per and zinc lead to regressive changes in the gut diverticula and damage to the stomach wall. Predatory animals which do not normally accumulate metals may as a result of their feeding behaviour attain a sufficient quantity of these metals to kill them. For example, an inshore demersal fish feeding on the ragworm may die as a result of the worm's ability to concentrate copper in its tissues. Copper and zinc discharged from estuaries may prevent Atlantic Salmon reaching their spawning grounds, for it has been discovered that they will avoid waters containing these pollutants even at very low concentrations.

Mercury and Silver The industrial uses of mercury compounds are numerous; they are used as fungicidal seed dressings, in paper making, and as catalysts in the manufacture of PVC. Numerous cases of sterility of seed-eating birds and predators, including man, have been traced to the habit of seed dressing with mercury compounds. This practice is also a hazard to coastal marine life which is exposed to mercury as a result of fresh-water run off. A recent research report that a very low concentration (1 part per billion) of fungicidal mercury is sufficient to cause a 50 per cent drop in photosynthetic activity of a phytoplanktonic test organism is particularly alarming, for such concentrations are frequently found at the mouths of rivers draining agricultural land and near industrial outfalls. It is possible that inshore phytoplankton (and consequently those animals that feed on it) are being seriously affected.

The concentration of mercury and silver found around certain industrial outfalls is also sufficient to cause abnormal or inhibited development of eggs and larvae of certain barnacles and sea urchins. Other marine organisms, however may accumulate metals without any readily apparent harm being done to them. Some shellfish and fish have such a high concentration of mercury within their tissues that people are advised not to eat them for fear of being poisoned. From 1953 to 1960 almost one hundred people were killed after eating fish and shellfish taken from Minamata Bay in Japan. The cause of their death was a lethal amount of mercury in the bodies of the marine life derived from the mercury-laden effluent of a plastics factory.

The danger of mercury in the marine environment has now been recognised by many governments, but how many other metals may be accumulating undetected in the bodies of sea life?

From the few examples cited it can be seen that the directly poisonous action of heavy metals is not the only consideration, for there is evidence that long-term accumulation and concentration of metals by marine organisms can lead, if not always to their own death, to death of others that eat them. Clearly discharge of heavy metals into coastal waters should be actively discouraged.

Pesticides and PCBs

Pesticides are deliberately applied in the terrestrial environment in order to control insect pests, weeds, fungi etc. They reach the sea not only as a result of land drainage, but also from the atmosphere. Indeed, it has been concluded by some American workers that the observed distribution of the chlorinated hydrocarbon pesticide DDT and its residues off the coast of California can only be explained by assuming distribution through the atmosphere. Corroboratory evidence for atmospheric distribution comes from the fact that organochlorine residues can be detected in ice and in the fatty tissues of penguins and seals from the Antarctic where pesticides to the best of our knowledge have never been applied.

Polychlorinated biphenyls (PCBs), unlike pesticides, reach the environment by accident. They are used in the manufacture of paints and varnishes, as softeners in plastics, and for improving electrical insulation in cables. Many high temperature lubrication oils now contain PCBs. PCBs reach the ocean in liquid waste from industrial and domestic sources, from decomposing rubbish dumped at sea, and from the atmosphere polluted by smoke from industry, motor vehicles and rubbish dumps.

The danger of both chlorinated hydrocarbon pesticides and PCBs is that they are extremely stable and persist for long periods of time without biodegrading into a harmless form. Some organochlorines have been in use for 30 years or more so that if only minute quantities have been reaching the sea during this period they have had time to build up in the water and sediments. In addition many invertebrates have the ability

Beach strandline in the age of the non-returnable container.

to concentrate them many thousands of times and store them in their fatty tissues in much the same way as metals are concentrated and stored.

Many planktonic species of animal and plant as well as fish and benthonic invertebrates are extraordinarily sensitive to organochlorine pesticides, especially in the earlier stages of their life history, and can be killed outright by residues reaching the sea by land drainage and in effluents from manufacturing plants. The waste from a parathion manufacturing plant on the Danish North Sea Coast led to many dead and dying lobsters being cast up on local beaches. Other species higher up food chains may be poisoned by eating animals and plants that have accumulated pesticides in their tissues. Sandwich Terns dying in tremors and convulsions in the Danish Waddenzee were found to have been poisoned by chlorinated hydrocarbons passed on from herrings and sand eels, which in turn had been feeding on planktonic and benthonic copepod invertebrates with a high level of organochlorine entering their diet due to pesticide discharge from the Rhine. By the time the pesticides had reached the Terns they had been concentrated many thousands of times. Due to the greater sensitivity to pesticides of some marine species as compared with others, the balance of certain ecosystems can be seriously affected, animals at the top of the food chain dying as a result of non-availability of a particular food source. The demise of the Californian Sardine industry has been attributed to such a situation.

