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# MARINE POLLUTION AND ZOOPLANKTON : SOME RECENT TRENDS IN MARINE POLLUTION STUDIES

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## ABSTRACT

The importance of marine zooplankton as integral component of marine food webs and the role that these organisms play in marine food production and transfer of pollutants to the higher trophic levels have been well documented. It has recently been realized that pollutants such as hydrocarbons, crude oil, heavy metals, pesticides, heated waste water and a wide range of organic and inorganic substances are harmful to the marine ecosystem. The presence of even very minute quantities of many of these pollutants may become harmful either due to their direct effect on zooplankton or indirectly due to the transfer of the pollutants to other trophic levels through zooplankton. The recent trend in marine pollution studies is therefore to find out the effects of very minute quantities of these pollutants on marine zooplankton and the methods of their accumulation and transfer to the organisms of higher trophic level including man. Bioassay studies to asses the effect of marine pollution have been carried out only with a few zooplankters such as copepods like *Acartia*, *Calanus*, *Eurytemora*, *Temora*, *Oithona*, *Centropages*, *Trigriopus* and *Euchaeta*, mysids like *Mesopodopsis* and *Mysidopsis*, Lucifer shrimp *Lucifer faxoni* and larvae of shrimps, lobsters and crabs in the static or in the continuous flow system. The field studies on live marine zooplankton include controlled ecosystem experiments. A review of laboratory and field studies concerning the effects of pollutants such as hydrocarbons, crude oil, heavy metals, pesticides and heated waste water on the survival, breeding, movement, faecal pellet production, growth and development on marine zooplankton is presented.

# INTRODUCTION

In the sea, the principal relationship between different organisms is connected with nutrition and this has resulted in various food chains and food webs between producers and consumers. According to a recent estimate, the amount of organic carbon fixed annually by the primary producers, the phytoplankton through photosynthesis in the world oceans is $1.9 - 2.3 \times 10^{10}$ tons (Alverson, 1975). In the oceans, the amount of primary consumers, the zooplankton that might be produced from fixed carbon is also enormous. According to alverson (1975) the amount of first stage carnivors may exceed $1.9 - 2.3 \times 10^{9}$ metric tons per year. In the entire Indian Ocean up to latitude 40°S, the total zooplankton biomass production has been found to be about $5.19 \times 10^{8}$ tons per year (Prasad *et al.*,1970). Several thousands of species of marine animals feed on plankton either at some stage in their lifecycle or throughout life. Therefore, the importance of plankton in the transfer of energy to the higher trophic levels through various food chains cannot be underestimated. It is because of this integrated relationship between zooplankton and animals of higher trophic levels, it has now been realised by the scientists all over the world that large amounts of various pollutants in the sea are accumulated and transferred to the animals of different trophic levels including man through zooplankton.

With the advancement of industrial and oil technology , large amount of various pollutants such as hydrocarbons, crude oil, heavy metals, pesticides, heated waste water and a wide range of organic and inorganic substances will be constantly released in the sea. Since long it was believed that many of these pollutants are harmful to marine animals only if released in large quantities into the sea. But recent studies have shown that even with the release of very small quantities, there are possibilities of long-term build up of persistant compounds and uptake of these compounds by phytoplankton and zooplankton, thus providing an entry into the marine food chains. Moreover, the pollutants as little as a few parts per million or even less have been found to be either lethal or sub-lethal to the millions of marine zooplankton. The sub-lethal concentrations interfere with various metabolic activities such as respiration, feeding, reproduction and growth.

