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Ecological Research Series

Annotated Bibliography on Biological Effects of Metals in Aquatic Environments

National Environmental Research Center
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ANNOTATED BIBLIOGRAPHY ON BIOLOGICAL EFFECTS OF METALS IN AQUATIC ENVIRONMENTS (No. 1-567)

By

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ABSTRACT

A total of 567 references on biological effects of metals to aquatic organisms were annotated and subsequently indexed by metal and by taxa. Preference was given to articles on toxicity of heavy metals to marine, estuarine, and anadromous species.

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SECTION I

INTRODUCTION

This initial volume is the result of a need for specific information on physiological, toxicological and metabolic impact of metals in the aquatic environment, primarily affecting marine and estuarine biota. During the past several years these data were gathered from a variety of sources, especially Water Pollution Abstracts, but also Sport Fishery Abstracts, Oceanic Index, Water Resources Abstracts and other sources. Whenever possible the original article was consulted and annotated. It is hoped that additional volumes in this subject area will be issued when more literature becomes available.

SECTION II

REFERENCES

References are arranged alphabetically by author and then numbered. Each reference is indexed by metal(s) and cross-indexed by taxonomic group(s) in the INDEX.

1. Abegg, R. 1950. Some effects of inorganic salts on the blood and tissue fluids of the bluegill, Lepomis macrochirus Raf. Physiol. Zool. 23:124-134.

To explain some of the effects on fish of pollution by industrial waste waters the author investigated the effect of some inorganic salts on the internal water balance of the bluegill, Lepomis macrochirus. He first determined the 24-hour median tolerance limit of the fish for each salt, that is, the concentration of the salt in which half the test animals could survive for a period of 24 hours. Fish were placed for 24 hours in test solutions of concentrations at the 24-hour median tolerance limit, at a temperature of 22 $\pm$ 0.2 C. The effects of the following salts were tested: sodium sulphate, chloride, orthophosphate, chromate, dichromate, and carbonate, and calcium and potassium chloride. A falling drop densiometer was used for measuring changes in the specific gravity of the blood of the fish, and the content of moisture was determined in a strip of dorsal muscle removed from one side of the fish. As controls, fish, under the same conditions as those in the test solutions, were placed in reference water, i.e. water containing all the major ions in concentrations and proportions typical of an average surface water of the United States. Solutions of sodium sulphate, chromate, and orthophosphate had no effect on the water balance of the fish exposed for 24 hours; all the fish survived, possibly because the fish used in these tests were larger than those used in the tests for determining the 24-hour median tolerance limit. Solutions of potassium and calcium chloride caused the fish to lose tissue fluids although the specific gravity of their blood varied only slightly from that of the control fish. Fish in a solution of sodium carbonate for 7 hours showed a gain in tissue fluid of 1.24 per cent over the controls, but no significant change in specific gravity of the blood was noted. The mean values for tissue fluid and specific gravity of the blood of fish in the sodium dichromate solution indicated a significant general hydration of the whole animal while sodium chloride had a dehydrating effect.

2. Abou-Donia, M.B., and D.B. Menzel. 1967. Fish brain cholinesterase--Its inhibition by carbamates and automatic assay. Compar. Biochem. Physiol. 21:99-108.

The normal brain acetylcholinesterase (AChE) activity of a marine fish, the shiner perch (Cymatogaster aggregata Gibbons), and some of its properties, is described as determined by a rapid automatic AChE assay suitable for environmental monitoring or for the determination of in vivo and in vitro inhibition properties of fish AChE. The acetylthiocholine-hydrolyzing activity of the shiner perch brain was found to be mainly AChE; much less activity was attributed to non-specific esterases and ChE. The AChE activity was activated by

Na^+, K^+, Ca^{2+}, and Mn^{2+} ions and inhibited by Ni^{2+}, Cu^{2+}, Pb^{2+}, Hg^{2+}, and Fe^{3+} ions ($Pb(NO_3)_2$ used at 26 mg/l caused 73% inhibition). Some activation of the AChE activity was noted with 1-butanol.

3. Affleck, R.T. 1952. Zinc poisoning in a trout hatchery. Aust. J. Mar. Freshw. Res. 3:142-169.

At a trout hatchery in Victoria, Australia, severe losses of fish have been experienced as a result of zinc being dissolved from the galvanized iron pipes of the water system by the rather acid water. In acid waters with a low concentration of mineral salts, 0.01 mg/l zinc is toxic to trout. Rainbow trout (Salmo garidnerii) are more susceptible to zinc poisoning at all stages of development than are brown trout (Salmo trutta). The concentration which is lethal varies among ova, sevins, fry, and fingerlings, but in general older fish are more susceptible to poisoning. Fish which survive exposure to dissolved zinc are less susceptible when subsequently exposed than are fish which have not previously been subjected to its effects. Under some conditions trout fingerlings will die after being in a zinc vessel for 15 minutes, but some effects of poisoning may be delayed; fish removed from zinc-contaminated water to zinc-free water may appear normal but may die within 48 hours. A coating of aluminum paint is not sufficient to protect galvanized iron from the action of acid water. As trout in rivers in Victoria are often subjected to high temperatures in summer, some studies were made to determine the lethal temperature. The lethal temperatures for fingerlings of both rainbow and brown trout were 29°-30°C, for adult brown trout 27°-28°C, and for adult rainbow trout 28°-29°C; these are similar to the lethal temperatures for trout reported from other parts of the world.

4. Agnedal, P.O. 1966. Calcium and strontium in Swedish waters, and accumulation of Strontium-90. Aktie bolaget Atomenergi, Stockholm. 34p.

Studies have been carried out on the uptake of calcium and strontium by fish in relation to the concentrations of these elements in the water, with particular reference to the accumulation of strontium-90; water from various Swedish lakes was used, with 3 species of fish (pike, perch, and roach). There was evidence that the concentration of strontium-90 in both water and fish had increased over the period 1960-1966. It was calculated that in water containing about 2 mg/l of calcium, a 10-fold increase in the existing concentration of strontium-90 would give strontium concentrations in fish muscle tissues close to the maximal permissible levels, but in lakes with higher concentrations of calcium (20-40 mg/l) the permissible level for strontium-90 in drinking water would be exceeded before hazardous concentrations accumulated in fish.

5. Agranat, V.Z. 1958. Certain data concerning cumulation of polonium-210 by water-living organisms. Med. Radiol; U.S.S.R. 3:65-69; Nuclear Sci. Abstr. 12:1122.

It was found that there was marked accumulation of polonium-210 in the bodies of fish in reservoirs where the concentration of polonium was much less than the maximum permissible concentration of 5×10^{-11}c. It is suggested that the maximum permissible concentration of polonium in water should be reduced.

6. Agre, A.L. and M.M. Telitchenko. 1963. Concerning the accumulation of radiostrontium by hydrophytes and detritus. Bull. Soc. Nat. Moscou, Ser. Biol. 68:133-137.

Results are given of studies on the removal of radioactivity from water by green and blue-green algae, diatoms, mosses, and some higher plants, and by detritus, using strontium-90 added to settled tap water as the experimental isotope. It was found that there was a difference in the amount of strontium-90 accumulated by the different species, and that about 80 per cent of the isotope was removed from the water by the detritus added to the water. The accumulation of strontium-90 by both aquatic plants and detritus took place basically according to the laws of sorption.

7. Ahuja, S.K. 1964. Salinity tolerance of Gambusia affinis. Indian J. Exp. Biol. 2:9-11.

The maximal salinity tolerance of the freshwater mosquitofish (Gambusia affinis) was determined by exposing acclimated fish to various concentrations (1.0-8.0 per cent total salinity) of salt solutions containing sodium chloride, potassium chloride, calcium chloride, magnesium sulphate, sodium sulphate and sodium bicarbonate. It was found that, at 20°-23°C, about 50 per cent of the fish were able to withstand a salinity of 5 per cent. Mortality increased with higher salinities; only about 5 per cent of the fish were able to withstand salinities as high as 8 per cent for periods of 35-41 days. Increased mortality occurred at lower (6°-7°C) and higher (32°-35°C) temperatures. During the experiments it was also observed that fish were able to survive in water with negligible concentrations of dissolved oxygen (0.18-0.22 mg/l), and did not appear to be adversely affected by high concentrations of carbon dioxide (13-69 mg/l).

8. Alabaster, J.S. 1967. The survival of salmon (Salmo salar L.) and sea trout (S. trutta L.) in fresh and saline water at high temperatures. Water Research, 1:717-730.

The survival of salmon and seatrout smolts, on sudden exposure to increased temperature, has been measured under field and laboratory conditions in both fresh and salt water. Smolts are more sensitive than parr when tested in fresh water, particularly if no special care is taken to acclimate the fish to the test conditions beforehand. Salmon smolts are most sensitive to an increase in temperature when exposed simultaneously to change from fresh to sea water, though the effect is much less even after only 7 hours prior acclimation to sea water; they are most resistant when tested in 30 per cent sea water. The results indicate that, at the beginning of the period of smolt migration, when the acclimation temperatures are about 8°C, the rise in temperature of cooling water used by power stations (6-9°C) is smaller than any change that could kill fish. At the height of the smolt season, with acclimation temperatures of 10-12°C, only abnormal increase in temperature such as might be the case with recirculating back to the cooling water intake, if accompanied by a change from fresh to sea water, without prior acclimation will be lethal.

9. Aldrich, D.V. and W.B. Wilson. 1960. The effect of salinity on growth of Gymnodinium breve Davis. Biol. Bull. 119:57-64.

In view of the sporadic nature of blooms of Gymnodinium breve, attempts have been made to determine possible relations between various environmental factors and these outbreaks. The authors exposed bacteria-free cultures of G. breve to media with salinities ranging from 0.3 to 46.0 parts per thousand; the best growth occurred with salinities between 27 and 37 parts per thousand, indicating that this organism is relatively stenohaline. Field observations by other workers have shown dense populations associated with salinities a few parts per thousand below those of the offshore waters of the Gulf of Mexico, but the present results suggest that this distribution is not a direct result of salinity as growth of the organism was not inhibited in cultures with salt concentrations equivalent to those of the open Gulf. Optimal growth did not occur in culture media with a salinity of 24 parts per thousand or less, and it is suggested that in estuaries salinity may be a limiting factor in the natural distribution of Gymnodinium.

10. Alexander, J.E. and E.F. Corcoran. 1967. The distribution of copper in tropical seawater. Limnol. Ocy. 12:236-242.

Ionic, particulate and total soluble Cu in waters off Florida were determined spectrophotometrically. Most of the Cu was in the soluble organic complex. Nearshore waters has more total copper (20 ug/l=20 ppb) than waters flowing through the center of the Straits of Florida (about 10 ppb). Ionic copper was always less than 2 ppb and particulate copper rarely exceeded 0.2 ppb.

11. Amend, D.F., W.T. Yasutake, and R. Morgan. 1969. Some factors influencing susceptibility of rainbow trout to the acute toxicity of an ethyl mercury phosphate formulation (Timsan) Trans. Amer. Fish. Soc. 98:419-425.

This study determined the influence of water temperature (13-20°C), dissolved oxygen (4-12 mg/l), water hardness as $CaCO_3$ (20-256 mg/l), and chloride ions (to 2 mM) on the susceptibility of rainbow trout (Salmo gairdneri) to the acute toxicity of ethyl mercury phosphate (EMP). The fish were exposed for one hour to 0.125 mg/l EMP, the active ingredient of Timsan, a commercial EMP formulation. The death rate because of the exposure to EMP increased with an increase in water temperature, a decrease in dissolved oxygen, and an increase in chloride ions; calcium appeared to have no effect. The effect of water temperature and dissolved oxygen was ascribed to changes in the respiration rate of fish, and a chemical explanation is presented for the effect of chloride ions.

12. Anderson, B.G. 1946. The toxicity threshold of various sodium salts determined by the use of Daphnia magna. Sewage Ind. Wks. J. 18:82.

A study was made to determine the toxicity to Daphnia magna of 38 sodium compounds which occur in trade waste waters. In the present experiments, 80 to 100 per cent of the control animals remained active for at least 48 hours. Observations on the animals in Lake Erie water, to which a sodium compound had been added, were therefore continued for 48 hours and the threshold concentrations of the compound, that is the highest concentrations which failed to immobilize the animals, were calculated for this period. The threshold concentrations, expressed as molar concentrations, were about the same for the acetate, bromide, chloride, formate, and nitrate of sodium, and these salts, as well as the sulphate and bicarbonate, were probably toxic only when present in sufficiently high concentrations to exert an unfavourable osmotic pressure. All the other sodium compounds tested were toxic in smaller concentrations than the salts already mentioned and their toxicity was due to factors other than osmotic pressure. Sodium bisulphate was toxic when it was present in sufficient concentration to make the pH value of the water less than 6. The toxicity of sodium bisulphite may also be due to its acidity, although it was toxic in water with a pH value slightly greater than 6. Sodium carbonate and sodium hydroxide appeared to be the only compounds which were toxic because of their alkalinity. Over a period of 48 hours sodium arsenite was slightly more toxic than sodium arsenate on the basis of molar concentration of the concentration arsenic; 40 times more arsenate than arsenite was required

to immobilize Daphnia in one hour. Sodium nitrate was 200 times as toxic as sodium nitrate and sodium sulphite was 12 times as toxic as sodium sulphate. The bromate, chlorate, iodate, bromide and chloride were relatively innocuous but the iodide was very toxic. The bromate and chlorate were more toxic than the bromide and chloride respectively. The monobasic phosphate was much less toxic than the dibasic and tribasic phosphates.

13. Anderson, B.G. 1948. The apparent thresholds of toxicity to Daphnia magna for chlorides of various metals when added to Lake Erie water. Trans. Amer. Fish. Soc. 78:96-113.

In relation to the polluting effects on streams of industrial waste waters, experiments have been made to determine the toxicity of 25 metal salts to Daphnia magna. Daphnids, not more than 8 hours old, were immersed for periods of 64 hours at 25°C in Lake Erie water containing solutions of the chlorides of sodium, calcium, magnesium, potassium, ammonium, strontium, tin, manganese, iron, lithium, antimony, barium, aluminium, cobalt, chromium, nickel, lead, zinc, copper, mercury, and cadmium and of silver nitrate to determine the concentrations which just failed to immobilize 50 per cent of the animals (threshold concentrations). The 64-hour exposure period was used to allow all of the animals to pass both first and second moulting stages as it has been shown that the susceptibility of daphnids to toxic substances increases during moulting. The threshold concentration for each of the salts tested is shown in a table, and graphs are given in which the period before immobilization of the daphnids is related to the concentration of the salts. Results are compared with those obtained by other workers for daphnids and other animals, especially fish. Some of the salts produced precipitates when added to Lake Erie water and some altered the pH values of the water.

14. Andrews, H.L., and Warren, S. 1969. Ion scavenging by the eastern clam and quahaug. Hlth. Phys. 17:807-810.

The uptake of iodine-131, strontium-85, and iron-59 from sea water by clams and quahaugs and the faecal excretion of these isotopes was studied. The concentrations of the isotopes in the faeces were considerably greater than those in the water, and it is suggested that this may be an important factor in the transfer of nuclides to bottom sediments.

15. Angelovic, J.W., J.C. White, and E.M. Davis. 1967. Interactions of ionizing radiation, salinity, and temperature on the estuarine fish, Fundulus heteroclitus. Proc. 2nd Natn. Symp. Radioecol., Ann Arbor, 1969: 131-141.

Studies were carried out to determine the synergistic or antagonistic influences of salinity and temperature upon the response of mummichogs (Fundulus heteroclitus) to ionizing radiation. In studies on the LD_{50} value of cobalt-60 radiation the fish were acclimated for at least 3 weeks in tanks of flowing sea water at the test combination of salinity (5, 15, or 25 per thousand) and temperature (12, 17, 22 or 27°C), and then exposed to doses of 0, 500, 1000, 1500 or 2000 rad from the cobalt-60 source. After irradiation the fish were placed in aquaria containing water with the test combination of salinity and temperature, deaths recorded daily, and the LD_{50} values were estimated graphically. The mummichogs became more sensitive to radiation as the temperature or salinity increased; low salinities had a protective influence but this appeared to be modified by changes in temperature. A dose of 2000 rads killed almost all the animals within 20 days at the upper limits of salinity and temperature. To study the pattern of mortality of mummichogs, a factorial experiment was designed for the derivation of equations from which the percentage mortality could be predicted, for different periods after irradiation, under varying conditions of temperature, salinity, and radiation dose (above the LD_{50} value). At intervals of 10, 20, and 30 days after irradiation, the mortality pattern depended respectively on temperature only; radiation dose and salinity-temperature interaction; and salinity-temperature interaction (this interaction became more significant as the period after irradiation increased). To study the efflux of sodium-22 from unirradiated mummichog and from the same fish after irradiation with 5000 or 7500 rads, the fish were exposed to water containing sodium-22 for 48 hours and then transferred to nonradioactive sea water at the acclimation salinity, and the loss of radioactivity was followed. Fish irradiated with the higher dose lost sodium-22 more rapidly than the controls at all salinities; higher salinities increased the rate of loss of sodium-22, particularly in the control fish. The influence of salinity and of the salinity-temperature interaction on the response of fish to irradiation are discussed including the possible role of the failure of the osmoregulatory system. The results illustrate the stresses to which estuarine biota may be exposed; and it is emphasized that the effects of increases in salinity (due to increased use of fresh water which causes salt intrusion), increases in temperature (due to use of water for cooling purposes), and disposal of radioactive waste waters, although individually harmless, may interact to produce deleterious effects on many estuarine species.

16. Anghileri, L.J. 1959. Study of the contamination of Prochilodus platensis (Sabalo) with fission products. Com. nac. Energ. Atom., B. Aires, Argentina: 20 p.

The uptake of fission products by the fish Prochilodus platensis immersed in contaminated water for 1, 2, 3, 10 and 30 days

was studied. Contamination of the fish begins by adsorption on the mucous coating. Activity in stomach and guts, liver and kidney increases as a result of adsorption from the mud particles on which the fish feeds. Analyses of the scales showed that strontium is fixed on them.

17. Angino, E.E., J.E. Simak, and J.A. Davis. 1965. Fixing of fallout material by floating marine organisms, Sargassum fluitans, and S. natans. Publs. Inst. Mar. Sci. Univ. Texas 10:173-178.

Gamma-spectrometric studies on samples of free-floating marine algae Sargassum fluitans and S. natans collected from the Gulf of Mexico indicated presence of the following radioactive isotopes (in decreasing order of fractional concentrations): cerium-144/promethium-144; ruthenium-106/rhodium-106; caesium-137 and zirconium-95/niobium-95; ruthenium-103/rhodium-103; and manganese-54, none of which could be attributed to natural radioactivity in the marine environment but only to fallout of fission products. The results complement those of others for the benthic alga Cystoseira barbata from the Black sea.

18. Anon. 1952. Toxic qualities of metals. Wat. Life 7:72.

The use of galvanized iron, aluminium, copper and brass in the construction of fish aquaria is discussed with reference to the toxic effect of the products of corrosion on fish. Zinc salts, which dissolve from galvanized iron, are harmful to fish as they precipitate proteins; concentrations of 1 mg/l may prove fatal to roach in a few hours. The toxicity of aluminium is very low, and little corrosion occurs in water owing to the formation of a protective film. Corrosion of copper and brass in water is rapid and the products are very toxic to fish; 0.1 mg/l copper may be fatal.

19. Anon. 1958. Hanford biology research. Annual report for 1957. HW-53500. Office of Technical Services, U.S. Dept. of Commerce, Washington, D.C.: 228 p.

Work carried out in the state of Washington, during 1957 on the effects of radioactive isotopes on plants, animals, humans and fish, is reported. It has been found that aquatic organisms accumulate caesium-137 in high concentrations, and this could constitute a hazard for man eating fish from water contaminated with caesium-137. Cereals were irrigated with effluent from the reactor, to study the uptake of isotopes by the plants. Little long-lived beta-emitting material was taken up by the plants, but zinc-65 and

chromium-51 did accumulate in plants watered with undiluted effluent. Experiments were carried out on the temperature tolerance of eggs and young whitefish from the Columbia river. Increased mortality occurred at increased temperatures. The toxicity of trivalent and hexavalent chromium to salmon was also investigated. Hexavalent chromium in a concentration of 0.2 mg/l was definitely toxic, retarding rate of growth and resulting in increased mortality, while trivalent chromium in the same concentration had no observable effect.

20. Anon. 1968. N.T.A. Spells hope for mine-polluted rivers. Atlantic Salmon J. 4:31-32.

The sodium salt of nitrilotriacetic acid (NTA) appears to hold promise of effectiveness against heavy metal pollution, i.e. zinc and copper escaping from the mining operations in northern New Brunswick and Newfoundland rivers has been detrimental to salmon smolt. It also seems to solve the problem of avoidance reactions. Further field trials will be needed before NTA can be considered a feasible solution to mine wastes.

21. Anon. 1970. Mercury contamination in the natural environment. A cooperative bibliography. U.S. Dept. of the Interior, Office of Library Services, Washington, D.C.: 32 p.

Environmental contamination by mercury is a current concern of many bureaus and offices of the U.S. Department of the Interior. The purpose of this bibliography is to provide access to the literature related to this subject for those people who are now beginning to work on the problem. Publications providing background and current information on the aspects of greatest concern to the Department have been selected from the large body of literature on mercury. English language material relating to fish, wildlife and water pollution has been given full coverage from the sources consulted. So large a body of literature exists on other phases of the problem, such as methods of analysis, agricultural uses, industrial health, and clinical medicine, that it could not all be included. The criteria for selection in these areas were close relationship to environmental contamination, recommendations of scientists, or the presence of literature reviews or substantial bibliographies. The literature was searched from 1960 to present. Some particularly relevant pre-1960 titles have been included.

22. Anwand, K. 1966. The enrichment of ^{45}Ca and ^{91}Y in fry of *Esox lucius* L. and *Anguilla anguilla* (L.). Verh. int. Verein. theor. angew. Limnol., 1965. 16:1124-1129.

After discussing the practical value of such investigations, the author reports studies on the uptake of calcium-45 (supplied as calcium carbonate) or yttrium-91 (supplied as yttrium chloride) by the fry of pike or eel exposed in aquarium water containing 10, 100, or 200 μc/l of these isotopes. Results show that the activity of calcium-45 in the fry increased continuously with the period of exposure to a level depending on the concentration in the water. After exposure for 2-3 days in water containing 100-200 μc/l, the level of activity reached in the fry was suitable for tagging purposes. There were unexplained differences between the behaviour of the 2 species of fish fry, and pike fry are more suitable for tagging than eel fry. The uptake of yttrium-91 was more complicated: in general, a relatively high level of activity in the fry after exposure for only 1 hour was followed by a decrease in activity and then by fluctuations, reaching a stable level of activity after 2 days. For calcium-45, the changes in the accumulation factor with time, which were independent of the degree of activity in the water, indicated that the uptake of this isotope was more rapid in pike fry than in eel fry. A similar tendency was noted with yttrium-91 after exposure for 1-2 days. Calcium-45 is considered preferable to yttrium-91 for tagging purposes.

23. Armitage, K.B. and L.J. Olund. 1962. Salt tolerance of the brook stickleback. American Midland Natur. 68:274-277.

Experiments are reported which demonstrate the physiological inability of the brook stickleback, Eucalia inconstans, to live in water of increased salinity. In survival experiments, the fish appeared normal in water containing 10 and 20 per cent of sea water, but activity decreased progressively at higher concentrations of sea water until all the fish died in 60 per cent sea water. On the basis of oxygen consumption, 10 per cent sea water was readily tolerated by the fish; 20 per cent sea water produced a marked stress, with marked increase in oxygen consumption; and higher concentrations of sea water caused decreases in oxygen consumption corresponding to the decreases in activity.

24. Arnold, E.L., and W.F. Royce. 1950. Observations of the effect of acid-iron waste disposal at sea on animal populations. Spec. Sci. Rep. U.S. Fish Wildlife Serv., Fisheries 11:12 pp.

Investigations are described on effects on bottom fauna and fish of the disposal at sea of about 275,000 kg per day of a solution of sulphuric acid and ferrous sulphate. Preliminary study showed that the waste water mixed with the upper 16 m of sea water and was buffered by the slightly alkaline sea water. It was possible, however, that some of the acid might reach the bottom.

The acid solution was discharged over an area of 6.4 km^2, and a similar area of the same size was used as a control. Photographs of the bottom were taken to determine the numbers of larger animals living on the surface of the bottom, and samples of the small burrowing animals were obtained by dredging. Surveys of both areas were made in the spring before discharge of the waste waters was begun and in November after acid had been dumped daily for a period of about 6 months. In both areas there was a decrease in the number of animals visible on the bottom and an increase in the number caught by the dredge over this period. These fluctuations may have been due to seasonal changes or to sampling errors. Fish in the disposal area were also present in considerable variety and numbers. More extensive studies are still required to determine what changes, if any, are caused by the disposal of acid-iron solution at sea. The survey has shown, however, that bottom animals were not completely destroyed by the discharge of waste waters, even immediately below the point of discharge.

25. Arthur, J.W., and E.N. Leonard. 1970. Effects of copper on *Gammarus pseudolimnaeus*, *Physa integra*, and *Campeloma decisum* in soft water. J. Fish. Res. Bd. Canada 27: 1277-1283.

Three invertebrate species were subjected to acute (96-hr), followed by long-term (6-week) copper exposures under continuous-flow bioassay conditions. Survival, growth, reproduction, and feeding were the responses used for measuring toxicant effects. The average 96-hr median tolerance limits (TL_m) values for *Campeloma decisum*, *Physa integra*, and *Gammarus pseudolimnaeus* were 1.7, 0.039, and 0.020 mg/l total copper, respectively. The total copper concentration having no effect after 6 weeks exposure for all three species was between 8.0 and 14.8 μg/l. The newly hatched amphipods obtained from the second 6-week study were exposed to copper for 9 additional weeks, and grew to the adult stage only in copper concentrations less than 4.6 μg/l. After 5 weeks exposure to a water system, survival of newly hatched *Gammarus* was markedly reduced when copper concentrations were between 12.9 and 6.2 μg/l.

26. Ashley, L.M. 1970. Action of iron salts in solution on goldfish. Prog. Fish-Cult. 32:109.

Goldfish (*Carassius auratus*) weighing 13 to 28 grams were exposed to ferrous or ferric chlorides or sulfates dissolved in distilled water. Salt content in this special environment ranged from low levels (5 and 10 mg/l) to high (50 and 100 mg/l), and ferric or ferrous cations were the only ones there except the few the fish excreted during confinement.

J. Amorim Machado Cruz, reporting on this study in his "Iron Salts in Ichthyopathology, a Histological and Histochemical Experimental Contribution" (Publications of Institute of Zoology, University of Porto Portugal, 1969), wrote that the fish showed acute toxicity response to repeated low-level baths lasting 6, 24, or 96 hours and to single exposures at high levels for 5, 30 or 60 minutes, or 3 hours. Gills of affected fish had epithelial edema, hypersecretion of mucus, inflammation, capillary congestion, destruction of respiratory epithelium, blockage of gill filaments and lamellae by a mucoferruginous precipitate, a very rare occurrence of intracellular iron in epithelial cells. Gill destruction was greatly aggravated by lowering the pH of the "bath" to less than 5.0.

Iron salts were most harmful immediately after they got into solution. Gill blocakge was most severe at this time, but was reversible. Dissolved iron salts in this special environment were rapidly ingested, absorbed by the digestive tract, and accumulated in the liver parenchyma. Some fish had iron precipitated in epithelial cells and in lumens of renal tubules. Fish responded similarly to exposure to the four iron salts tested.

27. Aten, A.H.W., J.W. Dalenberg, and W.C.M. Bakkum. 1961. Concentration of uranium in sea fish. Health Physics 5:225-226.

The concentration of uranium in fish obtained commercially in Amsterdam was determined by ultraviolet fluorescence in ash with sodium fluoride and 2 per cent lithium fluoride. The average concentration was found to be 2.1×10^{-5} mg per g. If the concentration of uranium in surface sea water is taken to be 1.1×10^{-6} mg per ml, as determined, this gives a concentration factor of 20 for fish.

28. Avargues, M., Ancellin, J., and Vilquin, A. 1968. Experimental investigations on the accumulation of radionuclides by marine organisms. Proceedings of the third international colloquim on medical oceanography. Fifth and sixth sessions: 87-100.

The hazards to man arising from discharge to the sea of radioactive waste waters were considered, and laboratory experiments to determine the accumulation of caesium-137, cerium-144 and ruthenium-106 in algae, crustaceans, molluscs, and fish were described. The results were tabulated and compared with those obtained by others from in situ studies in the region of the Windscale effluent outfall and from studies on concentration of stable caesium by aquatic organisms.

29. Avio, C.M. and L. Lenzerini. 1963. The uptake of cesium-137 by Chlorella vulgaris. Pubbl. Staz. Zool. Napoli 33:69-82.

The uptake of cesium-137 by Chlorella vulgaris was found to be directly related to the number of cells and the concentration of cesium up to saturation limits. Cesium concentrations greater than 100 μg per ml inhibited the growth of Chlorella.

30. Baker, J.T.P. 1969. Histological and electron microscopical observations on copper poisoning in the winter flounder (Pseudopleuronectes americanus). J. Fish. Res. Bd. Can. 26:2785-2793.

The effects of various concentrations of copper on the morphology of winter flounder were investigated using histological techniques and electron microscope analyses. High and medium levels of copper caused fatty deposits in the liver and necrosis in the kidney and destroyed haemopoetic tissue and cells in the gill lamellae. No copper-induced morphological changes were found in seven other organs examined. Light microscope studies showed that low levels of copper caused the epithelial cells to be vacuolated and the basilamellar region to be reduced in thickness; chloride cells took the place of lamellar mucus cells. Electron microscope observations showed that low levels of copper similarly caused mucus cells to be replaced by chloride cells and the epithelial cells to be vacuolated. Vesicles bound by a double membrane and myelin-like bodies were found in the cells and increased amounts of particulate matter adhered to the outer cell membrane.

31. Baker, P.F. and M.P. Blaustein. 1968. Sodium-dependent uptake of calcium by crab nerve. Biochim. Biophys. Acta 150:167-170.

Crab nerves gain calcium when immersed in sodium-free sea waters formulated with lithium, choline or dextrose. This net gain results from a large increase in calcium influx. The rate at which calcium is taken up depends on the sodium content of the cells, being highest in sodium-loaded cells. These experiments suggest that small changes in internal sodium might exert powerful effects on metabolism through changes in calcium influx and the concentration of free calcium within the cell.

32. Baker, P.F., M.P. Blaustein, A.L. Hodgkin, and R.A. Steinhardt. 1967. The effect of sodium concentration on calcium movements in giant axons of Loligo forbesi. J. Physiol., London 192:43-44.

In view of the evidence that there is a calcium-dependent component of the sodium efflux, experiments were performed to see whether there is a calcium influx associated with the sodium efflux. The influx of ^{45}Ca was increased in sodium-free media, especially sea waters based on lithium, and for any given external solution was increased by raising the internal sodium concentration in the axon. These experiments show that the properties of the calcium influx parallel those of the calcium-dependent sodium efflux; but it is not clear whether the two fluxes are tightly coupled. In sodium-free media the calcium efflux was reduced.

33. Baker, P.F., M.P. Blaustein, J. Manil, and R.A. Steinhardt. 1967. A ouabain-insensitive, calcium-sensitive sodium efflux from giant axons of Loligo. J. Physiol., London 191:100-102.

It has long been known that much of the sodium efflux from squid axons is coupled to the uptake of potassium ions. This process is largely unaffected by the concentration of calcium in the bathing medium; but is inhibited by low concentrations of the cardiac glycoside, ouabain. Evidence is presented for a second component of the sodium efflux the properties of which suggest that it represents a system entirely separate from that which effects sodium-potassium exchange. This new component of the sodium efflux is completely dependent on the presence of external calcium and is unaffected by very high concentrations of ouabain. An interesting feature of this calcium-dependent sodium efflux is that it increases approximately as the square of the internal sodium concentration whereas sodium-potassium exchange increases linearly with internal sodium. Although calcium-dependent sodium efflux is most marked in sodium-free media, especially sea waters based on lithium, some calcium-dependent flux is still detectable in sea water.

34. Baker, P.F. and J. Manil. 1968. The rates of action of K^+ and ouabain on the sodium pump in squid axons. Biochim. Biophys. Acta 150:328-330.

Removal of external potassium stops the operation of the sodium pump within a few seconds. This rate does not differ from the rate at which sodium-free sea waters block electrical activity in the same preparation. These results show that during sodium-potassium exchange the sodium pump is absolutely dependent on external potassium.

The rate of inhibition of the sodium pump by the cardiac glycoside ouabain was also investigated. The rate of inhibition was concentration-dependent, but at any given ouabain concentration

depended both on the metabolic state of the axon and also on the ionic composition of the external medium. The experiments suggest that, for ouabain to interact with the pump sites, some form of energy must be available within the axon.

35. Ball, I.R. 1967. The toxicity of cadmium to rainbow trout (Salmo gairdnerii Richardson). Water Research 1:805-806.

In view of considerable variation in reports on the toxicity of cadmium to different species of fish in static water, experiments were conducted in flowing water using rainbow trout as the test species. In hard water results showed a linear relation between median period of survival and concentration in the presence of 1-64 mg/l of cadmium, but there was little change in survival period at concentrations between 0.01 and 1.0 mg/l. Very low 7-day TL_m values (0.008-0.01 mg/l) were indicated although the initial response of the fish was slow, even at high concentrations. Similar results have been obtained in preliminary tests in soft water.

36. Ballard, J.A. and W.D. Oliff. 1969. A rapid method for measuring the acute toxicity of dissolved materials to marine fishes. Wat. Res. 3:313-333.

The toxicities of mercuric chloride and phenol to the marine fish Ambassis safgha were determined by a rapid residual oxygen method. The fish were kept in sealed containers in the presence of graded concentrations of the chemicals, and the oxygen concentrations at the time of death was measured either by an oxygen probe or by titration using the azide modification of the Winkler method. The toxicity threshold of phenol was much lower at 15°C than at 25°C, but that of mercuric chloride was unaffected by temperature. Results were compared with those using the standard method, and the median lethal concentrations found were of the same magnitude as the threshold values using the residual oxygen method.

37. Bandt, H.J. 1946. Increased damage to fish, especially by increase in toxicity caused by combinations of poisons. Beitr. Wass. Abwass. Fischereichem:15-23.

Increase in temperature of the water of a stream increases depletion of oxygen, accelerates respiration and other bodily activities of fish, and accelerates biological and chemical decomposition. Any infection such as attack by parasites, will decrease the resistance of fish to any toxic substance, and repeated additions to water of a toxic substance in amounts below the toxic limit may finally kill fish

because of the weakening effect of previous doses. Acid and alkaline waters can kill fish by a "corroding" action of the body surfaces, especially of the gills, and the reaction of the water also affects the action of other substances; reduction in pH value has been found to reduce the harmful effect of dissolved iron, and to increase the effect of insecticides containing arsenic and of oxygen deficiency. Excessive growth of algae may cause the water to become supersaturated with oxygen and also, by assimilation of carbon dioxide, can increase the pH value; the combination of these effects may be disastrous to fish. The toxicity of potassium and ammonium salts is reduced by the presence of sodium and to a less degree, of calcium salts. In experiments by the author on the toxicity of combinations of various metal sulphates, it was found that some combinations of two metals had toxicities very much greater than the sum of the toxicities of the separate salts. It appears that there is a relation between the position of an element in the periodic system and its biological activity and that the greatly increased toxicity of combinations of elements of two different groups is due to their simultaneous affect on different organs or parts of the body. The same appears to apply to common salts; for example the waste waters from the manufacture of Paris Green, a copper-arsenic compound, are much more toxic than those from the manufacture of calcium arsenite.

38. Banerjea, S., and E. Mitra. 1954. Preliminary observations on the use of copper sulphate to control submerged aquatic weeds in alkaline waters. Ind. J. Fish. 1, 1/2: 204-216 (Biol. Abstr. 31:2500).

It was found that even concentrations of 10 mg/l copper sulphate were ineffective for destroying water weeds in alkaline waters, because of the formation of copper hydroxide. A temporary phase of withering was observed after the first few days of the application but the vegetation revived again after about 3 weeks. When 10 mg/l copper sulphate was added after the pH value of the water had been lowered to 6.0, visible signs of withering appeared in 3-4 days and all the vegetation had decayed and settled to the bottom in about 25 days.

39. Baptist, J. 1966. Uptake of mixed fission products by marine fishes. Trans. Amer. Fish. Soc. 95:145-152.

Studies on uptake of fission-product mixtures by marine organisms were carried out over a 2-year period to determine their uptake by marine fish. Spot (Leiostomus xanthurus) and Atlantic croaker (Micropogon undulatus) were used to study uptake from sea water, and croaker and bluefish (Pomatomus saltatrix) were used to study the effects of single and repeated oral doses. Croaker and

spot were kept in separate tanks each containing 50 litres of radioactive sea water, under continuous aeration; the fission-product concentration was 1000 beta disintegrations per second per gram, the temperature 22°C-26°C, the pH value 7.7-8.0, and the salinity 32-35 parts per thousand. Single doses of 0.5 μc (beta) of a 450-day-old mixture, and gelatine capsules containing a 2.6-day-old mixture, were inserted into the stomachs of croaker and bluefish, respectively. Doses of 0.017 μc (beta) and 0.007 μc (gamma) of a 1-year-old mixture were given to bluefish in shrimp meat on alternate days for a total of 28 feedings: a fish sample taken after 10 days showed that little radioactivity had been accumulated and, therefore, the quantity of fission products in each dose was increased five times. The results are given in tables and graphs. Low levels of radioactive material were absorbed from sea water mainly because much of the activity was sorbed by the surfaces of the tanks. Croaker assimilated 14 per cent in 4 hours, after a single oral dose, and 94 per cent in 4 days. The low proportion of assimilation suggests that much of the fission-product material was particulate. Bluefish assimilated only 3 per cent of the repeated doses. The largest concentrations assimilated by croaker and bluefish from oral doses were found in the internal organs. It is suggested that assimilation by fish of fission products is mainly through the food chain, since only small amounts are accumulated directly from sea water.

40. Baptist, J.P. and C.W. Lewis. 1969. Transfer of ^{65}Zn and ^{51}Cr through an estuarine food chain. Proc. 2nd Nat. Symp. on Radioecology. U.S. A.E.C. Conf. 670503:420-430.

The transfer of assimilated and unassimilated ^{65}Zn and ^{51}Cr was followed through an experimental food chain which included phytoplankton, brine shrimp, post-larval fish, and mummichog. Both radionuclides were successively transferred through each level to the fourth trophic level, and the concentrations generally declines up the food chain. Assimilated concentrations of ^{65}Zn were higher than those of ^{51}Cr in all trophic levels. Experimental data were used to calculate theoretical maximum concentrations. Comparison of the results from the food chain with results of experiments on uptake from seawater indicated that the food chain was generally the more efficient pathway for uptake of ^{65}Zn and ^{51}Cr by all trophic levels except the second.

41. Baptist, J.P. and T.J. Price. 1962. Accumulation and retention of cesium-137 by marine fishes. U.S. Fish Wild. Serv. Fish. Bull. 206:177-187.

