed at the near shore area for many organisms at varying sites namely cumaceans at Paravur S₁, copepods at Neendakara S₃, Tangasseri S₆ and Paravur S₈, doliolids at Chavara S₁ and Neendakara S₃, decapod larvae at Chavara S₂, fish eggs at Neendakara S₄, fish larvae at Neendakara S₅ foraminiferans at Chavara S₆, gastropod larvae at Tangasseri S₇, isopods at Chavara S₈, and Paravur S₉, lamellibranch larvae at Neendakara S₆ and Tangasseri S₇, lucifers at Chavara S₁ and Neendakara S₃, mysids at Neendakara S₇ and Tangasseri S₈.

Table 1: Atmospheric temperature (°C) and relative humidity (%) along Kollam coast

<table>
<thead>
<tr>
<th>Season</th>
<th>Date of sampling</th>
<th>S₁</th>
<th>S₂</th>
<th>S₃</th>
<th>S₄</th>
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<th>S₆</th>
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<td>88</td>
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<td></td>
<td>03-09-2003</td>
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<tr>
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T = Temperature, H = Relative humidity, S₁ = Chavara nearshore, S₂ = Chavara offshore, S₃ = Neendakara nearshore, S₄ = Neendakara offshore, S₅ = Tangasseri nearshore, S₆ = Tangasseri offshore, S₇ = Paravur nearshore, S₈ = Paravur offshore.
medusae at Tangasseri S₅, nauplii larvae at all the four sites, ostracods at Chavara S₁, Tangasseri S₆ and Paravur S₇, polychaete larvae at Neendakara S₃, and Tangasseri S₅, protozoa larvae at Chavara S₁ and Neendakara S₃, radiolarians at Tangasseri S₅, siphonophores at Paravur S₇, stomatopods at Chavara S₁ and Paravur S₇, tintinnids at all the four sites, veliger larvae at Chavara S₁ and zoa larvae at Neendakara S₃ and Tangasseri S₅.

Copepods emerged as the major group claiming for 41.1% of the total zooplankton population along the entire study area. Even though the south west coast of India is considered to be rich in decapod larvae as reported by Menon and Paulinose (1973), the studies of Mathew et al. (1984) in the region of Alleppey mud bank have shown copepods to be the major group. The dominance of copepods in the south central west coast of India has been reported (Vijayaraghavan et al., 1982). The monthly percentage distribution of a few major zooplanktons namely copepods, amphipods, cladocerans, decapod larvae and nauplii larvae are shown in Figs. 2a to 2h. Copepod was one group which was uniformly distributed throughout the study area. This observation is in agreement with earlier studies (Mathew and Solomon, 1996).

Along the neustonic realm of Kollam coastal waters, the zooplankton community varied from station to station and season to season as observed by prior investigators (Robin et al., 2003). It was noted that protozoa larvae, medusae and isopods did not appear during the monsoon and lamellibranch larvae during the pre monsoon. The post monsoon period showed a similar trend in the appearance of organisms as the monsoon period. Siphonophores were represented more during the pre monsoon. During pre monsoon the dominance of copepods was overshadowed by cladocerans at S₁, S₃, S₄, S₅, S₆ and S₇. The pre monsoonal appearance of cladocerans at Kollam coast has been observed earlier also (Robin et al., 2003). The zooplankton peak was during pre monsoon, which is in conformity with earlier observation (Robin et al., 2003; Mathew and Solomon, 1996).

During the present study wide variations and fluctuations in zooplankton density was noted. At Chavara S₁ and S₂, the overall mean zooplankton density and PHC value during the study period was 767no/m², 875.66 no/m³ and 18.53μg/l, 17.05 μg/l respectively. The value of PHC at S₁ was moderately high during the study period relative to all the four sites. Even though a fish landing centre is absent at Chavara, fishing vessels playing across the waters may be responsible for the petroleum hydrocarbon content. Correlations derived for petroleum hydrocarbon content against zooplankton density showed significant negative correlation for cumaceans (r = −0.582, p < 0.05), lamellibranch larvae (r = −0.747, p < 0.01), nauplii larvae (r = −0.807, p < 0.01), radiolarians (r = −0.904, p < 0.01), tintinnids (r = −0.673, p < 0.05), chaetognaths
Fig. 2a Monthly percentage distribution of a few major zooplankton at Chavara site S₁

Legend of Fig. 2a

Legend of Fig. 2b

Legend of Fig. 2b
Fig. 2c Monthly percentage distribution of a few major zooplankton at Neendakara site S3

Legend of Fig. 2c

- Amphipods
- Cladocerans
- Copepods
- Decapod larvae
- Nauplii larvae

Fig. 2d Monthly percentage distribution of a few major zooplankton at Neendakara site S4

Legend of Fig. 2d

- Amphipods
- Cladocerans
- Copepods
- Decapod larvae
- Nauplii larvae
Fig. 2e Monthly percentage distribution of a few major zooplankton at Tangasseri site S5