Unfortunately, the investigations on the effects of various pollutants have so far been carried out only on the adult fish and other large animals. The determination of the fate of a potentially hazardous substance introduced in the environment is a precursor of any meaningful attempt to establish effective standard for regulatory purposes (Cairns, 1980). We should therefore consider the pathways of these pollutants and damage to millions of more delicate larvae, juveniles and other planktonic organisms. Damage to these organisms may neither show up immediately nor manifest at the place of discharge. If a pollutant is primarily connected with bottom sediments, the toxic tests should involve benthic organisms. On the other hand, the toxicity tests for a pollutant associated with water column should involve planktonic organisms, But the tests for most of the pollutants are performed on various fishes, crabs and other large animals because of their easy availability and laboratory maintenance. Some of these animals on which tests are carried out may not occur any time in the environment polluted with the same substance. Thus, the organisms likely to be exposed to a pollutant are often not those for which toxicity-tests information is available.

The purpose of this paper is to discuss (1) the recent estimates of pollution of various seas (2) the effects of the pollutants like hydrocarbons, crude oil, heavy metals, pesticides and heated waste water on marine zooplankton and (3) some of the recent bioassay stuides with zooplankton.

## CRUDE OIL AND HYDROCARBONS

High levels of crude oil or total hydrocarbons have been indentified at the areas of offshore drilling activities or along the tanker routes (Table 1). It is believed that very large amounts

TABLE 1. LEVELS OF HYDROCARBONS IN DIFFERENT SEAS

| Type of hydrocarbon | Locality | Concentration | Reference |
|---|---|---|---|
| Petroleum hydrocarbons | Arabian Sea<br>Bay of Bengal | 0-1000 µg/1 | Qasim and Sen Gupta, 1980. |
| Crude Oil | Adriatic Sea | 1.40-10.98 mg/1 | Corner, 1978. |
| Total Hydrocarbons | North Sea | 17-625 µ g/1 | Offenheiner et al,1977. |
| Total Hydrocarbons | Sargasso Sea | 239-559 µg/1 | Wade and Quirn, 1975 |

of oils are lost due to spills, fires and sinking of ships. The petroleum hydrocarbons also enter the sea from coastal refineries and along with the industrial waste, municipal waste and river runoff. The sea around India is also polluted mainly due to transport of oil from Gulf countries across the Arabian sea and Bay of Bengal. It has been observed that petroleum hydrocarbons in the surface waters range from 0 - 1000 g/1 (Qasim and Sengupta, 1980). However, the values of dissolved petroleum hydrocarbons have been found to vary considerably in the Arabian sea and the bay of Bengal.

*Heavy metals :* Metals occur in seawater either in solution or in particulate form. According to Stumn and Brauner (1975), the particulate form results from (1) precipitation of some insoluble compound of the element such as chromium hydroxide or lead carbonate and (2) adsorption of any metal ions on to some other particulate material such as clay minerals and organic détritus in seawater. All the heavy metals are relatively poisonous to the microscopic as well as macroscopic animals. However, mercury is considered as the most poisonous material. Data on the mercury concentration on the surface waters in different oceans has been presented in Table 2. The highest level of heavy metals such as copper, zinc, cobalt and nickel in dissolved state, on the surface and in deeper waters of the Arabian Sea measured in µg/1 has been found to be Cu, 19.9 and 15.7; Zn, 42.4 and 11.2; Co,5 and 2; and Ni, 16.3 and 5.6. In the Bay of Bengal, the highest level of these metals on the surface and deeper waters measured in µg/1 are Cu, 6.8 and 9.5; Zn, 15.3 and 20; Co, 0 and 7.9; and Ni, 12.2 and 11.2 (Qasim and Sengupta, 1980).

TABLE 2 : LEVELS OF MERCURY IN DIFFERENT SEAS

| Locality | Concentration (in dissolved form) | Reference |
|---|---|---|
| Indian Ocean | 0.5 - 127 ng/1 | Chester et al. 1973. |
| Bay of Bengal | 13 - 187 ng/1 | Singbal et al. 1978. |
| Atlantic Ocean | 0.5 - 22 ng/1 | Chester et al. 1973. |
| Pacific Ocean | 12 - 15 ng/1 | Gardner and Riley, 1975. |

*Other pollutants* :Several industrial and agricultural pollutants are discharged in large amount into the oceans annually. It has been estimated that airborne lead, polychlorinated biphenols (PCBs) and various pesticides are discharged in thousands of metric tons annually.