Results are given of laboratory experiments on the accumulation and retention of cesium-137 by various marine fish. The fish used were

post-larval summer flounder (Paralichthys denatatus), Atlantic croaker (Micropogon undulatus), bluefish (Pomatomus saltatrix), and little tuna (Euthynnus alleteratus), and comparison was made between accumulation direct from the water and from ingested doses; it was found that all the fish accumulated cesium readily through both pathways. The concentration of cesium-137 per unit weight in flounder was found to vary inversely with changes in the rate of weight increase, as the rate of accumulation was unrelated to rate of growth. Accumulation of cesium-137 in various tissues was similar for croaker, bluefish and little tuna; cesium was found, in decreasing concentration, in heart, liver, spleen, kidney, gills, gonad, muscle, skin and scales, blood, and bone. Retention was analysed by a method which determined the number of exponential functions involved, the rate of removal per unit time by each function, and the amount of substance at zero time represented by each rate function. Whole-body retention of cesium by flounder was expressed as two rate functions with biological half-lives of 5.3 and 36.9 days. Retention by certain tissues of croaker was expressed as multiple rate functions. These were, skin, three rate functions with half-lives of 6.2, 26.2 and 290 days; muscle, two rate functions with half-lives of 34.8 and 94.7 days; liver, four rate functions with half-lives of 0.7, 4.2, 24.1 and approaching infinite days; and gonad, two rate functions with half-lives of 13.4 and 911 days.

42. Bartoch, A. 1954. Practical methods for control of algae and water weeds. Publ. Hlth. Rep. 69:749-757.

Algae and water weeds are necessary for supporting aquatic fauna and for self-purification of water, but when they are unsightly and odorous, or when they interfere with important uses of water, control is necessary. In the control of algae, growth can be limited by the exclusion of light by inducing turbidity or by adding activated carbon to produce a carbon "black-out", by maintaining a high water level, and by depriving the algae of nutrients such as nitrogen and phosphorus by treating the incoming water. Increased use of phosphorus-bearing detergents emphasizes the need for wider consideration of phosphorus removal. Chemical control of algae was achieved by the addition of algicides, especially copper sulphate. Of the various methods for applying algicides, spraying from boats satisfactorily met the need for rapid and uniform distribution. A diagram is given of suitable apparatus for applying solutions of copper sulphate and a chart is included showing the amount required under varying conditions. The weak points in the use of copper sulphate, such as its toxic effect on fish, its accumulation as a precipitate of copper carbonate especially in highly alkaline waters, and its corrosive effect on equipment emphasize the need for its use by trained technicians only. In the search for other algicides, 2,3-dichloronaphthoquinone shows

promise as a selective algicide for blue green algae, the commonest cause of blooms in lakes. Water weeds can be controlled mechanically by pulling and cutting, and two new machines are mentioned which subsequently remove the plant growth, thereby eliminating odors of decay, killing of fish by oxygen depletion, and accumulation of rotting weeds. Non-mechanical means of control include the addition of a black dye, nigrosine, and the exclusion of light by the introduction of algal blooms. Sodium arsenite remains the cheapest and most efficient means of chemical control, other substances mentioned being expensive and toxic to fish. The amounts of arsenite required to treat different types of natural waters are given.

43. Battani, M., M.D. Chambost, and M. Leandri. 1968. Study of the contamination by iodine-131 and iron-59 of Ciona intestinalis Linn. Proceedings of the Third International Colloquium on Medical Oceanography. Fifth and Sixth Sessions:71-86.

The absorption by Ciona intestinalis of radioactive iodine and iron from contaminated sea water was studied in the laboratory and the results were summarized. Maximal concentrations of iodine and iron occurred in the animals after 6-7 days and 2-3 days, respectively, and biological equilibrium was attained after about 8-10 days. Young animals accumulated relatively more of both isotopes than adults, and accumulation was greatest in the tunic.

44. Batte, E.G., and L.E. Swanson. 1951. Control of fresh water snails (Intermediate hosts of liver flukes) in Florida. J. Amer. Vet. Med. Ass. 118:139-141.

The occurrence in Florida of two species of fresh-water snails which serve as intermediate hosts of liver flukes has been studied in relation to ecological factors and to the control of flukes. Right-handed snails seemed to prefer water with about 60 mg/l chlorides and 21 mg/l calcium and were in greatest abundance in water with a pH value of 7.5 to 8.5. Control of snails may be achieved by proper drainage by application of copper sulphate, or by filling in low areas. Complete drainage is difficult to attain in Florida and the cost of filling land is prohibitive. Copper sulphate applied at the rate of 9 kg per 1,300,000 liters to ponds or wet areas will effectively control the snails and various methods of applying it are briefly described.

45. Baughman, J.L. 1948. Appendix of papers on marine and fresh-water pollution. An annotated bibliography of oysters:613-667.

Brief abstracts are given of papers on pollution of fresh and salt waters which are of interest in the study of marine or aquatic biology.

46. Beasley, R.M. and E.E. Held. 1969. Nickel-63 in marine and terrestrial biota, soil, and sediment. Science 164:1161-1163.

A previously unreported radionuclide, nickel-63 (half-life, 92 years), produced in the testing of nuclear devices, was measured in biological and environmental samples from areas of the Pacific Ocean and the eastern seaboard of the United States. The concentrations of nickel-63 are low (maximum of 163 disintegrations per minute per gram of dry weight), but this radionuclide may be a useful tracer of oceanic processes because of its long-half-life and long residence time in the ocean.

47. Bedrosian, P.H. 1962. Relationship of certain macroscopic marine algae to zinc-65. Dissertation Abstracts 22:3146.

Experiments were conducted on uptake of radioactive zinc-65 from sea water by 3 macroscopic algae--Gracilaria foliifera, Enteromorpha prolifera, and Sphaceleria sp.--under various controlled conditions of light and temperature, with temperatures ranging from 5° to 25°C and light intensities ranging from 1 to 500 foot-candles. Maximum uptake occurred at about 500 foot-candles of light with temperatures of 18°-25°C; the more significant factors affecting uptake appeared to be the ratio of surface area to weight and the number of photosynthetic pigments in the algae. With both Gracilaria and Enteromorpha, uptake appeared to be mainly by absorption rather than adsorption. Approximate maximum concentration factors for these algae ranged from 1200 to 13,000 and were fairly independent of the concentration of zinc-65 in the water.

48. Benoit, R.J., J. Cairns, Jr., and C.W. Reimer. 1967. A limnological reconnaissance of an impoundment receiving heavy metals, with emphasis on diatoms and fish. In: Reservoir Fishery Resources Symposium. Publ. by Southern Div. Amer. Fish. Soc:69-79.

The purpose of this investigation is to determine the cause of the fishkills which were occurring sporadically in the Upper Sacramento River below Keswick Reservoir. An attempt was made in 1955 and 1956 to locate and identify materials in the water that might be causing the kills. The study was divided into four phases: (1) general reconnaissance and biological survey, (2) diatometer (a device

for suspending glass slides below the water surface to furnish a substrate for diatom growth) survey, (3) chemical survey, and (4) toxicity bioassays of certain waters and muds using salmon fingerlings as test organisms. A reconnaissance was made of the area from the Sacramento River just south of Redding, California, upstream to Lake Shasta, including Lakes Redding and Keswick. Twenty-one sampling stations were set up: three below Keswick Dam in Lake Redding and in the Sacramento River below Redding, eleven in Keswick Reservoir, and seven on tributaries flowing into Keswick Reservoir. The results of the biological survey indicated that the upper tributaries of Keswick Lake had a typical variety of flora and fauna but that one of the low tributaries, Spring Creek and its two branches, Slickrock and Boulder Creeks, were severely degraded by acid mine drainage. The degrading influence of Spring Creek could be detected at the low Keswick stations as well as at those in upper Lake Redding. The lower Lake Redding stations and the Sacramento River station downstream had normal biotas. The diatometer survey confirmed these results and added some important details. Diatometer studies during a freshet showed a pulse of increased damage to the diatom flora in lower Keswick Lake and the upper portion of Lake Redding. The chemical survey revealed conditions consistent with the results of the biological and diatometer studies. The waters of Spring Creek were found to have a very low pH and to contain high concentrations of iron, copper, and zinc. The delta muds of Spring Creek in Keswick Lake also contained quantities of these metals, and large quantities of hydrous iron oxides were sedimented in Keswick Lake below the entrance of Spring Creek. The results of the bioassays showed that both Spring Creek water and delta sediments were toxic. Analysis of various flow conditions indicated that at certain times toxic conditions could develop in lower Keswick Lake and upper Lake Redding because of the acid waters and heavy metals discharged from Spring Creek.

49. Berglund, F. and M. Berlin. 1969. Human risk evaluation for various populations in Sweden due to methylmercury in fish. In: Miller, M.W. and G.G. Berg (eds). Chemical Fallout, current research on persistent pesticides. Chas. C. Thomas publisher, Springfield, III:423-432.

Two estimates of "allowable daily intake" (ADI) of methylmercury are presented. One ADI, equivalent to 0.7 Hg/week, was calculated from the linear relationship between intake and erythrocyte levels of mercury among fish-eating individuals in Sweden. The second ADI, equivalent to 0.42 mg Hg/week, equals the estimated equilibrium dose in a subject with a body burden of 60 mg Hg due to methylmercury. It is estimated that such a body burden would be associated with a toxic or near-toxic mercury level in the brain. These ADI's would result in approximate mercury levels in the erythrocytes of 120 and 70 mg/g, respectively, i.e. twelve and seven times as high

as in a Swedish control population. Effects on the fetus or on the mitotic apparatus cannot be excluded at present. Only a small percentage of the Swedish population consumes enough freshwater fish to reach even the lower of the two ADI's proposed.

50. Bernard, F.J. and C.E. Lane. 1961. Absorption and excretion of copper ion during settlement and metamorphosis of the barnacle, Balanus amphitrite nireus. Biol. Bull. 121:438-448.

Concentration of copper in the gulf stream (normal sea H_2O) is 0.005 mg/kg. Excess Cu in sea H_2O during the cyprid-form developmental stages interferes with normal respiratory exchange. The barnacle absorbs Cu from the medium through permeable surfaces and eliminates excess Cu by excretion through the epithelia of the hindgut. Reservoirs of Cu storage have been identified. A metabolic role is suggested for Cu in normal physiology of barnacle settling stages.

51. Bernard, F.J. and C.E. Lane. 1963. Effects of copper ion in oxygen uptake to planktonic cyprids of the barnacle, Balanus amphitrite nireus. Proc. Soc. Exp. Biol. and Med. 113:418-420.

Toxicity of Cu was due to interrelated metabolic responses some of which were stimulated, while others were depressed. Cyprids adapted to each Cu concentration by adjusting their metabolism to a level such that no more Cu could be taken in than excreted. The increased O_2 uptake in sublethal Cu concentrations probably reflects increased motor activity.

52. Bernhard, M. 1965. Studies on the radioactive contamination of the sea. Annual Report, 1964. Laboratorio per lo Studio della Contaminazione Radioattiva del Mare: 36 p. Nuclear Science Abstracts, 1966. 20, No. 16725.

Factors influencing the uptake, accumulation and loss of radioisotopes, including lead, by marine organisms were studied.

53. Bernhard, M. 1968. Research on the metabolism of some radioactive elements in the marine environment. Proceedings of the third International Colloquim on medical oceanography. Fifth and Sixth Sessions:11-59.

In a review of studies on ionic regulation in marine fish, invertebrates, and algae, with a bibliography of 73 references, par-

ticular attention was paid to the accumulation of cesium, strontium, zinc, and ruthenium, which have radio-isotopes harmful to man. The concentrations of these elements and the physical forms in which they occur in sea water were considered in relation to their uptake and release by marine organisms.

54. Bernhard, M. and A. Zattera. 1969. A comparison between the uptake of radioactive and stable zinc by a marine unicellular alga. Proc. 2nd Nat. Symp. on Radioecology. Ann Arbor, Mich. 1967:389-398.

The uptake of ^{65}Zn and stable zinc by a marine unicellular alga (Phaeodactylum triconutum) and by a chelating resin (Chelex-100) was studied during a certain time interval in batch cultures.

In all experiments the distribution pattern of ^{65}Zn and stable zinc between the particulate matter (algae or chelating resin) and the natural and artificial seawater medium was different.

When the ^{65}Zn was added as ionic zinc, proportionately much more radioactive zinc was taken up than stable zinc. Adding the ^{65}Zn as Zn-EDTA-complex, however, to a batch containing seawater and Chelex the stable zinc was initially taken up at a higher rate than was ^{65}Zn. These preliminary results do not explain the difference in the distribution of radioactive and stable zinc, but the data do show that the uptake rate of the stable isotope does not necessarily follow the uptake rate of the radioactive isotope if the two are present in different physical-chemical states.

This possibility must be taken into account in tracer studies and in predictions of the distribution of radioisotopes in the environment based on the specific isotope content approach.

55. Bidstrup, P.L. 1964. Toxicity of mercury and its compounds. Elsevier Publishing Company, New York:112 p.

Following absorption by humans, mercury mercaptide is formed; variation in distribution and effect are dependent on this reaction. It is postulated the ultimate effect of mercury and its coupounds is due to enzyme inhibition. Enzymes affected or the extent of involvement is not known. Thiols are present in blood (to form Hg mercaptide) and mercury is thus transported rapidly in the blood stream. Mercury exists transiently (metallic form) in blood lipoids and is transported in this form to sensitive tissues, e.g. brain. Localization in particular tissues does not necessarily give rise to pathological changes.

56. Bijan, H., and R. Deschiens. 1956. Effect of barium salts on the mollusc vectors of schistosomiasis. Bull. Soc. Pat. Exot. 49:455-458; Biol. Abstr. 31:3518.

Aquaria tests showed that barium chloride in a concentration of 14.2 mg/l killed the snail Bulinus contortus; concentrations of 11.1 mg/l were fatal to the snail Planorbis glabratus, 200 mg/l killed goldfish, and 10 mg/l killed the aquatic plant Elodea canadensis. Both species of snails were killed by 20 mg/l barium nitrate with 200 mg/l fatal to goldfish, and 10 mg/l lethal to Elodea.

57. Binet, L. and P. Nicolle. 1940. Influence of the salinity of the ambient medium on the toxicity of mercuric chloride for the stickleback. C.R. Soc. Biol. Paris 134:562.

The influence of salt in the surrounding medium on the toxicity of mercuric chloride to the stickleback was studied. Fish survived for an average time of 106 min. at 18°C in water containing 10 mg/l mercuric chloride. When 0.1 per cent sodium chloride was added, the period of survival dropped to a minimum of 54 min. but rose to 105 min. when the content of salt was increased to 0.7 per cent; with a concentration of 1.5 per cent, the period of survival reached 190 min. but with higher concentrations it again decreased, being 131 min. with 2.5 per cent, and 84 min. with 3 per cent sodium chloride.

58. Bioko, Z.F. 1965. Changes of the functional state of isolated nerve caused by lead 1. Izvestiia Akademii Nauk SSSR; Seriia Biologicheskaia (Moscow) 3(6):96-102.

When a neuromuscular preparation of isolated frog sciatic nerve was reacted with a 1% solution of lead (Pb) nitrate, a typical parabiosis with 3-phase changes of excitability developed. During parabiosis, chronaxia and accomodation were first decreased and then elevated while lability was first increased and then decreased. Treatment with a solution containing potassium chloride and acetylcholine resulted in some functional restoration.

59. Bishai, H.M. 1961. The effect of salinity on the survival and distribution of larval and young fish. J. du Conseil 26: 166-179.

Newly hatched herring larvae (Clupea harengus) can live at salinities as low as 2.50 o/oo. They live better and longer in salinities from 10-15 o/oo than in higher or lower salinities.

Lump-sucker larvae (Cyclopterus lumpus) can live for at least 14 days at 9 o/oo but less than 5 o/oo is fatal in 24 hours. Acclimation to low salinities although causing an increase in resistance time, does not seem to affect the lower lethal limit of salinity (i.e. 6 o/oo).

Young plaice (Pleuronectes platessa) 38-50 mm in length can live at 5 o/oo for at least 10 days. Lower salinities can be tolerated for a few days. Even fresh water has no ill-effects on the fish for about 20 hours.

Salmonid alevins can live for at least 10 weeks at 25 o/oo. At 30 o/oo, salmon (Salmo salar) are more tolerant than brown (S. trutta) and sea trout (S. trutta fario) and brown is more tolerant than sea trout. At 40 o/oo salmon live for 18 days, brown trout 11 days, and trout for 9 days. At 50 o/oo alevins of the three live for about a week.

The resistance of the salmonoids to salinity changes seems not to change while the yolk-sac is not completely absorbed.

60. Blaska, J. 1941. The influence of copper, zinc, and iron on the survival of small organisms in water. Zverolik. Obz. 34:243. Biol. Abstr. 22:506.

In an investigation of the effect on small aquatic animals of water containing copper, zinc, or iron compounds it was shown that Daphnia magna and D. pulex were most sensitive and that Cyclops strenuus, C. insignis, and Chironomus plumosus were more resistant.

61. Blaustein, M.P. and A.L. Hodgkin. 1969. The effect of cyanide on the efflux of calcium from squid axons. J. Physiol. Lond. 200:497-527.

The paper deals with the effect of cyanide and external ions on the efflux of calcium from axons. Cyanide had little immediate effect on calcium efflux, but after 1½ h the efflux rose from 5 to 15 times its normal value. The effect was rapidly reversed when cyanide was removed. The extra efflux in cyanide seemed to be largely an exchange for external calcium and sodium since it was abolished by replacing Ca with Mg and Na with Li. Removal of Ca reduced the Ca efflux in cyanide to 1/3 and subsequent removal of Na reduced it to between 1/10 and 1/20.

A possible explanation of the cyanide effect is that calcium ions are released from a store and can then exchange with Ca and Na in the external medium. Evidence of an increase in free calcium was

that pretreatment with cyanide greatly increased the rate at which ^{45}Ca could be dialysed from axoplasm.

The experiments provide evidence for coupling between Na influx and Ca efflux and suggest that downhill movement of Na may give some of the energy for extruding Ca.

62. Bodansky, M. 1920. Biochemical studies on marine organisms. II. The occurence of zinc. J. Biolog. Chem. 44:399-407.

Zinc was found and quantitatively determined in 20 species of marine animals. The constancy of occurence indicated it is a normal constituent of the tissues of these forms. In the oyster zinc is distributed uniformly in digestive organ, mantle and gills. Muscle contained less Zn that other tissues. In 14 species of fish Zn varied between 2.5 mg/kg in mullet and 149.1 mg/kg in catfish.

63. Boëtius, J. 1960. Lethal action of mercuric chloride and phenylmercuric acetate on fishes. Medd. Komm. Havundersog., Kbh. 3(N.S.) (4):93-115.

In Denmark various mercury preparations are used as fungicides for the treatment of grain and beet seeds, and indiscriminate use of these preparations has caused some instances of fish mortality. Experiments have therefore been carried out on the effect of mercuric chloride and phenylmercuric acetate on fish, using as test organisms Tilapia, Eupomotis, Ambloplites, Lebistes, Salmo and Gasterosteus. From the relation between concentration of the poison and period of survival it appears that mercuric chloride is theoretically infinitely toxic. Its toxicity is related to both the temperature and the weight of the fish. Similar effects were obtained with phenylmercuric acetate. In sea water the toxicity of mercuric chloride gradually decreases while the toxicity of phenylmercuric acetate increases. Of the species examined Salmo and Gasterosteus seemed to be most sensitive to mercuric chloride and Salmo was most sensitive to phenylmercuric acetate.

64. Bombowna, M. and S. Wrobel. 1968. The chemical composition of the Wislow in the region of Krosno and its pollution with heavy metals (Cu, Cr, Ni). Acta Hydrobiologia. 10:439-452.

The report describes the pollution of the water in the Polish river Wislow in the region of Krosno with heavy metals (Cu, Cr, Ni) and cyanides in relation to the chemical composition of the water.

Results of hydrochemical and hydrobiological investigations showed that high concentrations of heavy metals and cyanides transformed the river into desert, and low concentrations affected most unfavorably the communities involved in self-purification.

65. Borght, O.V. 1963. Accumulation of radium-226 by the freshwater gastropod Lymnaea stagnalis L. Nature 197:612-613.

The author summarizes results of investigations on the possible use of the snail, Lymnaea stagnalis, as an indicator of radioactive contamination of the environment. When the animals were exposed for 24 hours to solutions containing 0.04 μc radium-226 per ml of tap water, 70±8 percent of the radium was removed from solution. After 7 days when some of the animals were killed and their radium content determined, they contained more than 90 percent of the radium originally in solution; the radium, like calcium and strontium, was found to accumulate mainly in the shell border. The concentration of radium-226 in the samples was determined by measuring the concentration of bismuth-214, which is equivalent to the concentration of radium produced after an equilibration period of 3 weeks in hermetically-sealed flasks; the bismuth-214 was determined using a well crystal with a single channel pulse-height analyser on the α-peak of 609 keV. Additional tests confirmed that the absorbed radium-226 was firmly fixed; this fact and the high concentration factor in the shells make the snail a good potential indicator for contamination by radium-226. Similar results were obtained for accumulation of calcium-45 and strontium-85 in L. stagnalis.

66. Borght, O.V.D., and S.V. Puynbroeck. 1967. Ionic regulation and radio contamination: "active transport" of alkaline earth ions in fresh water gastropods (Mollusca). Proc. Int. Symp. Radioecol. Concent. Process, 1966, Stockholm: 925-930.

The importance of ionic regulation in the contamination of aquatic organisms by radioactivity is stressed; and studies are reported, with graphic and diagrammatical results, on the exchange of alkaline earth ions between water and the freshwater snail Lymnaea stagnalis, which is used as a biological indicator of radioactive contamination. The snails were kept in tap water containing 20-40 mg/l calcium. Based on measurements of the calcium remaining in the solution, the rates of absorption of calcium by the animals, between the 5th and 10th hour of exposure, were 28, 24, and 19 μg of calcium per hour per animal, for calcium concentrations of about 70, 35, and 17 mg/l, respectively. The distribution of calcium-45 in the snails after exposure for 66 hours is shown diagrammatically; most of the calcium was in the border of the shell. In the blood the concentration

of calcium reached 150-200 mg/l; absorption of calcium ions occurs against an electrochemical gradient but measurements made to determine the role of the potential difference between the animal and the water (across the epithelium) showed that this would maintain an internal concentration of only about 30 mg/l. At all test temperatures (30°, 15°, and 6°C), calcium-45 and strontium-85 were absorbed by the animals but the rate of absorption was slower for strontium. The absorption of calcium was increased 1.4 times per 10°C increase in temperature between 6° and 16° C and 3 times per 10°C increase in temperature between 16° and 30°C, suggesting the more accentuated role of the metabolism in the absorption of calcium at higher temperatures.

67. Boroughs, H., S.J. Townsley, and R.W. Hiatt. 1956. The metabolism of radionuclides by marine organisms. I. The uptake, accumulation, and loss of strontium-89 by fishes. Biol. Bull. 111:336-351.

The authors describe experiments which were made to measure the uptake, accumulation, and loss of radio-strontium by the various tissues and organs of selected species of fish when the isotope is given orally, by intramuscular injection, and by the immersion of the fish in sea water enriched with strontium-89. Three types of fish were used; large pelagic fast-swimming carnivores, such as the tuna, Neothunnus macropterus; small carnivores common along reef and shore in the Hawaiian islands, such as Kuhlia sandvicensis; and Tilapia mossambica, a small sluggish herbivore. In the first experiment capsules containing strontium-89 were given orally to the pelagic fish, which were then kept for times varying from 1 hour to 27 days before being killed, and the various tissues and organs separated, cooked, dried and tested for radioactivity. It was found that excretion of most of the isotope occurs in a few hours. The small percentage remaining after one day persisted for the 27 days of the experiment. The retained strontium-89 was found mostly in the skeleton, and in descending order, in the gills, integument, muscle and viscera. Dark muscle, which has a better blood supply than light muscle, retains less strontium-89, and similarly bone retains less than the cartilaginous gill arches. In a second experiment capsules containing strontium-89 were fed to Tilapia, and in this case the rate of excretion was much slower, 50 per cent of the strontium still being retained after one day, and a relatively higher constant level being reached after about 4 days. Most of the radioactivity was found to be retained in the structural tissues. Similar experiments were carried out on Kuhlia sandvicensis, giving much the same results as for Tilapia. Experiments were then carried out in which the tuna fish and Tilapia were given an intramuscular injection of strontium-89. About three times as much strontium was found in the muscles of injected tuna as compared with fish which received the isotope orally, and the gills of injected tuna had only half the activity found in

orally-fed tuna. From 60-70 per cent of the dose injected into Tilapia muscle was retained by the fish for 14 days. In a final experiment numbers of Tilapia were put into sea water enriched with 1744 μc of strontium-89 per 20/1. After three weeks the fish had concentrated strontium from the water so that the ratio of strontium-89 in the fish to the strontium-89 in equal weight of sea water was 0.3. Relatively more radioactivity was found in the visceral organs, the remaining rank order of retention of radioactivity in the various tissues (skeleton, integument, gills and muscle) being the same as was observed after oral administration of strontium-89.

68. Boroughs, H., S.J. Townsley, and R.W. Hiatt. 1956. The metabolism of radionuclides by marine organisms. II. The uptake, accumulation, and loss of yttrium-91 by marine fish, and the importance of short lived radionuclides in the sea. Biol. Bull. 111:352-357.

The authors describe experiments made to measure the uptake, accumulation, and loss of yttrium-91 by the tissues and organs of Tilapia mossambica. Capsules containing 5.5 μc of yttrium-91 were extruded into the fish's stomach, and similar experimental procedure was carried out as in previous experiments (see preceding abstract). It was found that the rate of loss of yttrium-91 was very high, only 2 per cent of the dose being retained after 2 days. Of this amount about 40 per cent was retained in the visceral organs, the remainder in the muscles, skeleton, integument and gills in descending order. The authors point out that yttrium-91 may have little direct effect on man compared with the possible effects of strontium-90, but the retention of this and other short-lived fission products in marine organisms having a brief life span may possibly affect the biota, and thus affect man indirectly.

69. Boroughs, H., S.J. Townsley, and R.W. Hiatt. 1957. The metabolism of radionuclides by marine organisms. III. The uptake of calcium-45 in solution by marine fish. Limnol. Oceanogr. 2:28-32.

To determine whether marine fish require calcium in their diet, or whether they can take up an adequate amount from sea water non-feeding fish, (Tilapia mossambica) were put in artificial sea water containing calcium-45. The uptake was rapid at first, and then continued at a slow rate for the duration of the experiment (21 days). During this period the fish as a whole took up about 60 per cent of the calcium-45 in the water. Most of the radioactivity was recovered in the skeleton and integument, but the values obtained did not correspond to the elemental analysis of various fish for calcium. Apparently only a few per cent of the body calcium is

readily exchangeable. It is concluded that marine fish can take up calcium directly from sea water, and do not need a dietary source of this element. In comparison with a similar experiment using radioactive strontium it is concluded that marine fish discriminate against strontium in favour of calcium, either by excreting it faster or by absorbing it less.

70. Boschetti, M.M., and T.E. McLoughlin. 1957. Toxicity of sodium arsenite to minnows. Sanitalk 5 (4):14-18.

The authors describe experiments to determine the median tolerance limits of the minnow, Notropis hudsonius, to sodium arsenite. Median tolerance limits, under laboratory conditions, were 45 mg/l arsenic for 24 hours, 29 mg/l for 48 hours and 27 mg/l for 72 hours. Fish not killed after 72 hours in concentrations of 30-35 mg/l arsenic showed damage to fins and scales, diarrhea, heavy breathing and haemorrhage around the fin areas. Lower concentrations of arsenic had a corrosive effect on fin and tail tissues after 96 hours, but in some cases regeneration of the tissues occurred when the fish were transferred to arsenic-free water. No mortality occurred in concentrations of 15 ppm arsenic, which is the highest concentration used for control of water weeds.

71. Bougis, P. 1965. Effect of copper on growth of the pluteus of the sea urchin (Paracentrotus lividus). C.r. hebd. Séanc. Acad. Sci., Paris 260:2929-2931.

Experiments on the effect of adding copper to sea water have shown that a concentration of 10-20 µg/l retards the body growth of the pluteal larvae of the sea urchin. At these low doses, however, the growth of the arms is not affected and their regression is even retarded, prolonging the endotrophic phase. A concentration of 30 µg/l of copper affects the growth of the arms, and a concentration of 50 µg/l is lethal.

72. Boyce, R. and W.A. Herdman. 1897. On a green leucocytosis in oysters associated with the presence of copper in the leucocytes. Proc. Roy. Soc. London 62:30-38.

The disease was marked by presence of green granules in the amoebocytes. There were patches and streaks of green on the mantle and other parts of the integument, engagement of blood vessels, and masses of green colored leucocytes in the heart.

73. Brown, D.J. 1967. Migration characteristics of radionuclides

through sediments underlying the Hanford reservation. Int. Atom. Ener. Ag., Proc. Ser., Pap. No. SM-93/16, STI/OUB/156:215-228.

For more than 20 years large volumes of intermediate- and low-level radioactive waste waters have been discharged to the ground at Hanford, Wash. Author discusses the migration characteristics and spatial distribution of radionuclides in the underlying sediments, both in the zone above the water table and in the unconfined ground-water zone. All radionuclides with half-lives of less than 1 year, decay to below detection limits before they reach the water table, with the exception of ruthenium-103 and strontium-89 which can be detected for a maximal distance of about 1 km after entering the ground water. Nearly all the longer-lived isotopes are sorbed on sediments and retained in the first 10 m of the 60-m column of partially-saturated sediment, where they are fixed with relatively permanency; the trace amounts which are leached from the sediments are re-adsorbed in the saturated zone below the water table and, with the exception of tritium, technetium-99 and ruthenium-106 (which have poor sorption properties), all nuclides have reached concentrations below the limits of detection within 1 km of the disposal site. Tritium, technetium-99 and ruthenium-106 enter the ground water at about the same concentrations as those in the original waste waters and move at about the same rate as the ground water, being detected for distances of up to 24 km; however, at distances of 4 km from the disposal site, the concentrations of all 3 isotopes are below the established limits for drinking water, and there is no subsequent hazard to the Columbia river water.

74. Brown, J.H., and M.E. Bowles. 1965. Effect of enzymatic functional group inhibitors of the esterases of Crotalus atrox venom. U.S. Army Medical Research Laboratory, Fort Knox, Ky. Report No. 627:11 p.

The effects of several enzymatic inhibitors have been measured on the phosphodiesterase, phosphormonoesterase and esterase activities of Crotalus atrox venom (rattlesnake). Divalent lead ions (Pb acetate at 1000 and 2000 mg/l) activated phosphodiesterase had but little effect on phosphomonoesterase and esterase.

75. Brown, V.M. 1962. The accumulation of strontium-90 and yttrium-90 from a continuously flowing natural water by eggs and alevins of the Atlantic salmon and the sea trout. U.K. Atom. Ener. PG-Rep. 288:16 p.

Experiments were carried out on the uptake of strontium-90 and yttrium-90 from water by eggs and young of salmon and trout. At

equilibrium, the eggs were 4 times more radioactive than the water, most of the activity being associated with the protective egg membranes. Newly-hatched fish were about twice as radioactive as the water, but rapidly accumulated the two isotopes with growth. The presence of the isotopes in the water did not cause any significant increase in egg mortality.

76. Brown, V.M. 1968. The calculation of the acute toxicity of mixtures of poisons to rainbow trout. Water Research 2: 723-733.

Concentrations of Zn^{2+} and Cu^{2+} fatal to 50% of trout in 48 hours were 0.62 and 0.12 mg/l, respectively. Water hardness affects 48 h LC-50 of Zn (about 7 mg/l at 35 o/oo salinity vs 0.3 at 0.2 o/oo).

48 h LC-50 values obtained for zinc, and other substances on a stock of rainbow trout over a period of 9 months, varied by a factor of 2.5. The causes of this variation have not yet been identified.

77. Brown, V.M., and R.A. Dalton. 1970. The acute lethal toxicity to rainbow trout of mixtures of copper, phenol, zinc and nickel. J. Fish. Biol. 2:211-216.

The acute lethal toxicities to rainbow trout, Salmo gairdneri Richardson, of mixtures of copper and phenol, of copper, zinc and phenol, and of copper, zinc and nickel, over an exposure period of 48 h were determined. The concentrations selected for testing were such that each poison theoretically contributed equally to the toxicity of the mixture. It was found that the toxicities of these mixtures could be adequately predicted by summation of the fractional toxicities of the particular poisons which were present.

78. Brown, V.M., V.V. Mitrovic, and G.T.C. Stark. 1968. Effects of chronic exposure to zinc on toxicity of a mixture of detergent and zinc. Water Research 2:255-263.

The acute toxicity of soft alkylbenzenesulphonate to rainbow trout chronically exposed for 100 days to a "background" level of zinc of 0.8 mg/l was compared with its toxicity to control fish. It was found that fish acclimated to zinc did not acquire resistance to zinc poisoning when in the presence of detergent but responded to both poisons in the mixture, the poisons being additive in their toxicity. The zinc-exposed fish were more sensitive to the mixed poisons than the control fish but were not more sensitive than the controls when

exposed to detergent alone. Greater histological damage was caused to gill tissue by the mixture of zinc and detergent than by the same concentration of detergent alone and separate effects were observed for the two poisons at low concentrations. At high concentrations the damage caused by the detergents masked the effects of zinc.

79. Brungs, W.A. 1963. The relative distribution of multiple radio-nuclides in a freshwater pond. Thesis. Ohio State University, Columbus, Ohio:97 p.

Results are given of experiments on the distribution of radioactive isotopes in a plastic-lined pond filled with spring water and sand. The organisms introduced into the pond were carp (Cyprinus carpio), bluegills (Lepomis macrochirus), snails (Vivipara malleatus), bullfrog tadpoles (Rana catesbiana), and two species of clams, the thin-shelled Anodonta grandis and the thick-shelled Lampsilis radiata siloquoidea. Several weeks after the organisms were introduced, 4 mc each of cobalt-60, zinc-65, strontium-85, and caesium-137 were added to the water, and samples were collected for analysis over a period of 80 days. There was an initial rapid loss of cobalt-60, zinc-65 and caesium-137 from solution, the cobalt and zinc becomming associated with the suspended solids and the caesium being adsorbed on to the bottom sediments. Strontium-85 was removed gradually from solution. After 4 days, the water contained 8 per cent of the added cobalt-60, 4 per cent of the zinc-65, 5 per cent of the caesium-137, and 64 per cent of the strontium-85. More zinc-65 was found in biological samples than any of the other nuclides, except in some hard parts such as shell and bone where more strontium-85 was found. The primary consumers, carp, snails, tadpoles and clams, accumulated more of each nuclide than did the predatory bluegill. In general, soft parts rapidly accumulated more activity than did the hard parts, but gradually lost it as the concentrations of nuclides in the water decreased. Clam and snail shells and fish bone generally accumulated zinc-65 and strontium-85 for almost the whole duration of the experiment; young snails and clams accumulated more of these isotopes than did adults. After the final sampling from the pond, the remaining carp, snails and clams were placed in continuously renewed, uncontaminated water for 3 weeks, but no detectable loss of radioactive nuclides was observed. However, during the period the temperature of the water was low, about 15°C less than during the experiment, and the metabolic activity of the organisms was greatly reduced, so that any loss of radionuclides would be inhibited.

80. Brungs, W.A. 1965. Experimental uptake of strontium-85 by freshwater organisms. Health Physics 11:41-46.

Factorial experiments were conducted to determine the effects

of various concentrations of calcium, magnesium, sodium, and potassium on the uptake of strontium-85 by small bluegills (Lepomis macrochirus). Within the experimental range, only calcium was found to have any significant effect. After 80 days only 25 per cent of the strontium-85 remained in solution. The total calculated amount of activity in the experimental animals never exceeded 0-5 per cent of the amount added, and the remainder of the activity was associated with the bottom deposits. The results also indicated that the accumulation of strontium-85 by the test organisms was related to their age.

81. Brungs, W.A. 1969. Chronic toxicity of zinc to the fathead minnow, Pimephales promelas Rafinesque. Trans. Amer. Fish. Soc. 98:272-279.

A continuous-flow bioassay was conducted for 10 months to determine the chronic effect of zinc on fathead minnows (Pimephales promelas Rafinesque). Fish production, as based on survival, growth, and reproduction, was investigated. Reproduction by the test fish was almost totally inhibited at zinc concentrations that had no effect on survival, growth, or maturation of these same fish. At these same concentrations there was also no effect on survival of control eggs and fry. The number of eggs per female in the low zinc concentration (0.18 mg/l) was only 17 percent of the eggs produced in the control (0.03 mg/l of zinc). Application factors based on these data and the 96-hour median tolerance limit (9.2 mg/l) are discussed.

82. Bryan, G.W. 1961. The accumulation of radioactive caesium in crabs. J. Mar. Biol. Assn. U.K. 41:551-575.

The uptake of radioactive caesium-134 and potassium-40 from artificial sea water by different species of crabs was investigated. In all cases caesium was taken up more slowly than potassium, but at equilibrium a high concentration factor was attained for caesium. In Carcinus maenas the uptake of radioactive caesium was not affected by feeding on inactive food over a period of 1000 hours. The ratio between the rates of uptake of the two isotopes was not the same in the different species, and it is therefore concluded that it is not possible to predict accurately the rates of uptake of caesium-134 in other species of crabs from the results of short experiments with potassium-42. Loss of both isotopes from whole Carcinus was a slower process than uptake. Accumulation of isotopes took place through the body surface of unfed animals, but uptake of radioactive caesium from food is very rapid and complete.

83. Bryan, G.W. 1963. The accumulation of radioactive caesium by marine invertebrates. J. Mar. Biol. Assn. U.K. 43:519-539.

Studies were conducted on the accumulation of caesium-137 from sea water by species from the principal marine invertebrate phyla (viz protozoa, coelenterata, annelida, mollusca, arthropoda (crustacea), echinodermata, tunicata). Uptake of caesium-137 was compared with uptake of potassium-42 and with the distribution of inactive potassium. Caesium-137 is always absorbed more slowly than potassium-42 from sea water, but at equilibrium concentration factors for caesium-137 usually exceeded those for potassium-42 or inactive potassium. Caesium-137 is rapidly taken up by body fluids, but more slowly by tissues. In the case of potassium-42 and inactive potassium the difference is not so marked. The author suggests that there is a relationship between the final distribution in the body of caesium-137 and of inactive potassium.

84. Bryan, G.W. 1963. The accumulation of ^{137}Cs by brackish water invertebrates and its relation to the regulation of potassium and sodium. J. Mar. Biol. Assn. U.K. 43:541-565.

Studies were conducted of the relation between the ability of brackish-water invertebrates to regulate sodium and potassium and the accumulation of caesium-137. Sphaeroma hookeri, an isopod crustacean, and Potamopyrgus jenkinsi, a gastropod mollusc, were acclimated to a range of sea-water dilutions. In both species sodium and potassium fell with increasing dilution to a lower level which was still higher than that of the medium. In dilute sea water both conserve potassium rather than sodium; caesium-137 behaves more like potassium than sodium. Uptake of potassium-42 and caesium-137 was investigated in a range of sea-water dilutions. Potassium-42 is exchanged for inactive potassium more rapidly in higher sea-water concentrations; the author suggests that this may be due to an exchange diffusion component which increases with the salinity of the medium. Caesium-137 is accumulated to concentration factors approximately double those of inactive potassium over a sea-water concentration range of 2.5-100 per cent. Brackish-water species are, therefore, potentially a greater hazard than marine species since they accumulate caesium-137 to high levels in dilute media.

85. Bryan, G.W. 1964. Zinc regulation in the lobster Homarus americanus. I. Tissue zinc and copper concentrations. J. Mar. Biol. Assn. U.K. 44:549-563.