Legend of Fig. 2e

- Amphipods
- Cladocerans
- Copepods
- Decapod larvae
- Nauplii larvae

Fig. 2f Monthly percentage distribution of a few major zooplankton at Tangasseri site S6

Legend of Fig. 2f

- Amphipods
- Cladocerans
- Copepods
- Decapod larvae
- Nauplii larvae
Fig. 2g: Monthly percentage distribution of a few major zooplankton at Paravur site S,

Legend of Fig. 2g

<table>
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<td>Cladocerans</td>
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<td>Copepods</td>
</tr>
<tr>
<td>Decapod larvae</td>
</tr>
<tr>
<td>Nauplii larvae</td>
</tr>
</tbody>
</table>

Fig. 2h: Monthly percentage distribution of a few major zooplankton at Paravur site S.

Legend of Fig. 2h

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<td>Cladocerans</td>
</tr>
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<td>Copepods</td>
</tr>
<tr>
<td>Decapod larvae</td>
</tr>
<tr>
<td>Nauplii larvae</td>
</tr>
</tbody>
</table>
Table 3: Correlation coefficient and probability: Zooplankton (no/m³) and petroleum hydrocarbon content (µg/l) along the study area

| Name of organism        | S₁     | S₂     | S₃     | S₄     | S₅     | S₆     | S₇     | S₈     | S₉     | r      | p     | r      | p     | r      | p     | r      | p     |
|-------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|-------|--------|-------|--------|-------|--------|-------|
| Cladocerans             | 0.563  | 0.449  | 0.430  | 0.144  | 0.516  | 0.129  | 0.166  | 0.311  | 0.311  | p<0.05 | -0.078 | 0.125 | ERR    | ERR   | ERR    | ERR   | ERR    | ERR   |
| Decapod larvae          | -0.582 | -0.656 | ERR    | ERR    | ERR    | ERR    | ERR    | ERR    | -0.368 | p<0.05 | -0.443 | -0.415 | ERR    | ERR   | ERR    | ERR   | ERR    | ERR   |
| Foraminifera            | 0.688  | -0.760 | 0.771  | 0.633  | 0.699  | 0.059  | 0.198  | 0.283  | -0.182 | p<0.05 | 0.05   | 0.274  | ERR    | ERR   | ERR    | ERR   | ERR    | ERR   |
| Fish eggs               | 0.166  | 0.447  | 0.332  | 0.151  | 0.448  | 0.300  | 0.325  | 0.166  | -0.185 | p<0.05 | -0.415 | -0.124 | ERR    | ERR   | ERR    | ERR   | ERR    | ERR   |
| Gastropod larvae        | 0.283  | -0.274 | -0.182 | 0.157  | 0.462  | -0.051 | -0.794 | 0.460  | 0.131  | p<0.05 | ERR    | ERR    | ERR    | ERR   | ERR    | ERR   | ERR    | ERR   |
| Isopods                 | -0.747 | -0.348 | -0.803 | -0.668 | -0.824 | -0.254 | -0.230 | -0.747 | 0.124  | 0.05   | -0.124 | -0.272 | -0.018 | -0.18  | ERR    | ERR   | ERR    | ERR   |
| Lamellibranch larvae    | 0.369  | -0.272 | -0.108 | ERR    | ERR    | ERR    | ERR    | -0.215 | 0.079  | 0.05   | -0.156 | -0.534 | -0.420 | -0.635 | 0.033  | 0.111  | 0.05   | 0.038  |
| Medusae                 | 0.260  | 0.163  | -0.110 | 0.598  | 0.082  | 0.359  | 0.478  | 0.657  | 0.526  | p<0.05 | 0.600  | 0.598  | 0.05   | ERR    | ERR    | ERR    | 0.359  | 0.478  |
| Nauplii larvae          | -0.807 | -0.534 | -0.420 | 0.05   | 0.635  | 0.033  | 0.038  | 0.657  | 0.526  | p<0.05 | 0.600  | 0.598  | 0.05   | ERR    | ERR    | ERR    | ERR    | ERR    |
| Ostracods               | -0.064 | 0.416  | 0.615  | 0.021  | 0.05   | 0.04   | 0.05   | 0.215  | 0.079  | 0.05   | 0.312  | 0.296  | 0.05   | 0.152  | 0.05   | 0.343  | 0.05   |
| Polycheate larvae       | 0.735  | 0.284  | 0.474  | 0.206  | 0.264  | 0.330  | 0.313  | 0.904  | -0.246 | 0.05   | -0.538 | -0.092 | -0.800 | -0.175 | 0.422  | 0.05   | 0.235  |
| Radiolarians            | ERR    | ERR    | ERR    | ERR    | ERR    | -0.364 | -0.309 | ERR    | ERR    | ERR    | ERR    | ERR    | 0.05   | 0.05   | 0.05   |
| Siphonophores           | 0.456  | 0.232  | 0.135  | 0.387  | 0.021  | 0.006  | 0.05   | 0.657  | 0.375  | 0.05   | 0.420  | 0.036  | 0.05   | ERR    | ERR    | ERR    |
| Spermatozoids           | -0.673 | -0.323 | -0.368 | -0.212 | 0.578  | 0.123  | 0.210  | 0.149  | 0.05   | 0.05   | 0.05   | 0.146  | ERR    | ERR    | ERR    |
| Veliger larvae          | -0.331 | 0.811  | -0.374 | -0.082 | 0.109  | 0.314  | 0.05   | -0.331 | 0.811  | p<0.05 | 0.05   | 0.140  | ERR    | ERR    |