Thermal pollution mostly occurs due to discharge of warm cooling waters from electrical and nuclear power plants. It is known that even in the most efficient nuclear power plants only about 40% of the heat produced by the reactor is actually used for generating current. The remaining heat mostly ends up in the cooling water which is discharged into the coastal waters, estuaries and other water bodies. The temperature in the vicinity of the power plant may rise to even 14°C or more. It is expected that increasing urbanization and more extensive settlement near the coastal regions will increase the problem of thermal pollution to a greater extent.

## EFFECTS OF POLLUTANTS ON MARINE ZOOPLANKTON AND RECENT BIOASSAY STUDIES

The pollutants enter into the body of the zooplankton and accumulate, mainly in three ways: (1) from phytoplankton diets, (2) from assimilation of particulate diets and (3) by direct uptake from solution in seawater. A number of long-chain hydrocarbons ($C_{22}$ - $C_{33}$) have been detected in various organs of different zooplankters. These hydrocarbons are exogenous in origin and are found in crude oils. Corner (1978) has reported the presence of carsinogen benzo (a) pyrene (BP) in large amounts upto 400 ug/kg dry weight in mixed plankton from areas prone to pollution. Levels of various hydrocarbons in mixed plankton and in copepods and arrow worms are given in Table 3.

TABLE 3 : LEVELS OF HYDROCARBONS IN MARINE ZOOPLANKTON

| Species | Hydrocarbon levels | Reference |
|---|---|---|
| Mixed plankton | Benzo (a) pyrene (BP)<br>Upto 400µg/Kg dry weight | Corner, 1978. |
| Mixed plankton | Hydrocarbon<br>19.5µg -85.3µg/g | Fondekar, et al, 1980. |
| Calanus finmarchicus<br>(Copepod) | Pristane<br>0.46 - 0.68% dry weight | Corner, 1978. |
| Sagitta elegans<br>(Arrow worm) | Pristane<br>0.02% dry weight | Corner, 1978. |

Field observations in areas prone to pollution have shown that the levels of mercury, cadmium, nickel and lead are quite high in zooplankton. The mercury level as high as 5.3 ppm, in zooplankton has been observed in the New York Bight (Davies, 1978). Zooplankton of Sorfjord, Norway have been found to contain mercury upto 25 ppm dry weight (Skei *et al*, 1976). It is interesting to note that the mercury level in zooplankton collected off Minimata, Japan was found to be in the range of 0.14 - 2.6 ppm (Hirota *et al*, 1974).

The maximum concentration of heavy metals measured in ppm dry weight in zooplankton occuring in the Arabian sea and the Bay of Bengal has been reported to be Cu, 232 and 228; Zn, 22494 and 1701; Co, 783 and 32; and Ni, 17 81, respectively (Kureishy and George, 1977; George and Kureishy, 1979). These studies therefore indicate that the average concentration of heavy metals in marine zooplankton is higher in the Arabian sea than in the Bay of Bengal. According to Qasim and Sengupta (1980), the higher values in the Arabian sea are probably due to a greater availability of metals in diluted form.

It is therefore very clear that various zooplankters can accumulate different pollutants from the sea in various ways, even if the pollutants occur in small quantities in the environment. A recent trend in marine pollution studies is therefore to find out the effects of these pollutants on zooplankton and the methods of their transfer to the marine animals of higher trophic levels. this information can be obtained either by field studies or laboratory experiments.