Concentrations of Zn have been determined in the tissues of normal lobsters from sea water containing about 5 μg/l of Zn. The blood usually contains about 6 μg/g of Zn, mostly in the serum, while the soft tissues contain between 10 and 50 μg/g. Long exposure to sea water containing 100 μg/l of Zn fails to alter the Zn concentrations of the blood, muscle and gonads, but increases the levels

in the urine, excretory organs, hepatopancreas and gills. This result suggests that extra Zn is absorbed from high Zn sea water, possibly via the gills, and that two methods by which this is removed from circulation are by urinary excretion and absorption by the hepatopancreas.

Changes in the blood Zn concentration produced by injection are rectified quite rapidly in the same way. Injections failed to change the Zn concentrations of muscle and gonads.

Further experiments showed that Zn can be absorbed rapidly from the stomach and reaches the blood partly at least via the hepatopancreas. Again, this extra Zn is removed from the blood by urinary excretion and by absorption in the hepatopancreas. Eventual removal of Zn in the hepatopancreas probably takes place via the blood and excretory organs rather than via the gut. The role of the gills and gut in the regulation of the body Zn content has not yet been studied.

86. Bryan, G.W. 1965. Ionic regulation in the squat lobster Galathea squamifera with special reference to the relationship between potassium metabolism and the accumulation of radioactive caesium. J. Mar. Biol. Assn. U.K. 45:97-113.

Studies on the ability of decapod crustacea to accumulate radioactive caesium were conducted with the squat lobster Galathea squamifera. This animal was shown to regulate the concentration of potassium in its plasma when in dilute sea water and in artificial sea water with reduced potassium content. In the presence of potassium-42 a rapid exchange takes place with inactive potassium in the plasma. Absorption of radioactive caesium is slower, but a higher concentration factor is eventually attained for the whole animal. Similar tissue/plasma ratios for radioactive caesium and potassium were found in the case of muscles, but for all other tissues the ratio for ceasium was much higher. The concentration in the tissues is the limiting factor for the uptake of both isotopes. Accumulation of radioactive caesium is unaffected by the concentration of inactive caesium in the sea water, but a low potassium content increases the concentration factor for both caesium and potassium. Absorption and loss of potassium and caesium take place mainly across the body surface; urinary excretion of both isotopes was found to be negligible.

87. Bryan, G.W. 1969. The absorption of zinc and other metals by the brown seaweed Laminaria digitata. J. Mar. Biol. Assn. U.K. 49:225-243.

The absorption of zinc and zinc-65 from filtered sea water by Laminaria digitata was studied in the laboratory, and it was found

that there was a linear relation between the amount of zinc absorbed and the zinc concentration in the water, although relatively more zinc-65 was absorbed from low than from high concentrations. Rapidly growing portions of the seaweed absorbed about 1½ times more zinc-65 per unit area than slow-growing portions, although higher zinc-65 concentrations were achieved by the slow-growing parts because of their lower superficial weight. Added manganese, cadmium, and copper reduced or stopped the uptake of zinc-65; except for copper added at high concentrations, which partially killed the tissues, the effect was largely reversible. Analyses of trace metal concentrations in the seaweed and in sea water from coastal areas of Cornwall and Devon are given.

88. Bryan, G.W. and E. Ward. 1965. The absorption and loss of radioactive and non-radioactive manganese by the lobster, Homarus vulgaris. J. Mar. Biol. Assn. U.K. 45:65-95.

A study of the uptake and release of manganese by lobsters has shown that 500-g animals absorb about 0.4 μg of manganese per day from sea water containing the normal concentration of 2 μg per liter. Losses of manganese from such lobsters are estimated to be about 25 μg per day, the balance being obtained by absorption from food. The average concentration of manganese in the muscles is less than 1 μg per g, and this figure was not altered appreciably when starved lobsters were held in sea water containing 100 and 1000 μg of manganese per liter. The injection of 10 μg of manganese into the stomach resulted in a small, temporary increase in the muscle concentration. Experiments using radioactive manganese confirmed that the rate of absorption by the muscles is very low and is not affected by loading with inactive manganese.

89. Bugelski, Y.Y. 1957. Some peculiarities in the movement of zinc, lead, and copper in the ground waters of the polymetallic deposits of Central Kazakhtan. Geochemistry, Moscow 1957:84-90.

Samples of ground water from the neighbourhood of five main deposits of metals were analysed. Zinc was found to travel furthest in the water, copper the next, and lead the least distance. The movement of these metals in the rain-poor district depends on the structure of rocks and the pH value of the water.

90. Burdick, G.E., and M. Lipschuetz. 1948. Toxicity of ferro- and ferricyanide solutions to fish, and determination of the cause of mortality. Trans. Amer. Fish. Soc. 78:192-202.

Fish were killed in 20 km stretch of a stream into which were discharged trade waste waters containing ferro- and ferricyanide at concentrations considerably less than those generally accepted as non-lethal. An investigation was made to determine the cause of mortality and to establish the lethal concentration of these compounds in natural waters. When solutions of potassium ferro- and ferricyanide are exposed to light, particularly in the presence of oxygen, the complex molecules decompose with formation of cyanide or hydrocyanic acid. In laboratory experiments various concentrations of ferro- and ferricyanide in tap water were exposed to sunlight, diffuse light, and darkness, and the solutions were tested periodically to determine the maximum content of residual cyanide which occurred. Results indicated that when equivalent concentrations of the two compounds were exposed simultaneously to sunlight, the maximum concentration of residual cyanide developed in approximately the same period for the two compounds. In solutions of equal concentration exposed to similar light conditions a slightly higher residual content of cyanide occurred at lower temperatures. A higher residual content of cyanide developed in solutions containing 2.3 mg/l ferrocyanide than developed in 2.3 mg/l ferricyanide solutions but in solutions containing 1 mg/l a higher residual concentration was attained with ferricyanide solution. Low concentrations of potassium ferrocyanide did not decompose in the dark or in diffuse light at a rate sufficiently high to produce concentrations of cyanide that would be toxic to fish. Solutions, containing 4,000 mg/l ferrocyanide, on exposure to diffuse light, gave a cyanide content of 0.3 mg/l and were toxic to fish within 24 hours. Factors, other than light, which may have affected the results are discussed, including the effects of the type of vessel used and type of water (distilled water, tap water, water in which fish had been reared, and water buffered with bicarbonate). It has been shown that the presence of 0.19 mg/l cyanide is toxic to Rhinichthys atratulus and Semotilus atromaculatus, killing all the fish within 76 hours. Although 1 mg/l either ferro- or ferricyanide produces a content of cyanide greater than 0.19 mg/l it is thought that under natural conditions some cyanide would be released into the atmosphere and some would recombine in the dark or be lost through secondary action. The presence of approximately 0.3 mg/l cyanide causes 50% mortality to these species in 5¼-7½ hours. As an exposure period of this length could occur during daylight on any day, the occurrence of 0.3 mg/l cyanide was chosen as the toxic concentration of ferro- and ferricyanides. On this basis, it appeared that toxic concentrations of cyanide would occur when 1.45 mg/l ferrocyanide or 1.34 mg/l ferricyanide was present.

91. Cabejszek, I. and M. Stasiak. 1960. Investigations on the influence of some metals on aquatic life, using the Daphnia magna index. Roczn. Zakl. Hig., Warsz. 11:303-312.

Experiments are described on the toxicity of metal compounds frequently present in industrial waste water, using Daphnia magna as the test organisms. Metals tested included chromium, manganese,

iron, cobalt, nickel, and copper. The order of the metals according to toxicity was found to be: copper, chromium, cobalt, nickel, manganese. The toxic action was slow and increased with time; a definite increase was evident after 48 hours. The sulphates of the metals were less toxic than the chlorides. Iron reduces the pH value of the medium.

92. Cabejszek, I. and M. Stasiak. 1960. Investigations on the toxicity of some metals in water using Daphnia magna as indicator. Roczn. Zakl. Hig., Warsz. 11:533-540.

Using Daphnia magna as an index, the toxic action of various metals in water was investigated. The order of toxicity was mercury, cadmium, arsenic, zinc, lead, tin. Toxic action increased slowly with time. A definite increase of toxicity was found with lead chloride, sodium arsenite, and arsenates. With chlorides and sulphates of the same metal, the sulphate was more toxic than the chloride.

93. Cairns, J. 1957. Environment and time in fish toxicity. Indust. Wastes 2:1-5.

The author discusses the toxicity of industrial waste waters to fish. Experiments have shown that the idea that fish avoid toxic materials in the water is a false one. Factors to be taken into consideration when planning bioassay tests include variations in natural conditions which affect the toxicity of certain compounds. Variations in temperature, hardness of the water, pH value, and dissolved oxygen content were all found to affect the toxicity of such substances as potassium dichromate or naphthenic acid. Synergism and antagonism of waste substances in water must also be studied. Experiments showed that whereas minnows could stand a concentration of 8.0 mg/l zinc or 0.2 mg/l copper alone for 8 hours, if the two were mixed together the minnows succumbed in a solution containing only 1.0 mg/l zinc and 0.025 mg/l copper. Alternatively the antagonism of substances may produce a biologically safe waste water. Other factors to be considered are the variability of the natural population, and the time taken to make accurate bioassay tests. Therefore each test should be carried out having full regard to all the variable factors involved.

94. Cairns, J. and A. Scheier. 1957. The effects of periodic low oxygen upon the toxicity of various chemicals to aquatic organsisms. Proc. 12th Industr. Waste Conf., Purdue Univ. Engng. Extn. Sec. No. 94:165-176.

Experiments were carried out to determine the effect of periodic low concentrations of oxygen on the tolerance to various

chemicals of the bluegill sunfish, Lepomis macrochirus, and a pulmonate snail, Physa heterostropha. It was thought useful to include a pulmonate snail, as many of these animals rarely or never come to the surface for air. The chemicals tested were potassium dichromate, zinc chloride, naphthenic acid, and potassium cyanide, only the latter two chemicals being tested on the snail. It was found that periodic low concentrations of dissolved oxygen, such as may occur in streams during the night, decreased the tolerance of bluegill to zinc chloride, naphthenic acid, and potassium cyanide, but had no effect on the toxicity of potassium dichromate. The tolerance of snails to naphthenic acid and potassium cyanide was also lowered, except in tests using a race of snails from deep ponds with a low concentration of dissolved oxygen. In addition to reduced tolerance, the effect of periodic low concentrations of oxygen was to reduce considerably the range between the highest concentration allowing survival and the lowest concentration causing death.

95. Cairns, J. and A. Scheier. 1958. The relationship of bluegill sunfish body size to tolerance for some common chemicals. Proc. 13th Industr. Waste Conf., Purdue Univ. Engng. Extn. Ser. No. 96:243-252.

Experiments were made to determine the tolerance of 3 different sizes of bluegills to some common chemicals including calcium chloride, potassium cyanide, sodium nitrate, cresol, sodium carbonate, sodium bicarbonate, sodium sulphate, zinc chloride, ammonium chloride, potassium dichromate, potassium chromate, phenol, sodium hydroxide and hydrochloric acid. The results are given in a table and discussed briefly. For most chemicals there was little difference in the 96-hour median tolerance limits for the three sizes of fish. The most marked differences occurred with calcium chloride and phenol. The pH value also had a marked effect, small and medium size fish being more tolerant to high pH values and large fish more tolerant to lower pH values. The size of the fish did not affect the way in which the fish reacted to toxic concentrations nor the period of exposure before response occurred.

96. Cairns, J. and A. Scheier. 1958. The effects of temperature and hardness of water upon the toxicity of potassium dichromate to the common bluegill sunfish. Trans. Northeast Wildl. Conf. 1:86-98.

Experiments were carried out on the toxicity of potassium dichromate to the bluegill sunfish in both soft and hard water at 18°C and 30°C during exposure for periods of up to 96 hours. The toxicity of dichromate was affected more by the degree of hardness of the water than by the temperature. The experimental concentrations

of dichromate that resulted in 50 per cent death of sunfish in 96 hours were 320 mg/l in soft water at both 18°C and 30°C, 382 mg/l in hard water at 18°C, and 369 in hard water at 30°C.

97. Cairns, J.J. and A. Scheier. 1964. The effects of sublethal levels of zinc and of high temperature upon the toxicity of a detergent to the sunfish Lepomis gibbosus (Linn.) Notulae Naturae 367:1-4.

Since alkylbenzenesulphonate, zinc and increased temperature all affect the respiratory system of fish and might well occur together in a polluted water, it was decided to investigate the resistance of fish to zinc and high temperatures after exposure to ABS. Sunfish (Lepomis gibbosus) were exposed for 30 days to ABS in concentrations sufficient to cause marked damage to the gills, and were then exposed either to sublethal concentrations of zinc chloride or to high temperatures. The results indicated that prior exposure to ABS did not cause any marked changes in tolerance to either zinc or increased temperature.

98. Cairns, J., A. Scheier, and J.J. Loos. 1965. A comparison of the sensitivity to certain chemicals of adult zebra danios, Brachydanio rerio (Hamilton-Buchman) and zebra danio eggs with that of adult bluegill sunfish, Lepomis macrochirus. Raf. Notulae Naturae 381:1-9.

Experiments on the effect of zinc chloride, potassium cyanide, naphthenic acids, potassium dichromate, and a synthetic detergent on different species of fish have shown that it should not be assumed that different species or even different stages in the life cycle of a single species will have the same relative response to different toxic materials. Any measurements defining the toxic nature of a material must take into account species differences and changes in sensitivity during the life cycle of the species.

99. Cairns, J. Jr. and A. Scheier. 1957. The effects of temperature and hardness of water upon the toxicity of zinc to the common bluegill (Lepomis macrochirus Raf.). Notulae Naturae 299: 1-12.

Results indicate little difference in toxicity of Zn ion in dilution water of some quality with temperature varying from 18°to 30°C. More Zn is required in hard water, than in soft water, to kill fish. Variation of physical and chemical environment was kept to a minimum during test period. Concentrations fatal to 50% in ninety-six hours in soft water ranged between 2.86 and 3.63 mg/l in a temperature

range of 18° to 30°C. In hard water over same temperature range the concentration was 10.13 to 12.30 mg/l (18° to 30°C).

100. Calapaj, G.G. 1966. Manganese-54 contamination of the sea. Acta Isotop. 6:253-259.

Based on practical experience, the author concludes that among marine organisms the bivalve Pinna nobilis is the most effective accumulator of manganese-54, because of its ability to accumulate stable manganese; Chlamis varia and C. sinuosa show similar characteristics, but to a lesser extent. It is suggested, therefore, that Pinna nobilis should be used as the test organism in areas where manganese-54 is the critical isotope discharged.

101. Carey, A.G., Jr. 1969. Zinc-65 in echinoderms and sediments in the marine environment off Oregon. Proc. 2nd Nat. Symp. on Radioecology. U.S. A.E.C. Conf. 670503:380-388.

Artificial radionuclides, induced in water used as a coolant in the Hanford reactors, are discharged into the Pacific Ocean by the Columbia River. Gamma-ray spectrometric measurements show that levels of ^{65}Zn decrease in both sediments and benthic animals with distance from the mouth of the river and with depth of water. Although ^{65}Zn decreases rapidly in animals below 400 meters, it was detected to 2900 meter depths in animals but not in the sediments. Levels of ^{65}Zn in benthic animals appear to be associated with depth, distance from the point source, position of the Columbia River plume in the surface waters, and ecology of the organisms. The bottom fauna is thought to be important in determining the distribution of induced radionuclides on the ocean bottom.

102. Carey, A.G., W.G. Pearcy, and C.L. Osterberg. 1966. Artificial radionuclides in marine organisms, in the northeast Pacific Ocean off Oregon. Proc. Symp. Int. Atom. Ener. Agency, 303-319.

A 4-year study of radioactivity in marine organisms (Pacific Ocean off Oregon) showed the presence of induced nuclides, such as zinc-65. These originated from cooling water of the Hanford reactors. Induced nuclides and fission products were found in organisms up to 490 km from the coast and at depths down to 2860 m. The concentrations of zinc-65 in marine organisms showed seasonal maxima, associated with seasonal movements in the position of the Columbia river plume. Before the end of atmospheric testing of nuclear devices, zirconium-95-niobium-95 were found in the fauna at all depths, and the amounts of these short-lived isotopes in the benthic fauna from the deepest stations were greater than expected.

103. Carpelan, L.H. 1961. Salinity tolerances of some fishes of a southern California coastal lagoon. Copeia 1961:32-39.

A coastal lagoon in California, which was open to the ocean during the first 6 months of a period of study, was closed off during the next 8 months. After the bay was closed, the salinity of the water increased from 35 parts per thousand to over 60 parts per thousand, and the summer temperatures were 4-5°C higher than when the lagoon was open. Of 10 species of fishes trapped in the lagoon when it was closed, most tolerated the changing conditions until the salinity reached 50-55 parts per thousand, and no upper limit of tolerance was observed for Fundulus parvipinnis, Girella nigricans, or Antherinops affinis littoralis, some of which were still thriving at a salinity of 63 parts per thousand when observations ceased.

104. Carpenter, K.E. 1924. A study of the fauna of rivers polluted by lead mining in the Aberystwyth District of Cardiganshire. Annals Appl. Biol. 11:1-23.

Flora and fauna were affected by discharges of galena particles and by lead salts in diffusible form through chemical interaction with the natural water. Clogging of fish gills with resultant death was ascribed to the galena-grit. Following cessation of lead mining an increase in flora and fauna was rapid.

105. Carpenter, K.E. 1925. On the biological factors involved in the destruction of river fisheries or pollution due to lead mining. Annals Appl. Biol. 12:1-13.

Toxicity of mine wastes to aquatic life was attributed to soluble lead salts. Flood waters tended to mix lead which had settled with a resultant increase of Pb in solution. The fatal effect of lead was dependent on quantity in solution, and this can be constantly renewed in fast moving streams.

106. Castell, C.H., B. Smith, and W. Neal. 1970. Effects of transition metal ions on the extractable protein of fish muscles. J. Fish. Res. Bd. Canada 27:701-714.

The addition of 10-50 mg/l of several transition metal ions rapidly decreased the extractable protein content of blended fish muscle. The most active metals were Cu^{++} and Cr^{++} followed by Sn^{++} and Cd^{++}. Other ions tested, Ce^{++}, Zn^{++}, Ni^{++}, Co^{++}, Fe^{++}, Fe^{+++}, V^{++}, and Mn^{++}, brought about relatively little or no change in extractable protein nitrogen (EPN) values. Effects of the metals differed with muscle from different species. Lean fish were more

susceptible than either fatty fish or shellfish. Of all the species tested the metals had the least effect on scallops. A limited number of tests indicated that fish that were badly emaciated through starvation were more susceptible to the metal-induced change than normal individuals of the species.

Addition of certain amino acids, notably cysteine, histidine, glutamic acid, and tryptophane, protected the muscle against metal-induced reduction of EPN. With lean fish, the amino acids that protected the muscle against metal-induced change in the protein also protected it against metal-induced oxidation of the lipids; with fatty fish, protection against rancidity was somewhat less; the invertebrates seemed to be normally protected against both without the addition of amino acids. This natural immunity of marine invertebrate muscle to changes induced by the addition of heavy metal ions may be in part attributed to their normally high content of free amino acids.

107. Chakravarti, D. and R. Eisler. 1961. Strontium-90 and gross beta activity in the fat and nonfat fractions of the liver of the coconut crab (Birgus latro) collected at Rongelap Atoll during March 1958. Pacific Science 15:155-159.

The values for strontium-90 and gross beta activity in the fat and nonfat fractions from the livers of 12 coconut crabs (Birgus latro) collected at Rongelap Atoll during March, 1958, are presented.

Although fat constituted an average of 47 per cent by weight on a wet weight basis (74 per cent on a dry weight basis), gross beta activity of the fat fraction amounted to less than 0.5 per cent of the total activity on a wet weight basis. Fat content on a wet weight basis had a range of 31 to 65 per cent. There is a linear relationship between strontium-90 activity and gross beta activity. Since the fat content of coconut crab liver is variable and the fat fraction contains practically no radioactivity, it is suggested that the radioactivity (and mineral content) of liver samples be compared on the basis of the nonfat solids.

108. Chang. P.S. 1965. Effects of pollution on oysters and fish in Taiwan In Biological Problems in Water Pollution Third Seminar August 13-17, 1962. U.S. Public Health Service 999-WP-25:368-369.

Owing to rapid industrial development, the coastal waters of the Taiwan archipelago have become polluted by trade waste waters, containing large amounts of copper, sulphur, zinc, and harmful organic substances. The resultant adverse effects on oysters and fish are

discussed with examples from Kaohsiung bay, where the osyters have become green and poisonous owing to accumulation of copper salts (the concentration of copper reaching 1180 mg per kg compared with 5.6 mg in normal oysters).

109. Chen, C.W. 1968. A kinetic model of fish toxicity threshold. Thesis, University of California:144 p. (Diss. Abstracts 29, 13:3342.)

To facilitate the determination of the threshold level of a pollutant that will produce acute fish toxicity, a kinetic model of fish poisoning has been developed, with which bioassay data can be used to estimate the rates of toxication and detoxication; the threshold value is then deduced theoretically on the basis that mortality will not occur as long as the rate of detoxication keeps pace with the rate of toxication. The model was verified to a limited extent by experiments with zinc and cyanide, alone and together, using common guppies as the test animals. For the mixture of poisons tested, the variations in the overall threshold were found to be linearly related to the concentration of one toxicant while the other was kept constant.

110. Chesselet, R. and C. Lalou. 1965. Role of "detritus" in the fixation of radionuclides in the marine environment. C.r. hebd. seanc. Acad. Sci. Paris 260:1225-1227.

In studies on uptake of radionuclides by marine plankton, the authors found that plankton samples contained large amounts of detritus composed of fragile transparent particles which appeared to originate from the decomposition of marine vegetable matter. This detritus was found to adsorb considerable amounts of cerium-141 and -144, praseodymium-144, ruthenium-103 and -106, rhodium-106, zirconium-95 and niobium-95. Since such detritus serves as a food source for zooplankton and benthic fauna, it probably plays an important role in the transfer of radioactivity in the food chain.

111. Chesselet, R., C. Lalou, M. Aubert, and J.P. Gambarotta. Recent studies on the radioactivity of plankton and of organic refuse. Cah. Cent. Etud. Rech. Biol. Oceanogr. Med. 17: 67-97. Nuclear Science Abstracts 1966 20:5016.

A detailed study of the coastal waters of the Mediterranean near Nice in 1963, showed the importance of plankton and organic debris in concentrating radioactive fallout isotopes as zirconium-95, ruthenium-103 and -106, and cerium-141 and -144. From observations on the effects of rate of fallout on the activity of the water and the activity of the

plankton it is concluded that, at least for the isotopes studies, the contamination of zooplankton is related mainly to the injection conditions of the particles rather than to the specific activity of the sea water.

112. Chipman, R.K. 1959. Studies of tolerance of certain freshwater fishes to brine water from oil wells. Ecology 40: 299-302.

The salt water separated from crude oil at oil wells in the vicinity of New Orleans, La., is pumped back underground, but occasionally backs up into an earthen impoundment built for the purpose. Seepage water from the impoundment drains into a pond, increasing the salinity of the water. The effects on the fish were investigated by periodic collection of all the dead fish during a period of increasing salinity. Further laboratory experiments were carried out to determine the lethal limits for some of the species of fish under experimental conditions. Ten species of fish, all of freshwater origin, were killed during a period of high salinity in the pond. Another 10 species showing a high tolerance to the brine water remained in the pond and were identified after killing with rotenone. The highest salinity at which each species was collected is given, and where possible field data are compared with the lethal limits determined in the laboratory. The results suggest that the fishes more closely related to marine species and those that are at present expanding into the marine environment are more tolerant of the periods of high salinity than fishes of freshwater origin.

113. Chipman, W.A. 1944. The role of pH in determining the toxicity of ammonium compounds. Thesis (Ph.D.) University of Missouri, 1934; Microfilm Abstr. 5 (2):2-3.

Experiments made to determine the effect of pH value on the toxicity of ammonium salts to aquatic animals are described. In solution ammonium salts dissociate chiefly into ammonium ions and acid ions, but small amounts of the free acid and of ammonium hydroxide are also formed; the hydroxide dissociates further forming water and ammonia gas. The pharmacological action of solutions of ammonium salts is due both to ammonium ions and to free ammonia. Experiments showed that alkaline ammonium salts were much more toxic to goldfish than were the acid salts; for example, a 0.005 N solution of ammonium carbonate in distilled water killed goldfish in 3.58 hours on an average, although a 0.1 N solution of ammonium chloride did not kill the fish within 12 hours. The toxicity of solutions of ammonium chloride was much greater when prepared with tap water than when prepared with distilled water. A 0.05 N solution of ammonium chloride prepared with distilled water was not toxic to goldfish, but

it became toxic when sodium hydroxide, sodium carbonate, or disodium hydrogen phosphate were added; the increase in toxicity was proportional to the decrease in free hydrogen ions. Addition of sodium dihydrogen phosphate which increased the acidity of the solution did not make it toxic. A direct relation between pH value and toxicity of solutions of ammonium chloride to fish, amphipods, and cladocerans was demonstrated. This variation in toxicity was apparently directly associated with the dissociation of the ammonium salt, as the results were the same whatever salt was used to regulate the pH value. The author concludes that the toxicity of ammonium salts is directly related to the amount of undissociated ammonia in the solution; this is determined by the concentration of free hydrogen ions present.

114. Chipman, W.A. 1967. Some aspects of the accumulation of chromium-51 by marine organisms. Proc. Int. Symp. Radioecol. Concent. Process, 1966, Stockholm; 931-941.

The uptake and accumulation of chromium-51 by marine organisms is discussed in relation to experiments on the chemical and physical forms of chromium present in sea water and the rate of turnover within the organisms, using the marine polychaete "bristle" worm, Hermione hystrix, as the test animal. The addition to sea water of chromium-51 in the form of trivalent chromic chloride solution resulted in an immediate change and a loss of radioactivity from the water owing to formation of colloidal chromic hydroxide and filterable radioactive particles, and to adsorption on surfaces; the number of filterable particles increased with time and after 96 hours 82 per cent of the radioactivity remaining in the water was in this form. There was, however, no change in form when chromium-51 was added to sea water in the form of hexavalent sodium chromate; an ionic solution was obtained with virtually no formation of filterable particles and no loss of radioactivity by adsorption on surfaces. Since it was therefore not feasible to follow the uptake of trivalent chromium by animals if it was added to the water, experiments were made with the chromium-51 associated with the bottom silt in which the animals were living (the nuclide, in the form of chromic chloride solution, was stirred with a seawater suspension of bottom silt, the silt was allowed to settle, when virtually all the chromium was found to be with the silt, sea water was allowed to flow over the silt, and worms were added). Chromium-51 was determined in both worms and silt at intervals over a period of 22 days and it is concluded that the trivalent chromium-51 taken into the digestive tract of Hermione was not transferred to the body and accumulated. When the worms were exposed to hexavalent chromium, added to the sea water in the form of sodium chromate, the hexavalent chromium entered the worms readily, and the initial uptake was rapid (the concentration in the worms exceeded that in the sea water in less than a day); but subsequent accumulation was slow, the rate of accumulation did not diminish during the 19-day period of

observation, and at the end of this period the radioactivity of the worms was nearly 12 times that of the water.

115. Clemens, H.P. and W.H. Jones. 1954. Toxicity of brine water from oil wells. Trans. Amer. Fish. Soc. 84:97-109.

In the southwest U.S.A., brine from oil wells is a major source of pollution. These brines contain a mixture of calcium, sodium, magnesium and potassium chlorides, and little is known of the tolerance of fish and invertebrates to them. Experiments were therefore made to determine the tolerance levels of certain species of freshwater fish and invertebrates to waste brines. The results were expressed as median toxicity threshold (M.T.T.), or concentration giving the median survival in 96 hours. The brines used contained 119,000 mg/l chloride, 59,700 mg/l sodium, 11,100 mg/l calcium, 2,070 mg/l magnesium, 1,140 mg/l potassium and 7.0 mg/l iron, and had a hardness of 36,200 mg/l (as calcium carbonate) and a pH value of 5.0. The M.T.T. for 10 species of fish in brine diluted with tap water ranged from 11.2 per cent by volume for plains killifish to 4.2 per cent for fathead minnows. The toxicity thresholds for the other fish tested were gambusia 7.4, white crappie 6.1, green sunfish and bluegill 5.5, channel catfish 5.4, red shiners 5.1, black bullheads 5.0, and largemouth bass 4.6 per cent. The M.T.T. for a given species of fish was found to vary with variations in the chemical composition of the brine. It was found that plains killifish could be acclimatized to the presence of high concentrations of chloride, but red shiners kept in brine for over 4 months showed little if any acclimatization. The toxicity threshold for red shiner was the same at temperatures of 8°, 23°, and 26°C, but the rate of death increased with increase in temperature. Similar results were obtained with red shiner and fathead minnow in sodium chloride solution, but the median toxicity threshold for gambusia in sodium chloride was higher at 28°C than at 23°C. Of the 10 invertebrates tested, the most susceptible organism was Daphnia pulex, with a toxicity threshold of 1.8 per cent by volume, and the most resistant was crayfish (Cambarus) with a threshold of 8.7 per cent. The thresholds for the other invertebrates were Diaptomus clavipes 3.1, Physa 3.2, free-ranging mayfly 16, Hyalella azteca 3.8, tubifex worms 4.9, Hexagenia 5.1, and damselflies and drangonflies 7.2 per cent. Experiments were also made to determine the median toxicity thresholds for certain fish and invertebrates in solutions of sodium chloride in tap water, for comparison with the threshold values in waste brines. The thresholds for plains killifish, gambusia, and black bullhead, expressed as mg/l of the hypothetical combination of sodium chloride in the brine, were higher in brine than in sodium chloride. For these fish the ions in the brine may have acted antagonistically to each other. For green sunfish, red shiner, and fathead minnow, the toxicity thresholds were lower in the brine than in sodium chloride. In these cases, the ions in the brine may have acted synergistically, or the brine may

have contained toxic soluble oil products. In all cases, however, the toxicity thresholds in the brine fell within the fiducial limits of the thresholds in sodium chloride. Better agreement between the results was obtained when the thresholds in brine and in sodium chloride were expressed for each solution as both mg/l chloride and mg/l sodium. For plains killifish, gambusia, and bullheads the thresholds were closer when expressed as mg/l sodium than as mg/l chloride, but for green sunfish, red shiner, and fathead minnow the results were in closer agreement when expressed as mg/l chloride. These results suggest that some ions are more toxic to certain fish than to others. A comparison of the chloride ion tolerance of 3 species of fish and 3 kinds of invertebrates under laboratory conditions and in the field indicated that the degree of tolerance was similar under both conditions for all the forms studied. It is stressed that further studies on the toxicity of waste brines should include investigations on the antagonistic effects of cadmium, magnesium, sodium and potassium in the presence of chloride.

116. Clemens, H.P., and K.E. Sneed. 1958. Effect of temperature and physiological condition on tolerance of channel catfish to pyridylmercuric acetate (PMA). Progr. Fish-Cult. 20:147-150.

The authors report on work carried out to investigate the possible toxicity of pyridylmercuric acetate, used for controlling diseases and parasites of channel catfish. It was found that tolerance of fingerling channel catfish to PMA increased as the water temperature decreased and results suggest that a dose of 2 mg/l for 1-2 hours should be relatively safe for use on fingerlings. There appears to be some difference in the toxicity threshold values for fish of different ages. One-week-old fry were more susceptible to PMA than either yolk-sac-fry or fingerlings when exposed for 24 hours, but the difference was minimized at longer exposure periods. The tolerance of fingerling channel catfish to PMA acetate also varies with the physiological condition of the fish; this was demonstrated in a series of experiments which suggest that the chemical is effective for controlling diseases and parasites commonly contracted in troughs and the greater the frequency of the treatment the greater is the tolerance of the fish. A series of tests were carried out to investigate delayed mortality. Three-week-old channel catfish, suffering from an epidemic of Amphileptus, were exposed to the chemical for 1 hour but no delayed mortality was exhibited at any concentration of the chemical; a 4-5 hour exposure, however, at the higher concentrations of PMA caused a delayed mortality that was apparent within 24 hours.

117. Coche, A.G. 1967. Osmotic regulation in juvenile Oncorhynchus

kisutch (Walbaum). 1. The salinity tolerance of 50-day old fry. Hydrobiologia 29:426-440.

The experiments carried out suggest a tolerance to 18 o/oo salinity for salmon fry 44 days old; Coho salmon of age 59 days survived in 22 o/oo. Another experiment tested the effect of acclimatizing fry 59 days old for 9 days to 21 o/oo salinity; these survived the next 7 days at 28 o/oo salinity. The direct transfer of 59 day old fry from 24 o/oo salinity to fresh water could be entirely successful.

118. Cook, R.S. and D.O. Trainer. 1966. Experimental lead poisoning of Canada geese. J. Wildlife Manag. 30:1-8.

Canada geese (Branta canadensis) were fed No. 4 lead (Pb) pellets; 4 pairs received 5, 10, 25 and 100 Pb pellets, respectively, and 2 single geese 2 and 50 pellets. Gross signs of poisoning appeared 5 to 7 days following ingestion. The length of time until signs of disease or death occurred was related to the amount of Pb ingested: 25 or more pellets caused death within 10 days while 10 or fewer pellets permitted survival up to 72 days. Ingestion of large numbers of pellets resulted in a rapid increase of Pb levels in the blood and acute poisoning with early death. Ingestion of fewer pellets caused a slower increase of blood Pb and chronic poisoning with more typical signs. The pellets seemed to erode at a constant rate regardless of the number in the gizzard, with 66% of the Pb pellet volume being eroded within the first 3 days after exposure and the remaining volume in 45 days. Normal blood Pb levels for Canada geese were 0.018 to 0.037 mg per 100 g while in the blood of Pb-poisoned geese the Pb concentration ranged from 0.320 to 1.680 mg per 100 g, with a peak being reached between the 3rd and 10th day. Lead-poisoned geese lost weight progressively. Necropsy findings included impaction of the proventriculus, roughened and stained gizzard lining, enteritis, distended gall bladder, and discolored liver. Histopathological findings on examination of liver, kidney, heart, lung, gizzard and pancreas are described. Periodic blood smears showed no evidence of stippled erythrocytes. The great susceptibility of Canada geese to Pb poisoning and the possibility of an increased vulnerability during the breeding season were discussed.

119. Corner, E.D.S. and B.W. Sparrow. 1956. The modes of action of toxic agents. 1. Observations on the poisoning of certain crustaceans by copper and mercury. J. Mar. Biol. Ass. U.K. 35:531-548.

Experiments were made to determine the toxicity of copper, as copper sodium citrate, and mercury, as mercuric chloride, mercuric iodide and ethylmercuric chloride, to the three crustaceans, Artemia salina, Elminius modestus, and Acartia clausi. Elminius and Acartia were much more sensitive than Artemia to all the poisons tested. The

toxicities of the 3 mercuric compounds to Elminius and Acartia were similar, but mercuric iodide and ethylmercuric chloride were much more toxic to Artemia than was mercuric chloride. Mixtures of the copper compound and one of the mercuric compounds were found to exhibit more than additive toxic effects towards Artemia. These effects were much more marked with mixtures of copper and mercuric chloride than with mixtures of copper and either mercuric iodide or ethylmercuric chloride. Preliminary exposure of Artemia to a sublethal dose of copper rendered it much more sensitive to subsequent poisoning by mercuric chloride and, to a lesser extent, to poisoning by the other mercuric compounds, but did not render it more susceptible to copper poisoning. Similarly, treatment with a sublethal dose of one of the mercury compounds rendered Artemia more sensitive to copper poisoning, but not to mercury poisoning. These "sensitizing" effects were found to be partly eliminated by washing the treated animals with a solution of either cysteine or reduced glutathione. Further experiments with Artemia showed that copper depresses their respiration without significantly affecting their mobility. Mercury does not appear to have this effect. The results obtained in these experiments are discussed in relation to current theories of the mechanism of the action of heavy metal poisons.

120. Corner, E.D.S. and B.W. Sparrow. 1957. The modes of action of toxic agents. II. Factors influencing the toxicities of mercury compounds to certain crustacea. J. Mar. Biol. Ass. U.K. 36:459-472.

In previous experiments, the toxicities of ethylmercuric chloride and mercuric chloride to two species of crustacea were compared. The results of these experiments suggested that the toxicity of mercury compounds is affected by their rate of penetration and further studies on this aspect have now been made. The relative toxicities to Artemia and Elminius of a number of organomercury compounds were measured and a study was made of the extent to which these values are related to the lipoid solubilities of the compounds and their abilities to interact with proteins. With both species it was found that all the mercury compounds tested were more toxic than mercuric chloride, that primary alkylmercuric chlorides were more toxic than the corresponding secondary compounds, and that toxicities increased as the homologous series of primary compounds is ascended. It was also found that Elminius was more sensitive to each mercury compound than was Artemia, and that differences between the toxicities of the poisons to Elminius were much smaller than the corresponding differences observed with Artemia. No relation was observed between the toxicities of the compounds and their abilities to combine with proteins, as estimated by inhibition of urease. In general, compounds with high lipoid solubilities were found to be more toxic. The results of the experiments are consistent with the view that organomercury compounds act by penetrating the test animals.

121. Corner, E.D.S. and F.H. Rigler. 1958. The modes of action of toxic agents. III. Mercuric chloride and n-amyl-mercuric chloride on crustaceans. J. Mar. Biol. Ass. U.K. 37:85-96.

Experiments were made on the mode of action of n-amyl-mercuric chloride and mercuric chloride on Artemia salina and Elminius modestus. Differences between the susceptibilities of Artemia and Elminius to the poisons are not related to differences in the amounts of these compounds which the animal can tolerate in their tissues, but are directly related to the rates at which the poisons are accumulated. Experiments with reduced glutathione have given results consistent with the view that most of the mercury taken up by either species penetrates into the tissues and does not act simply by becoming attached to their surfaces. Direct evidence of the penetration of mercury compounds into a crustacean was obtained in experiments with the prawn, Leander serratus, in which considerable amounts of mercury were detected in the antennary glands.

122. Crance, J.H. 1963. The effects of copper sulphate on Microcystis and zooplankton in ponds. Progressive Fish-Culturist 25:198-202.

Results of investigations to determine whether copper sulphate can be used in low concentrations to control Microcystis in ponds and whether these concentrations of copper sulphates influenced the abundance of zooplankton in the ponds are summarized. An appreciable decrease in the number of colonies of Microcystis generally occurred in the ponds after an application of 0.05-0.08 mg/l copper sulphate and there appeared to be an inverse relationship between the abundance of Microcystis and the numbers of zooplankton present. The numbers of zooplankton usually increased within a few days after an application of copper sulphate, copepods being the dominant species present in all except one of the ponds, in which cladocerans and copepods were about equal in abundance. The maximum period that Microcystis remained at what was considered to be a controlled status after application of copper sulphate was approximately 25 days, the characteristic odor being evident for 2-3 days after application. It is possible that Microcystis becomes more resistant to copper sulphate as the season progresses and/or after repeated application of copper sulphate. There was no indication that reduction of this alga after applications of 0.05-0.08 mg/l caused fish to suffer or die from oxygen deficiency.

123. Crandall, C.A. and C.J. Goodnight. 1962. Effects of sublethal concentrations of several toxicants on growth of the common guppy, Lebistes reticulatus. Limnol. Oceanog. 7:233-239.