As disturbing as the direct kills attributed to pesticides are the numerous sub-lethal effects that have been reported in scientific papers. These include alterations in body chemistry, disturbance of growth and gonad formation, interference with thermal acclimation mechanisms, lowering of resistance to disease, and changes in the basic behaviour patterns of various species. Of necessity much of this experimental work has been carried out on commercially important shellfish and fish but this does not mean that other groups of animals are any the less affected.

Organophosphorous and carbamate pesticides which are now being used increasingly for pest control are much less stable than organochlorines and consequently do not accumulate through food chains to the same degree. There is thus less chance that animals higher up the food chains will receive sufficiently large doses of pesticides to affect their biology.

The chemical similarity between PCBs and organochlorine pesticides suggests similar physiological effects on marine organisms. However, at present little is known of the adverse effects of PCBs, although in laboratory experiments it has been shown that these chemicals can effect the production of sex hormones in such a way that animals are rendered infertile. It may not be entirely coincidental that the fertility rate of guillemots at breeding sites on the British West coast is dropping. In September 1969 between 10 and 15,000 dead sea birds, mostly guillemots, were washed up along the west coast of Britain. Although it is by no means certain what caused their deaths, fatty tissues of the birds contained relatively high amounts of PCBs.

Marine life will be increasingly placed at risk if the release of chlorinated hydrocarbon pesticides and PCBs into the environment is allowed in anything but very small quantities. No-one will deny the short-term benefits that have been reaped by the use of DDT and its derivatives but we have got to consider the long-term consequences of their use. Already in a confined area like the Baltic marine species contain on average 8-10 times more DDT than the same species in the North Sea. Organochlorine pesticides should only be used in an emergency and should not be applied as a prophylactic.

Radioactive waste

Radiation has long been recognised as a factor constituting a potential hazard to human populations, if not to marine life. Radioactive materials reach the sea (1) from the atmosphere (2) as a result of natural leaching of rocks containing radioactive compounds (3) from containers of radioactive waste dumped at sea (4) from outfall pipes of coastal nuclear installations.

Due to concern over the wide dissemination of radioactive dust following nuclear explosions in the atmosphere very small amounts of radioactive dust take place above ground. Hence only very small amounts of radio active dust in excess of the background quantities now reach the sea via the atmosphere.

In certain coastal areas of the world high background radiation is present due to naturally occurring radionucleides in the soil. Unfortunately, there is as yet no published information available on the effects on marine life in these areas, although statistical surveys on human populations in one of these regions has shown a significantly higher than normal rate of occurrence of chromosome abnormalities.

Radioactive wastes of short half-life can be stored at the point of production until inactive, but the problems of storage of wastes which decay at a slow rate are enormous. Much radioactive waste is stored in heavily shielded containers on land, but other wastes are encased and dumped in selected deepwater sites in the ocean. Due to the high cost of providing adequate shielding for dumped containers, some do not completely prevent escape of radiation. It must be accepted, therefore, that damage to marine life may occur in the region of these dumps.

The continuous discharge of low level radioactive wastes from coastal nuclear plant may also be causing sub-lethal damage to marine life in the vicinity of the discharge point. For it has been shown experimentally that low levels of radiation can cause chromosomal damage, with subsequent growth abnormalities, in both marine invertebrates and vertebrates. Effects may be even more subtle, as there is some evidence to suggest that exposure of fish to radiation can reduce their ability to tolerate changes in temperature and salinity.

Marine organisms, such as algae and shellfish, which concentrate metals cannot discriminate between radioactive and non-radioactive elements. Thus the radiation levels in certain organisms may be many thousands of times higher than that in the surrounding seawater. For example, oysters gathered some 250 miles from a nuclear source were seen to contain 200,000 times more radioactive zinc than the surrounding ocean. In theory the existing regulations relating to the discharge of radioactive waste take into account the ability of many organisms to concentrate elements in their tissues. However, the number of species examined in relation to the number occurring in coastal waters is very small.

It is certainly unwise to set any acceptable dose levels of radiation as far as marine life is concerned in view of the subtle nature of radiation damage unless they are based on long-term statistical experiments.