Studies with live marine zooplankton with reference to pollution are still sparse. So far, only a few nearshore and estuarine copepods such as *Acartia*, *Centropages*, *Temora*, *Eurytemora*, *Euchaeta*, *Eucalanus*, *Pseudiaptomus*, *Paracalanus*, *Oithona* and *Tigriopus* have been used to study the effects of different pollutants (Bhattacharya and Kewalramani, 1973, 1976; Bhattacharya, 1981, 1984; Kontogiannis and Barmet, 1973; D'Aostine and Finney, 1974; Spooner and Corkett, 1974; Barmet and Kontogiannis, 1975; Berdugo *et al*, 1977; Ott *et al*, 1978; and Corner, 1980). The mysid shrimp. *Mesopodopsis orientalis* in India and *Mysidopsis bahia* and *M. bigelowi* in USA have been used for pollution studies (Bhattacharya and Kewalramani, 1973; Bhattacharya, 1982; Nimmo *et al*, 1977, 1978, 1981; Nimmo and Hamekar, 1982; Gentile *et al*, 1982). The bilogical effects of fuel oil on *Lucifer* have been observed by Lee *et al*, (1978).

The effects of various pollutants on zooplankton have been studied either in the laboratory or in the field. In the laboratory, the experiments have been carried out either in a static or a continuous flow system. The procedures have also been designed for short term bioassay study or for the entire life cycle toxicity test. Another recent concept is to carry out controlled ecosystem experiments. In such experiments, the enclosures containing whole ecosystem set-up in inshore areas are subjected to natural light and temperature. In some of these enclosures, known concentrations of pollutants such as crude oil, heavy metals etc. are added while others serve as control.

It is important to consider the effects of hydrocarbons on phytoplankton, zooplankton and the entire food chain. So far, only a few studies have been made on zooplankton. Crude oil of different concentrations has been found to be lethal to many zooplankters such as copepods like *Acartia*, *Centropages* and their larvae. The effects also vary according to the type of crude oil. It has been observed that 0.1 $ml^{-1}$ of certain crude oil killed the copepods like *Acartia*.and *Oithona* within 24 hours (Corner, 1978). The effects of various hydrocarbons and crude oils on mixed zooplankton, copepods, and the eggs and larvae of certain crabs, lobsters and fishes have been given in Table 4. The results indicate that these hydrocarbons and crude oil are not only letal but when present in low concentration they interfere with feeding rates, respiration, power of locomotion and development.

Experiments with *Mesopodopsis orientalis* have shown that crude oil as low as 0.003 $ml^{-1}$ concentration is highly toxic to the animals, killing all the animals within 24 hours (Bhattacharya, 1986). In experiments with the hydrocarbons, a concentration of 0.062 $ml^{-1}$ of toluene and benzene were found lethal to the adults as well as juveniles (Bhattacharya, 1986). Anderson *et al*.(1974) studied the toxic effects of crude and refined oil on estuarine zooplankton (Table 5). Lee *et al*.(1978) observed that in case of *Lucifer faxoni*, the critical level of toxicity of freshly prepared WSF of No.2 fuel oil was 0.2 ppm so far as survival and feeding is concerned. Lee and Nicol (1977) also observed that the coastal zooplankton are more resistant to the WSF No.2 fuel oil than the oceanic zooplankton.

All heavy metals are relatively poisonous to various zooplankton and they affect the life of these animals in different ways (Table 6). The heavy metals such as mercury, cadmium, nickel, zinc and lead have been found to be lethal to different zooplankton at a very low concentration (Gentile *et al*;1982;Nimmo