Studies were conducted to determine the effect on growth of guppies following exposure to sublethal concentrations of toxic substances. Lead, zinc, and sodium pentachlorophenate were used at concentrations of 2.2 mg/l for lead nitrate (1.25 mg/l as lead); 5 mg/l for hydrated zinc sulphate (1.15 mg/l as zinc), and 0.5 mg/l for sodium pentachlorophenate. In addition some fish were tested in 5 mg/l lead nitrate (2.48 mg/l as lead) and hydrated zinc sulphate (2.30 mg/l as zinc). Newborn fish were added to the test and control solutions; after 30 days they were weighed individually, and re-weighed at 15-day intervals until the 90th day. Daily observations were made for the presence of sexually mature fish and any dead fish. It was found that all three substances retarded growth, increased mortality and delayed sexual maturity; and suggests that conditions that permit prolonged survival may still be adverse to fish populations.

124. Cross, F.A., J.M. Dean and C.L. Osterberg. 1969. The effect of temperature, sediment,and feeding on the behavior of four radionuclides in a marine benthic amphipod. Proc. 2nd Nat. Symp. on Radioecology USAEC Conf. 670503:450-461.

Laboratory studies were conducted to determine the effects of temperature, feeding, and presence of sediments on the behavior of ^{65}Zn in a new species of gammarid amphipod (*Anonyx* sp.). This benthic amphipod was captured in 80 meters of water off the Oregon coast. In the feeding experiments, ^{144}Ce, ^{46}Sc, and ^{51}Cr were used in addition to ^{65}Zn. Accumulation and elimination rates of ^{65}Zn were temperature dependent, although the effect appeared to be minimal within this organism's normal temperature range. Elimination rates of ^{65}Zn were increased in the presence of sediment and were significantly greater in feeding than in non-feeding amphipods. *Anonyx* which fed on adult *Artemia* labeled simultaneously with ^{65}Zn, ^{144}Ce, ^{46}Sc, and ^{51}Cr retained 55% of the ^{65}Zn and less than 10% of the ^{144}Ce and ^{46}Sc. Transfer of ^{51}Cr was not measurable. Zinc-65 loss during molting depended upon whether the zinc had been accumulated from food or from water. When uptake was from water, approximately 20% of the ^{65}Zn body burden was lost with the cast exoskeleton, whereas only 2.0% was lost when ^{65}Zn was accumulated from food. The potential role of *Anonyx* in the cycling of radioactivity in the marine environment is discussed.

125. Cross, F.A., S.W. Fowler, J.M. Dean, L.F. Small and C.L. Osterberg. 1968. Distribution of zinc-65 in tissues of two marine crustaceans determined by autoradiography. J. Fish. Res. Bd. Can. 25:2461-2466.

The distribution of radioactive zinc in the benthic amphipod Anonyx sp. and the euphausiid Euphausia pacifica, after storage for eight days in filtered sea water containing zinc-65 (25 μc per liter) and stable zinc (20 μg per liter), was determined from autoradiographs prepared from tissues. Zinc-65 was found to be predominantly localized in the exoskeleton and interstitial spaces of the myofibrils of each animal, and was present also in the gut and hepatopancreas of Anonyx and in the eye of E. pacifica. The ecological implications of these results are discussed.

126. Csanady, M. 1967. Spread of pollution by heavy metals and cyanides in ground water. Magy. tudom. Akad. orv. Tudom. Osztál. Közl. 18:481-493. Chemical Abstracts 1968, 68: 7848.

Analyses of ground water and water from wells near a small plating plant without waste treatment facilities showed the presence of high concentrations of hexavalent chromium and cyanide. This pollution was very marked in wells 19 and 37 m away in the direction of the natural ground-water flow; in the opposite directions light contamination was noted for a distance of 40-60 m. Measures to prevent a recurrence of such pollution are discussed.

127. Cushing, C.E. and N.S. Porter. 1969. Radionuclide cycling by periphyton: an apparatus for continuous in situ measurements and initial data on zinc-65 cycling. 1969. Proc. 2nd Nat. Symp. on Radioecology. Ann Arbor, Mich. 285-290.

A system is described which permits the continuous measurement of uptake and cycling of radionuclides between stream periphyton and a controlled aqueous environment. The system was designed to avoid inherent difficulties in aquaria studies, i.e., the necessity of destroying or sub-sampling the community for sequential analyses, the lack of a continuous flow of water over the algae to simulate stream conditions, and the inability to maintain a fixed ambient radionuclide concentration because of immediate uptake and recycling by the organisms. The apparatus permits evaluation of the effects of individual physical and chemical environmental factors in either an open one-pass system or in a closed recirculating system.

Preliminary results of six uptake and two retention experiments using ^{65}Zn in the closed system are presented.

128. Cusick, J. 1967. Mucous cell response of the guppy to heavy metals and water quality. Thesis. Univ. of Cincinnati, Cincinnati, Ohio, 143 p. Dissertation Abstracts 1967, 28, B, 2664.

Investigations on the possibility of using the response of lingual mucous cells of the common guppy as an indicator of the presence of heavy metals (copper, nickel, and zinc) showed that a reduction in the numbers of mucous cells and a thinner epithelium occurred in fish exposed to zinc in diluted water at pH 6. Since zinc-induced mortality is associated with a depletion of mucous cells while copper-induced mortality is not, it is concluded that these metals have different sites of toxic activity and this accounts for the synergistic effect of copper-zinc mixtures. Zinc damage to the epithelium was found to be more likely to occur when the water lacked sodium, calcium, or magnesium; it is suggested that these cations have a protective action by competing with zinc for adsorption-desorption sites at the epithelial barrier membrane surfaces.

129. Dahl, J. 1963. Transformation of iron and sulphur compounds in soil, and its relation to Danish Inland Fisheries. Trans. Amer. Fish. Soc. 92:260-264.

Lignite mining and land drainage have caused oxidation of the pyrite content of the soil in Denmark with consequent destruction of fisheries when the polluted water reaches the rivers. The bottom of the river Tim in western Jutland is covered with ferric hydroxide deposits and all fishing grounds are destroyed owing to discharges from an old lignite mine and drainage from surrounding fields. The Soby lake has also had its entire fish stock destroyed by drainage from a lignite mine. Treatment of lignite mine discharge water with lime to neutralize sulphuric acid and precipitate iron compounds before they reach their receiving stream is successful and widely practiced, but it is impracticable to neutralize drainage from peat bogs.

130. Davies, A.G. 1967. Studies on the accumulation of radio-iron by a marine diatom. Proc. Int. Symp. Radioecol. Concent. Process, 1966, Stockholm:983-991.

Iron is present in sea water in particulate form, probably as hydrous ferric oxide, which can scavenge radionuclides of other elements. Investigations were conducted on the adhesion of the particulate oxide to surfaces of phytoplankton, for use in assessing the part played by phytoplankton in the dispersion of radioactive discharges. Experimental details are given of the method used, which involved reproducible liquid movement produced by rotation of a straight uniform glass rod coaxially suspended inside a fixed glass cylinder. Freshly-precipitated iron chloride labelled with iron-59 was put in the cylinder, sea water was added, the cylinder was placed round the already rotating rod, and at least 12 hours were allowed for equilibrium to be reached. An equal volume of sea water

was used in a similar manner to remove the iron from the walls of the cylinder. The distribution coefficient, defined as the ratio of the number of counts per minute in the wall washings and in an equal volume of the original sea water was independent of the concentration of iron and can therefore be used to calculate the concentration of iron in the suspension. Assuming that the same distribution applies in the presence of diatoms, it is possible, by measuring the iron on the vessel walls, to separate the total iron in suspension into the quantity associated with the diatoms and the remainder in free suspension. For measurements on diatoms, a known population of cells (Phaeodactylum tricornutum) was added to the sea water before addition of ferric chloride. The results are corrected for adherence of diatoms to the walls of the cylinder. For a wide range of concentrations of total iron and cell populations, data are tabulated on the quantities of iron found associated with the diatoms and in free suspension. With iron concentrations higher than 27 g per liter severe clumping of the diatom cells occurred. When aged suspensions of hydrous ferric oxide were added to the sea water or diatom suspension, the particles would not adhere to the cylinder and the suspension was therefore rotated in a round-bottomed flask. In all cases, the iron adsorbed by the diatoms could be removed completely by sea water adjusted to pH 10 and there was no evidence that any measurable quantity of iron had been metabolized. The practical implications of these results are discussed including calculation of the fraction of the introduced radioactivity which is accumulated by the cell population owing to surface adhesion.

131. Davies, A.G. 1969. Iron, chelation and the growth of marine phytoplankton. I. Growth kinetics and chlorophyll production in cultures of the euryhaline flagellate Dunalliela tertiolecta under iron-limiting conditions. J. Mar. Biol. Assn. U.K. 50:65-86.

By using an apparatus designed to permit the rotation of the culture vessels, it was possible to reduce the concentrations of iron, as hydrous ferric oxide to levels which restricted the growth of the plant cells, as, under these conditions, much of the oxide adhered to the vessel. At the lowest iron concentrations used, the growth rate was eventually controlled by the rate of detachment of the oxide from the vessel and the cells then contained the minimal level of iron which would allow growth to continue. This minimal level was found to decrease as the cells in the iron-deficient stock cultures adapted to the medium. The concentrations of residual iron, not removed from the sea water in the culture medium by filtration through a 0.1 μm pore-size membrane filter, were shown to be similar to those of the added iron in certain cases, and had therefore to be included in the total iron available for growth. Using a chelating agent to fractionate the iron associated with the cells, it was possible

to estimate the metabolically bound iron. The rates of growth were found to be related to this metabolic iron by a hyperbolic expression. Rate constants obtained using the expression were in good agreement with those observed directly in cultures where the iron concentrations were sufficient to permit exponential growth. Chlorophyll a production by the cells was largely dependent upon that fraction of the metabolic iron which was supplied by the residual iron, the added form being much less effective in this respect. This had suggested that chlorophyll production in phytoplankton may require the presence of organo-iron complexes.

132. Davis, C.C. 1948. Studies of the effects of industrial pollution in the lower Patapsco river area. II. The effect of copper as pollution on plankton. Publ. Chesapeake Bay Lab. 72:1-12.

A study was made of the relation between the concentration of iron in mud, resulting from pollution by copper, and the number of plankton organisms present in the Patapsco river, Md. Methods of sampling and counting plankton in mud and plankton samples are described and their limitations are discussed. In interpreting the results only diatoms were considered as they were present in large numbers and were easily detected. Results indicated, though no direct correlation was obtained, that the precipitating particles of ferric hydroxide tend to carry down plankton into the bottom mud, but that the number of organisms at a particular point is not related to the extent of pollution at that point.

133. DeCalventi, I.B. 1965. Copper poisoning in the snail *Helix pomatia* and its effect on mucous secretion. In Symposium on Mucus in Invertebrates. Ann. N.Y. Acad. Sci. 118:1015-1020.

Snails exposed to $CuSO_4$ solutions of 0.01 to 0.1 mg/l of Cu showed severe signs of toxicity. There was an increase in mucous secretion and no response to tactile stimuli. Cu was precipitated from solution by mucous. There were no significant changes following 1 hour exposure to 0.01 mg/l Cu in histology of mucous secreting cells of foot and mantle. Histochemical characteristics of the acid mucopolysaccharides were not altered upon exposure to the Cu concentration studied. Mucopolysaccharides from foot and mantle were histochemically different. Mucous secreting cells of mantle contained sulfated groups.

134. Dempster, R.P. 1955. The use of copper sulphate as a cure for fish diseases caused by parasitic dinoflagellates of the genus *Oodinium*. Zoologica 40:133-137.

At the Steinhart Aquarium, San Francisco, Calif., copper sulphate in concentrations ranging from 0.4 mg/l to 0.8 mg/l were found to be relatively non-toxic to tropical marine fish, but effective in eradicating the gill and skin infections caused by the dinoflagellate Oodinium. Because of the toxicity of higher concentrations of copper, it is essential to control the concentration in the aquarium water closely. A colorimetric method for the determination of copper, using sodium diethyldithiocarbamate as indicator, is described. Velvet disease, which is caused by the freshwater flagellate Oodinium limneticum, also appear to be cured by treatment with copper sulphate.

135. Deschiens, R. and V. Molinari. 1957. The toxic effect on molluscs of granulated zinc. Bull. Soc. Pat. Exot. 50: 62-65.

Aquarium experiments showed that snails died within 24 hours in the presence of zinc in granular form. Further investigations are required on the effect in natural conditions.

136. Deschiens, R., V. Molinari, and D. Bartrand. 1957. The action of "zinc-water" as a toxic agent on molluscs. Bull. Soc. Pat. Exot. 50:59-61.

Aquarium experiments were made to test the action of different zinc compounds on snails (Planorbis glabratus and Bulinus contortus), which serve as intermediate hosts for schistosomes. The results show an oligodynic effect of zinc, which was probably strongly ionized, even in concentration of 1 mg/l. Also the snails concentrated zinc and copper ions in their bodies to toxic amounts. This capacity is a natural physio-pathological property of certain types of snail. It is possible in certain cases to determine the toxic effect of a chemical substance on molluscs by the amount of active ions which are formed in the tissues of the snail.

137. DeSouza, C.P. and E. Paulini. 1966. Laboratory tests with triphenyl-lead molluscicide. Revista Brasileira de Malariologia e Doencas Tropicais 18:247-251.

The molluscicidal activity of triphenyl-lead acetate was tested on mature snails (Biomphalaria glabrata) and on their 0-1 and 4-5-day-old eggs. Freshly-laid eggs showed the highest susceptibility; the LC_{50} at 24 hr exposure was 0.13 mg/l (in a water emulsion) for 0-1-day-old eggs. This decreased to 0.23 mg/l for 3-4-day-old eggs and to 0.48 mg/l for the mature snails. The corresponding figures for sodium pentachlorophenol were 0.15, 0.25, and 0.15 mg/l.

138. Dilling, W.S. and C.W. Healy. 1926. Influence of lead and the metallic ions of copper, zinc, thorium, beryllium and thallium on the germination of frogs spawn and on the growth of tadpoles. Annals Appl. Biol. 13:177-188.

Lead is more toxic to ova than to spermatozoa. Lead salts partly or wholly inhibit development of frog eggs with inhibition most pronounced by the 10th day. Lead retards growth of tadpoles by 50% in one month. Colloidal lead preparations have comparable action. Thorium salts also acted as an inhibitor to ovum development. Zinc salts did not retard ovum development but were fatal to tadpoles or delayed growth. Copper salts were fatal to tadpole on emergence, as was thallium. Beryllium had little effect. Solutions of metals were of similar strength.

139. Dilling, W.S., C.W. Healy, and W.C. Smith. 1926. Experiments on the effects of lead on the growth of plaice (Pleuronectes platessa). Annals Appl. Biol. 13:168-176.

No evidence has been obtained to show that trace levels of ionic lead in sea water can retard metamorphosis of plaice embryos. Lead in colloidal form apparently does not kill young plaice, but retards growth while fish are in the lead medium. Acute lead poisoning precipitates protein on the gill filaments.

140. Dorfman, D. and W.R. Whitworth. 1969. Effects of fluctuations of lead, temperature, and dissolved oxygen on the growth of brook trout. J. Fish. Res. Bd. Can., 26:2493-2501.

Brook trout were exposed to daily doses of lead under conditions of fluctuating dissolved oxygen and temperature, and were weighed at intervals. A dosage of 25 mg/l reduced growth, but little or no effect on growth resulted from lower concentrations. Interpolated 96-hour TL_m values were greater than the highest concentrations tested. In a separate experiment, trout exposed to constant levels of lead for 4 days had a 96-hour TL_m value of 3.12 mg/l of lead.

141. Doudoroff, P. and M. Katz. 1950. Critical review of literature on the toxicity of industrial wastes and their components to fish. I. Alkalies, acids, and inorganic acids. Sewage & Industr. Wastes (Sewage Wks. J.) 22:1432-1458.

The authors review literature on the toxicity to fish of certain substances occurring in trade waste waters including strong alkalies, ammonia, acids, carbon dioxide, chlorine and cyanogen chloride, hydrogen sulphide, carbon monoxide, sulphur dioxide, and high

concentrations of oxygen. It appears that fish can tolerate pH values of 5.0-9.0. Strong alkalies are not toxic if the concentration is such that the pH value is not greater than 9.0; at pH values below 9.0, solutions of ammonia and ammonium salts may be toxic. At pH values of 5.0 or less, strong mineral acids, such as sulphuric acid, and some weaker organic acids, such as citric and exalic acids, may be toxic, other weak and inorganic and organic acids, such as hypochlorous, hydrocyanic, boric, and chromic acids are toxic at slightly higher pH values. Sensitivity of fish to carbon dioxide varies considerably. Low concentrations of hydrogen sulphide, free chlorine, cyanogen chloride, carbon monoxide, ozone, phosphine, and sulphur dioxide are very toxic.

142. Doudoroff, P. and M. Katz. 1953. Critical review of literature on the toxicity of industrial wastes and their components to fish. II. The metals, as salts. Sewage Industr. Wastes 25:802-839.

The authors review literature on the toxicity to fish of simple inorganic salts of metals, including studies on the relative toxicity of various metals, antagonism and synergism of metallic cations and hydrolysis and precipitation of metal compounds in natural waters, mode of action of metal salts and the role played by anions, and the effects in toxicity tests of temperature, volume of test solution, and acclimatization of fish. Metals which are dealt with individually include aluminium, arsenic, barium, cadmium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, mercury, nickel, potassium, silver, sodium, strontium, tin, and zinc. It is concluded that in dilute physiologically unbalanced solutions of single metal salts all metals are toxic to fish, but in mixed salt solutions the metals are often less toxi- because of the antagonism between different metals. However, some highly toxic metals, such as zinc and copper, are strongly synergistic and a mixture of salts of these metals can be much more toxic to fish than are the individual solutions. The toxicity of many metals is markedly affected in temperature, concentration of dissolved oxygen, and volume of the experimental solution. The least toxic metals are sodium, calcium, strontium, magnesium, potassium, lithium, barium, and manganous and cobaltous ions, while highly toxic metals include silver, mercury, copper, lead, cadmium, aluminium, zinc, nickel, and trivalent chromium. Hexavalent chromium, in solution as chromates and dichromates, is less toxic than trivalent chromium in simple solutions of chromic salts. Solutions of permanganates are much more toxic than are solutions of manganous salts containing an equivalent concentration of manganese. The toxic concentrations of iron have not been established accurately, and further work on this is required.

143. Doudoroff, P., G. Leduc, and C.R. Schneider. 1966. Acute toxicity to fish of solutions containing complex metal cyanides, in relation to concentrations of molecular hydrocyanic acid. Trans. Amer. Fish. Soc. 95:6-22.

Published indirect evidence indicating that the toxicity of solutions of complex metal cyanides to fish is a function of the concentration of molecular (not ionized) HCN is reviewed. The influence of pH on toxicity of the nickelocyanide complex could be explained only by assuming that HCN is the toxic factor. Recent re-evaluation of the dissociation constant of the tetracyanonickelate (II) ion has confirmed the above interpretation of toxicity test results.

By means of a recently published method for determination of molecular HCN by gas-liquid chromatography, it was possible to demonstrate conclusively that this factor virtually alone determined the acute toxicity to bluegills of the various solutions of simple and complex cyanides. Median immobilization times for bluegills in the solutions varied independently of total cyanide concentrations but were clearly related to molecular HCN levels. Two of three tested solutions containing the silver-cyanide complex proved exceptional; their toxicity produced symptoms strongly suggestive of heavy-metal poisoning and was deemed referable to toxicity of the complex anions or of silver cations. Changes in CO_2 content and pH of the medium occurring at gill surfaces had no appreciable influence on the toxicity of the nickelocyanide complex, presumably because dissociation is not very rapid.

Bluegills dying in complex metal cyanide solutions containing no silver showed typical symptoms of cyanide poisoning only, whereas most of those that died in solutions containing cyanide and silver showed before death also pronounced superficial coagulation of mucus suggestive of heavy-metal poisoning. Bluegills that died in about 400 minutes or sooner in a fresh test solution containing the $Ag(CN)_2$ complex at pH 6.0 probably died largely or entirely of cyanide poisoning. The slower death of the fish in solutions with higher pH and determined molecular HCN concentrations near and below 0.12 mg/l evidently was due primarily to a lethal agent other than HCN. The molecular HCN concentration in the least toxic test solution containing silver (with pH 7.5) was barely measurable indicating very slight dissociation of the complex, yet the fish placed in this solution lived little longer than did those exposed to a similar solution (with pH 6.5) having a molecular HCN concentration near 0.12 mg/l. This result was a first indication that the $Ag(CN)_2^-$ion itself, unlike the $Ni(CN)_4^=$ion, has considerably toxicity to fish, and that the toxicity of the slightly alkaline dilution was attributable mostly or entirely to this lethal factor. Silver ion, which derives from dissociation of the complex anion and is exceedingly toxic, may have caused

or contributed to the toxicity of one or both of the slowly lethal solutions (pH 6.5 and 7.5). The concentration of silver ion in the two acid solutions (pH 6.0 and 6.5), at least, is believed to have been limited by the low solubility of silver chloride and the moderately high concentrations of chloride ion (about 75 mg/l or less) resulting from the use of HCl for acidification of the water. Withdrawal of silver ion from the solutions through the formation of minute amounts of insoluble (colloidal) silver chloride, which was not detected, probably resulted in liberation of cyanide from the complex and formation of more HCN than would have been present in the absence of chloride ion. Authors suggest that cuprocyanide ions may have toxicity great enough to be of practical importance when very little free cyanide is present.

144. Drabkina, B.M. 1962. Effect of water of different salinities on the survival of sperm, eggs and larvae of sturgeons. Vopr. Ekol. Vys. Shkol. Moscow. 8:54-55.

Experiments have shown that sturgeon sperm is most active in water with a salinity of 2 parts per thousand; salinities of 6-8 parts per thousand have an inhibiting effect. Sturgeon eggs could be fertilized in waters with salinities of 1·2 and 4 parts per thousand.

145. Duke, T.W. 1967. Possible routes of zinc-65 from an experimental estuarine environment to man. J. Water Pollut. Contr. Feder. 39:536-542.

Results are given on distribution of zinc-65 introduced into an experimental pond connected to an adjoining estuary in North Carolina to determine routes and rates by which zinc-65 could be returned to man from an estuarine environment and to determine the organisms that could be used as indicators of presence of zinc-65 in estuaries. It was found that shellfish accumulated zinc-65 rapidly and to higher levels than did other organisms, and the zinc-65 accumulated in the edible portions of these animals could easily have been transferred to humans. If man were to use the organisms from the pond periodically as a source of food, the clams, which had the highest specific activity, would be the greatest potential source of zinc-65; if, however, seafood from the pond was eaten only once, more radioactivity would be received from the oysters since the meat of these animals contained the largest amount of radioactivity. Under the conditions in the experimental pond, scallops were found to be good indicators of the presence of zinc-65 if samples were collected one day after the isotope was added to the water; oyster, however, retained zinc-65 longer than did the scallops and after 100 days contained more of

the isotope on a whole-animal basis. It is pointed out that the results of these experiments cannot be applied directly to other estuaries with different conditions of pH value, temperature, salinity, and rates of water exchange, since all these factors affect the movement of zinc-65 in the environment.

146. Duke, T.W., J.P. Baptist, and D.E. Hoss. 1966. Bio-accumulation of radioactive gold used as a sediment tracer in the estuarine environment. U.S. Fish Wildl. Serv., Fish. Bull. 65:427-436.

Laboratory and field studies have been carried out to investigate the possibility of the uptake by marine organisms of radioactive gold used to trace the movement of sediment. When an aqueous solution of radioactive gold was placed directly in the gut of blue crabs (*Callinectes sapidus*), toadfish (*Opsanus tau*), and croakers (*Leiostomus xanthurus*) there was little transfer of the isotope to various body tissues. Toadfish which were fed radioactive gold in aqueous solution retained more of the activity than did fish fed the same amount of radioactivity sorbed on clay particles. When organisms and bentonite clay were kept for 25 days in sea water containing radioactive gold, crabs accumulated the most activity, followed, in descending order, by clams, clay, and fish. In field experiments in which sediment-sorbed radioactive gold was introduced into Cape Fear river, N.C., the maximal amount of activity in caged organisms (oysters, crabs, and fish) was detected in oysters 17 hours after the isotope was released, and amounted to 70.9 m μc per g wet weight; indigenous free-swimming organisms collected 41 hours after the radioactivity was released contained no detectable radioactive gold.

147. Duke, T.W., J.N. Willis, and T.J. Price. 1966. Cycling of trace elements in the estuarine environment. I. Movement and distribution of zinc-65 and stable zinc in experimental ponds. Chesapeake Science 7:1-10.

Observations have been made on the movement and distribution of zinc-65 and the distribution of stable zinc in water, sediments, and biota of two estuarine ponds, one of which was essentially a closed system and the other was connected to an adjoining estuary. In the closed pond zinc-65 was taken up rapidly by the sediments and biota, and after one day only 66 percent of the zinc-65 remained in the water. In the other pond about 82 percent of the zinc-65 was flushed out by tidal action in the first day, and of the remainder 36% was in the bottom deposits, 59 percent in the water and suspended solids, and 5 percent in the biota. After 100 days, in both ponds, most of the zinc-65 was associated with the bottom deposits.

148. Duke, T., J. Willis, T. Price, and K. Fischler. 1969. Influence of environmental factors on the concentrations of zinc-65 by an experimental community. Proc. 2nd Natn. Symp. Radioecol., Ann Arbor, 1967:355-362.

In laboratory experiments on the effects of salinity, temperature, pH value, and total concentration of zinc on the accumulation of zinc-65 from sea water by benthic estuarine organisms (oysters, clams, scallops and mud crabs) and their sediment substrates; each factor was studied at two levels and a polyfactorial approach was used to indicate the interaction between the environmental factors. Tabulated and diagrammatical results show that each of the four factors affected the accumulation of zinc-65 in animals and sediments, but there was no significant effect attributable to interaction between the factors and no one factor affected all the components of the community. Concentration factors for zinc-65 varied inversely with salinity and total zinc concentration and directly with temperature and pH value. The implications of these results are considered. As shown graphically, there were significant temporal variations in the concentration factors for control animals and sediments, possibly owing to the different biochemical composition of the animals and the physico-chemical composition of the sediments at different times of the year; and it is therefore emphasized that the exact conditions of the experiment must be specified when reporting concentration factors for estuarine organisms.

149. Dunson, W.A. 1969. Concentration of sodium by freshwater turtles. Proc. 2nd Natn. Symp. Radioecol., Ann Arbor, 1967:191-197.

Evidence has accumulated that freshwater turtles (Pseudemys) are physiologically adapted to the aquatic habitat, and the rate of ionic exchange of turtles must therefore be taken into account when studying the cycling of ions in the freshwater ecosystem. In-vivo and in-vitro studies were made to obtain further data on some aspects of sodium exchange. The influx of sodium was localized in the membranes of the oral and cloacal regions and was inhibited by zinc. In fresh water with a sodium concentration of 575 mg/l the turtle would have a concentration factor of 300 for sodium and when turtles are coming out of hibernation the influx of ions may be increased considerably. Further studies are recommended to determine the importance of turtles in the concentration of dissolved radionuclides.

150. Dunster, H.J. 1958. The disposal of radioactive liquid wastes into coastal waters. 2nd U.N. Int. Conf. Peaceful Uses Atom. Energ., A/Conf. 15/p/297:22 p.

An account is given of the sampling of fish, seaweed, sea-bed

material, and shore sand in environments affected by the discharge of radioactive waste waters from the Windscale Works of the U.K. Atomic Energy Authority, Sellafield, Cumb. and the results obtained up to the end of 1957 are tabulated. In addition to determinations of the total β-activity, individual estimations were made of plutonium, strontium, and ruthenium in fish and seaweed, since these are both used as food. Sampling was carried out at distances up to 50 km from the outlet; at this distance the activities determined did not differ significantly from background levels. The maximum permissible levels for radioactivity in marine materials are discussed; the values adopted at Windscale are tabulated and were used in conjunction with the results of sampling to determine the maximum permissible rate of discharge from the plant. The maximum permissible discharge is limited by the amount of radioactivity accumulated in the seaweed, most of which grows within 20 km of the outlet and is used almost directly as food. From the results obtained, it is concluded that the rate of disposal of radioactivity in these coastal waters is adequate to permit the safe release of some 20,000 curies of total β-activity per month at a point about three km off this part of the Cumberland coast. Specific limitations are necessary for strontium-90, ruthenium-106, and plutonium. The applicability of these results in assessing the problem of disposal of radioactive waste waters in other coastal waters is discussed, and preliminary surveys near the Dounreay reactor, Scotland, and the Winfrith Health Establishment, near Weymouth are summarized.

151. Edgington, D.N., S.A. Gordon, M.M. Thommus, and L.R. Almodovar. 1970. The concentration of radium, thorium, and uranium by tropical marine algae. Limnol. Ocean. 15:945-955.

Twenty species of marine algae were collected between 1961 and 1968 from coastal waters of Puerto Rico and analyzed chemically for total organic material, protein nitrogen, and calcium, and radiochemically for the naturally occurring alpha particle emitters ^{226}Ra, ^{232}Th, and ^{238}U. Study of these data suggests that the concentration of radium,thorium, and uranium by tropical marine algae is controlled by two mechanisms: (1) ion-exchange or coprecipitation of the ion with the calcium carbonate matrix, and (2) complex formation with either the protein nitrogen or some other compound of the organic fraction. Radium (and possibly thorium) apparently is concentrated by both mechanisms, the dominant one depending on the phylum. For the Rhodophyta and the highly calcified Chlorophyta it is the former and for the Phaeophyta the latter. Uranium is concentrated by the first mechanism.

152. Eisler, R. 1967. Tissue changes in puffers exposed to methoxychlor and methyl parathion. U.S. Bur. Sport Fish. Wild. Tech. Paper 17:1-15.

Adult northern puffers Sphaeroides maculatus (Pisces: Tetraodontidae) were exposed for periods up to 45 days to either .030 mg/l of the organochloride insecticide methoxychlor, 20.2 mg/l of the organophosphorous insecticide methyl parathion, or to a combination of .015 mg/l of methoxychlor and 10.1 mg/l of methyl parathion. These concentrations will produce approximately 5 per cent mortality in 96 hours under the conditions of the experiment. Periodically, fish from each group were analyzed for whole blood and serum constituents and for content of sodium, potassium, calcium, magnesium, zinc and iron in selected tissues.

Puffers subjected to .03 mg/l of methoxychlor remained as active as the controls, ate readily when offered shucked clams, and experienced no significant mortality. No statistically significant differences at the 0.01 level were observed between methoxychlor-exposed puffers and controls for any of the parameters investigated.

Groups exposed to methyl parathion alone, or to methyl parathion in combination with methoxychlor, refused to eat during the study, were sluggish, and, after exposure for 96 hours, exhibited a rapid increase in the rate of death. Survivors, when compared to controls, had less hemoglobin, erythrocytes, a lower hematocrit, complete inhibition of serum esterase enzymes, less magnesium in liver, and less zinc in liver and in gill filament; these differences were significant at the 0.01 level.

Profiles were constructed based on the effects of each insecticide on blood and tissue components. The visual patterns provided by these profiles suggest a means of identifying unfavorable environmental conditions before the appearance of obvious morphological or physiological changes.

153. Eisler, R. 1967. Variations in mineral content of sandbar shark vertebrae (Carcharhinus milberti). Naturaliste Canadien 94:321-326.

Cervical vertebrae from three length-frequency groups of Carcharhinus milberti were ashed and assayed for Ca, Fe, Mg, Zn, Na and K. These six metals constituted 28.4% of the total ash weight in samples from the smallest (mean total body length 64 cm) size groups of sharks, but only about 10% from both medium (129 cm) and from large (209 cm) sharks. Small sharks contained about three times more Ca per sample than either medium or large sharks and this would account for differences in mineral content among groups. The concentrations of both Na and K were similar in all size groups. Those of Zn and Fe on the other hand, were highest in small sharks and lowest in large sharks, while the reverse was true for Mg. Studies of the elementary chemical composition of vertebrae may be useful in evaluating the rates and processes of elasmobranch aging.

154. Eisler, R. 1967. Acute toxicity of zinc to the killifish, Fundulus heteroclitus. Chesapeake Science 8:262-264.

Adult mummichogs, F. heteroclitus, were subjected to different concentrations of zinc as $ZnCl_2$ at 24 o/oo salinity, pH 8.0 and 20°C. At 192 hours all subjected to 43 mg/l of Zn and lower were alive and indistinguishable from controls. Among survivors there were no appreciable differences at 192 hours in zinc content of various tissues as determined by atomic absorption, regardless of initial amount of zinc in solution. All mummichogs subjected to 157 mg/l or 180 mg/l of zinc died between 24 and 48 hours. Dead mummichogs contained about seven and eight times more zinc in whole fish and in gill arch, respectively than controls.

155. Eisler, R. 1971. Cadmium poisoning in Fundulus heteroclitus (Pisces: Cyprinodontidae) and other marine organisms. J. Fish. Res. Bd. Canada 28:1225-1234.

In acute toxicity bioassays with $CdCl_2 \cdot 2\frac{1}{2}H_2O$ at 20°C and 20 o/oo salinity, the concentrations fatal to 50% of the organisms of various marine species in 96 hours ranged between 0.32 and 55.0 mg/l Cd^{2+}. The order of sensitivity was sand shrimp, Crangon septemspinosa (0.32); hermit crab, Pagurus longicarpus (0.32); grass shrimp, Palaemonetes vulgaris (0.42); starfish, Asterias forbesi (0.82); soft shell clam, Mya arenaria (2.2); green crab, Carcinus maenus (4.1); oyster drill, Urosalpinx cinerea (6.6); mud snail, Nassarius obsoletus (10.5); sand worm, Nereis virens (11.0); striped killifish, Fundulus majalis (21.0); bay mussel, Mytilus edulis (25.0); sheepshead minnow, Cyprinodon variegatus (50.0); and mummichog, Fundulus heteroclitus (55.0). Mummichogs were more susceptible to cadmium exposures at 20 than at 5°C and at 5 o/oo than at 15, 25, or 35 o/oo. Additional studies with mummichogs clearly demonstrated that 96 hours was not sufficient to adequately evaluate cadmium toxicity to this species. Mummichog whole body cadmium residues determined by atomic absorption provided a useful index of cadmium body burden among fish surviving exposure. However, cadmium residue data from dead mummichogs were of limited worth owing to accumulation after death.

156. Eisler, R. and G. LaRoche. 1972. Elemental composition of the estuarine teleost, Fundulus heteroclitus (L.). J. Exp. Mar. Biol. Ecol. 8:121-134.

Elements not detectable in whole ashed Fundulus regardless of age, sexual condition, or season were Ag, Al, Au, Ba, Be, Cd, Co, Cr, Cs, Li, Ni, Pb, Rb, and Tl. Elements that were consistently measurable were Ca, Cu, Fe, K, Mg, Mn, Na, Sr, and Zn. Studies with 6 length-frequency size groupings showed that graded increases in total

body length (TL) were associated with progressive increases in whole body concentration of Ca and Sr and decreases in K, Mg, Na, and Zn. On an ash weight basis, heads were comparatively low in K, Fe, Mg, Zn, and Sr and carcasses comparatively high in K and low in Cu, Fe, Sr, and Na. Viscera contained high concentrations of most elements when compared to heads and carcasses, especially Fe, Zn, Sr, and Cu.

In a combined study on effect of TL, water temperature and salinity, and acclimatization period on whole body elemental content, it was determined that large fish of 84 mm TL contained more Ca, and less Cu, K, Mg, Na, and Zn per unit weight than small fish of 47 mm TL. Within each size group, fish kept at 5° or 20°C at salinities of 9 o/oo or 27 o/oo exhibited essentially the same elemental composition after 30 days. However, fish held for 30 days when compared to those held only 3 days contained significantly less Ca, Na, K, Mg, Zn, Cu, and Mn.

In another study on effects of seawater formulation, feeding frequency, and medium replacement rate on whole body elemental composition, changes were least pronounced during a 30-day period among fish that were fed daily (vs weekly), that were held in a seawater formulation developed by our laboratory (vs "natural" sea water, or a commercial preparation), and among groups with the medium replaced twice weekly (vs no replacement).

Selected data on elemental composition available for other species of teleosts and elasmobranchs are presented and discussed.

157. Eisler, R. and P.H. Edmunds. 1966. Effects of endrin on blood and tissue chemistry of a marine fish. Trans. Amer. Fish. Soc. 95:153-159.

Adult northern puffers, *Sphaeroides maculatus*, were exposed to graded concentrations of endrin, a chlorinated hydrocarbon insecticide, at 20°C, 24 o/oo salinity, and pH 8.0. All animals subjected to 0.01 mg/l of endrin died within 24 hours. At concentrations of 0.001 mg/l of endrin, or lower, no mortality occurred within 96 hours.

Blood and tissue samples from fish surviving the 96-hour exposure were analyzed by photoelectric colorimetry and atomic absorption spectroscopy. Mean hemoglobin content and relative liver size of puffers exposed to endrin concentrations of .001, .0005, .0001, or .00005 mg/l were not significantly different from those of controls. Authors found no meaningful changes in levels of serum chloride, gamma-globulin, and uric acid, but did find that the concentrations of sodium, potassium, calcium, and cholesterol in serum were consistently higher

in experimental animals than in controls. Moreover, concentrations of sodium, potassium, calcium, magnesium, and zinc in the livers of test animals were consistently lower than in those of the controls. Concentrations of the same cations in gill tissue fluctuated widely.

Exposure to sublethal concentrations of endrin impaired liver function, as evidenced by the transfer of major cations from the hepatic tissue into the serum and by elevated serum cholesterol.

158. Eisler, R. and M.P. Weinstein. 1967. Changes in metal composition of the quahaug clam, Mercenaria mercenaria, after exposure to insecticides. Chesapeake Science 8:253-258.

Adult quahaug clams (Mercenaria mercenaria) in sea water with a salinity of 24 parts per thousand, a pH value of 8.0, and a temperature of 20°C, were subjected to ranges of concentrations of malathion and methoxychlor; all survived exposure for 96 hours, including those subjected to the highest concentrations of 37 mg/l malathion and 1.0 mg/l methoxychlor. Atomic absorption analysis of shelled clams and tissues showed, in comparison with control clams, consistent changes in levels of sodium, potassium, magnesium, iron, and especially calcium and zinc. Profile patterns of the metal contents of tissues of insecticide-exposed and control clams are shown.

159. Ellis, M.M. 1937. Detection and measurement of stream pollution. U.S. Government Printing Office, Washington. U.S. Dept. of Commerce, Bureau of Fisheries, Bull. No. 22 (from Bull. U.S. Bur. Fish 48:365).

A collection of information, from the literature and from the experimental and field work of various agencies, on the conditions necessary if fish are to thrive and on the specific effects of various types and components of polluting effluents. The first part, on the physical and chemical characteristics of water suitable for freshwater fish, deals with methods of sampling water, mud, plankton, mussels and fish, the equipment used for field studies, the determination and effects on the fauna of the concentration of dissolved oyxgen, pH value, ionisable salts (carbon dioxide, iron and ammonia), suspensoids, depth, and temperature, and the effect of stream pollution on bottom conditions. The section on the action of polluting materials on fish deals with injuries to gills and external structures and with substances which enter the body and exert true toxic action. The section on the lethal action of specific substances discusses the use of goldfish and Daphnia magna as test animals and gives tables of the results of investigations of the effects of osmotic pressure, sodium chloride, acids, metallic compounds, sulphur and selenium compounds, and various other compounds found in industrial wastes. Data are given of the limits of toxicity of 114 substances found in polluting effluents.