r = Pearson's coefficient, p = Probability, p < 0.01 Significant at 1% level, p < 0.05 Significant at 5% level, p > 0.05 Not significant, ERR - Absent.
Zooplankton and PHC along Kollam coast.

At Neendakara, the overall mean zooplankton density and PHC value during the study period was 718.91 no./m$^3$, 727.75 no./m$^3$ and 20.96 µg/l, 15.92 µg/l at S$_1$ and S$_2$ respectively. Neendakara, which is the cradle of seafood industry, showed rather high petroleum hydrocarbon content in the coastal waters which is in agreement with the observations of prior investigators (Sarthre et al., 2000 and Robin et al., 2002). At S$_3$, the PHC value was high during the study period, relative to all the four sites. Hectic fishing activities during the season are causative to the high oil content. Except for lamellibranch larvae ($r = -0.803$, $p < 0.01$ at S$_1$ and $r = -0.668$, $p < 0.05$ at S$_3$) and ctenophores ($r = -0.653$, $p < 0.05$) which was negatively correlated with petroleum hydrocarbon content, no other organism showed significant negative correlation at Neendakara.

At Tangasseri, the overall mean zooplankton density and PHC value during the study period was 700.5 no./m$^3$, 741.88 no./m$^3$ and 21.95 µg/l, 14.41 µg/l respectively. At S$_3$, zooplankton density was lowest and PHC value was highest observed during the study period relative to all the four sites. Tangasseri harbours lesser number of fishing vessels than Neendakara. Yet, the higher oil content is due to the lower tidal flushing at the promontory, causing greater deposition of oil at the coastal waters, the oil being trapped at the headland. The correlations at S$_3$ for fish larvae ($r = -0.685$, $p < 0.05$), lamellibranch larvae ($r = -0.824$, $p < 0.01$), lucifers ($r = -0.888$, $p < 0.01$), nauplii ($r = -0.635$, $p < 0.05$), polychaete larvae ($r = -0.640$, $p < 0.05$) and radiolarians ($r = -0.800$, $p < 0.01$) were all significant at Tangasseri.

Paravur S$_3$ and S$_4$ recorded overall mean zooplankton density PHC value of 1351.3 no./m$^3$, 1390 no./m$^3$ and 9.93 µg/l, 9.40 µg/l respectively. At S$_4$, zooplankton density was highest and PHC value lowest during the study period relative to all the four sites. The low oil content in the Paravur coastal waters is attributed to the fact that at this fishing village, country boats are more in vogue than mechanized boats. Amphipod ($r = -0.780$, $p < 0.01$); chaetognaths ($r = -0.720$, $p < 0.01$ at S$_1$ and $r = -0.638$, $p < 0.05$ at S$_3$); gastropod larvae ($r = -0.794$, $p < 0.01$); appendicularian ($r = -0.750$, $p < 0.01$); copepods ($r = -0.605$ $p < 0.05$) and fish larvae ($r = -0.651$, $p < 0.05$) showed significant negative correlation at Paravur.

Imbalance in zooplankton population arises from the fluctuation in the environmental conditions resulting in poor upwelling, rise in sea surface temperature, under water disturbances, altered monsoons and water currents, which are the main natural causes. Pollution, especially due to oil spills is only one of the major man made causes for the imbalance. The abundance of phytoplankton supports notable increase in zooplankton. The coastal belt of the Arabian Sea is enriched with nutrients during the south west monsoon resulting in phytoplankton abundance. High concentration of primary food generally results in the swarming of a few herbivores/omnivores such as copepods and amphipods (Goswami and Shrivastava, 1996).

It is known that the dose and duration of oil exposure will never reach the threshold limit in the open sea. Moreover these organisms can reproduce rapidly and any population reduction can soon be restored (Nair, 2001). In the course of our study, we have observed negative correlation between PHC and zooplankton density only for a few organisms. The overall impact appears minor. The observed decrease in the case of certain groups was only relative, in the sense that a group was considered less abundant because of the very high abundance of certain other group or groups in the same area, which shadowed all others as observed by Mathew and Solomon (1996).

Yet, off the upwelling coast of Kollam the inverse relationship of zooplankton density to petroleum hydrocarbon content observed for a few organisms is a matter of concern as it may in the long run affect the pelagic fishery of the region as a whole. Hence, regional coastal ocean monitoring is imperative for effective environmental management and sustainable development of Kollam coast.

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