TABLE 4 : EFFECTS OF HYDROCARBONS AND CRUDE OIL ON MARINE ZOOPLANKTON

| Pollutant | Concentration of pollutant | Zooplankton | Effect | Reference |
|---|---|---|---|---|
| Naphthalene | 1.04 mg/1 | Eurytemora affinis (copepod) | Feeding completely inhibited in 24 hr. | Berdugo et al, 1977. |
| 2,3,5-Trimethyl naphthalene | 0.316 mg/1 | Eurytemors affinis | 24hr LC 50 | Ott et al, 1978. |
| Naphthalene | 0.008-0.012 mg/1 | Larvae of Cancer magister (crab) | 100% mortality in 24-36 hr. | Sanborn and Mali 1977. |
| South Louisiana Crude oil | lmg/1 | Larvae of Homarus americanus (Lobster) | High mortality, less feeding activity | Porns, 1977. |
| Venezuela crude oil | 0.86mg/1 | First stage larvae of Homarus americanus | 96 hr LC 50 | Wells and Sprague 1976. |
| Louisiana Crude | 220 mg/1 | Larvae of Cancer productus (Crab) | 96 hr LC 50 | Porns, 1977. |
| Kuwait crude | 250 mg/1 | Larvae of Cancer productus. | 96 hr LC 50 | Vaghan, 1973. |
| Venezuela crude | 100 mg/1 | Eggs and larvae of Clupea harangus membras (Fish). | Halformed larvae | Linden, 1976. |
| WSF No.2 Fuel Oil | All except 50% oil stock | Mixed coastal zooplankton | 50% mortality in 24 hr. | Lee and Nicol, 1977. |
| WSF No.2 Fuel oil | 20% | Mixed oceanic zooplankton | 50% mortality in 22.5 hr. | Lee and Nicol, 1977. |

TABLE 5 : EFFECTS OF HYDROCARBONS AND CRUDE OIL ON THE MYSID SHRIMP

| Pollutant | Concentration of pollutant | Species of mysid shrimp | Effect | References |
|---|---|---|---|---|
| Benzene | 0.062 ml/1 | Mesopodopsis orientalis | 24 hr LC 50 | Bhattacharya, 1986. |
| Toluene | 0.062 ml/1 | Mesopodopsis orientalis | 24 hr LC 50 | Bhattacharya, 1986. |
| Bombay High Crude | 0.003 ml/1 | Mesopodopsis orientalis | 24 hr LC 50 | Bhattacharya, 1986. |
| No.2 Fuel oil WSF | 0.9 ppm | Mysidopsis almyra | 50% mortality in 48 hrs. | Anderson et al,1974. |
| Banker C Residual WSF | 0.9 ppm | Mysidopsis almyra | 50% mortality in | Anderson et al,1974. |

TABLE 6 : EFFECTS OF HEAVY METALS ON THE MYSID SHRIMP

| Pollutant | Concentration of pollutant | Temperature and salinity | Zooplankton | Effect | Reference |
|---|---|---|---|---|---|
| Cadmium | 100 µg/1 | 21°C, 30% | Mysidopsis bigelowi | 96 hr LC 50 | Gentile et al, 1982. |
| Cadmium | 110 µg/1 | 21°C, 30% | Mysidopsis bahia | 96 hr LC 50 | Gentile et al, 1982. |
| Cadmium | 15.5 µg/1 | 25-28°C<br>10-17% | Mysidopsis bahia | 96 hr LC 50 | Nimmo et al, 1987, 78. |
| Cadmium | 10 µg/1 | 21°C, 30% | Mysidopsis begelowi and M. bahia | No development of brood pouch | Gentile et al, 1982. |
| Mercury | 3.5 µg/1 | 20°C, 30% | Mysidopsis bahia | 96 hr LC 50 | Gentile et al, 1982. |
| Mercury | 1.65 µg/1 | 20°C, 30% | Mysidopsis bahia | Delay in sexual maturity decrease in production of juveniles | Gentile et al, 1982. |
| Nickel | 508 µg/1 | 20°C, 30% | Mysidopsis bahia | 96 hr LC 50 | Gentile et al, 1980. |
| Nickel | 1.41 µg/1 | 20°C, 30% | Mysidopsis bahia | Delay in sexual maturity Decrease in production of juveniles | Gentile et al, 1982. |
| Zinc | 498 µg/1 | 20°C, 30% | Mysidopsis bahia | 96 hr LC 50 | Gentile et al, 1982. |
| Lead | 2960 µg/1 | 20°C, 30% | Mysidopsis bahia | 96 hr LC 50 | Gentile et al, 1982. |

*et al*; 1977, 1978). The heavy metals also reduce respiration, feeding, growth, development, sexual maturity and may also be responsible for morphological aberrations (Gentile *et al*; 1982). Reeve *et al*, (1977) have observed that mercury is more toxic than copper in certain zooplankton. The egg production in copepods is reduced and may be practically stopped in high concentration of copper and mercury. In a copepod, *Acartia tonsa* the egg production was completely stopped at 50 µg/1 concentration of copper (Reeve *et al*; 1976).