160. Ellis, M.M. 1947. Toxicity of phenyl-mercuric lactate for fish. U.S. Fish. Wild. Serv. Spec. Sci. Rep. 42.

Tests were made to determine the toxicity to goldfish (Carassius auratus) of phenyl-mercuric lactate which may be discharged to streams in the waste waters from the processing of pulp. Results showed that water at a pH value of 7.7 to 7.8 containing 0.5 mg/l or more phenyl-mercuric lactate, killed all of the fish in 16 hours or less. In concentrations of 0.05 mg/l or less the fish made erratic movements but all survived. The lowest concentrations caused death was about 0.10 mg/l. Phenyl-mercuric lactate coagulates the gill tissues and the mucus film on the gill filaments and breathing is affected. In poorly oxygenated water, fish succomb more rapidly than in well-aerated water. Alteration in the pH value within the limits pH 6.3 and 9.0 within which the fish are not affected by alkalinity or acidity, did not affect the toxic properties of phenyl-mercuric lactate. In terms of the content of mercury, phenyl-mercuric lactate is more than twice as toxic as mercuric chloride. The minimum concentration of phenyl-mercuric lactate which is lethal to fish depends partly on the species. Trout, minnows, and the gizzard shad have low respiratory tolerance and will succumb at greater dilutions than goldfish which have a high respiratory tolerance.

161. Ericksen, L.V. and K. Kaemmerer. 1960. The effect of mine waste waters containing metal salts on the biological conditions in a river system. Gas-u. Wasserfach 91:16-18.

As a result of damage to fish caused by water pumped from workings where iron ore was mined, examinations were made at 11 points over a 70-km stretch of the channel to which the waste water was pumped, the stream into which the channel discharged, and the larger stream into which the first stream flowed. The damaging effects had been ascribed to lead but examination of the mine waters showed lead was present only in traces. Nickel, iron, and manganese were found in mine water at quantities of about 50 mg/l; the water was turbid and yellow. The subsidiary stream above the channel carrying the mine waters and the main stream above its confluence with the subsidiary stream were biologically normal but after the addition of the mine waters there was an almost complete absence of life for a stretch of some 50 km. Chemical investigations and tests of toxicity showed that there was no direct poisoning by the iron, manganese, or nickel salts and damage to fish is ascribed to the presence of finely divided iron hydroxide which was deposited on the skins and in the gills of the fish and on plankton. Lower down the main stream, another tributary, carrying waste waters from brown coal mines entered. Almost immediately the biological condition of the water improved and normal water life rapidly returned. It appeared that the finely divided iron hydroxide was absorbed on suspended particles of brown coal.

162. Evans, D.H. 1967. Sodium, chloride and water balance of the intertidal teleost, Xiphister atropurpureus. I. Regulation of plasma concentration and body water content. J. Exp. Biol. 47:513-517.

Studies were undertaken to determine the degree of regulation of sodium, chloride and water displayed by the intertidal teleost, Xiphister atropurpureus, over a range of salinities. The plasma concentrations of sodium and chloride declined by approximately 15% in 10% sea water (1100 mg-Na/kg) and the intracellular species increased by approximately 6% in 10% sea water.

163. Evans, D.H. 1967. Sodium, chloride and water balance of the intertidal teleost, Xiphister atropurpureus. II. The role of the kidney and the gut. J. Exp. Biol. 47:519-534.

The rate of loss of sodium, chloride and water via the urine and the rate of intake of sodium, chloride and water by ingestion of the medium was determined for the euryhaline teleost, Xiphister atropurpureus. The urinary losses of sodium and chloride were approximately 100 mg/kg fish/day in both 100% sea water (11,000 mg-Na/kg) and 10% sea water. The ingestion of sodium and chloride by drinking the medium amounted to approximately 90 mg/kg fish/day in 100% sea water and approximately 2 mg/kg fish/day in 10% sea water. The low rate of urine flow in 10% sea water and the low drinking rate in 100% sea water indicate a relative impermeability to sea water in both salinities.

164. Evans, D.H. 1967. Sodium, chloride and water balance of the intertidal teleost, Xiphister atropurpureus. III. The roles of simple diffusion, exchange diffusion, osmosis and active transport. J. Exp. Biol. 47:525-534.

The effluxes of ^{22}Na, ^{36}Cl and tritiated water from the euryhaline teleost, Xiphister atropurpureus were determined in 100% sea water (11,000 mg Na/kg) and 10% sea water. Only the flux of sodium in 100% sea water contained an exchange diffusion component. The relative impermeability of Xiphister is shown by its low fluxes of sodium, chloride and water in both salinities. In 10% sea water the permeability to sodium declines while the permeability to chloride and water remained at sea water levels. In both salinities diffusion and active transport are the major components of the sodium and chloride balance of Xiphister.

165. Ezell, H., L.L. Sulya, and C.L. Dodgen. 1969. The osmotic fragility of some fish erythrocytes in hypotonic saline. Comp. Biochem. Physiol. 28:409-415.

Osmotic fragility curves of erythrocytes from eleven species of marine teleosts from the Gulf of Mexico are of the normal sigmoid type. The mean corpuscular fragility value is generally consistent within a species but varies widely among the different species. Two species of gars, Lepidosteus osseus and L. productus, have erythrocytes which are resistant to hemolysis in hypotonic sodium chloride solutions.

166. Farley, J. 1955. Use of sodium arsenite for controlling aquatic plant growths. Publ. Wks. N.Y. 86 (7):73.

The Fish and Wildlife Service of the U.S. Department of the Interior has found sodium arsenite effective in controlling submerged aquatic plants. Its use is restricted to control of aquatic weeds but discouraged in the larger isolated water areas which produce essential plant food for wild fowl. Results obtained by application in powder or liquid forms are discussed. Toxic effects of sodium arsenite make careful handling essential where humans and cattle are concerned; fish are less susceptible to the poison.

167. Federov, A.F. 1963. Biological indicators of weak radioactive contaminations in northern seas. Nauch. Dokl. Vyss. Shkol., Biol. Nauk. 1:92-95.

The author describes a method for estimating the radioactivity of sea water by means of crayfish. The beta activity of the crayfish due to potassium-40 is determined, and from this the activity of the sea water is estimated, using a corrective coefficient that characterized the ability of the crayfish to concentrate the various radioactive isotopes found in the water.

168. Fedii, S.P. 1959. Effect on fishery of drainage water from metallurgical plants. Ryb. Khoz. 11:18-20. Biol. Abstracts 1967, 48:10820.

A study was made of the effect of metal works waste waters on two reservoirs in U.S.S.R. When the reservoir was full, the concentration of iron in the water at a point 300 m from the outfall was 5 mg/1, and at a distance of 1 km it was 1 mg/1. When the water level was low, the waste waters spread further into the reservoir and caused death of fish, especially in winter.

169. Feldt, W. 1966. Radiation protection aspects in the supervision of fish in their radioactive contamination. Proc. Instint. Congr. Radiat. Prot:395-400.

The ecological role of strontium and caesium is reviewed and experimental data are reported on the concentrations of strontium-90 and caesium-137 in various species of marine and freshwater fish. The use of the discrimination factor in calculations on contamination, and the effect of the salt content on the concentration factor are also considered. On the basis of these observations the planning of a suitable superivsion program for fish is discussed, taking into account the possible transfer of radioactive isotopes from fish to man.

170. Feldt, W. and J.Z. Lange. 1962. Contents of strontium-90 and caesium-137 in bream from territorial waters of North Germany. Lebensmittelunters u.-Forsch. 117:103-113.

Concentrations of strontium-90 and caesium-137 in bream from flowing and still waters in north Germany were determined. Fish from still waters contained higher concentrations of the nuclides, and particularly of caesium-137 than fish from the river Elbe. Strontium-90 was accumulated preferentially in tissues rich in calcium (bones), but caesium-137 was accumulated mainly in tissues rich in potassium (muscle).

171. Fisher, A. 1956. The effect of copper sulphate on some microorganisms in fish ponds. Bamidgeh 8(3):39-43; Biol. Abstr. 33:708.

The effect of different concentrations of copper sulphate on Daphnia, Cyclops, and chironomids in distilled, tap and pond water, was studied. Daphnia was found to be most sensitive and Cyclops least so. Toxicity increased with increase in concentration and increase in temperature, and decreased with increase in pH value. With equal concentrations, the chemical was most toxic in distilled water and least so in pond water. The addition of soil to pond water lowered the pH value and thus increased the toxicity. Most of the copper remains in the water and only a very small amount is retained by the soil.

172. Fitzgerald, B.W. 1962. Zinc and zinc-65 in shellfish of Fishers Island Sound and its estuaries. Dissertation Abstracts 23: 1522.

Oysters from Fishers Island Sound were placed in sea water to which was added various zinc salts labelled with zinc-65, and the effect of the different anions on the uptake of zinc was observed. The results obtained indicated that the levels of zinc-65 in oysters in this area are low compared with those obtained from the Pacific coast of U.S.A. Complexing of the zinc considerably reduces the rate and extent of uptake.

173. Fitzgerald, G.P. and S.L. Faust. 1963. Factors affecting the algicidal and algistatic properties of copper. Appl. Microbiol. 11:345-351.

Laboratory studies have indicated that 5 different sources of copper (copper sulphate, a mixture of 1 part copper sulphate and 2 parts citric acid, and the commercial preparations Algeeclear, Cuprose (Texas) and Cuprose (Nalco) are all equally effective as toxic agents for algae, but the constituents of the medium in which the tests are carried out have a marked effect on the results, the source of iron used in the media being particularly important. Studies carried out in bacteria-free media indicated that copper was just as toxic when in a precipitated form as when in solution. A sub-culturing technique is described for determining whether a certain concentration of a chemical is algicidal, algistatic or non-toxic in action against a specific alga.

174. Fitzgerald, B.W., J.S. Rankin, Jr. and D.M. Skauen. 1962. Zinc-65 levels in oysters in the Thames River (Connecticut). Science 135 (3507):926.

Results are given of studies, over a 12-month period, on uptake of zinc-65 by oysters from three selected sites in the Thames River, Conn. The highest levels of radioactivity were found in March 1961 oysters from a bed situated opposite the U.S. submarine base; these contained 1632 μμc per kg of moist tissue. Subsequently the activity decreased. None of the samples assayed contained sufficient activity to represent a hazard to health.

175. Floch, H., R. Deschiens and Y.L. Corroller. 1963. The molluscicidal properties of Chevreul's cupro-sulphite in the prophylaxis of schistosomiasis. Bull. Soc. Path. exot. 56: 182-189.

Chevreul's copper sulphite is a selective molluscicide which is recommended for the control of snail vectors of schistosomiasis in rivers and fishponds. All Australorbis glabratus and Bulinus contortus snails are killed in 3 days or less after exposure to 1 mg/l and in 5 days after exposure to 0.25 mg/l, while eggs of the snail Lymnaea stagnalis are killed in 2 days at 10 mg/l but not in 1 day at 10 mg/l. Copper sulphite also kills goldfish, guppies and sticklebacks in 1 day at 90 mg/l; toad and frog tadpoles in 1 day at 15 mg/l, in 2 days at 10 mg/l, and in 3 days at 5 mg/l; dragonfly larvae in 1 day at 40 mg/l or 3 days at 20 mg/l; Daphnia longispina in 1 day at 2 mg/l; the water weed Lemnia media in 10 days at 10 mg/l; and green algae in 10 days at 10 mg/l. The residual activity of 1 mg/l of the chemical lasts for a year at room temperature.

176. Folsom, T.R., O.R. Young, and C. Sreekumaran. 1969. An estimate of the response rate of albacore to caesium. Proc. 2nd Natn. Symp. Radioecol., Ann Arbor 1967: 337-345.

To assist in ecological studies on the concentration of caesium by fast-moving marine animals, such as the albacore (tuna), a general form of mathematical framework has been adopted for connecting the dynamic response rate with the ultimate equilibrium in the fish. From tabulated data on the concentrations of natural and radioactive caesium in surface sea water and albacore samples from the north-east Pacific in 1965-1966, it appears that albacore concentrate caesium to relatively high levels. The concept of accumulation coefficient is explained and illustrated schematically as a function of the change in concentration with time after the environmental concentration has been increased by a known amount. The response of fish to environmental concentrations which increase (or decrease) uniformly is also considered, with a diagram showing the hypothetical response of tissue in an idealized fish travelling at uniform rate through an ocean which has a constant concentration gradient. Analysis of data from the north-east Pacific Ocean gave values of 106 $\pm$ 4 for the accumulation coefficient and 19 $\pm$ 6 days for the biological half-life of radioactive caesium in albacore. The data suggest that by 1966 the pattern of fallout derived from the nuclear tests of 1961-62 had become distorted by the major currents in the area. Late in 1965, the surface concentration tended to persist downwards to a depth of at least 200 m but in 1967, at several points, intense concentrations (sometimes 2-3 times the surface value) persisted at depths near 100 m which are reached by tuna-food organisms and frequently by tuna themselves; this stratification is being studied.

177. Fontaine, M., and R. Vibert. 1952. Anadromous migration of the salmon, Salmo salar L., and salinity gradient. Ann. Sta. Cent. Hydrobiol. Appl. 4:339-345.

To determine whether salmon, in migrating upstream to the breeding grounds, were guided by decrease in the concentration of salts, measurements were made of the electrical conductivity of the water in the river Adour and its tributary system and points on the course followed by the majority of fish. Results showed that although the general tendency was for the electrical conductivity to decrease from the lower reaches, unaffected by tidal water, to the upper reaches there was one reach where the gradient was reversed owing to the high concentration of salts in water of the tributary. Salmon apparently migrated against this increasing concentration of salts and it was concluded that salt concentration was not a guiding factor for the particular species (Salmo salar) investigated.

178. Foreman, E.E., and W.L. Templeton. 1958. The uptake of zirconium-95 and niobium-95 by Porphyra sp. U.S. Atomic Energy Authority, R&DB(W) TN-187: 16 pp.

Experiments were carried out at Windscale, Cumb., to determine the rate and extent of uptake of the radioactive isotopes zirconium-95 and niobium-95 by the edible seaweed, Porphyra umbilicalis. The half-lives and the maximum permissible concentrations of the radio-isotopes in water supplies are given. The concentration factors of both isotopes in Porphyra after 34 and 73 days in sea water of constant activity, were determined. Studies were also made on the release of zirconium and niobium from the radioactive seaweed; the loss in radioactivity after 6 and 65 days was 50 per cent and 96 per cent respectively.

179. Foster, R.F. and J.F. Honstead. 1967. Accumulation of zinc-65 from prolonged consumption of Columbia river fish. Health Physics 13:39-43.

Fish caught in the Columbia river, Washington, downstream from the Hanford reactors were eaten once each week for more than a year to obtain information on the amount of radioactivity that might be accumulated by persons living in the neighborhood. During a 12-month period about 11 kg of fish were consumed, amounting to about 3000 nc of phosphorus-32 and 800 nc of zinc-65. The accumulation of zinc-65 in the consumer was measured weekly in a whole-body counter and it was found that the maximal body burden of about 130 nc was reached on the 104th day and again on the 310th day. After the initial increase to equilibrium the body burden was about 7 times the weekly intake, and this was greater than anticipated from published data. The reduction of zinc-65 body burden following the last meal of contaminated fish was observed for 511 days, indicating an effective half-life of 162 days.

180. Foster, R.F., and P.A. Olson. 1951. An incident of high mortality among large rainbow trout after treatment with pyridlymercuric acetate. Progr. Fish-Cult. 13:129-130.

An account is given of the use of pyridylmercuric acetate (PMA) to control infection of salmonoid fish by Chondrococcus columnaris. PMA in a concentration of 2 mg/l was administered for 1 hour to yearling trout but 13% of the fish died. Two weeks later a similar treatment caused the loss of 10% of the fish. No fish died after a third treatment when the fish were not fed until 24 hours after the administration of PMA. An outbreak of Ch. columnaris and infection by Ichthyophthirius occurred in two ponds and to eliminate the latter, treatment was given three times with salt and once with roccal.PMA was administered to study its effect on the bacterial infection. Very few fish died as a result of this treatment but 11 days later when PMA was used again there was a heavy loss of fish.

181. Fowler, S.W. and L.F. Small. 1967. Molting of Euphausia pacifica as a possible mechanism for vertical transport of zinc-65 in the sea. Int. J. Oceanol. Limnol. 1:237-245.

Studies have shown that in the presence of large concentrations of zinc-65 (10-25 μc/l) considerable amounts of the isotope are taken up by the exoskeleton of Euphausia pacifica. Since this organism is abundant in the North Pacific, with a moulting frequency of 5 days, it is suggested that accumulation of zinc-65 in the exoskeleton could be a major mechanism of vertical transport of the isotope.

182. Fowler, S.W., L.F. Small, and J.F. Dean. 1969. Metabolism of zinc-65 in euphausiids. Proc. 2nd Nat. Symp. of Radioecology. USAEC Conf. 67053, Ann Arbor, Mich. 1967:399-412.

Authors studied uptake and retention of ^{65}Zn by the pelagic crustaceans Euphausia pacifica and Thysanoessa spinifera. Experiments were performed at three temperatures (5, 10, and 15°C) and two concentrations of radiozinc (10 and 25 μCi/l). Weight-specific uptake and elimination of ^{65}Zn by dead (formalin-preserved) animals and by live animals (before molting) were statistically similar over all temperatures and ^{65}Zn concentrations tested. Molted exoskeletons averaged 41% of total live body activity. Dissection of euphausiids into exoskeleton, eyes, and muscle and gut combined showed that the largest fraction of radiozinc was always associated with the exoskeleton. The second largest fraction was associated with muscle and gut, with a smaller fraction in the eyes and body fluid. Autoradiographs showed that ^{65}Zn mainly was located on the exoskeleton and between the muscle fibers, not intra-myofibrillar. Weight-specific activity varied inversely with weight, suggesting a surface area phenomenon for uptake and loss.

An inverse linear relationship between animal weight and percentage of total activity in exoskeletons, with a concomitant positive linear relationship between animal weight and percentage of total activity in muscle and gut, also suggested that uptake and elimination of ^{65}Zn were largely a function of surface area. The Q_{10} for ^{65}Zn uptake (5-15°C) was almost twice that for oxygen consumption. The relationships between ^{65}Zn uptake and dry weight, and between oxygen consumption and dry weight, varied by an order of magnitude. Authors conclude from this evidence that ^{65}Zn uptake from water is neither directly nor indirectly related to euphausiid metabolism. Some of the factors that make radiozinc uptake a poor index of metabolism (particularly molting) are responsible for making euphausiids potentially important in the cycling of radioactivity from "hot" pools in the sea.

183. Fowler, S.W., L.F. Small, and J.M. Dean. 1970. Distribution of ingested zinc-65 in the tissues of some marine crustaceans. J. Fish. Res. Bd. Canada 27:1051-1058.

Autoradiographs of tissues of euphausiids and shrimps fed ^{65}Zn through a food chain showed the isotope located primarily in the interstitial spaces between muscle fibers, in the eye, within the exoskeleton, and on the interior surface of the exoskeleton. Comparisons of the autoradiographic evidence with concentrations of radiozinc and stable zinc in the various dissected tissues were in good agreement. The specific areas of ^{65}Zn localization were much the same as those seen in an earlier study of similar organisms that accumulated ^{65}Zn directly from sea water; thus, it appears that ^{65}Zn, and therefore zinc, is highly labile in marine crustaceans and will accumulate in certain specific locations regardless of the mode of uptake. The rates at which various tissues became saturated with ^{65}Zn were dependent upon mode of uptake. However, because most of the ^{65}Zn was located intercellularly and not intracellularly, most ingested zinc apparently accumulates in excess of the animals' needs and is not used metabolically.

184. Friend, A.G. 1963. The aqueous behavior of strontium-85, cesium-137, zinc-65, and cobalt-60, as determined by laboratory-type studies. In Transport of radionuclides in freshwater systems. Report of a meeting held at Univ. of Texas, January 30-February 1, 1963. U.S. Atomic Energy Commission, Div. Technical Information TID-7664: 43-60.

Aquarial studies were designed to determine the effects of the principal cations occurring in natural waters (calcium, magnesium, sodium and potassium) on the uptake of strontium-85, cesium-137, zinc-65 and cobalt-60 by small bluegill fish. Results so far indicate that, over the range of concentration 0.2-20 mg/l only calcium has any effect on the uptake of strontium; as the concentration of calcium is increased, the uptake of strontium is depressed. The shallow freshwater pond used for the semi-natural studies was lined with black polyethylene to permit retention of added radionuclides and allow a radionuclide mass balance at the end of the experiment. Spring water, washed sand, clay samples, and the selected biota (fish, clams, snails, and tadpoles) were added to the lined pond; and after about one month an aqueous mixture of the test radionuclides was distributed over the surface by a pump and hose.

Cobalt-60, zinc-65 and cesium-137 were rapidly lost by the water to other pond media, the losses being respectively about 73, 60, and 47% after 1 day and 92, 96, and 95 per cent after 4

days. However, there was little loss of strontium-85 from the water, as would be expected in view of the high concentrations of calcium in the system. Only a small amount of strontium-85 became associated with the suspended solids, but cobalt-60, zinc-65, and, to a lesser extent, cesium-137 were taken up rapidly. These results were similar to those from field studies. The uptake of cesium-137 by samples of illite, kaolinite, and montmorillonite clays immersed in the pond is shown graphically and data are also tabulated for the maximum uptake of cobalt, zinc, strontium and cesium. The highest level of uptake was that for strontium-85 on montmorillonite. The uptake by calcium montmorillonite was generally greater than that by natural sodium montmorillonite, probably owing to the greater permeability of the calcium clay paste; but there were no differences in the uptake by calcium, sodium, or natural forms of kaolinite. Chemical studies on the state of the radionuclides adsorbed in the pond indicated that for illite clay most of the cobalt-60 was in the acid-soluble or the reductant-soluble form; up to 60% of the zinc-65 and 75-85% of the cesium-137 were irreversibly fixed in the clay; and about 85% of the strontium-85 was in an easily-exchangeable form. From the fractionation studies, it is suggested that the removal of radionuclides from the water in the pond experiment can be attributed to specific components of the pond sediments, zinc-65 and cesium-137 being removed by the illitic clays, strontium-85 by the carbonates and oxides, and cobalt-60 by both the acid-soluble carbonates and oxides and by the reductant-soluble iron oxides. The accumulation of radionuclides by carp was consistently greater than that by bluegills, probably owing to their feeding at different trophic levels. Cobalt-60 and zinc-65 were taken up rapidly and cesium-137 less rapidly by both fish, their concentrations reaching a maximum value, but the concentration of strontium-85 continually increased in both the bone and the flesh of both fish. Uptake of these four radionuclides by clams was similar to that in fish.

185. Fromm, P.O. and R.M. Stokes. 1962. Assimilation and metabolism of chromium by trout. J. Water Pollut. Control Feder. 34:1151-1155.

Experiments in which trout (Salmo gairdneri) were exposed to different concentrations of chromium as chromate, showed that the fish can accumulate chromium from water containing as little as 0.001 mg/l. With concentrations of chromium below 0.01 mg/l, uptake of chromium became constant after exposure for 10 days, indicating that excretion was equal to uptake. As uptake of chromium by fish is a passive phenomenon, the amount accumulated depends on the concentration in the water and the period of exposure. The in vitro respiration of pyloric caeca, liver and kidney tissue from fish exposed to 1 mg/l of chromium for up to 39 days was not significantly different

from that of control fish. With regard to the disposal of chromium waste waters, these results indicate that short-term exposure to relatively large slugs of chromium would be less harmful to fish than prolonged exposure to very low concentrations. It is not advisable to discharge chromium waste waters into a small static body of water, as the maximum concentration of chromium that can be tolerated indefinitely by aquatic animals has not yet been established.

186. Fujihara, M.P. and R.T. O'Brien. 1964. Toxicity of deuterium oxide to the freshwater fish Aequidans portalagrensis: survival of embryos and young fish. U.S. Atom. Ener. Comm. HW-SA-3627: 10 p.

Studies on the toxicity of deuterium oxide to eggs and young of the cichlid Aequidans portalagrensis showed that the sensitivity of the eggs depended on the stage of development, the earliest stages being more sensitive; no eggs survived in 40% deuterium oxide. Young fish of various ages survived in 30% deuterium oxide, but a concentration of 40% was lethal.

187. Fujiya, M. 1960. Studies on the effects of copper dissolved in sea water on oysters. Bull. Jap. Soc. Sci. Fish. 26: 462-468.

Regressive changes were found in the digestive diverticulum tissue, with desquamation and necrosis of the stomach epithelium in oysters cultured in water containing copper at 0.1-0.5 ppm for 2 weeks. The 96-hour TL-50 value in 30 o/oo seawater, pH 8.2 at 12°C = 1.9 mg/l.

188. Fukai, R., H. Suzuki, and K. Watanake. 1962. Strontium-90 in marine organisms during the period 1957-1961. Bull. Inst. Oceanogr. Monaco 1251: 16 p.

Various marine organisms, including seaweed Eisena bicyclis, crustaceans (decapods, mysidaceans, euphausids), tuna, salmon, sardine, herring, clam (Tapes japonica), and starfish (Astropecten scoparius, Distolasterias nipon, Ceramaster japonicus, L. quinaris collected over the period 1957-1961 were analysed for strontium-90. The results indicate that the concentration of strontium-90 in marine organisms was generally lower than in terrestrial organisms during the same period. The concentration of Sr-90 varied from species to species in the same group of organisms and also varied within the same species, depending on the date and place of collection. Some organisms collected in 1959 at depths greater than 1000 m contained strontium-90, suggesting transport of strontium from the surface to the deep layer. In spite of relatively wide variations of stable strontium content

among various species, the ratios of strontium to calcium by weight were fairly constant within the same group of organisms, and the strontium:calcium ratio obtained suggests the relative discrimination of strontium to calcium by marine organisms in their metabolic processes.

189. Gaglione, P. and O. Ravera. 1964. Manganese-54 concentration in fallout, water and Unio mussels of lake Maggiore, 1960-1963. Nature 204:1215-1216.

It is considered that the ability of Unio mancus var. elongatulus to concentrate manganese-54 in its tissues might be used to detect low-level contamination of the environment by this isotope. The concentrations of manganese-54 in water from lake Maggiore, Italy, fallout, and Unio were measured during 1960-1963 and the results, which are compared graphically, show that the mussel could be used to indicate the extent of contamination by radioactive manganese. During this period the increase in concentration of manganese-54 in the mussels due to increasing size (calculated to be about 11%) was negligible compared with the total increase, but it could be significant in some circumstances. The distribution of manganese-54 in the body of the mussel is reported and compared with that of the stable isotope. It was found that Anodonta cygnea also has a marked ability to concentrate manganese in its tissues, but to a lesser degree than Unio.

190. Garder, K. and O. Skulberg. 1965. Radionuclide accumulation by Anodonta piscinalis Nilsson (Lamellibrachiata) in a continuous flow system. Hydrobiologia 26:151-169.

To study the long-term accumulation of radioactive isotopes by a freshwater lamellibranch, Anodonta piscinalis, under conditions similar to its natural environment, test animals were exposed over a period of 125 days to controlled concentrations of selected radionuclides in a model channel through which water was pumped continuously from a nearby river; a control channel was also operated to determine the effects of variations in background radioactivity. The accumulation of radionuclides was determined in the body and valve portions of the organisms. Individual isotopes studied, in decreasing order of affinity for the animals, were phosphorus-32, strontium-89, cerium-144, ruthenium-103, cesium-137, and zirconium-95/niobium-95. After exposure for one month, the radioactivity had reached an approximately constant level in both the body and valve portions of the animal; and subsequently the level of radioactivity fluctuated, probably owing to seasonal and physiological changes.

191. Gardner, G.R. and P.P. Yevich. 1970. Histological and hematological responses of an estuarine teleost to cadmium. J. Fish. Res. Bd. Canada 27:2185-2196.

Pathological changes attributable to cadmium poisoning were observed in the intestinal tract, the kidney, and the gills of Fundulus heteroclitus after exposure to 50 mg/l of the metal. Microscopic examination revealed pathological changes of the intestinal tract as early as 1 hour after exposure, in the kidney after 12 hours, and in the gill filaments and respiratory lamellae after 20 hours. These manifestations of cadmium poisoning bear resemblance to the pathological changes that have been demonstrated clinically and experimentally in mammals.

The examination of circulating blood elements revealed rapid and striking changes among cells of the eosinophil lineage. The abundance of eosinophils increases steadily to a level approximately 45% above the usual amount. Indications of the cellular increase occurred as an early rise four hours after exposure.

A reduction in the relative numbers of mature eosinophils was evident in imprints of head kidney tissue. Nuclear anomalies were associated with the thrombocytes of specimens after eight hours exposure; however, these changes were not noticeable at either earlier or later time periods.

192. Getsova, A.B. and G.A. Volkova. 1964. Accumulation of radioactive isotopes of phosphorus, yttrium, iodine and mercury by larvae of aquatic insects. Zool. Zh. 43:1077, Nuclear Science Abstracts 1965. 19:5270.

In experiments on the uptake of radioactive isotopes by aquatic invertebrates, larvae of 7 typical aquatic insects were placed in separate aquaria containing pond water to which was added 10 μc of iodine-131, mercury-203, phosphorus-32 or yttrium-91, per liter. The radioactivity of the insects and the water was measured after 2, 4, 8, and 16 days. Yttrium and mercury were accumulated to the greatest extent by most species, phosphorus had a high coefficient of accumulation in only two species, and iodine was accumulated to only a small extent in all species.

193. Gileva, E.A. 1960. Accumulation coefficients of seven radioisotopes by three freshwater algae. C.R. Acad. Sci. U.R.S.S. 132:948-949.

Limited experiments on the uptake of sulphur-35, calcium-45, iron-59, cobalt-60, zinc-65, rubidium-86 and zirconium-95 by Scenedesmus

Cladophora, and Spirogyra showed that iron, zinc and zirconium were taken up strongly, rubidium and calcium less so, and sulphur and cobalt only slightly. Uptake by the single celled alga Scenedesmus was much weaker than by the filamentous algae. The results confirm the feasibility of using algae to purify radioactive waste waters.

194. Glaser, R. 1966. Exchange and metabolism of trace elements in freshwater mussels with special reference to accumulation mechanisms of radionuclides. Zool. Jb. Abt. Allgem. Zool. Physio. 72:1-114.

Experiments have shown that cobalt-58, zinc-65, zirconium-95, and cerium-133, are intensively concentrated in the shells and tissues of Dreissensia polymorpha, but concentration of caesium-137 is less intense and reaches a saturation factor of about 22 in the muscle within 1 month. The resorption of cobalt, zinc and cerium by the gastro-intestinal tract was greater than that of the other metals studied. Uptake of the nuclides was reduced or prevented by addition of EDTA. Formalin had no effect on uptake by the byssus or shell but did increase the permeability of the tissues.

195. Glazunov, V.V., V.P. Parchevski and D.G. Fleishman. 1963. The variation of the fission product content of Cystoseira in the Black Sea. Dokl. Akad. Nauk SSSR, 152:1222-1224.

Determinations of radioactivity of samples of brown seaweed (Cystoseira barbata) from the Black Sea over a period of years indicates that fission products accumulate in the seaweed and are removed from the water as it dies and settles out in the sediment.

196. Gohar, H.A.F., S.E.E. Hashish, A. Hassan, and K. Moulokhia. 1964. An experimental study of strontium-90 contained in marine animals following possible release of radioactive waste in sea water. 3rd U.N. Conf. Peaceful Uses Atom. Ener. ALCONF. 28/P/811:15 p. Nuclear Science Abstracts, 1964, 18:4940-4941.

The authors discuss the uptake and release of strontium-90 by the soft tissues and shells of the gastropod Nerita forskalii recluz, which normally contains high concentrations of strontium in the shell and occurs widely in the Red Sea, Indian Ocean, and warmer parts of other oceans.

197. Goncalves, N.B. and R.D.R.L. Soares. 1955. Molluscicide activity of copper ricinoleate. Rev. bras. Malariol. 7:445-454; Biol. Abstr. 31:3518.

Experiments in an artificial pond showed that even low concentration of copper ricinoleate had greater immediate and delayed molluscicidal effect on Australorbis glabratus than had either copper sulphate or pentachlorophenol. A 1.25% alcohol solution sprayed round the edge of the pond killed 95% of the snails within 1 hour. The compound is cheap and easily prepared; and in water it forms a stable emulsion with a tendency to deposit very fine particles on vegetation, thus prolonging its toxic effect.

198. Goodman, J. 1951. Toxicity of zinc for rainbow trout (Salmo gairdnerii). Calif. Fish Game 37(2):191-194.

The toxicity of zinc to rainbow trout was studied, and it was shown that 6 mg/l zinc was lethal to fingerling rainbow trout exposed for 48 hrs. or less. Fish that were 4 weeks old or less could not tolerate 4 mg/l but with increase in age tolerance was developed.

199. Gordon, M.S. 1959. Osmotic and ionic regulation in Scottish brown trout and sea trout (Salmo trutta L.). J. Exp. Biol. 36:253-260.

Adult brown trout (Salmo trutta L.) of both sea-run (sea trout) and freshwater stream (brown trout) forms were captured in the vicinity of Aberdeen and acclimatized to full-strength sea water for periods of up to five months.

Blood serum samples from these fish were analysed for freezing-point depression, chloride, sodium and potassium concentrations.

The patterns of regulation of these concentrations are very nearly the same in both forms. Brown trout and sea trout, at least in eastern Scotland, thus appear to be virtually identical in osmotic and ionic regulatory abilities. However, there is a possibility that there is a difference between the two forms with respect to mechanisms controlling blood acid-base balance.

The patterns of regulation shown by Scottish fish are the same as those shown by American hatchery fish treated similarly. The different populations of the species seem not to have diverged significantly from one another in this regard after many generations of more or less complete genetic isolation.

The species Salmo trutta is strongly homoiosmotic. Internal concentrations are either unchanged or increase by less than 10% above freshwater levels with long-term acclimatizations to half and full sea water. The brown trout is the first salmonid species known to regulate so well.

200. Gordon, M.S. 1959. Ionic regulation in the brown trout (Salmo trutta L.). J. Exp. Biol. 36:227-252.

The osmotic and ionic regulatory abilities of adults of the euryhaline brown trout (Salmo trutta) have been studied in experiments roughly duplicating the stresses of migration from freshwater to the sea. Brown trout will survive indefinitely in full sea water if acclimatized to it at rates inversely related to the temperature.

Blood serum samples have been analysed for Na, K, Cl, and total P; muscle samples for Na, K, Cl and total solids. Changes in the concentrations of these constituents following transfers from fresh water to 50% and 100% sea water have been studied. Transfers were made throughout the year and at temperatures of 10° and 20°C.

Following transfers to 50% sea water at 20°C, blood concentrations rose significantly above fresh-water levels, but returned very nearly to these levels after about a week. Transfer from 50% sea water to 100% sea water at 20°C, caused the same sequence of changes. Transfer to 100% sea water at 20°C, was fatal, and associated with very high serum concentrations. Many fish survived transfer to 100% sea water at 10°C, however, and showed evidence of internal concentrations returning to fresh-water levels after 10 days. The brown trout is strongly homoiosmotic on a long-term basis.

Both survival and regulatory ability were lower during the summer. There were also seasonal variations in the blood and muscle concentrations of fish in a given state of acclimatization.

Muscle concentration changes closely paralleled blood changes. Extracellular volume remained constant, so muscle concentration changes were attributable to changes in intracellular water. The muscles did not act as storage sites for sodium and potassium.

201. Gordon, M.S. 1963. Chloride exchanges in rainbow trout (Salmo gairdneri) adapted to different salinities. Biol. Bull. 124: 45-54.

Estimates of rates of exchange of body chloride, both total exchanges and exchanges across the integument and by way of the gut and kidneys, have been made in rainbow trout (Salmo gairdneri) acclimatized to various salinities between fresh water and sea water (salinity 32 o/oo). Radioactive chlorine-36 was used as a tracer of chloride movements.

Neither total Cl exchanges nor integumentary exchanges varied in proportion with changes in the magnitude of the transintegumentary osmotic gradients maintained by the fish. This result is interpreted

as indicating that changes in the permeability to water of the integument (probably primarily the gills) are an important part of the salinity adaptation process in rainbow trout.

Laboratory diuresis and exchange diffusion of chloride are discussed as possible complications in this interpretation.

202. Grabske, R. 1966. A survey of the responses of rat-liver mitochrondria to simple metal cations. U.S. Atomic Energy Commission Document No. UCRL-50168: 18 p.

Isolated rat-liver mitochondria, incubated in a medium containing succinate inorganic phosphate, KCl, and Tris, were exposed to 50 different metal cations. Recordings were made of changes in respiration, pH, and light scattering in response to the added metal ions. The ions tested were classed as respiratory stimulators, respiratory inhibitors, and inducers of mitochondrial swelling. The response to Ba was qualitatively similar to the responses of Ca, Sr, and Mn, indicating that Ba may be actively transported by rat-liver mitochondria by a mechanism similar to the well-known transport systems of Ca, Sr, and Mn. Cu, Ag, Au, Zn, Cd, and Hg all induced mitochondrial swelling and, with the exception of Au, inhibited respiration. Cu, Ag, and Cd, however, briefly stimulated respiration prior to its ultimate inhibition. The elements of the lanthanide series induced a slight amount of swelling, but did not effect respiration. Of the 50 ions tested, 23, one of which was Pb, were apparently inert.

203. Grande, M. 1967. Effect of copper and zinc on salmonid fishes. Proc. 3rd Int. Conf. Water Pollution Research, Munich, 1966. 1:96-111.

In connection with investigations on copper-zinc pollution in a salmon and trout river in northern Norway, laboratory experiments were carried out on the effects of these metals on the eggs, fry, and fingerlings of Atlantic salmon (Salmo salar), brown trout (Salmo trutta), and rainbow trout (Salmo gairdneri). In the experiments with fry in the yolk-sac stage there was little or no mortality during exposure for 21 days to concentrations up to 0.04-0.06 mg of copper and 0.5-1.0 mg of zinc, per liter; there was evidence that brown trout were slightly more tolerant to both metals than were rainbow trout and salmon. Concentrations of copper as low as 0.02 mg/l appeared to have certain sublethal effects on salmon fingerlings, but this was not observed with zinc. In the experiments with eggs, it was found that small additions of copper and zinc reduced the percentage of eggs hatching, and the survival of salmon eggs was affected by concentrations of zinc lower than those that had any effect on the fry. Low concentrations of zinc also delayed the hatching of salmon eggs and, to a lesser extent,

of brown trout eggs, when live salmon eggs that were overdue in hatching were punctured to release the larvae into the zinc solution, the larvae developed normally, and it is suggested that the zinc effects the enzymic processes that cause softening of the capsule a few hours before hatching. Further experiments to investigate the effect of soluble organic matter on the toxicity of copper and zinc indicated that the toxicity was reduced, probably as a result of metals being complexed by the organic compounds.

204. Greenfield, L.J. 1964. Uptake of radionuclides by micro-organisms. Emphasis upon the mechanism of uptake of calcium in marine bacteria compared with the mollusc, Strombus gigas. U.S. Atom. Ener. Comm. TID-20499: 62 p.