According to Reeve *et al*.(1976) the rate of feeding can easily be determined by observing faecal pellet production rate if the zooplankton are provided with standerdised food supply. They observe that there was areduction of about 40% in the rate of faecal pellet production by the copepod *Calanus plumphchrus* when exposed to 5 µg/1 of copper for 14 days. However, the same reduction in faecal pellet production was obtained only in four days in another copepod, *Metridia pacifica*.

Zooplankton of coastal waters and estuaries are subject to severe stresses such as pesticidal and biocidal stresses due to the increased demand for pesticides and coastal power plants. However, only a few studies have been carried out on the toxic effects of these pollutants on marine zooplankton. Many important pesticides such as dimlin (benzoylphenyl urea), phorate (organophosphate) and methyl parathion (organophosphate) have been found to cause death of the mysid shrimp *Mysidopsis bahia* within 96 hours at a concentration of 1.97 µ g/1 and 0.77 ug/1, respectively (Nimmo *et al*; 1981). A concentration of 0.39 µg -1 of kepone (chlorinated hydrocarbon) was found to be responsible for the drastic reduction in the production of young ones in *M. bahia* (Nimmo and Hamekar, 1982). Effects of some important pesticides of marine and estuarine zooplankton are given in Table 7.

The concentration of chlorine in discharged cooling waters usually ranges between 0.05-1.00 mg/1 total residual chlorine (Beauchamp, 1969; Brungs, 1977. It has been demonstrated by Roberts *et al*; (1975), Capuzzo *et al*.(1976) and Capuzzo (1979) that concentrations of chlorine in this range are toxic to several species of marine zooplankton.

A slight rise in the temperature due to heated waste water in coastal waters and estuaries may affect the zooplankton in different ways and may even kill them particularly in tropical waters since these animals live very near their upper temperature tolerance limits. It is been observed by Bhattacharya (1972) that the lethal temperature (24 hr $LC_{50}$) of various zooplankton

TABLE 7 : EFFECTS OF PESTICIDES ON MARINE ZOOPLANKTON

| Pollutant | Concentration of pollutant | Zooplankton | Effect | Reference |
|---|---|---|---|---|
| Dimilin (Diflubenzuron) -Benzoylphenyl urea | 2.06 g/1 | Mysidopsis bahia (Mysid shrimp -Juvenile | 96 hr LC 50 | Nimmo et al, 1980. |
| Methyl Parathion -Organophosphate | 0.77 g/1 | Mysidopsis bahia - Juvenile | 96 hr LC 50 | Nimmo and Hamakar, 1982. |
| Phorate (Thimat) -Organophosphate | 0.33 g/1 | Mysidopsis bahia - Juvenile | 96 hr LC 50 | Nimmo and Hamakar, 1982. |
| Kepone - Chlorinated hydrocarbon | 0.072 g/1 | Mysidopsis bahia - Female | 6% less growth | Nimmo and Hamakar, 1982. |
| Kepone - Chlorinated hydrocarbon | 0.39 g/1 | Mysidopsis bahia - Female | About 50% less production of young | Nimmo and Hamakar, 1982. |
| Endrin - Chlorinated hydrocarbon | 1.2 g/1 | Larvae of Palaemonetes pugio (Grass shrimp) | 96 hr LC 50 | Tyler-Shreedar, 1979. |