To investigate the source of calcium carbonate in the formation of marine molluscan shells, studies were made with the immature queen conch, Strombus gigas, using sodium carbonate labelled with carbon-14 as a source of inorganic carbonate, and L-alanine, labelled with carbon-14, L-serine and L-glutamic acid as organic sources. The uptake of the labelled compounds and of calcium-45 (as calcium chloride) was determined in relation to the physical activity of the animal. It was found that the conch can use many substances dissolved in sea water as a source of carbonate, and that the site of absorption is not limited to the gut wall. Studies were also made on the role of marine bacteria in biological calcification in the sea using Pseudomonas piscicida, a bacterium found in shallow-water marine sediments; calcium-45 and alanine labelled with carbon-14 were used as tracers. It was concluded that at least two mechanisms are directly involved in the uptake of calcium and magnesium from sea water by P. piscicida, and that as the cells age increased amounts of calcium carbonate are deposited, but deposition of magnesium carbonate remains relatively constant.

205. Grindley, J. 1946. Toxicity to rainbow trout and minnows of some substances known to be present in waste waters discharged to rivers. Ann. Appl. Biol. 33: 103 ff.

The toxicity to fish of a given substance is affected by the type of water in which the substance is dissolved, the concentration of the poison, the temperature, the pH value, and the degree of oxygenation of the solution, and the species, size, and condition of the fish. Some of the substances used were dissolved in Watford tap water and others in aerated distilled water. Aeration was continued during the tests. Minnows of unknown age and rainbow trout about 1 year old and 75 to 100 mm long were used as test animals. In tests with sodium arsenite and sodium arsenate in tap water it was found that neutralized solutions of sodium arsenite were more toxic to

minnows than were solutions of sodium arsenate containing an equal concentration of arsenic. Minnows overturned after 36 hours in a solution of sodium arsenite containing about 20 mg/l arsenic, and after about 16 hours in a solution of sodium arsenate containing about 250 mg/l arsenic. The fish did not recover after removal to fresh water.

The only solution of zinc sulphate tested was one containing 25 mg/l zinc in distilled water; the mean period of survival of trout in this solution before overturning was 133 minutes. All fish died after transfer to fresh water. In tests with solutions of potassium chromate and potassium dichromate in distilled water the temperature was maintained at 18°C; the pH value was not adjusted. At equivalent concentrations of chromium, solutions of potassium dichromate were more toxic than solutions of potassium chromate. In solutions containing 20 mg/l chromium and in which the pH value was greater than 5.0, trout survived for about 60 hours in solutions of potassium chromate and for about 72 hours in solutions of potassium dichromate. As the content of chromium was increased the pH value of solutions of dichromate was reduced and the toxicity increased more rapidly than did that of solutions of chromate. The toxicity of solutions of potassium chromate was almost proportional to the concentration of dissolved chromium, but with solutions of potassium dichromate the toxicity increased rapidly up to the equivalent of 400 mg/l chromium. Between 400 and 1000 mg/l the toxicity increased only slightly, and above 1000 mg/l the toxicity increased rapidly again. The limiting concentrations below which solutions of potassium chromate and potassium dichromate were non-toxic to rainbow trout appeared to be equivalent to slightly less than 30 mg/l chromium. Some fish which had been immersed in the lower concentrations of chromate, and some which had been in solutions of dichromate, recovered on transfer to fresh water. The fish which recovered after being in solutions of dichromate were usually those which had been the first to overturn; this suggests that the fish were affected by the acidity of the solution rather than by any specific toxic effect of the dichromate. In tests on the toxicity of ammonium compounds, yearling rainbow trout were immersed in solutions of ammonium chloride and ammonium sulphate in distilled water, in tap water, and in mixtures of distilled water and tap water. When equivalent amounts of the two salts were dissolved in equal volumes of the same type of water there was no appreciable difference in the toxicity of the two solutions; with both salts the toxicity was greater when dissolved in hard water than in distilled water. In distilled water the limiting concentration below which solutions of the ammonium salts were non-toxic was probably equivalent to slightly less than 100 mg/l ammonia; in tap water solutions containing 50 mg/l ammonia were slightly toxic to trout. Only a small porportion of the fish which had overturned recovered on being transferred to fresh water.

206. Guskova, V.N. and L.N. Guffein. 1964. Some experimental data on the effect of natural uranium on the sanitary condition of a body of water. Radioakt. Izotop. Gidrobiol. Metod. Sanit. Gidrobiol., Moscow-Leningrad: 21-28. Biological Abstracts 1966, 47:6774.

Experiments have shown that the presence of up to 0.5 mg/l of uranium disturbs the oxygen balance of water and inhibits the development of enteric bacteria such as Escherichia coli; concentrations up to 5 mg/l inhibit biochemical oxidation; and a concentration of 100 mg/l kills water fleas in 1-2 days. Uranyl nitrate affects mineralization processes for a considerable distance beyond the point of entry into the water.

207. Gustafson, P.F. 1967. Comments on radionuclides in aquatic ecosystems. Proc. Int. Symp. Radioecol. Concent. Process. 1966, Stockholm: 853-858.

After reviewing data which show that the concentration of cesium-137 is generally 1-2 orders of magnitude greater in freshwater fish than in ocean fish, probably owing to the higher concentration of potassium in ocean water, the author reports investigations on the metabolic behavior of cesium-137 in Red Lake, Minn., involving analyses of water, bottom deposits, and various species of fish. Data are tabulated showing that the 3 trophic levels of fish which form a food chain concentrate cesium-137 by factors of 2 and 5 going from mixed small fish to perch and from perch to northern pike, and there are corresponding increases in the ratio of cesium-137:potassium. The overall concentration factor from lake water to edible fish was 2760. Bottom deposits showed uniform concentrations of cesium-137 in the lake proper, with an accumulation near the mouth of the principal river flowing into the lower lake. Comparing data for previous seasons, fish showed increasing levels of cesium-137 up to 1965, suggesting that the concentrations of cesium-137 in fish depend on the total accumulation of the isotope in the lake ecosystem, rather than upon the rate of accumulation. Manganese-54 and zinc-65 were also detected in salmon, and observations on other fish tended to verify the hypothesis that these 2 isotopes are retained only by euryhaline fish, as a result of their unique osmoregulatory system.

208. Gustafson, P.F. 1969. Cesium-137 in freshwater fish during 1954-65. Proc. 2nd Nat. Symp. on Radioecology. U.S.A.E.C. Conf. 670503: 249-257.

Concentrations of ^{137}Cs from worldwide fallout have been determined in samples of small perch and walleyes preserved in alcohol taken from Red Lakes, Minnesota, during 1954 through 1965. Measurements

were made in bulk samples by means of gamma ray spectrometry. Collections of fish made each year during the month of July, from near the same location within the lake, were provided by Professor Lloyd Smith of the University of Minnesota.

The deposition rate and the total accumulation of ^{137}Cs in the Red Lakes area were derived from data obtained elsewhere in the region by making corrections for differences in local precipitation. The ^{137}Cs levels observed in fish changed fairly rapidly in response to changes in fallout rate; however, there was a substantial contribution from the accumulated deposition of this radionuclide in the aquatic ecosystem which acts as a sink for this radionuclide. Solution of a mathematical expression relating to the concentration of ^{137}Cs in fish to the total amount of ^{137}Cs present in the lake and its rate of deposition, indicated 25 to 80% of that found in fish came from the long-term accumulation. This accumulation was the more important source for ^{137}Cs uptake by fish during times of low fallout rate. The highest concentration in fish was ∿600 pCi/kg seen during 1963; by 1966 it had decreased to ∿250 pCi/kg.

The effective half-time for ^{137}Cs in the lake system, as inferred from the small fish, was 2½ years. The persistence of ^{137}Cs in a freshwater system is in sharp contrast to the behavior of terrestrial levels. The continuing availability of ^{137}Cs to freshwater fish suggests that they will provide an important source of dietary ^{137}Cs, for some time, for persons who depend on them for food.

209. Gustafson, P.F., S.S. Brar, D.M. Nelson and S.E. Muniak. 1967. Radioactive ^{54}Mn and ^{65}Zn in euryhaline fish. Can. J. Zool. 45:729-735.

Examination of euryhaline fish showed significant accumulations of radioactive zinc and manganese which could not be detected in stenohaline fish, even when both types were taken from the same locality. Of the euryhaline species, those taken from freshwater environments contained manganese-54 but not zinc-65, while those taken from the oceans, where the ratio of radioactive to stable zinc is greater, contained both radionuclides. The herring-like alewife (but not other euryhaline species) also appeared to accumulate radioactive lead and polonium. It is suggested that the complex osmoregulatory system of these fish and hormonal effects prior to spawning are responsible for the accumulation of these radionuclides.

210. Gutknecht, J. 1963. Zinc-65 uptake by benthic marine algae. Limnol. Ocean. 8:31-38.

Results are given of some experiments on the effect of various environmental factors on uptake and loss of zinc-65 by benthic algae

(Ulva lactuca, Porphyra umbilicalis, Fucus vesiculosus, and Laminaria agardi). It was found that increase in pH value enhanced uptake of zinc-65 and retarded its loss in Ulva, Porphyra and Laminaria, a similar effect of pH value was observed in killed algae of the same species, which in all cases absorbed more zinc-65 than the live seaweed. The addition of carrier zinc to natural sea-water wash solutions has little effect on the rate of loss of zinc-65 from radioactive algae, but there was a slight increase in rate of loss of zinc-65 when the temperature of the wash solution was increased. Polarographic determination of the natural zinc content of the algae showed that Fucus had the highest concentration (829 mg per kg dry weight) and Porphyra had the lowest (123 mg per kg). Exposure to light stimulated both the uptake and loss of zinc-65. Two inhibitors, uranyl nitrate and phenylurethane both retarded uptake of zinc. The biological half-life of zinc-65 in algae in the light and in the dark was estimated; Fucus showed a much higher retention of zinc-65 than either Porphyra or Ulva.

211. Gutknecht, J. 1965. Uptake and retention of cesium-137 and zinc-65 by seaweeds. Limnol. Ocean. 10:58-66.

Tabulated and graphical results are given of experiments on the uptake and retention, by various seaweeds, of cesium-137 and zinc-65. For none of the species tested was there any significant relation between growth rate and either concentration factor or biological half-life. The effects of various factors, including light, presence of exogenous substrates, exposure to nitrogen in the dark, and internal and external concentrations of ions were investigated. For both isotopes, but especially for cesium-137, uptake was stimulated by light, although a certain, variable, amount of uptake did occur in the dark, and it is suggested that consideration might be given to releasing radioactive waste waters during the night to minimize uptake.

212. Haider, G. 1964. Heavy metal toxicity to fish. I. Lead poisoning of rainbow trout (Salmo gairdnerii) and its symptoms. Zeitschrift fur angewandte Zoologie 51:347-368.

Rainbow trout were chronically poisoned in an aquarium by adding small amounts of lead acetate to the water for two to three months or by giving lethal doses orally or by injection. In acute poisoning, the gill epithelium and inner organs were destroyed and the fish died of suffocation. Staining with silver sulfide revealed the presence of lead in bones, liver, kidneys, gills and spleen.

213. Halsband, E. and I. Halsband. 1963. Haematological changes in fish as a result of toxicity. Arch. Fischwiss. 14:68-85.

Studies are described on the effect of toxic substances on Salmo gairdneri. Laboratory experiments were conducted with sodium and potassium chlorides, magnesium sulphate, phenol, ferric nitrate and X-ray radiation to determine tolerances levels, metabolic rate and haematological changes. It was found that, once the threshold level of disturbance had been reached, a change occurred in the blood. Results indicate that both the surface area of the erythrocyte and the haematocrit value increase or decrease with changes in the concentration of toxic substances. After the first day changes occurred in the metabolic rate; after four days the physiological disturbances increased to such a degree that death occurred. X-ray radiation increased the haematocrit value after two days; this was followed by a decrease after four days and after nine days the haematocrit value was below normal.

214. Hampson, B.L. 1967. Restricted dispersion of zirconium-95 and of niobium-95 after release to the sea in nuclear fuel reprocessing effluent. Health Physics 13:1093-1103.

The dispersion of the radionuclides zirconium-95 and ruthenium-106 after their discharge to sea was studied, using the alga Porphyra umbilicalis as an indicator organism to integrate short-term fluctuations in the sea-water concentrations of the nuclides. It was found that, compared with ruthenium-106, the dispersion of zirconium-95 and niobium-95 was restricted and their rate of removal from the sea water to the bottom deposits by chemical processes was greater than the rate of mixing of the sea water immediately round the point of discharge with more distant sea water.

215. Hampson, M.A. 1967. Uptake of radioactivity by aquatic plants and location in the cells. 1. The effect of pH on the Sr-90 and Y-90 uptake by the green alga Ulva lactuca and the effect of stable yttrium on Y-90 uptake. J. Exp. Botany 18:17-53.

In studies on the uptake of strontium-90 and yttrium-90 from sea water by Ulva lactuca, it was found that at pH 8, in the absence of added carrier, Ulva reached a strontium-90 equilibrium at 0.32 times the concentration in the water within 3 hours, but rapidly depleted the water of yttrium-90. With addition of stable yttrium, yttrium-90 equilibrium was reached within 3 hours, with a concentration factor of 550. In the absence of the carrier, yttrium-90 remained on the outer surface of the plants, but when carrier was added yttrium-90 entered the cells and was deposited in the protoplasmic inclusions, where strontium-90 was also located. A reduction in pH value from 8 to 6.5 caused a slight increase in the uptake of strontium-90 and a large increase in the uptake of yttrium-90, but over the pH

range 5.8-5.1 the uptake of yttrium-90 was greatly reduced. At pH values below 6 the alga died within 5 days. The effect of pH value on strontium uptake is thought to be due to changes in equilibrium in the carbonate-bicarbonate system. II. Uptake of Ce-144 by the freshwater plant Nitella opaca. Ibid. The uptake of cerium-144 by Nitella from pond water at pH 7.7 without added carrier was studied over a period of several months; some of the cells were then transferred to clean water for further observation. It was found that cerium-144 equilibrium was approached after 100 days, when the whole plant had 26,000 times more activity than water. Under these conditions, most of the cerium-144 was located in the cell wall, although small but significant amounts entered the protoplasm and cell sap. When freshly taken up, the cerium-144 was freely exchangeable, but after about 10 days it became more firmly bound and was not released again. The differences between the location of cerium-144 in Nitella and of yttrium in Ulva are discussed.

216. Hanks, R.W. 1965. Effect of metallic aluminum particles on oysters and clams. Chesapeake Science 6:146-149.

Laboratory experiments were carried out to determine the effect on oysters (Crassostrea virginica) and clams (Mya arenaria) of powdered aluminium, used in photogrammetric studies of water currents. Although the metal particles were removed by the filtering activity of these organisms, there was no detectable increase in aluminium concentration in the tissues, and it is concluded that they reacted to aluminium particles as they would to any other inorganic material of the same particle size.

217. Hannerz, L. 1966. Accumulation, retention and elimination of zinc-65 in freshwater organisms studied in pond experiments. Proc. 1st Int. Congr. Radiat. Prot.:417.

Radioactivity was recorded continuously in the water, sediments, plants, invertebrates, and fish (young pike, roach fry, and pike fry) in an artificial pond lined with polyethylene sheets and fed continuously with water from Lake Mälar, Sweden, to which zinc-65 was added to give a mean concentration of about 3×10^{-6} μc per ml. Zinc-65 accumulated in the bottom deposits with a concentration factor of about 20,000; only low concentrations were found in emergent parts of water weeds but much higher concentrations occurred in submerged parts, indicating considerable surface absorption in which the microflora and microfauna were believed to play an important role. High concentrations of zinc-65 were also found in invertebrates, with concentration factors of 1700 for chironomid larvae, 590 for snails, and 400 for leeches. The concentration of zinc-65 in fish showed considerable variations and was inversely related to the length of

the fish; the mean concentration factor for pike was about 1250. When the concentration of zinc-65 in the water was changed, the concentration in sediments and submerged parts of plants followed the concentration in the water closely, indicating that an exchange equilibrium is reached rapidly for these types of material. Emergent parts of plants, however, accumulated zinc-65 throughout the experiment. When pike were transferred from the pond to a tank with running water from Lake Mälar, there was no decrease in the concentration of zinc-65 over a period of more than 6 weeks.

218. Hannerz, L. 1968. Experimental investigations on the accumulation of mercury in water organisms. Rep. Inst. Freshwat. Res. Drottingholm, No. 48:120-176.

High concentrations of mercury in fish from many lakes and streams in southern and central Sweden prompted a series of laboratory and field studies with mercury compounds (phenylmercuric acetate, methylmercuric hydroxide, methoxyethylmercuric hydroxide, mercuric chloride, and mercuric nitrate) labelled with mercury-203, and various species of aqautic organisms. Accumulation and retention of mercury compounds, in terms of concentration factors, are tabulated and discussed for various aquatic plants, invertebrates, sediments, and fish, and the elimination of mercury from fish after discontinuance of the mercury supply is shown in a table and graphs. There was no appreciable assimilation of mercury in plant tissues, but the concentrations were 10-20 times higher in submerged than in emergent parts owing to surface adsorption. The uptake of mercury by animals was not related to their trophic level but depended on several factors such as metabolic rate and feeding habits. Sediments always contained high concentrations of mercury which was adsorbed on and settled with particles in the pond water. The exchange of mercury was rapid between plants and water but less rapid between invertebrates and water; in the sediments, a considerable portion of the mercury could not be exchanged. In fish, the rate of uptake of mercury, both from water and food, is fast, while the rate of elimination is slow, giving high concentration factors, which differ for the different organs, and for the different compounds tested (methyl mercury was taken up most readily). The uptake was also affected by the size of the fish and the concentration of electrolytes in the water (uptake of methoxyethyl mercury was lower in brackish water than in salt water). There were differences in the results from ponds and clean tanks and there is evidence to suggest that the chemical nature of organic mercury compounds is easily changed in natural waters, so that the mercury is available for uptake by the biota as a mixture of compounds no matter what chemical form of mercury was introduced.

219. Harrison, F.L. 1969. Accumulation and distribution of ^{54}Mn and ^{65}Zn in freshwater clams. Proc. 2nd Nat. Symp. on Radioecology. U.S.A.E.C. Conf. 670503:198-220.

The accumulation and distribution of ^{54}Mn and ^{65}Zn in the freshwater clam Anodonta nuttaliana Lea was followed for 147 days under conditions where the concentrations of Mn and Zn in the water remained constant. The amounts of the radionuclides in the clam bodies increased essentially linearly during the uptake period. The concentrations of ^{54}Mn and ^{65}Zn showed considerable variation from tissue to tissue, but generally the concentrations within a given tissue were equivalent. Steady-state conditions of accumulation and loss were reached after about 100 days in the digestive tract, gonad, muscles and excretory organs. However, in the calcareous tissue, mantle and gills, steady-state conditions were not reached in the 147 days. The rates of accumulation were found to be dependent on the concentration of the stable element in the water, the temperature and size of the animals. The rates of loss of the stable element from the clam body were slow -- the large long-lived pool of Mn having a half-life of about 1300 days, that of Zn of 650. Measurements of specific activities indicated that in all parts of the body a large fraction of the Mn and Zn was in pools with which the radionuclides did not exchange. In Anodonta nuttalliana Lea, the main storage site in the body of Mn and Zn as well as Ca was in 1- to 2-micron granules in the calcareous tissue.

220. Harry, H.W. and D.V. Aldrich. 1958. The ecology of Australorbis glabratus in Puerto Rico. Bull. World Hlth. Org. 18:819-832.

Under laboratory conditions, low concentrations of zinc, copper, cadmium, and silver produce a distinct distress syndrome in snails.

221. Harry, H.W. and D.V. Aldrich. 1963. The distress syndrome in Taphius glabratus (Say) as a reaction to toxic concentrations of inorganic ions. Malacologica 1:283-289.

The most obvious symptom is the continued extension of the cephalopedal mass without attachment of the foot following exposure to copper salts. Those in distress are unable to feed or crawl to the surface to renew their air bubble. Recovery is possible within a few hours if the medium is replaced within 24 hours.

222. Harvey, R.S. 1963. Uptake of radionuclides by freshwater algae and fish. U.S. Atom. Ener. Comm. DPSPV-63-30-3:12 p.

In order to select a suitable indicator species for routine environmental monitoring, concentrations of radioactive isotopes in fish (bluegill, bass, and catfish) in a nuclear reactor cooling water pond were measured over a period of nine months. The bluegill, containing higher concentrations of zinc-65 and strontium-89, 90 and only slightly lower concentrations of cesium-134, 137, was selected. Data on uptake by algae were also obtained.

223. Harvey, R.S. 1969. Effects of temperature on the sorption of radionuclides by a blue-green alga. Proc. 2nd Nat. Symp. on Radioecology. U.S.A.E.C. Conf. 670503:266-277.

Effects of a 15°C temperature differential on the sorption of ^{137}Cs, ^{85}Sr, ^{65}Zn, ^{59}Fe, ^{57}Co, and ^{54}Mn by the filamentous blue-green alga, Plectonema boryanum, are reported. The sorption pattern for ^{57}Co differed from all others in that concentrations per gram of algae were highest at 25°C and decreased with temperature up to 40°C. The concentrations of ^{54}Mn increased with temperature up to 35°C. There was no positive correlation between water temperatures and sorption levels for ^{65}Zn, ^{59}Fe, ^{85}Sr, and ^{137}Cs although the concentration of each radionuclide was slightly higher at 40°C than at lower temperatures.

224. Harvey, R.S. 1969. Uptake and loss of radionuclides by the freshwater clam Lampsilis radiata (Gmel.). Health Physics 17:149-154.

The uptake and loss of radionuclides by the freshwater clam, Lampsilis radiata, were studied under natural conditions at the Savannah River Laboratory, S.C., to determine whether or not this species could be used as a sensitive indicator of low concentrations of isotopes in a soft-water stream and whether accumulation of radioactivity in the soft tissues would contribute a significant radiation dose to humans. Clam specimens were exposed to very low concentrations of 8 radioactive isotopes for 91 days and were then transferred to fresh water for 56 days. Except for strontium-90, all the nuclides studies were concentrated in the soft tissues; only strontium-90, manganese-54, and cesium-137 were concentrated significantly in the shells. At apparent equilibrium, the concentration factors for soft tissues were 220 for cesium-137, 240 for sulphur-35, 440 for chromium-51, 790 for cobalt-60, 900 for cerium-144, 2400 for manganese-54, and 4100 for zinc-65. The biological half-life of each nuclide was estimated; the short-lived components, with half-lives of 25 days, represented up to 60% of the radioactivity in the soft tissues.

225. Hasanen, E., S. Kolehmainen, and J.K. Miettinen. 1966. Biological half-times of cesium-137 and sodium-22 in different fish species and their temperature dependence. Proc. 1st Int. Congr. Radiat. Prot.:401-406.

Experiments were carried out with five species of fish in laboratory aquaria or in nylon-net cages in lake Suolijarvi, Finland, to determine the biological half-time of cesium-137 when administered orally in known doses, usually of about 250 nc. Results are tabulated and for one species, rainbow trout, are also illustrated graphically, showing that the excretion of cesium-137 from fish follows 2 exponential equations, the first representing removal of a fast component (usually 5-10% of the amount administered, but 25% in trout and 50% in carp) with a half-life of a few days, and the second representing removal of a slow component with a half-life of 200 days for perch, and, depending on the age of the fish, 57-100 days for roach and 20-80 days for rainbow trout. The biological half-life of the slow component was also affected by temperature, increasing from 20 days at 20°C to 36 days at 7-8°C for 1-year-old rainbow trout, and from 55 days at 20°C to 120 days at 10°C for 5-year-old carp. Experiments with sodium-24 showed a similar dependence on temperature (a 10°C-decrease in temperature reduces the excretion rate by about one-half), although the biological half-lives were much shorter (at 20° and 10°C, respectively, these were 7 days and 15 days for perch; 7 days and 11 days for roach, and 10 days and 25 days for carp).

226. Hasanen, E., S. Kolehmainen, and J.K. Miettinen. 1967. Biological half-time of cesium-137 in three species of freshwater fish: perch, roach and rainbow trout. Proc. Int. Symp. Radioecol. Concent. Process., 1966, Stockholm:921-924.

After reviewing the literature on the excretion of cesium-137 from various species of fish and distinguishing between the smaller "fast" fraction with a short biological half-life and the larger "slow" fraction with a much longer biological half-life, the authors describe studies with the species of fish most common in Finland. The biological half-life of cesium-137 in small perch (6-months old at the beginning of the study) was investigated in laboratory aquaria, giving for the slow component, which represented about 83% of the total excretion, a half-life of 200 ± 12 days at 15°C in tap water (conductivity 250 mho) dechlorinated by active charcoal. Larger fish were studied in nylon-net cages in the Suolijarvi lake (conductivity 55 mho). A mobile counter was modified to permit "whole body" measurements of cesium-137 in the live fish. Results are tabulated for perch, roach, and rainbow trout in the lake water at 15° ± 5°C and also illustrated graphically for the

roach. The biological half-life varied considerably with the species. In perch, the slow component, which represented 88-96% of the total excretion, had a half-life of 175-200 days, which did not appear to depend on age; but in roach and trout the half-life of the slow component varied from 55 to 100 days and from 25 to 80 days, respectively, depending on the age of the fish, and the fast component represented 6-9% and 24-34%, respectively, of the total excretion. The rate of excretion was reduced at lower temperatures (about 5°C).

227. Hasanen, E. and J.K. Miettinen. 1963. Cesium-137 content of freshwater fish in Finland. Nature 200:1018-1019.

Results of studies on the concentration of cesium-137 and potassium in freshwater fish in Finland show that the concentration of cesium-137 in various fish varies markedly, and occurs within the range of 0.6-6 μμc per kg. There is a tendency for the radioactivity to diminish when the fish feed on bottom fauna instead of plankton. In general, the radioactivity of whitefish rose during 1962, radiochemical analyses of pike and trout supported this observation. The radioactivity of samples from the Arctic Ocean is only about 1/20th of that of the Lapland samples; it also seems that the cesium-137 values of the fish in southern Finland and somewhat lower than those in Lapland. It would appear that the fish obtain most of their radioactive cesium from their food, even though a small proportion may enter through the gills. Also, it seems feasible that the high concentrations of cesium-137 present in the fish of prey from two humus-type lakes are accumulated in food chain. No clear correlation between the age of fish (of the same species) and the concentration of cesium present has been observed. Similar results have been obtained in Sweden.

228. Hassall, K.A. 1962. A specific effect of copper on the respiration of Chlorella vulgaris. Nature 193:90.

Addition of salts of heavy metals to Chlorella vulgaris cells shaken in phosphate buffer solution (pH value 6.0) often increased endogenous respiration temporarily but, with the exception of silver, each high concentration did not cause respiratory inhibition for many hours. Copper, however, differed from all the other metals tested (including barium, manganese, nickel and lead) in that its effect on respiration depended on the environmental conditions during the period of treatment. Results show that shaking had a marked effect in delaying the toxic effect of copper -- when shaking was stopped the copper rapidly became toxic. More copper was absorbed in a given period (except during short periods) by the cells in unshaken vessels than in shaken vessels, but the lower rate of

respiration in unshaken vessels is not clearly related to the amount of copper added or to that present in the cells. Respiration was accelerated in cells shaken continuously with copper even though the concentration of sorbed copper was greater than the lethal concentration of cells in stationary tubes. Preliminary results indicate that lack of oxygen is a factor leading to high copper toxicity. While the possibility of a change in the nature of the applied copper under anaerobic conditions cannot be excluded, it is possible that under these conditions either the internal distribution of copper is different or a respiratory system exists to which copper is highly specific poison.

229. Hasselrot, T.B. 1965. A study of remaining water pollution from a metal mine with caged fish as indicators. Vattenhygien 21:11-16.

Studies were carried out in a river in Northern Sweden, polluted by deposits from waste waters discharged from a metal mine, and by washings from similar deposits in a tributary stream, to determine the toxic effects on fish. Cages containing young salmon and minnows were placed at 12 stations in the river. The trial period was 5 days; fish were inspected daily and tests were made for any changes in the physicochemical characteristics of the water surrounding the cages. The area at the confluence formed a boundary of toxicity and a barrier for fish arriving from further upstream. It was found that the river is still unsuitable for fish life for about 6 km downstream from the confluence. The presence of zinc appeared to be mainly responsible for the toxic effect on fish, possibly in conjunction with smaller amounts of other metals present in the water.

230. Hasselrot, T.B. 1968. Report on current field investigations concerning the mercury content in fish, bottom sediment and water. Rep. Inst. Freshwat. Res. Drottingholm No. 48:102-111.

Young salmon were exposed in net cages in lakes and rivers upstream and downstream from factories discharging waste waters containing mercury. After one or two months, examination of the fish showed clearly increased contents of mercury in fish exposed below pulp mills (discharging organic mercury) and below a chlorine alkali plant (discharging inorganic mercury); the contents of mercury in fish held near the points of discharge were considerably higher in summer than for corresponding exposure periods in winter. The concentration of mercury increased initially in the blood corpuscles, reaching a maximum of about 1000 ng per g, and then increased in the liver to considerably higher values, while the concentration in muscle

increased much more slowly. Studies on pike caught under natural conditions showed great differences in the mercury content of fish upstream and downstream of a cellulose mill even after the mill had ceased to use organic mercury compounds. The mercury content of bottom deposits also showed marked differences above and below the mill a year after the use of mercury compounds had ceased. Analysis of water samples indicated a higher concentration of mercury in water layers adjacent to sediment contaminated by a previous discharge of organic mercury, but no similar tendency has been observed for solution of mercury from bottom deposits downstream from a plant discharging inorganic mercury.

231. Hazel, C.R. and S.J. Meith. 1970. Bioassay of king salmon eggs and sac fry in copper solutions. California Fish and Game 56:121-124.

Flowing water bioassay of chinook salmon (Oncorhynchus tshawytscha) eggs and fry in a copper solution indicated that eggs are more resistant to the toxic effects of copper than fry. Copper concentrations of 0.08 mg/liter did not noticeably affect the hatching success of eyed eggs, but concentrations as great as 0.04 mg/liter were acutely toxic to fry and concentrations of 0.02 mg/liter caused increased mortality and inhibited growth.

232. Heather, C.J. 1966. The structure and biology of Alcyonidium gelatinosum. Proc. Royal Soc. Medic. 59:1120-1121.

Alcyonidium gelatinosum, a bryozoan, is exclusively aquatic and occurs in many parts of the world, particularly the Northern Hemisphere. The adult colony lives on the seabottom, usually attached by a mucilaginous secretion to seaweeds, rocks or shells. Research with this material centered on the possible association of toxic plants or animals, the intake of irritant organic matter and the manufacture and/or concentration of irritant substances from ingested materials. Analysis of a homogenized sample of material gave the following results for inorganic elements: zinc, appreciable amounts; copper, trace; nickel, 20 mg/kg; manganese, 20 mg/kg; tin, very few tenths percent; cobalt, vanadium, lead, strontium, none detected.

233. Herbert, D.W.M. and D.S. Shurben. 1963. A preliminary study of the effect of physical activity on the resistance of rainbow trout (Salmo gairdnerii Richardson) to two poisons. Ann. Appl. Biology 52:321-326.

In studies on the effect of activity on susceptibility to poisons, yearling rainbow trout were exposed to various concentrations of zinc sulphate and ammonium chloride in still water and in water stirred at three known velocities. The concentration of ammonium chloride which killed 50 per cent of fish swimming at 85 per cent of their maximum sustainable speed for 24 hours was 0.81 times that for still water, and the corresponding factor for 48-hour exposure to zinc sulphate was 0.7. There was no increase in susceptibility for speeds up to 55% of the maximum sustainable speed. Oxygen consumption of fish at varying swimming speeds was measured, and its influence on susceptibility to poisons is discussed.

234. Herbert, D.W.M. and D.S. Shurben. 1964. The toxicity to fish of mixtures of poisons. I. Salts of ammonia and zinc. Ann. Appl. Biology 53:33-41.

Experiments with rainbow trout in solutions of NH_4Cl and $ZnSO_4$ were done to examine the empirical rule that a mixture of two poisons, P and Q, should be at threshold concentrations for acute toxicity when $Ps/Pt + Qs/Qt = 1$ (s = concentration in solution; t = threshold concentration when testing one poison). In every case the rule under examination provided a better description of the data than models based on the hypothesis of independent joint action.

235. Herbert, D.W.M. and D.S. Shurben. 1964. The toxicity of fluoride to rainbow trout. Water Waste Treat. J. 10: 141-142.

In areas where fluoridation of water supplies is practiced, sewage effluents may contain up to 1 mg/l fluoride, and it is important to know whether this would have any effect on fish in the receiving stream. Laboratory experiments were, therefore, carried out to determine the toxicity of fluoride to rainbow trout, in both soft and hard waters. The results indicate that in soft water 1 mg/l fluoride would be unlikely to kill more than 0.01% of a trout population, which is negligible in comparison with the natural death-rate, and in hard water fluoride is even less toxic. In addition, since sewage usually receive dilution with river water, the actual concentration of fluoride in the water would normally be much less than 1 mg/l.

236. Herbert, D.W.M. and J.M. Vandyke. 1964. The toxicity to fish of mixtures of poisons. II. Copper-ammonia and zinc-phenol mixtures. Ann. Appl. Biology 53:415-421.

The applicability of the following predictive formula was tested: Ps/Pt 50 + Qs/Qt 50 = 1; where P, Q = 2 poisons; s = concentration of poison in solution; t 50 = threshold level of median resistance.

With ammonia-copper mixtures, this method of predicting the threshold concentration becomes progressively less adequate as lower percentage mortalities are considered.

For $CuSO_4 \cdot 5H_2O$ the threshold levels at 2 hours and 48 hours were 2 mg/l and 0.2 mg/l, respectively.

237. Herbert, D.W.M. and H.T. Mann. 1958. The tolerance of some fresh-water fish for seawater. Salm. Trout Mag. 153:99-101.

In order to determine the tolerance of some fresh-water fish in sea water, an experiment was carried out with roach (Rutilus rutilus, L.) and perch (Perca fluviatilis, L.) to observe the effect of transferring them suddenly from freshwater to mixtures of fresh and sea water. It was found that the perch could withstand about 1½ times the salinity tolerated by roach, and it appears that perch could tolerate a sudden rise in the salinity to about 45 per cent sea water for several days, but that roach could tolerate only about 30 per cent.

238. Herbert, D.W.M. and A.C. Wakeford. 1964. The susceptibility of a salmonid fish to poisons under estuarine conditions. I. Zinc Sulfate. Inter. J. Air Water Pollut. 8:251-256.

Experiments were conducted on the effect of zinc sulphate on Atlantic salmon smolts and yearling rainbow trout at various salinities. It was found that the resistance of both types of fish to zinc sulphate increases with increases in salinity up to 30-40% sea water, at which salinity rainbow trout can withstand for 2 days 15 times and salmon 13 times as much zinc sulphate as in fresh water. A further increase in salinity to 72% sea water, however, reduces the tolerance to zinc. Salmon smolts were more susceptible to zinc than rainbow trout in fresh water and at all salinities tested, and it is stressed that results of toxicity tests carried out with rainbow trout should be applied with caution to estuaries through which salmon pass.

239. Herde, K.E. 1957. Studies in the accumulation of radio-active elements in Oncorhynchus tschawytscha (chinook salmon) exposed to a medium of pile effluent water. U.S. Atom. Energ. Comm., HW-3-5064: 21 p; Nuclear Sci. Abstr. 13:1331.

Investigations were carried out to determine the total accumulation of radioactive elements in fish exposed to cooling water from a nuclear reactor. Data are reported on the accumulation of sodium-24 and other longer-lived elements in the fish, including the rate of accumulation of radioactive materials during controlled exposure for various periods, the effect of temperature on the rate of accumulation, evidence of accumulation of varied amounts of longer-lived materials, the significance of the excretion factor when fish containing sodium-24 are removed to fresh water, and individual variations in fish regarding their metabolism buffer ability or tolerance to radioactive materials.

240. Herdman, W.A. and R. Boyce. 1899. Oysters and disease. An account of certain observations upon the normal and pathological histology and bacteriology of the oyster and other shellfish. Lancashire Sea Fisheries Memoir No. 1:1-60.

The cause of green oysters may be an accumulation of copper salts or may be due to a green pigment. Large amounts of copper salts are harmful to oysters.

241. Hibiya, T. and M. Oguri. 1961. Gill absorption and tissue distribution of some radionuclides (Cr-51, Hg-203, Zn-65 and Ag-110 m, 110) in fish. Bull. Jap. Soc. Sci. Fish. 27:996-1000.

Radioactive nuclides were used to study the rate of absorption of some heavy metals through the gills of the Japanese eel, Anguilla japonica. Zinc, mercury, chromium and silver were absorbed at rates of $0.7-4.1 \times 10^{-6}$, $0.3-3.2 \times 10^{-6}$, $0.8-1.9 \times 10^{-8}$, and $1.2-4.2 \times 10^{-7}$ mg per hour, respectively. The distribution and accumulation of the nuclides in the body were studied by injecting the nuclides into the air bladder of goldfish. The results obtained differed with the different nuclides; zinc, mercury, chromium and silver were accumulated abundantly by the intestine, kidney, head kidney and liver, respectively.

242. Hiyama, Y. 1962. Studies on uptake of radio-isotopes by edible marine products. Progress Reports Tokyo University 1960-62: 51 p. Nuclear Science Abstracts 1965, 19: 5445.

Experiments were carried out to determine the concentration factors of several radionuclides (that is, the ratio of the concentration of nuclide in tissues or organs to the concentration in the surrounding water for representative edible marine organisms, including

fish, shellfish, and algae). It was found that the rate of uptake, or time required to reach equilibrium, varied according to the nuclide, the organism, its age, and the temperature of the water. Equilibrium concentration factors differed with the kind of tissue or organ, the organism, and the nuclide, but were not affected by water temperature or concentration of the nuclide in the water. The presence of a carrier in the water reduced the concentration factors for iodine-131, cobalt-60, zinc-65 and cadmium-115 m, but had no effect on those of cesium-134 and strontium-89. In the case of iron taken up by algae, the concentration factor was also affected by light. Uptake of the nuclides also depended on the form in which they occurred in the water particularly if they were in the particulate or colloidal state. It is recommended that the concentration factors for radioactive isotopes in edible marine organisms should be taken into account when evaluating the hazards caused by radioactive contamination of sea water.

243. Hobden, D.J. 1969. Iron metabolism in Mytilus edulis. II. Uptake and distribution of radioactive iron. J. Mar. Biol. Assn. U.K. 49:661-668.

Mytilus edulis absorbs radioactive "soluble" iron from citrated water either directly or via adsorption on to the mucus used in feeding. The adsorption slows or ceases after 3-7 days when the total iron uptake is about 1% of the total body content. In order of decreasing radioactivity, iron is absorbed into the byssus threads, renal organ, digestive gland, gut epithelia, gills, walls of heart and blood sinuses and gonadal and muscular tissues. The iron persists when the animals are transferred to clean sea water.

244. Hoffman, D.O. and R. Zakhary. 1951. The effect of temperature on the molluscacidal activity of copper sulphate. Science 114:521-523.

Experiments were made on Biomphalaria boissyi, the intermediate host of Schistosoma, to determine the effect of temperature on the molluscacidal activity of copper sulphate. Results indicated that as the temperature increased from 14° to 26°C the concentration of copper sulphate required to cause 50 per cent of the snails to die was reduced from 13 mg/l to 0.25 mg/l. The importance is stressed of temperature as a factor in the control of snails which may transmit bilharziasis.

245. Holland, G.A., J.E. Lasater, E.D. Neumann, and W.E. Eldridge. 1960. Toxic effects of organic and inorganic pollutants on young salmon and trout. Washington State Dept. Fisheries, Research Bulletin 5: 278 p.