TABLE 8: UPPER LETHAL TEMPERATURE OF VARIOUS ZOOPLANKTON OF BOMBAY COASTAL WATERS AT 35% SALINITY

| Name of zooplankton | Lethal Temperature |
|---|---|
| HYDROMEDUSAE | |
| Liriope tetraphylla | 34°C |
| Podocoryne ocellata | 34°C |
| CTENOPHORES | |
| Pleurobrachia globosa | 34°C |
| Beroe cucumis | 34°C |
| COPEPODS | |
| Euchaeta wolfendini | 34°C |
| Eucalanus subcrassus | 33°C |
| Acartia spinicauda | 35°C |
| Pseudodiaptomus ardjuna | 35°C |
| Tortanus barbatus | 34°C |
| MYSID | |
| Mesopodopsis orientalis | 33°C |
| DECAPODS | |
| Lucifer faxoni | 33°C |
| Acetes indicus | 35°C |
| Penaeus indicus (post-larvae) | 36°C |

of Bombay coastal waters lies between 33° and 36°C(Table 8). It is interesting to note that the temperature of Bombay coastal waters usually varies between 22° and 32°C. It is also known that increasing water temperature affects respiration, heart beat, reproduction, development and various other physiological processes of marine zooplankton.

## DISCUSSION

In the early years of planktology, the limited knowledge on the subject allowed only quantitative and qualitative studies on these organisms. As planktology evolved, man's interest in marine zooplankton increased manifold. The importance of marine zooplankton as integral component of marine food webs and its close relation to fishery production was gradually revealed (Russel *et al*; 1971). It was also realised that because of the maximum production of plankton, the coastal areas are the main source of marine food production. According to Ryther (1969), the open sea is a biological desert, which produces a negligible fraction of the fish catch and has little future potential The coastal water produced almost the entire shell fish crop and nearly half the total fish crop. However, with the advancement of industrial and oil technology, large amount of various pollutants are constantly released into the coastal waters and estuaries with little regard for the marine environment. According to Blumer (1972), "Oil pollution is only one of many unrelated causes which contribute to the deterioration of the environment."

The seas have become a dumping ground for waste products considering that the nature can absorb any amount of pollutant. But this has been proved to be not true. The fact is "that nature has a tremendous capacity to recover from the abuses of pollution, so long as the rate of addition does not exceed the rate of recovery of the environment. When this limit is exceeded, however, the deterioration of the environment is rapid and sometimes irreversible" (see Blumer, 1972).

To understand the long and short term effects of various pollutants on the marine ecosystem, much more investigations are needed concerning marine zooplankton. It is necessary to analyse various toxic substances and find out their effects on both phytoplankton and zooplankton in order to asses the extent to which the primary and secondary production in the sea will be affected. It is also essential to find out the concentration of these compounds at various trophic levels including fish and the pathways of the toxic compounds.

The levels of various pollutants in different areas of the oceans prone to pollution are quite alarming. According to Corner (1978), the amounts of crude oil found in the Adriatic sea (1.40-10.98 mg/1) would affect species of zooplankton including the larval stages of certain fish and that the maximal levels of total hydrocarbons reported from the North sea (625 $\mu g^{-1}$), the Sargasso sea (559 µg/1) and Goteberg Harbour (710 µ g/1) are sufficiently high to affect the zooplankton like clam larvae and adult copepods. On the basis of these observations it is very clear that the sea around us is also polluted and the zooplankton can be equally affected.

It is very difficult to forecast how much and to what extent the ocean life will be affected due to more inputs of various pollutants into the oceans. It is therefore necessary to encourage bioassay studies using live marine zooplankton, if the effects of various pollutants on marine ecosystem is to be properly understood and before our marine ecosystem is damaged to a point of no return. For the bioassy studies, the standardised methods for mass culture as well as continuous culture must be developed for marine zooplankton. It is true that the culture or even maintenance of most marine zooplankton in the laboratory is difficult. We should therefore try to extrapolate the results from the small number of test species to a large number of species likely to be exposed in the field. According to Cairns (1980), single-species toxicity tests often must be used to make estimates of response of threshold of communities. It is therefore suggested that the bioassay studies should be carried out for the determination of short-term lethality and then proceed with various increasingly sophisticated long-term tests to obtain a reasonable estimate of pollution risk.

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