Studies on the toxic effects of trade waste waters and their constituents on salmon and trout are reported, including the effect of waste waters from pulp mills; the supernatant portion of wastes from the production of acetylene; detergents; fungicides; germicides; glues; herbicides; insecticides; naphthalene; pea-vine silage liquor; phenol and phenolic wood preservative waste waters from the manufacture of plastic boats; potassium phenylacetate; tannic acid; and various inorganic substances, including ammonia, arsenic trioxide, barium chloride, residual chlorine, mono-and dichloramine, chlorine plus ammonia, potassium chromate, chromium sulphate, cupric nitrate and sulphate, sodium fluoride and sodium sulphide. The effects of the hardness and the pH value of the water were also examined. Young salmon (chinook, chum, pink, and silver), and sometimes rainbow trout, were used as the test fish in both short-term (3 days) and long-term (up to 30 days) toxicity tests. The experiments with pulp mill waste waters also included studies on the ability of the fish to avoid dangerously-polluted waters, and on the effect of sulphite waste liquor on herring eggs. The results are tabulated and discussed for each of the compounds and a table summarizing all the data is appended, giving the apparent tolerance level and the critical level for each compound. The effects of some of the pollutants varied according to the type of medium (fresh or sea water), species and size of fish, and period of exposure.

246. Holliday, F.G.T. and J.H.S. Blaxter. 1960. The effect of salinity on the developing eggs and larvae of the herring. J. Mar. Biol. Assn. U.K. 39:591-603.

In connection with studies on osmoregulation in the herring and on the range of conditions which herring eggs and larvae might tolerate in nature and in rearing tanks, experiments were carried out on the effects of salinity on developing eggs and larvae. It was found that fertilization, development, and hatching of the eggs occurred in salinities ranging from 5.9 to 52.2 parts per thousand; both the developing eggs and larvae were larger when incubated in the lower salinities and their relative water content was higher. The salinity tolerance of both spring- and autumn-spawned larvae was found to be between 1.4 and 60.1‰ for 24 hours and between 2.5 and 52.5‰ for 168 hours. When larvae were transferred from one salinity to another extensive osmotic changes occurred in the body fluids; under these conditions larvae experienced and survived internal body fluid concentrations equivalent to salinities of 8.7-22 per thousand. A regulatory mechanism exists, however, which returns the body fluids to a more limited range (about 12.3‰) within 24 hours. It is concluded that the osmotic forces encountered in nature will not constitute a serious hazard to herring larvae.

247. Holliday, F.G.T. and J.H.S. Blaxter. 1961. The effects of salinity on herring after metamorphosis. J. Marine Biol. Assn. U.K. 40:37-48.

The salinity tolerance of herring 9 to 24 cm long is between 6 and 40-45 o/oo. When transferred to different salinities, herring experienced and survived blood concentrations equivalent to salinities of 13-22.5 o/oo. A recovery to near normal (15.8 o/oo) took place in all salinities within the tolerance range.

Badly descaled herring in sea water showed large increases in blood concentration before death. High glomerular count in kidneys is the probable reason why herring can stand low salinities for long periods.

248. Holtzman, R.B. 1969. Concentrations of the naturally occurring radionuclides ^{226}Ra, ^{210}Pb, and ^{210}Po in aquatic fauna. Proc. 2nd Nat. Symp. on Radioecology, U.S.A.E.C. Conf. 670503:535-546.

The concentrations of ^{226}Ra, ^{210}Pb and ^{210}Po were determined in hard and soft tissues of freshwater and marine fish, shellfish, seals and whales and in some of the dietary components of whales. The ^{226}Ra concentrations were fairly independent of the species at about 5 pCi/100 g bone ash and 0.2 pCi/100 g wet soft tissue. The concentrations of both the ^{210}Pb and ^{210}Po in a given tissue were equal to or greater than those of the parent, ^{226}Ra. In bone from fish and seal the concentrations of the ^{210}Pb and ^{210}Po were similar to those found in human bone, about 15 pCi/100 g ash. Fish muscle contained about 0.2 pCi ^{210}Pb/100 g wet and about 10 times this specific activity of ^{210}Po. The activities of both of these nuclides in the soft tissues of clams, oysters and squid were higher by one order of magnitude than in fish muscle. In bone and muscle taken from a fin whale, concentrations of these nuclides were similar to those found in fish. By contrast, teeth from sperm whales had concentrations of ^{210}Pb one order of magnitude greater than those in bones of fin whales. The higher concentrations of ^{210}Pb in sperm whales seem to be correlated with those found in some of the components of the diet -- copepods, euphausiids, and possibly squid.

249. Horn, W.M.V. and M. Katz. 1946. Pyridylmercuric acetate as a prophylactic in fisheries management. Science 104:557.

Some of the mercurial compounds used for controlling slime in pulp and paper mills are discharged in the waste waters. Experiments to determine the effect of pyridylmercuric acetate on fish and other aquatic organisms indicated that this compound in high dilutions

could be used for controlling infection of fish in hatcheries. In experiments with Lake Emerald shiners (Notropis etherinoides) in water with a temperature of 12°C, a pH value of 7.38 to 7.72, and a methyl orange alkalinity of 266 mg/l, only 52% of fish in the control group survived after five days; the organism causing the death of the fish was not identified. Seventy-five % of the fish survived in a solution containing 0.05 mg/l pyridylmercuric acetate, 78% survived in a 0.10 mg/l solution and 96% survived in a 0.15 mg/l solution. Higher concentrations of pyridylmercuric acetate are toxic to fish.

250. Hoss, D.I. 1964. Accumulation of zinc-65 by flounder of the genus Paralichthys. Trans. Amer. Fish. Soc. 93:364-368.

Since zinc-65 is one of the more abundant isotopes discharged in waste waters from nuclear reactors, and zinc is an essential element in the metabolism of most animals, experiments were carried out on the accumulation of zinc-65 from water and food by 3 species of flounder (Paralichthys dentatus, P. albigutta, and P. lethostigma). When concentration factors were calculated it was found that the fish accumulated zinc-65 to higher levels from food than from water. The initial rate of accumulation of zinc-65 from water depended on the concentration of the nuclide in the water.

251. Houston, A.H. 1959. Osmoregulatory adaptation of steelhead trout (Salmo gairdneri Richardson) to sea water. Can. J. Zool. 37:729-748.

Steelhead trout transferred from fresh water into sea water exhibited two distinct phases in osmoregulatory adaptation. The first, or adjustive phase, was distinguished by marked departures from fresh-water levels and distribution of water and electrolytes. Increases in muscle chloride space indicated transfer of fluids from cells into the extracellular compartment. Plasma levels of water, chloride, sodium, and potassium rose, while that of calcium remained relatively constant. The ratio of plasma sodium to chloride fell sharply suggesting a condition of acidosis. Cellular calcium concentrations rose markedly, while smaller increases were seen in chloride and potassium levels. Changes in calcium appeared to be a function of both cellular dehydration and electrolyte uptake. Changes in cellular potassium concentrations were related primarily to dehydration since tissue levels of this ion fell slightly in sea water. The roles of active electrolyte excretory processes, and the passive withdrawal of ions from the circulating fluids by complex formation, have been considered as osmoregulatory mechanisms leading to the establishment of the second, or regulative, phase of adaptation to sea water.

252. Houston, A.H. 1959. Locomotor performance of chum salmon fry (Oncorhynchus keta) during osmoregulatory adaptation to sea water. Can. J. Zool. 37:591-605.

Transfer into sea water produced an immediate and marked depression of the cruising speed of chum salmon fry. Despite considerable recovery from this initial effect the fish exhibited a continuing slight depression of cruising speed over the entire experimental period (80 hours). Variations in total body levels of chloride and water were significantly correlated with changes in cruising speed, suggesting that variations in activity might be related to the process of osmoregulatory adaptation to sea water. Possible mechanisms underlying this effect have been discussed.

253. Houston, A.H. and L.T. Threadgold. 1963. Body fluid regulation in smolting Atlantic salmon. J. Fish. Res. Bd. Can. 20:1355-1369.

Parr-smolt metamorphosis in yearling Atlantic salmon was accompanied by variations in plasma and tissue electrolyte levels, and in tissue water distribution. Plasma chloride declined sharply with the onset of smoltification, but recovered to values somewhat higher than those seen in parr with the attainment of the silvery parr stage. Some decrease, with no evidence of a secondary increase, was observed in tissue chloride concentrations. Changes in chloride space values suggested that parr-smolt metamorphosis is also characterized by a shift of tissue fluids from the extracellular to the cellular phase. These variations in water-electrolyte balance are thought to reflect a premigratory activation and secondary suppression of the extrarenal salt excretion systems employed for osmotic and ionic regulation in sea water.

254. Hubschman, J.H. 1967. Effects of copper on the crayfish Orconectes rusticus. I. Acute toxicity. Crustaceana 12:33-42.

Crayfish subjected to 6 mg/l of Cu as $CuSO_4$, in a flow through system, survived exposure for 24 hours but all died by 10½ days post-exposure.

Exposure to 2.5 mg Cu/l for 8 hours once a week for three weeks produced 100% kill in 20 days after the last exposure; one exposure of 24 hours to 2.5 mg/l Cu produced 100% kill in 15 days (vs 10½ days for 6 mg/l); eight 24 h exposures one week apart produced 100% kill in 8 days, after the last exposure.

Continuous exposure to 1 mg/l killed all adults in 16 days, juveniles in 6 days and younger stages in 0.5 days.

Effect of copper on embryos (13-14 day exposure)

mg/l	% mortality (living vs dead young at hatching)
0.5	100
0.25	52
0.125	10
0.06 and lower	<1

In discussion, author notes that 0.35 mg/l of Cu^{2+} as carbonate kills 90% of the barnacle Balanus balonoides in two days, and that two to five days were required for concentrations between 0.6 and 1.0 mg/l when the metal was supplied in the form of citrate. Animals remained alive for two weeks at levels <.06 mg/l. The marine copepod Nitocra spinipes (Boeck) had mortality rates of 42% at 26 mg/l, 21% at 2.6 mg/l, 11% at 0.26 mg/l and 1.3% at .026 mg/l Cu in 24 hours.

255. Hubschman, J.H. 1967. Effects of copper on the crayfish Orconectes rusticus. II. Mode of toxic action. Crustaceana 12:141-150.

At very high concentrations (i.e. >100 mg/l) copper coagulates proteins and acts as a fixing reagent. At concentrations >1 mg/l there is inhibition of respiratory enzymes. At levels <1 mg/l and >.5 mg/l Cu^{2+}, author observed degenerative effects of cells and tissues including disruption of glutathione equilibrium.

At concentrations <0.5 mg/l author observed that neither succinate utilization or endogenous respiration is measurably affected. Detoxification occurs at a rate sufficient to prevent the copper from inhibiting these systems in hepatopancreas homogenates. At low concentrations Cu^{2+} has a chronic effect on cell maintenance i.e. crayfish antennal gland.

256. Hueck, H.J. and D.M. Adema. 1968. Toxicological investigations bearing on pollution problems in the North Sea. TNO Nieuws 23:58-64.

To determine the concentration of pollutants in aquatic food chains, continuous flow tests were carried out using Chlorella pyrenoidosa and Daphnia magna, with copper as the toxic agent. The concentration factor for the alga was higher than that determined previously by other investigators. A concentration of 0.056 mg/l inhibited the growth of Daphnia but the alga could tolerate concentrations as high as 1 mg/l. However, when fed algae grown in a medium containing copper, Daphnia died only when the copper concentration was raised to 0.56 mg/l indicating that Daphnia was able to tolerate higher levels of copper in food organisms than in aqueous solutions.

257. Hunn, J.B. 1963. Uptake, distribution and excretion of the radionuclide I-131 by rainbow trout (Salmo gairdnerii). Thesis, Michigan State University, East Lansing, Mich.: 126 p.

Rainbow trout were exposed for 24 hours to various solutions (distilled water, tap water, 0.6% sodium chloride solution and 66% Ringer's solution) containing carrier-free iodine-131, and samples of various tissues were then examined to determine the relative accumulation and distribution of iodine-131. It was found that the uptake of iodine-131 by the gills of trout is inhibited by sodium thiocyanate and reduced by chloride, and is inversely related to the calcium concentration in the medium. Iodine-131 in the blood of trout is more than 90% ionic, and at 14°C its biological half-life is 1-7 days. Determination of iodine storage capacity of the tissues showed that 30% of the total body iodine may be contained in the muscle. Iodine is lost from the body by the gills and in the urine.

258. Hunn, J.B. 1969. Chemical composition of rainbow trout urine following acute hypoxic stress. Trans. Amer. Fish. Soc. 98:20-22.

Rainbow trout (Salmo gairdnerii) were anesthetized with MS-222, catheterized, and introduced into urine collecting chambers. Twenty-four hours after introduction, a 4-hour accumulation of urine was collected to serve as the control. Water flow to the chambers was then discontinued for 30 minutes during which the oxygen content of the water existing in the chamber dropped from 4.9 to 2.8 mg/l. Following this hypoxic stress fresh water was restored and accumulated urine samples were taken for analysis at 1, 4, and 20 hours post-hypoxic stress. Rainbow trout excrete abnormally high concentrations of Na, K, Mg, Cl, and inorganic PO_4 following hypoxia.

259. Hunter, B.F., and N.R. Merton. 1965. Occurrence of lead poisoning in a wild pheasant (Phasianus colchicus). California Fish and Game 51:207.

A dead male pheasant, without signs of having been shot, was found at the Grizzly Island Waterfowl Management area. Necropsy revealed 29 lead (Pb) shots or fragments thereof in the gizzard; the weight of this Pb was 3.6 grams. Analysis of the bird's tissues revealed 42 mg/kg Pb in the breast tissue and 168 mg/kg in liver, which is far above the normal of up to 1 mg/kg in either breast of liver. Mensch (unpublished), after force-feeding experimental pheasants with Pb shots, found Pb values of 50 and 143 mg/kg, respectively, for breast and liver.

260. Hutter, O.F., and A.E. Warner. 1967. Action of some foreign cations and anions on the chloride permeability of frog muscle. J. Physiology 189:445-460.

Evidence was obtained for the existence in skeletal frog muscle of a specific cation binding system capable of lowering the chloride (Cl) permeability. The effect of several metal ions upon the efflux of Cl^{36} from frog muscles equilibrated in solutions with a high potassium chloride concentration was tested. It was found that the presence of bivalent nickel, cobalt and lead in 10^{-4}M or higher concentrations had no detectable influence on the Cl^{36}-efflux.

261. Ichikawa, R. 1961. On the concentration factors of some important radionuclides in marine food organisms. Bull. Jap. Soc. Sci. Fish 27:66-74.

From a survey of the literature, the author discusses the concentration factors for the radionuclides of manganese, iron, cobalt, strontium, iodine and cesium by fish, molluscs, crustacea, sea urchins and algae. Data were not available for the concentration of strontium by fish, but the factor is less than one in other cases except for brown algae. Invertebrates concentrate iodine 2 or 3 times more strongly than fish, and algae also concentrate iodine strongly. Iron and manganese are concentrated highly by most organisms; zinc is also highly concentrated, but cobalt is least concentrated of the nuclides. The nuclides of iron, cobalt, manganese and zinc are quite important in aquatic food chains, and possibly more so than strontium and cesium because of high concentrations, but the permissible level of the last two in human diet is extremely low.

262. Ichikawa, R., M. Oguri, and N. Takoda. 1962. Metabolism of radionuclides in fish. III. Comparative behavior of strontium and calcium at gill absorption in environmental water with different amount of calcium. Nippon Suisan Gukkaishi 28:1160-1163.

Effect of calcium concentration in water on uptake of strontium and calcium by gills of fish was studied by a gill perfusion technique using calcium-45 and strontium-89, with Japanese eel, Anguilla japonica, as the test fish. Concentrations of calcium in the water were 30, 60 and 190 mg/l. Results obtained were similar to those in previous experiments where the calcium concentration was 100 mg/l, and it is concluded that the strontium-calcium discrimination factor in gill absorption of fish is approximately 0.7 and does not vary much over a wide range of calcium concentrations.

263. Idler, D.R., and B.J. Szeplaki. 1968. Interrenalectomy and stress in relation to some blood components of an elasmobranch (Raja radiata). J. Fish. Res. Bd. Canada 25:2549-2560.

From the literature there was a doubt as to whether interrenalectomy would result in elevated plasma potassium levels in an elasmobranch. In this study no elevation was observed by comparison with sham-operated thorny skate (Raja radiata) held in sea water for up to 44 days post-operative. Blood calcium levels were significantly elevated in the interrenalectomized animals between 13 and 23 days but the increase was only 10%. There was no change in osmolality, sodium chloride, magnesium, or urea which can be attributed to interrenalectomy. Noteworthy was the manner in which both sham and interrenalectomized animals were able to maintain plasma electrolyte levels during the long period of starvation after surgery. Whenever significant changes occurred during the course of the experiment, sham and interrenalectomized fish were similarly affected, apart from the exception noted for calcium. Plasma urea levels were significantly depressed after interrenalectomy when the skates were held in a 3:1 mixture of sea water:fresh water for 7-9 days. The same trend was observed for sham-operated animals but the decrease was not significant. Normal animals maintained plasma urea in 75% sea water but not in 60% sea water.

264. Il'in, D.I., Yu.I. Moskalev, and A.I. Petrova. 1958. The accumulation of radio-elements in certain groups of water organisms. Atom. Energ. 5:171-174; Nuclear Sci. Abstr. 13:379.

Studies of the accumulation of radioactive elements by living organisms in water have shown selective uptake of phosphorus-32, strontium-89, strontium-90, cesium-137, and sodium-24 by plankton and fish. The concentration of phosphorus-32 was 3-4 times higher in fish, plankton, and deep-sea organisms than in water, and the concentration of strontium-89, strontium-90, and cesium-137 were 2-3 times higher.

265. Iorgulescu, A., M. Oncescu, O. Serbanescu, and R. Porumb. 1965. Active gamma fission products identified in sea plankton. Studii Cerc. Biol., Ser. Zool. 17:571-577; Nuclear Science Abstracts 1967, 21:4090.

Analyses of samples of zooplankton collected from the surface layers of the Black Sea near the Romanian shore showed the presence of the fission products antimony-125, tellurium-125, ruthenium-106, cerium-144, and cesium-137. In view of these results it is suggested that the radioactivity of other marine organisms should be investigated.

266. Irukayama, K. 1967. The pollution of Minamata Bay and Minamata disease. Proc. 3rd Int. Cont. Water Pollution Research, Munich, 1966. 3:153-180.

Results of studies are presented on the relation between pollution of Minamata Bay, Japan, with mercury compounds from a chemical plant and the occurrence of Minamata disease, a severe neurological disorder common in the area. In 1960, facilities for treatment of the waste waters were put in operation; treatment comprises adjustment of the pH value to 10 with calcium hydroxide, coagulation with sodium alginate, and removal of the suspended solids in a centrifugal rotary stirrer. Since the treatment plant began operation no mercury has been discharged to the bay, and there has been a gradual decrease in the concentration of mercury in fish and shellfish in the bay. In the manufacture of acetaldehyde from acetylene, using mercuric oxide in sulphuric acid as catalyst, a wet sludge is produced and this was analysed and was found to contain an organic mercury compound which was isolated and identified as methylmercury chloride. The same compound was also isolated from shellfish in the bay. The toxicity of this and other organic mercury compounds to animals was investigated, and they were found to produce symptoms typical of Minamata disease. It is concluded that so long as no mercury compounds are discharged the danger from eating fish and shellfish from the bay will gradually decrease, but care must be taken to prevent the discharge of the mercury sludge from the acetaldehyde plant.

In the discussion that followed the occurrence of a similar disease in Niigata City, Japan, among fishermen along the Agano River is described. The hair of all the patients was found to contain mercury, the amount being related to the quantity of river fish eaten. Fish from the river were also analysed and were found to contain mercury The cause of the pollution was attributed to the Kanose factory which, until early 1965, manufactured acetaldehyde from acetylene, using mercury as a catalyst. In the discussion appended, Dr. Nozaki pointed out the importance of providing adequate treatment for all waste waters containing highly toxic alkyl metal compounds, and described the development of a method for the treatment of waste waters from the manufacture of tetraethyl lead. The usual treatment for these waste waters is chemical coagulation which is effective in removing inorganic lead compounds but does not remove the organic compounds. Studies showed that the organic lead compounds could be removed by a strongly acid cation-exchange resin (Amberlite 200); the resin could be regenerated with caustic soda. The relatively small volume of eluate could then be chlorinated and steam-heated to convert the organic lead compounds to inorganic compounds which could be removed by coagulation in admixture with the other process waste waters. A flow diagram of the complete treatment system is included.

267. Irukayama, K., F. Kai, F. Fumjiki, and T. Kondo. 1962. Studies on the causative agent of Minamata disease. III. Industrial wastes containing mercury compounds from Minamata factory. Kumamoto Medical Journal 15(2):57-68.

An organomercury compound has been extracted from the sludge from the chemical plant at Minamata, Japan, and its properties compared with the mercury compound isolated from fish and shellfish in Minamata Bay. It is suggested that this compound may be a cause of Minamata disease.

268. Ishikura, S. and C. Shibuya. 1968. Analysis of mercury of fishes and soils of Agano River. (In Japanese). Eisei Kagaku, 14 (4):228-230. Selected Water Resources Abstracts 3(17): p. 30.

The analysis of mercury was carried out to clear the occurrence of poisoned patients caused by organic mercury around the Agano River. The mercury content was estimated photometrically from the mercury dithizonate which was isolated from dithizon extract of oxidative degradation product of samples such as soils, fishes and waters. It was found that the soils obtained near the draining exit of Shyowa Denko and Nippon Gas Kagaku contained high amounts of mercury, whereas the mercury was not detected clearly in any waters. Some fishes were also found to keep the high concentrations of the total mercury and organic mercury.

269. Ishizaka, O., Y. Ito, and S. Yamamoto. 1966. Determination of the toxicity of food additives by their effects on the life cycle of Chlorella. I. Cultures and Method. Nagoya Shiritsu Daigaku Yakugakubu Kenkyu Nempo 14:66-78; Chemical Abstracts 68:Abstr. No. 20598h, 1968.

Toxicities of food additives were examined by cultivating L- of Da-type Chlorella vulgaris in Arnon culture medium or L-type Chlorella on an agar plate containing Arnon medium. L-type Chlorella was stimulated by magnesium or <0.05% zinc acetate, and inhibited by mercury > silver > copper > cadmium > nickel > Pb > cobalt > zinc > iron > calcium, and >0.05% zinc acetate.

270. Ivanov, V.N. 1967. Effect of radioactive substances on the embryonic development of fish. Proc. 2nd Int. Oceanogr. Conf., Moscow, 1966: 185-190.

Eggs of various species of fish from the Black Sea were incubated in solutions of strontium-90, yttrium-90, and cerium-144 of

different activities, and the effects of the radioactivity on morphology and survival of the larvae were measured. It was found that the mitotic activity decreased and the number of chromosome aberrations increased with increasing radioactivity. The uptake of various radioactive isotopes from sea water by growing fish eggs was also studied; nuclides of cerium, iron, and yttrium accumulated on the surface of the eggs, but cesium and strontium became localized in the embryo tissues and the amount absorbed increased with time.

271. Jackim E., J.M. Hamlin, and S. Sonis. 1970. Effects of metal poisoning on five liver enzymes in the killifish (Fundulus heteroclitus). J. Fish. Res. Bd. Can. 27:383-390.

Activities of five liver enzymes (acid and alkaline phosphatase, catalase, xanthine oxidase, and ribonuclease) from Fundulus heteroclitus surviving exposure to 96-hr TL_m concentrations of salts of six metals (lead, copper, mercury, beryllium, cadmium, and silver) differed markedly from those of unexposed fish. Changes in enzyme activity produced by the exposures were not necessarily the same in magnitude or direction as those observed when the salts were introduced directly into the enzyme preparations. It is proposed that changes in liver enzyme activity may be useful as a kind of biochemical autopsy tool for diagnosing sublethal metal poisoning in fish.

272. Jennings, C.D. 1968. Iron-55 in Pacific Ocean organisms. Thesis. Oregon State University.

Large amounts of iron-55 from nuclear tests in 1961 and 1962 have been deposited in the Pacific Ocean and concentrated by marine organisms. Since the concentration of iron in the ocean is low, the marine organisms have a high specific activity for iron-55. This specific activity was found to vary among five species of Pacific salmon, being highest in sockeye salmon and lowest in chinook salmon. Since 1964 the concentration of iron-55 in the salmon has decreased, related to a decrease in iron-55 in the surface layers of the ocean.

273. Jenkins, C.E. 1969. Radionuclide distribution in Pacific salmon. Health Physics 17 (3):507-512.

The following gamma-emitting radionuclides were detected and measured in four species of Pacific salmon: ^{54}Mn, ^{60}Co, ^{137}Cs, ^{226}Ra, ^{22}Na, ^{40}K, ^{46}Sc, ^{51}Cr, ^{57}Co, ^{59}Fe, ^{65}Zn, ^{88}Y, ^{110m}Ag, ^{140}Ba, ^{152}Eu, ^{203}Hg, and ^{208}Tl. The concentration of the first two decreased in muscle tissue of salmon caught from Northwest Alaska through Southern Alaska to the Washington-Oregon coast by factors of about 1.5 to 3 and 4.5 to 12, respectively. The concentration of ^{137}Cs decreased only about 25%.

Concentrations of ^{226}Ra in the tissue of Alaskan salmon were high enough to cause natives who ate the fish to exceed their maximum permissible level. Among the factors affecting the distribution pattern of the radionuclides were the amount present in the Columbia River and the nuclear tests conducted by the Chinese.

274. Jernejcic, F. 1969. Use of emetics to collect stomach contents of walleye and large mouth bass. Trans. Amer. Fish. Soc. 98: 698-702.

Three ml of arsenous acid (1.8 mg arsenic total) were effective in causing walleye to regurgitate their stomach contents into the throat. Residual arsenic in the fish flesh was well below recommended safe levels (<80 mg/l arsenic). Three ml of tartar emetic = antimony potassium tartrate ($SbOH\ (C_4H_2O_6K_2)\cdot\frac{1}{2}H_2O$), equivalent to 1.0 mg antimony total, caused projectile vomiting in largemouth bass. Tartar emetic would be more effective than arsenous acid in identical situations.

275. Jernelov, A. 1969. Conversion of mercury compounds. In Miller, M.W. and G.G. Berg (eds). Chemical Fallout, Current research on persistent pesticides. Chas. C. Thomas Publisher, Springfield, Ill.:68-74.

It has been shown in Sweden that fish contain methylmercury in instances where the original discharge contains other types of mercury compounds. Mercury discharge in the form of metallic mercury, inorganic divalent mercury, phenylmercury and alkoxy-alkylmercury can all be converted in nature to methylmercury.

276. Johnels, A.G. and T. Westermark. 1969. Mercury contamination of the environment in Sweden. In Miller, M.W. and G.G. Berg (eds). Chemical Fallout, current research on persistent pesticides. Chas. C. Thomas Publisher, Springfield, Illinois: 221-239.

By means of activation analysis, the mercury content in feathers of eleven terrestrial birds species has been studied. Of these the goshawk (*Accipter gentilis*) is presented in this paper. The material has been derived from museum collections and from living or freshly killed birds; it covers a period of more than 100 years. These studies reveal nearly constant mercury levels from the middle of the previous century until 1940. After that, a well documented increase in mercury contamination occurs, amounting to at least ten to twenty times the previous level. In 1940 alkylmercury compounds began to be used as seed dressings. The synchronous appearance of

increased mercury accumulation in birds indicates that the seed dressing agents are a main source of contamination in the terrestrial environment.

Activation analysis of the mercury content in axial musculature of pike (Esox lucius) has been used for estimating the level of mercury in the aquatic environment. The mercury concentration factor in pike is 3000 or more. The relation between the mercury content and the weight or age of fish specimens is described. A graphical method has been used to establish the figure for the mercury content in pike specimens of 1 kg. Those figures have been used for geographical comparison. The effect of water contamination from industrial waste is demonstrated in some cases. There are indications that mercury also appears as an airborne pollution, mainly affecting the water environment. In contrast with the goshawk, where a sudden rise of mercury concentration in feathers occurred together with the onset of the use of methylmercury compounds in agriculture, two fish-eating birds species show a gradual increase in mercury content since the previous century. This indicates that the mercury contamination of the water follows the general increase in industrial activity. A number of sources of mercury contamination are discussed, and it is concluded that in many areas human activities have raised the mercury level of the environment far above natural levels.

277. Johnels, A.G., T. Westermark, W. Berg, P.I. Persson, and B. Sjostrand. 1967. Pike (Esox lucius L.) and some other aquatic organisms in Sweden as indicators of mercury contamination of the environment. Oikos 18:323-333.

By means of activation analysis, mercury was determined in the axial musculature of pike (Esox lucius) and the results were used to estimate the level of mercury present in the aquatic environment. The concentration factor from water to pike is of the order of 3000 or more. The relation between the mercury content and the weight and age of the fish is discussed, and the effect of industrial contamination is illustrated by comparing the mercury content of pike from points above and below the discharge of waste waters containing mercury. There are strong indications that mercury also occurs as an air-borne pollutant affecting the aquatic environment. Authors conclude that human activity has increased the mercury content of the environment far above the natural levels.

278. Jonderko, G. and Z. Dabrowski. 1964. The effect of heavy metal salts and calcium disodium and magnesium disodium versenate on the activity of serum phosphomonoesterase. I. In vitro studies. Archivum Immunologiae et Therapiae Experimentalis 12 (5):592-601.

The behavior of phosphomonoesterase 1 in the presence of equimolar concentrations of heavy-metal salts and chelating agents was studied in vitro with human blood serum. Two milliliters of the blood serum, using sera of 17 healthy patients with conditions unrelated to intoxication was incubated for 1 hour at 37°C with manganese sulfate, copper sulfate, mercury (Hg) chloride, lead (Pb) acetate and cobalt sulfate in amounts giving serum concentrations of 5×10^{-6}, 1×10^{-5} and 2×10^{-5}M after solution. The activity of phosphomonoesterase 1 was then determined in the test and in control samples. Sera of 10 individuals were used to study the "prophylactic" and "therapeutic" effect of calcium disodium versenate (EDTA) on the enzyme activity by incubating the sera with EDTA either before or after incubation with the heavy metals.

The degree of inhibition of the enzyme activity increased as the concentration of the heavy metals increased from 5×10^{-6} to 1×10^{-5} and 2×10^{-5}M, with Hg and Pb showing the strongest effect. After prophylactic application of EDTA, Hg and Pb also caused significantly greater inhibition of enzymatic activity than the other salts but significantly less than EDTA alone or than Hg and Pb without preincubation with EDTA. Incubation with EDTA for one hour after incubation with the heavy metals (therapeutic use) caused a significantly greater decrease of phosphomonoesterase activity than incubation with EDTA prior to incubation with the metal salts (prophylactic use of EDTA).

The conclusion was drawn that prophylactic use of EDTA is more effective than therapeutic use. There was little change in effect when serum was incubated with EDTA for 1, 2 or 24 hours. Since all heavy-metal salts including those of Pb inhibit phosphomonoesterase at concentrations above 5×10^{-6}M, determination of the activity of this enzyme may serve as a nonspecific diagnostic test in intoxication with these metals.

279. Jonderko, G. 1964. The effect of heavy metal salts on the activity of lactic dehydrogenase. Wpyw soli metali ciezkich na aktywnosc dehydrogenazy mleczanowej. Polskie Archiwum Medycyny Wewnetrznej 34:1583-1586.

The effect of manganese sulfate, cadmium sulfate, mercury chloride, lead acetate and cobalt sulfate in concentrations of 5×10^{-6}, 1×10^{-5} and 2×10^{-5}M on the activity of lactic dehydrogenase of human erythrocytes was studied *in vitro*. The results showed that the salts inhibited the action of the enzyme in a concentration as low as 5×10^{-6}M.

280. Jones, J.R.E. 1964. Fish and river pollution. R.E. Butterworth and Co. (Publishers) Ltd. London. 212 p.

In this book, the author's purpose is to summarize and review the experimental and field research that has been carried out on the effects of pollution on fish and to bring together much of the useful data. Chapters are included on the effects on fish oxygen-reducing effluents, metals, respiratory depressants such as cyanides and sulphides, inorganic gases, acids and alkalis, synthetic detergents and soaps, phenols and associated substances, heated effluents, suspended matter, and complex effluents. References are appended to each chapter, and included are a check list of the fishes most commonly used in experimental work on the effects of pollutants and related studies, as author index, and a subject index.

281. Jones, R.F. 1960. The accumulation of nitrosyl ruthenium by fine particles and marine organisms. Limnol. Ocean. 5:312-325.

Nitrosyl ruthenium-106 complexes occur in radioactive waste waters resulting from the nitric acid treatment of irradiated uranium rods which is sometimes discharged to coastal waters. Investigations were therefore conducted on the uptake of nitrosyl ruthenium-106 from sea water by fine particles, algae, and animal life. It was found that the uptake by sand and silt is proportional to the surface area of the particles and is enhanced by the presence of ferric hydroxide on the particles; although the uptake follows an adsorption isotherm, the ruthenium is difficult to remove, suggesting chemical binding probably due to the formation of an insoluble complex between the ruthenium and the ferric hydroxide. Uptake of ruthenium-106 by marine algae is also a surface phenomenon, involving formation of a complex with the extracellular polysaccharide material, which varies with the different species, probably owing to differences in the chemical composition of the cell surface. The marine diatom, Phaeodactylum cornutum is as effective as fine particles of sand in adsorbing and retaining ruthenium-106 from sea water. Mussels accumulate the isotope principally by adsorption on the shell, and plaice (Pleuronectes platessa) in the gut, gills, and skin, with only an insignificant amount in the flesh. Since differences were observed in the uptake from sea water of nitrosyl-nitrato ruthenium-106 and the nitrosyl ruthenium-106 complexes in waters from both a plutonium separation process and a uranium purification process these solutions were studied chromatographically and it was concluded that differences in physical and chemical forms of ruthenium were present; therefore in laboratory studies on the fate of radioactive waste waters discharged to an aquatic environment the actual treated waste water should be used, or the pure solution of the particular nuclide should be altered to conform with the physical and chemical nature of the nuclide present in the effluent.

282. Jones, J.R.E. 1938. The relative toxicity of salts of lead, zinc, and copper to the stickleback (Gasterosteus aculeatus L.) and the effect of calcium on the toxicity of lead and zinc salts. J. Exper. Biology 15:394-407.

Addition of calcium salts to $PbNO_3$ or $ZnSO_4$ reduces the toxicity of these salts to Gasterosteus. Fifty mg/l of Ca (as nitrate or chloride) will annul the toxicity of a 10 mg/l solution of lead or a 20 mg/l solution of zinc. It is concluded that, in the presence of sufficient calcium, the interaction between the lead, or zinc, and the mucus secreted by fish does not take place. This conclusion was endorsed by experiments in vitro on the slime secreted by the eel, Anguilla anguilla.

283. Jones, J.R.E. 1940. The toxicity of the double chloride of mercury and sodium. I. Experiment with Phoxinus phoxinus L. J. Exper. Biology 17:325.

Mercuric chloride does not ionize in aqueous solution, but in the presence of NaCl forms the double chlorides $NaHgCl_3$ and Na_2HgCl_4 which ionize readily. It had been claimed that the ionization of mercuric chloride, thus effected, is accompanied by an increase of toxicity, a decrease of toxicity, or that toxicity of the solution remains unaltered. An investigation with the minnow P. phoxinus using NaCl to convert $HgCl_2$ to the double chloride was performed. There was no marked change when ten times the quantity of NaCl needed was added. Any adverse affects were due to physical rather than chemical aspects. A marked prolonged survival time occurs with excess NaCl.

284. Jones, J.R.E. 1940. A study of the zinc-polluted river Ystwyth in North Cardiganshire, Wales. Ann. Appl. Biol. 27:368.

A study of the River Ystwyth in North Cardiganshire has shown that the destructive effect of pollution by zinc on river fisheries may be as serious as that caused by lead mining. In the river valley there are disused metalliferous mine workings which still continue to discharge water, heavily polluted with zinc salts and to a less extent with lead salts. Pollution caused by drainage of surface water from exposed dumps of mine refuse is comparatively unimportant. The main stream of the river at normal level carries 0.7-1.2 mg/l of zinc in solution and a trace to 0.05 mg/l of lead, and the bed is silted up with broken rock, rubble and gravel carried down from the mine workings. The main stream is completely devoid of phanerogamic vegetation and submerged grass and bryophytic vegetation is extremely scanty. The fauna is limited to Insecta, Platyhelmia, and Hydracarina. The absence of fish is directly associated

with the chemical condition of the water, and the absence of Mollusca and Malacostracan Crustacea also appears to be due to the pollution. The nature of the insect fauna is determined by the physical nature of the stream rather than by its chemical condition, the most abundant insects at all points being species characteristic of swift water and living upon or beneath stones. Certain species of insects appear to be very tolerant of pollution by zinc, and some species are found living in the most heavily polluted of the streams of the river valley. The rarity of planarians and the absence of oligochaetes and leeches may be due to the scouring action of the mine refuse and rubble of the river bed upon sluggish soft-bodied animals.

285. Jones, J.R. 1948. A further study of the reactions of fish to toxic solutions. J. Exp. Biol. 25:22-34.

The toxicity of sulphides, lead nitrate, ammonia, and abnormally acid and alkaline waters to the stickleback, Gasterosteus aculeatus, was studied. Gasterosteus reacted negatively (that is, tried to avoid the solution) to a solution of 27.3 mg/l sodium sulphide almost immediately; at lower concentrations a progressively longer time was taken to react (about 47 min in a 3.1 mg/l solution). In concentrations from 19.5 to 39 mg/l reaction time was always shorter than the period of survival of fish continually immersed in the solutions. In a solution of 6,640 mg/l lead nitrate fish reacted negatively at first and then positively. The positive reaction did not appear to be due to acidity of the solution or to impairment of the sense organs but may have been due to the osmotic pressure of the solution. Fish reacted negatively to 664-3.2 mg/l solutions but reactions to weaker solutions were not well defined. The minnow, Phoxinus phoxinus, was much more sensitive to lead nitrate than were sticklebacks; it showed immediate negative reaction to a solution of 116 mg/l $Pb(NO_3)2$. Tests with a single minnow showed that it reacted negatively to a 1.67 mg/l solution within 10 minutes. Reactions of sticklebacks to acid and alkaline water in the range of pH 3.2 to pH 12.0 were studied. Fish reacted negatively to water with a pH value of less than 5.4 or greater than 11.4. From pH 6.0 to pH 11.0 there was no definite reaction. In a solution of 680 mg/l ammonia, sticklebacks showed immediate negative reaction but with a 170 mg/l solution reaction was slow and some fish were overcome by exposure to the highly toxic solution. With 17-1.7 mg/l solutions a definite positive reaction occurred. The importance is stressed of covering a wide range of concentrations in studying the reactions of fish to toxic substances, as reactions vary considerably with concentration and with the sensitivity of the test fish.

286. Jones, J.R.E. 1958. A further study of the zinc-polluted river Ystwyth. J. Anim. Ecol. 27:1-14.

A further study has been made of conditions in the river Ystwyth, North Cardiganshire, which a previous investigation showed to be polluted by lead and zinc from disused mine workings. The present survey indicated that lead pollution has become negligible, but zinc still occurs in concentrations of 0.2-0.7 mg/l, according to river level, although mining operations were discontinued 35 years ago. Above the mines there is a rich flora, but below the sources of pollution it is poor in quantity and variety. The fauna consists almost entirely of lithophilous insects. The available food supply is very limited in variety, and the main food source appears to be detritus. Although limited in variety the invertebrate fauna seems quantitatively adequate to feed a reasonable number of fish, and brown trout now occur in the river. It appears that the pollution will continue for some time, though with slow improvement.

287. Joyner, T. 1961. Exchange of zinc with environmental solution by the brown bull head. Trans. Amer. Fish. Soc. 90:444-448.

Juvenile Ictalurus nebulosus (Pisces:Ictaluridae) were exposed to dilute solutions of $ZnCl_2$ (tagged with Zn^{65}). Initial uptake of zinc was rapid during the first few hours, but cumulation proceeded at a reduced rate after 12 hours. Higher zinc levels were found in viscera and gills, and lower amounts in skin, muscle and bone. Swallowed water did not add appreciably to zinc content of the gastro-intestinal tract. Bioassay was in 6 mg/l solution of $ZnCl_2$. One half of accumulated Zn was lost in one day after transfer to fresh H_2O, and slightly more after seven days. There was no apparent damage to the fish from exposure to Zn levels as high as 12 mg/l for 2 weeks, nor from radiation of Zn^{65}.

288. Joyner, T. and R. Eisler. 1961. Retention and translocation of radioactive zinc by salmon fingerlings. Growth 25:151-156.

Twenty-five chinook salmon fingerlings were immersed for twenty-four hours in 5 liters of lake water containing 0.2 mg/l of zinc labelled with 18.5 microcuries of zinc-65. Periodic assays of the gamma radioactivity in the fish showed that the rapidly growing fish had removed approximately 2% of the radioactive zinc from the medium and had retained nearly all of it for 63 days after transfer to flowing lake water. The increase with time in the percent of total body radioactivity contributed by the vertebral column, head, and visceral mass indicates an accumulation of zinc in these parts at the expense of the remainder of the fish.

289. Kaeding, J. 1958. The salt load on rivers of central Germany. Wasseur-Wass Techn. 8:25.

Pollution of the Wipper, Saale, Unstrut, and Elbe by waste waters from the potash industry has increased the chloride contents and hardness to such an extent that the use of the water is seriously affected. At the mouth of the Wipper the water contains 930 mg/l of chlorine and 75° (German) of hardness; at the mouth of the Unstrut the values are 590 mg and 50°; in the Saale of Grize 1600 mg and 75°; and in the Elbe at Magdeburg 350 mg and 17°.

290. Kalabina, M.M., K.A.M. Viss, A.S. Razumov, and Ts. I. Govskaja. 1944. Effect of the toxic substances in effluents from non-ferrous metal industries on the micro-organisms and biochemical processes associated with the self-purification of water in storage basins. Gigiena 9:1.

Samples of the waste waters and solutions containing certain of the toxic constituents, such as copper and lead, were diluted with river water polluted with sewage and were stored, in light and in the dark, at a temperature of 18-20°C for a sufficient period for self-purification to take place; a control sample containing only the polluted river water was also set up. Bacterial counts were then made, development of the organisms was observed microscopically, and at intervals, contents of copper, lead, ammonia, nitrite and nitrate, pH value and oxygen demand were determined. The results showed that in the presence of even comparatively small amounts of copper and lead, development of the micro-organisms and the process of self-purification were retarded. Addition of more than 0.1 mg/l of copper causes an appreciable decrease in the numbers of bacteria; after a period, which increases as the concentration of copper is increased, the numbers of bacteria begin to increase again, though no increase was observed in concentrations of 50 and 100 mg/l of copper. At concentrations of 0.5 mg/l copper, development of all types of micro-organisms was retarded and processes of nitrification and of biochemical consumption of oxygen were inhibited; the process of ammoniation, however, was unaffected. The toxic concentration of lead for bacteria was 1 mg/l and for flagellates and infusoria was 0.5 mg/l. The biochemical oxidation of organic matter was inhibited at concentrations of 1 mg/l of lead and the process of nitrification was retarded when 0.5-1 mg/l lead was presented.

291. Kalninya, Z.K. and G.G. Polikarpov. 1968. Strontium-90 accumulation factor in plankton of different bodies of water. Radiobiologiya 8:160-161.

Studies on the accumulation of strontium-90 by plankton from eutrophic, mesotrophic and dystrophic lakes during the summer of 1966

showed that, owing to the low calcium content (4-6 mg/l) of the water in dystrophic lakes, plankton in this type of lake have a greater capacity for accumulating strontium-90 than plankton in other types of lakes.

292. Kameda, K., M. Shimizu, and Y. Hiyama. 1968. On the uptake of zinc-65 and the concentration factor of zinc in marine organisms. I. Uptake of zinc-65 in marine organisms. J. Radiation Res. 9:50-62.

In experiments on the uptake of zinc-65 by different marine organisms, it was found that the concentration factors differed for different organisms as well as for different tissues, and ranged from 3 to 20 for fish, from 50 to 400 for shellfish, and from 15 to 500 for sea urchin. However, the final concentration factors may be higher than this, since equilibrium was not reached in many of the organs and tissues during the 42-day experimental period.

293. Kaplan, H.M. T.J. Arnholt, and J.E. Payne. 1967. Toxicity of lead nitrate solutions for frogs (Rana pipiens). Laboratory Animal Care 17:240-246.

A study was conducted to determine if the common laboratory frog, Rana pipiens, suffers toxic effects when held in tanks containing residues of Pb. Six groups of 24 frogs each were immersed in Pb nitrate solutions containing 25 to 300 mg/l Pb; 2 groups of 20 frogs each were immersed in solutions containing 500 and 1,000 mg/l Pb, respectively, to study changes in the gastric mucosa and the red blood cells; some frogs were kept in solutions of 25 mg/l Pb for 40 days to observe histopathologic effects on liver and stomach. Twenty-four control frogs were immersed in distilled water. A marked sloughing of the skin was noted in about 20 days in all frogs at 25 mg/l Pb and in about 7 days at 300 mg/l. A permanent loss of the normal semi-erect posture occurred in all concentrations, with atony appearing in about 90% of the animals at 25 mg/l Pb after 25 days and in about 100% at 300 mg/l Pb after 10 days. Total loss of the righting reflex was seen only at 150 to 300 mg/l Pb. Excitement, salivation and muscular twitchings were evident when frogs were first exposed to Pb solutions. Internally, a progressive darkening of liver, gall bladder, kidney and spleen was observed, and there was excessive bile excretion at all Pb concentrations. After immersion for 48 hours at 1,000 mg/l Pb or for 2 weeks at 500 mg/l Pb, the gastric mucosa was eroded or destroyed. Frogs exposed to 25 mg/l Pb for 40 days had Pb deposits in the liver. Red and white blood cell counts decreased with increasing Pb concentrations. Basophilic stippling of erythrocytes occurred after exposure for 2 weeks to 500 or 100 mg/l Pb, but there was no definable stippling at 25 mg/l Pb. Many frogs died at the higher Pb concentrations.

Frogs in municipal or well waters are apparently in no danger of Pb poisoning; however, in laboratory tanks freshly coated with Pb compounds such as litharge, they may suffer toxic effects.

294. Kariya, T., S. Eto, N. Yamaguchi, and K. Suzuki. 1969. Studies on the postmortem identification of the pollutant in fish killed by water pollution-XI. On acute poisoning with tin plating solutions. Bull. Jap. Soc. Sci. Fish., 35:1172-1178. (In Japanese with English abstract).

Tin content of tissues was determined by the phenylfluorone method. In tin plating, two kinds of plating solutions are commonly used, viz alkaline and acid. Experiments showed that the 48 hour median tolerance limits of these 2 kinds of tin plating solutions to goldfish were approximately 100 mg/l Sn. Sn was not detected in control fish bodies, but was clearly detected in the bodies of fish killed by either of the two kinds of solutions. The bodies of fish, killed by tin plating solutions, showed values higher than 13.0 γ/g Sn, while the bodies of fish still living in tin plating solutions showed values lower than that. It was also possible to detect Sn even in fish washed by running tap water for 24 hours after death. The distribution of tin in seven parts of the fish body was examined under two conditions. Sn was detected in all the parts examined under the condition that fish were killed by tin plating solutions. Under the other condition, the fish were soaked in tin plating solutions for 15-24 hours after being killed by suffocation. Sn was detected in skin, gill and muscle, but not in the spleen, hepatopancreas and kidney. The bodies of fish killed by solutions containing organic tin compounds showed very low values of tin content as compared with fish killed by tin plating solutions.

295. Kariya, T., H. Haga, Y. Haga, and K. Kimura. 1969. Studies on the postmortem identification of the pollutant in fish killed by water pollution - X. Acute poisoning with lead. Bull. Jap. Soc. Sci. Fish. 35:1167-1171.

A lead solution (lead nitrate) of 3 mg/l was found to be fatal to rainbow trout in 23-24 hours and the 48 h TLm was found between 1 and 3 mg/l Pb. The nature of the water used for preparing the lead solution influences considerably the toxicity of lead; hard water (2.0 meq/l alkalinity) resulted in a great reduction of the toxicity. Lead content of tissues was determined by the Diphenylthiocarbazone method. Lead levels of the control fish were less than 0.34γ/g Pb and 0.25γ/g Pb on an average. Lead content of fish killed by lead solutions was higher than that of the control fish. When the body of fish was washed with running tap water for 24 hours after death, lead content decreased to 60.2-95.5% of the initial

values. Seven parts of the fish body were examined for distribution of lead in two cases. In the first case, fish were killed by a lead solution and in the second, fish were soaked in a lead solution after death by suffocation. In both cases the gills showed the highest value of lead content among the seven parts and the muscles showed the lowest. Lead content of the gill was higher in the first case than in the second case. It was of interest to note that lead was detected scantily in the liver and alimentary canal in the second case. It should be pointed out that in the diagnosis of lead poisoning it is important to know the distribution of lead in the carcass.

296. Katsuki, Y. and T. Hashimoto. 1969. Shark pit organs:enhancement of mechanosensitivity by potassium ions. Science 166 (3910):1287-1289.

The mandibular pit organs of pelagic sharks, which respond sensitively to monovalent cations, often show neural discharges synchronized with respiratory gill movement. The mechanosensitivity of the organs is remarkably enhanced by application of potassium ions on the same end organ, respiratory movement remaining constant. In view of their mechanosensitivity to an increase of potassium ions in the cell environment, as well as their chemosensitivity, the pit organs of sharks, rather than the canal organs which have no chemosensitivity, may be designated as a better model of the inner ear of higher animals.

297. Ketchum, B.H., J.C. Ayers, and R.F. Vaccaro. 1942. Processes contributing to the decrease of coliform bacteria in a tidal estuary. Ecology 33:247-258.

The author derives equations for evaluating the effects of dilution, bactericidal action of sea water, and action of predatory organisms in reducing the numbers of coliform bacteria in a tidal estuary and describes their application to conditions in the Raritan River in 1949. The numbers of coliform organisms were found to decrease from 110,000 per ml at New Brunswick, where the salinity was less than 4o/oo, to less than 100 per ml at the mouth of the river where the salinity was 21-24 o/oo. The combined processes of dilution, bactericidal action, and predatory activities were found to be responsible for more than 99% of the decrease. The most important single factor was the bactericidal action of the sea water and the least important was dilution. The factors effecting the disappearance of bacteria which is not accounted for by the three processes considered are more important than dilution or predation but much less important than the bactericidal action, it is suggested that the unevaluated process may have been due to sedimentation.

298. Kevern, N.R. 1964. Strontium and calcium uptake by the green alga, Oocystis eremosphaeria. Science 145:1445-1446.

Using strontium-85 and calcium-45 as tracers, studies were made on the uptake of calcium and strontium by the green unicellular alga Oocystis eremosphaeria when cultured under controlled conditions in media containing the two elements in the concentrations found in freshwater environments. Uptake of both elements was rapid for the first day, slightly greater than the growth rate of the population for the next nine days and parallel to the growth rate subsequently, indicating equilibrium between the cellular and media concentrations. Uptake of each element is directly proportional to its concentration in the medium and variations in the concentrations of either element have slightly inverse effects on the uptake of the other element. Formulae are presented for predicting the uptake of strontium and calcium. Increased uptake of strontium when the concentration of calcium was very low suggests that the algae use strontium in place of calcium when calcium is limiting. Therefore, a significant reduction in the uptake of strontium could be produced by adding calcium only if the existing concentration of calcium were limiting. Uptake of strontium and calcium by Oocystis is best explained as a chemical equilibrium reaction.

299. Khmeleva, N.N. 1962. Accumulation of strontium, calcium, cerium, and yttrium radio-isotopes by crustacea. Radiobiologiya 2:944-946.

Experiments on the uptake of strontium-90, calcium-45, cerium-144 and yttrium-91 by Gammarus lacustris showed the strong ability of crustacea to accumulate radioactive isotopes, particularly cerium. Addition of EDTA caused a marked reduction in the uptake of calcium, cerium and yttrium but caused a four-fold increase in the uptake of strontium.

300. King, S.F. 1964. Uptake and transfer of cesium-137 by Chlamodomonas, Daphnia, and bluegill fingerlings. Ecology 54: 852-859.

The uptake of cesium-137 by Chlamydomonas, Daphnia pulex, Daphnia magna, and bluegill fingerlings from water and labelled food was studied at different cesium and algal concentrations. Increases in the concentration of cesium in the water raised the amount concentrated in the alga and daphnids, but the concentration factor for Daphnia pulex was 3 times that for Daphnia magna; the uptake of cesium from water by the bluegills was negligible. Increases in the algal concentration in the water decreased the uptake of cesium by the alga,

but increased the uptake by D. pulex. Algal density did not affect the uptake of cesium by the alga and daphnids was greater at 22° than at 8°C. Concentration factors of about 4 and 8 were obtained for bluegill muscle tissue when the fish were fed on labelled D. magna and D. pulex respectively about 13% of the activity available from both species was retained in muscle tissue.

301. Kirpicnikov, V.S., A.N. Svetovidov, and T.S. Trosin. 1956. Absorption and output of radioactive calcium by Daphnia, Cyclops, and guppies. C.R. Acad. Sci. U.R.S.S. 110:1122-1125.

Daphnia and Cyclops placed in water containing calcium chloride labelled with radioactive calcium-45 were found to concentrate the calcium, so that after 47 hours they contained about 1380 mg/kg fresh weight. When they were transferred to non-radioactive solutions, the loss of radioactivity was rapid, the concentration of radioactive calcium in their bodies being halved in 30 min. Guppies were fed on Cyclops which had concentrated radioactive calcium, and the guppies then took up calcium-45, but the process was slow. Direct uptake of calcium-45 from the water by the guppies was more rapid. Calcium-45 taken up in 3 hours in this way disappeared only slowly from the body.

302. Kiyoura, R. 1963. Water pollution and Minamata disease. Int. J. Air Water Pollut. 7:459-470.

Minamata disease is a severe neurological disorder which has been recognized among people living near Minamata Bay, Kyushu, Japan. It was first suggested that it was caused by consumption of seafood contaminated with a mercury compound from the waste water of a chemical plant discharged to the bay. Further studies by various workers, however, indicate that pollution of the bay by the waste water is not excessive when compared with other similar cases in Japan, and the concentration of mercury in sea water in this area is of the same order as in other bays of southern Kyushu. In other parts of the country, the same kinds of seafoods, containing high concentrations of mercury, are eaten and no outbreak of a similar disease has been reported. It is suggested, therefore, that the disease must be caused by factors other than the mercury in the waste waters.

303. Klassen, C.W., W.A. Hasfurther, and M.K. Young. 1948. The toxicity of hexavalent chromium to sunfish and bluegills. Proc. 4th Industr. Waste Conf., Purdue Univ. Extn. Ser. 68:229-237.

A study has been made of the toxicity to fish of waste waters from electroplating containing hexavalent chromium. The waste waters were added to spring water, with a total hardness of 294 mg/l and a pH value of 7.7 to 8.2, to give a content of 22-83 mg/l chromium. Bluegills and several varieties of sunfish were exposed to the solutions for periods of up to 46 days. Results showed that in hard alkaline water containing 50 mg/l chromium or less both species could survive for at least a month. With high concentrations (more than 70 mg/l) most fish died within 14 days. There was considerable variation in the tolerance of individual fish and from the limited number of tests made no definite relation could be found between the period of survival and concentration of chromium. Examination of fish that died during exposure to high concentrations of chromium showed that chromium was present in the body cavity or that internal organs had deteriorated. Factors which may have affected sensitivity of the fish are discussed.

304. Klement, A.W. and I.E. Wallen. 1960. A selected list of references on marine and aquatic radiobiology. U.S. Atom. Ener. Comm. TID-3903, U.S. Dept. Commerce, Office of Technical Services, Wash. D.C.:42 p.

This report contains 422 references to papers on the biological aspects of the pollution of marine and aquatic environments by radioactivity. An author index is also provided.

305. Kolehmainen, S., E. Haesaenen, and J.K. Miettinen. 1966. Cesium-137 levels in fish of different limnological types of lakes in Finland. Health Physics 12:917-922.

Results of studies are reported on limnological characteristics of 12 lakes and 3 rivers in Finland and on Cs-137 levels in several fish species. The lakes ranged from oligotrophic to fully eutrophic, with the conductivity ranging from 11 to 79 mho units, the color from 5 to 100 mg/l of platinum, and the permanganate demand from 8 to 144 mg/l. The concentration of cesium-137 in fish was inversely related to the conductivity of the water, and was also affected by the feeding habits of the different fish and the general limnological character of the waters, but did not appear to be related to the total beta-activity of the water, which varied only slightly.

306. Kolehmainen, S., E. Haesaenen, and J.K. Miettinen. 1967. Cesium-137 in fish, plankton and plants in Finnish lakes during 1964-5. Proc. Int. Symp. Radioecol. Concent. Process., 1966, Stockholm:913-919.

With a view to elucidating the behavior of cesium-137 in the ecosystem of lakes, radioecological investigations were carried

out on 26 eutrophic, oligotrophic, and dystrophic lakes, 4 rivers in Finland, and on the Gulf of Finland. Graphical and tabulated data are reported on the chemical characteristics of the waters and the cesium-137 contents of fish (perch, pike, burbot, roach, and whitefish), zooplankton, and aquatic plants. The concentration of cesium-137 in the organisms was inversely proportional to the concentration of potassium in the water, probably because the concentration of inactive cesium in the water is extremely low and potassium acts as a non-isotopic carrier. Piscivorous fish were 2-3 times more radioactive than those eating bottom animals or plankton. Cs-137 varied with the biological half-life of the isotope in the particular specie i.e. although perch feeds on plankton when young, on bottom animals during its growth period, and on small fish only when fully grown it had a higher concentration of radioactivity than the other fish species probably owing to the longer biological half-life, of 200 days at 15°C. The concentration of cesium-137 in fish from the brackish water of the Gulf of Finland of salt concentration about 4-5 parts per thousand, is only about one-hundredth of that in fish from the nutrient-deficient lakes, and this is attributed to the differences in electrolyte content. The limnological character of the lakes affects the rate of change of the concentration of cesium-137 in the biota: maximal body burdens in fish were reached a considerable period after the maximal fallout; in fish of eutrophic lakes the maximum occurred in 1964 but in oligotrophic lakes the burden was slightly higher in 1965 than in 1964.

307. Koroleva, N.V. 1960. Tolerance of young salmon (Salmo salar) to various degrees of water salinity. Nauch-Tekh. Byul. Gos. Nauch.-Issl. Inst. Ozern. Rech. Rybn, Khoz. 12:33-34.

Fingerlings and year-old salmon of various sizes were kept for 15 days in 10, 15, 20 and 25% salt solutions. The results showed that tolerance of salinity increased with increase in size of the fish; fingerlings weighing about 1 g survived 10% salinity but could not tolerate 15%, while yearlings weighing 6-10 g survived a salinity of 15%.

308. Kovalsky, V.V., I.E. Vorotnitskaya, and V.S. Lekarev. 1967. Biogeochemical food chains of uranium in aquatic and terraneous organisms. Proc. Int. Symp. Radioecol. Concent. Process., 1966, Stockholm:329-332.

The migration of uranium in ecological food chains has been studied in a lake where the concentration of uranium in the water (3.0×10^{-6} per cent) exceeded the average content in sea water and was nearly double the average concentration in rivers and

freshwater lakes. Results showed that uranium accumulates in aquatic organisms indirectly via the food chain and that the amount of uranium accumulation by fish differs with the species, corresponding to the amount of uranium absorbed with the food (the greatest amounts were absorbed by plant-eating fish such as carp and the least amounts by predatory fish such as trout). Uranium was concentrated particularly in the gonads of fish and also in the cell structure of Charaphytae (these organisms contained 3-5 times as much uranium as other algae).

309. Kozn, Y. and T. Tomiyama. 1949. Studies on factors governing the productivity of water. III. The influence of chemical constituents of water upon the mortality of young rainbow trout. Bull. Jap. Soc. Sci. Fish. 15(6):277-282; Biol. Abstr. 26:1022.

Analyses were made of the water of 11 trout hatcheries to determine constituents of the water. A straight line was obtained when mortality was plotted against the logarithm of age of the fry in months. The slope represented intensity of mortality which was found to be directly proportional to concentration of silica and inversely proportional to the concentration of calcium in the water.

310. Krumholz, L.A. 1954. A summary of findings of the ecological survey of White Oak Creek, Roane County, Tennessee, 1950-1953. U.S. Atom. Energy Comm. Tech. Inform. Serv., ORO-132:54 p.

Results are given of an ecological survey of White Oak Creek which was made during 1950-1953 to investigate the effects of radioactive waste waters from the Oak Ridge National Laboratory on the flora and fauna. The waste waters consist of a mixture of chemical wastes from laboratory, pilot-plant, and full-scale operations. Some wastes are radioactive and some are not. Before they reach the creek they pass through retention ponds to permit decay of the radioactive isotopes. Sewage is also discharged after sedimentation and chlorination. Results showed that all living plants are capable of selectively concentrating specific radioactive nuclides. The commonest radioactive elements concentrated were strontium, cesium, ruthenium, rare earths, and zirconium. Only in the case of the American elm tree was enough radioactive material concentrated to cause obvious damage to tissue. Filamentous algae accumulated much greater amounts of radioactivity than phytoplankton. Radioactive phosphorus was selectively concentrated in greater amounts than other radioactive elements. The rate of growth of all species of fish was slower in White Oak Lake, in which the waste waters are held before discharge to the creek, than in other nearby impounded waters and the life span was as much as 25% shorter. Fish

selectively accumulated radioactive materials far in excess of the amounts occurring in the water. Cesium was concentrated in the soft tissues and strontium, and to a lesser extent phosphorus, was concentrated in the hard tissues. Two species apparently were unable to maintain their populations in these circumstances. Muskrats and woodchuck also accumulated radioactive elements in large amounts. The view is held that circumstantial evidence against the continued discharge of radioactive waters to surface waters is very strong.

311. Krumholz, L.A. 1963. Biological transfer of natural and fallout radionuclides in streams. In Report of a working meeting held at Univ. of Texas, January 30-February 1, 1963. U.S. Atomic Energy Commission Div. Technical Information TID-7664:261-267.

Studies, including analyses of water and biota, are reported on the fate of radioactivity entering Doe Run, Ky., from soils and fallout. Radioactivity was accumulated by the various organisms throughout the 9½-mile length of the stream but there was no pattern of accumulation when the total aspect of the stream was considered. Particular attention was given to radioactivity in the food chain of Cottus (fish). The studies also indicated the importance of allochthonous detritus, since as much as 40-60% of the total nutrients in the stream were derived from leaves from the surrounding trees. Studies on the growth form of Fissendens, the moss on the bed of part of the river, showed that there are micro-currents within the moss beds and the concentrations of oxygen, carbon dioxide, and other chemicals show differences of one or two orders of magnitude between the surface and the deep parts of the bed. Further downstream there are stands of Potamogeton, Nitella, Myriophyllum, and finally watercress and forget-me-not, both of which concentrate large amounts of radioactivity.

312. Kuenzler, E.J. 1969. Elimination and transport of cobalt by marine zooplankton. Proc. 2nd Nat. Symp. on Radioecology, USAEC Conf. 670503:483-492.

Zooplankton are significant agents in cycling of cobalt in surface layers of the sea and in its transport through the thermocline. Net hauls in the eastern Pacific Ocean in spring 1962 showed that, over the whole day, the mean biomass (wet weight) in the upper 100 m was 3.87 g/100 m^3, of which 42% were copepods, 13% were pyrosomas, 13% were siphonophores, 11% were salps and doliolids, and 11% were chaetognaths. The diurnally migrating zooplankton amounted to 4.16 g/m^2, of which 22% were copepods, 19% were pyrosomas, 20% were siphonophores, 18% were salps and doliolids, 6.5% were medusae, and 4% were chaetognaths.

Using data from the literature on cobalt content of zooplankton and of seawater and measured values for cobalt elimination rates of zooplankton, the turnover time for cobalt in the upper 100 m was calculated to be about 13 years. Similarly, diurnally migrating zooplankton carry down and eliminate below the thermocline a quantity of cobalt equal to that in the upper 100 m in about 56 years. Transport of Co through the thermocline by migrating zooplankton may often equal or exceed the transport by vertical eddy diffusion.

313. Kuenzler, E.J. 1969. Elimination of iodine, cobalt, iron, and zinc by marine zooplankton. Proc. 2nd Nat. Symp. on Radioecology, USAEC (Conf. 670503):462-473.

Measurements of elemental elimination rates were made using zooplankton labeled by fallout from a nuclear test and upon zooplankton labeled with tracers. The rates at which elements were eliminated by zooplankton depended on the element, the animal species, and the time since they became labeled. In experiments performed soon after labeling, copepods had elimination rates of 1-6%/hr for I, 4-6%/hr for Co, and about 1%/hr for Zn; Sagitta, 22%/hr for I, 11%/hr for Co, and 3%/hr for Zn; euphausiids, 1%/hr for I and Co, and 5%/hr for Zn; pteropods, 5-6%/hr for I and Fe, and 1-3%/hr for Co and Zn.

Filtration and ion-exchange techniques indicated the physical and chemical form of the eliminated products. Most of the iodine eliminated by zooplankton was probably I^-, but copepods also eliminated some cationic form. Much of the eliminated iron was particulate, but significant amounts were soluble anionic (Pyrosoma, Salpa) or non-exchangeable (Sagitta). Some eliminated cobalt was particulate, but most was cationic. Eliminated zinc also was frequently found in the particulate fraction, but exchangeable and non-exchangeable zinc were also eliminated.

314. Kujala, N.F. 1966. Artificial radionuclides in Pacific salmon. Thesis, Oregon State Univ., Corvallis, Oregon:62 p.

Pacific salmon, Oncorhynchus, concentrate certain gamma-emitting radionuclides (zinc-65, manganese-54, potassium-40, and cesium-137) in their viscera. In some cases, the pattern of concentration of the nuclides appears to be related to the position of the Columbia River "plume"; thus, fish whose migratory paths are far south of the river contain more zinc-65 and less manganese-54. In other cases the nuclide concentrations can be explained, at least in part, by differences in feeding habits: the more carnivorous chinook and coho salmon accumulate the highest concentrations of zinc-65, manganese-54 and cesium-137, while sockeye salmon, which feed on plankton, accumulates less radioactivity, with manganese-54 the dominant nuclide, some zinc-65, but no cesium-137. The effects of diet on concentration

of radioactivity in salmon were investigated by analysing stomach contents; crab larvae concentrated manganese-54 and zinc-65 while euphausiids concentrated only zinc-65.

315. Kujala, N.F., I.L. Larsen, and C.L. Osterberg. 1969. Radioisotope measurements of the viscera of Pacific salmon. Proc. 2nd Nat. Symp. in Radioecology, U.S.A.E.C. Conf. 670503:440-449.

Pacific salmon, Oncorhynchus spp., concentrate certain gamma-emitting radionuclides (^{65}Zn, ^{54}Mn, ^{40}K, ^{137}Cs) in their viscera. In some cases the pattern of concentration of radionuclides seems related to the position of the freshwater plume of the Columbia River, a well-known source of ^{65}Zn in the northeast Pacific Ocean. Fishes whose migration paths were far south of the river had more ^{65}Zn, but less ^{54}Mn. In southeastern Alaskan waters there was a distinct difference in relative abundance of ^{65}Zn and ^{54}Mn in salmon. Manganese-54 was the dominant isotope in salmon of northern Alaskan waters and ^{65}Zn was more prominent in the spectra of fishes from Canadian and contingent United States waters. The Columbia River plume undoubtedly accounted for this increase in ^{65}Zn.

Concentrations of radionuclides differ with species and stocks of salmon. The chinook and coho salmon, which feed more on small fishes than the sockeye, accumulated the highest concentrations of ^{65}Zn, ^{54}Mn and ^{137}Cs. On the other hand, the sockeye, feeding on a lower trophic level, had low radioactivity, with ^{54}Mn the dominant radionuclide, some ^{65}Zn and no ^{137}Cs. The chum and pink salmon examined most nearly resembled the sockeye in radioactivity.

Ocean food habits and migratory pathways both appear relevant to the levels of artificially produced gamma-emitters in the viscera of salmon.

316. Kurland, T., S.N. Faro, and H. Siedler. 1960. Minamata disease. The outbreak of a neurologic disorder in Minamata, Japan, and its relationship to the ingestion of seafood contaminated by mercuric compounds. World Neurology 1960:370-395.

The occurrence of a degenerative disease of the brain at Minamata, Japan, was found to be associated with eating fish and shellfish from Minamata Bay, to which is discharged mercury-containing waste waters from a factory where mercuric chloride is used as catalyst in the production of vinyl chloride from acetylene and hydrogen chloride. Large amounts of mercury were found in the waste waters and in the bottom mud in the bay. The waste waters now receive treatment before discharge to remove the mercury, and the spent catalyst is dumped after removal of the mercury by distillation.

317. Kushmerick, M.J. and R.J. Podolsky. 1969. Ionic mobility in muscle cells. Science 166 (3910):1297-1298.

The diffusivities of ionic potassium, sodium, sulfate and adenosine triphosphate inside a frog muscle cell are reduced by a factor of two, relative to diffusivities in aqueous solution. The diffusion coefficients of nonelectrolytes are reduced by the same factor, showing that the diffusion of the ions is retarded by physical, rather than chemical, interactions. In contrast, the diffusivity of the calcium ion, which is taken up by the sarcoplasmic reticulum, is reduced fiftyfold.

318. Lackey, J.B. 1959. Shellfish and radioactivity. Engng. Prog. Univ. Fla. Leaflet 115:8 p.

The author reviews known information on the effects of radioactivity on shellfish, dealing with sources of radioactivity; fate of radioisotopes in the sea; effects on food, reproduction, and larvae; and dangerous levels of activity in shellfish for human consumption. He concludes that there is always some natural radioactivity in shellfish due at least in part to potassium-40. Shellfish are filter feeders and therefore will ingest radioactive micro-organisms ranging in size from bacteria to much larger organisms, and thus acquire radioactivity at varying rates and amounts, depending on various environmental factors.

319. Laurent, P.J. 1956 (1958). Resistance of fresh-water crustaceans to the action of sodium chromate. Verh. Int. Ver. Limnol. 13: 590-595.

In studies to investigate organisms requiring a shorter duration of toxicity test than fish, it was found impossible to use Asellus, owing to cannibalism of groups in captivity and excessive mortality when the individual organisms were isolated. The results of tests with Gammarus pulex were more satisfactory and are shown graphically. In a solution containing 85 mg/l of sodium chromate, total mortality occurred after 160 minutes, and with a dose of 4.3 mg/l after 68 hours 30 minutes. In these two solutions, the greatest mortality occurred after 13 hours 10 minutes, and 24 hours 25 minutes, respectively. The delay before the first signs of intoxication was not, however, related to the concentration of chromate. When the time of greatest mortality was plotted against concentration, both on logarithmic scales, a straight line was obtained, in the range 4.3-85 mg/l of chromate.

320. Leandri, M., J. Charrel, and D. Omes. 1963. Trials of experimental decontamination of mediterranean shellfish polluted by radioactive waters. Rev. Hyg. Med. Soc., Paris, 11:411-416.

Experiments indicated that shellfish experimentally contaminated with radioactivity do not appear to possess any biological powers of decontamination; the rate of decontamination is similar to the rate of decrease of the contaminating isotope.

321. Leandri, M., J. Charrel, and D. Omes. 1963. Study of experimental contamination of certain currently consumed mediterranean shellfish. Rev. Hyg. Med. Soc., Paris 11:401-410.

Experiments on the uptake of radioactive iodine-131 and iron-59 by the principal types of edible Mediterranean shellfish showed that maximum contamination occurs between the 4th and 7th days of exposure, and the extent of the contamination varies with the type of shellfish. Greatest uptake occurs in the shell, the body fixing only 1/50 to 1/10 of the iodine-131 taken up by Mytilus galloprovincialis.

322. Lear, D.W. and C.H. Oppenheimer. 1962. Biological removal of radio-isotopes Sr-90 and Y-90 from sea water by marine micro-organisms. Limnol. Ocean. 7 (Supplement): XLIV-LXII.

Experiments were carried out to develop accurate and practicable experimental methods for determining the uptake of radioactive isotopes by micro-organisms. Methods investigated included autoradiography of bacterial colonies grown on radioactive media (this method does not lend itself to quantitative measurement and with the procedures employed selective uptake of isotopes from mixtures cannot be readily detected); uptake of radioactive isotopes from liquid media (this procedure possibly delineates the materials truly incorporated into the cells from those loosely bound by surface force on the cells); and chemical fractionation of cellular components of washed radioactive cells (this procedure indicates the nature of the binding agencies involved in the true uptake of isotopes). The organisms used were the marine bacterium, Serratia marinorubra, and the marine phytoplankton, Platymonas subcordiformis, and the isotopes were a carrier-free mixture of strontium-90-yttrium-90 in equilibrium of decay. From the results, which are given in tables and graphs and discussed, various recommendations are made for carrying out experiments on uptake of radioactivity by micro-organisms.

323. Lebedeva, G.D. 1959. The accumulation of cerium-144 by year-old carp and Elodea. Med. Radiol. U.S.S.R. 4(4):73-77.

Laboratory experiments have shown that the accumulation of radioactive cerium in the tissues and organs of carp and in Elodea is directly proportional to the radioactivity of the water. Cerium is taken up more rapidly by Elodea than by fish. The greatest concentration of cerium is found in the gills and internal organs. Excretion of cerium from the organs is very slow; 8-41% of the isotope still remained in the fish after they had been kept in pure water for 3 months.

324. Lebedeva, G.D. 1966. Influence of different salt composition of water on cesium-137 accumulation and excretion in freshwater fish. Radiobiologiya 6:556-559.

The maximal accumulation of cesium-137 by freshwater fish (yearling carp) from water containing $1x10^{-7}c$ per liter occurs in the muscle tissue after 1-2 months and in bone after 2.5-3 months. Uptake of cesium-137 can be reduced considerably by increasing the concentration of potassium and sodium in the water.

325. Liepolt, R. and E. Murer. 1958. The toxic action of copper sulphate on water organisms. Wass. u. Abwass. 1958:335-353.

The author describes tests on the toxicity of dissolved copper to rainbow trout, minnows, and various fish-food organisms, with special reference to the effects of hardness, temperature, and pH value. Tables of results show the limits of toxicity to the various animals; sensitivity is more easily compared by the rapidity of action. The symptoms of poisoning shown by the various test animals are described. Toxicity at high temperatures and in soft water are considerably greater than at low temperatures and in hard water. Copper sulphate remains in solution to a greater extent in acid water and is thus more toxic. No effect was observed in fish when copper was taken by mouth.

326. Linn, D.W. 1963. The effects of radium on certain goldfish blood constituents and organs. Thesis, Utah State University, Salt Lake City, Utah. 116 p.

Goldfish were immersed in water containing radium under controlled conditions, and observations were made on blood changes and deposition of radium in bone and internal organs. The blood characteristics studied were the micro haematocrits, total plasma

proteins, white blood cell counts, and differential ratios. Both bone and internal organs were found to accumulate radium, but the pattern of uptake and concentration were rather inconsistent.

327. Lloyd, R. 1960. The toxicity of zinc sulphate to rainbow trout. Ann. Appl. Biol. 48:84-94.

Investigations are reported on the toxicity of zinc sulphate to rainbow trout (Salmo gairdneri) in waters of different chemical and physical properties, with special reference to the effects of hardness, temperature, and concentration of dissolved oxygen. Zinc sulphate was less toxic to rainbow trout in hard water than in soft water; the response curve obtained by plotting log concentration of zinc against the median period of survival was linear in very soft water and curvilinear in hard water approaching an apparent threshold concentration, below which zinc was not toxic. Fish exposed to concentrations of zinc below the threshold value acquired an increased resistance to higher lethal concentrations. Zinc was markedly less toxic in water containing calcium chloride than in borehole water where the hardness was due to calcium bicarbonate. Decreases in temperature increased the survival time for a given concentration of zinc in borehole water, but had little effect on the threshold concentration. A reduction in the oxygen concentration of the water increased the toxicity of zinc, but the effect was reduced when the fish were previously acclimatized to the concentration of dissolved oxygen used in the tests. The death of the fish did not appear to be due to coagulation of mucus on the gill surface, but tests using zinc-65 as a tracer suggested that death was caused by damage to the tissues of the gills themselves. There was no difference in the toxicity of zinc chloride and zinc sulphate.

328. Lloyd, R. 1961. Effect of dissolved-oxygen concentrations on the toxicity of several poisons to rainbow trout (Salmo gairdnerii Richardson). J. Exp. Biol. 34:447-455.

A reduction in the dissolved-oxygen concentration of the water from air-saturation increased the toxicity to trout of zinc, lead, and copper salts and of a mixture of monohydric phenols by about the same extent. This increase in toxicity is attributed to a physiological reaction by the fish to the change in environment, independent of the nature of the poison. Using two theoretical methods to calculate the relation between the increase in toxicity of poisons and the reduction in dissolved-oxygen concentration, and comparing the results with experimental data, it is concluded that most, if not all, of the increase in toxicity of poisons in water of low dissolved-oxygen concentration is caused by the increase in the rate of respiratory flow, and any environmental or physiological change which affects the rate of respiratory flow of a fish will also

affect the concentration of poison at the surface of the gill epithelium, a known relationship existing between these two factors. This relation will be the same for all poisons except those, such as ammonium salts, where the toxicity depends on ionization and is affected by the pH value of the water; the additional increase in toxicity observed experimentally with such compounds was accounted for by a theoretical calculation of the difference between the pH values of the bulk of the solution and that at the gill surface.

329. Lloyd, R. 1961. The toxicity of mixtures of zinc and copper sulfates to rainbow trout (Salmo gairdnerii Richardson). Ann. Appl. Biology 49:535-538.

The toxicity to rainbow trout of a mixture of Zn and Cu sulfates in relatively low concentrations can be calculated from the toxicities of the individual metals by assuming that they exert a similar joint action. Higher concentrations of the mixture in soft water exhibit a synergistic action.

330. Lloyd, R. 1965. Factors which affect the tolerance of fish to heavy metal poisoning. In Biological Problems in Water Pollution, Third Seminar, U.S. Dept. Health, Education and Welfare, Aug. 13-17, 1962. Public Health Service 999-WP-25: 181-186.

Heavy metals (salts of Zn, Cu, and Pb) cause epithelial cells to swell and separate from pilaster cells of the lamellae, and finally to slough off. The amount of Zn required to kill a fish is quite small (analysis of gills for Zn, after exposure to Zn solution, showed only 2 X normal content). The small amount of Zn required and its mode of action suggested a defined lethal threshold. The threshold is at the point where the blood stream no longer can carry away metal ions from the epithelial cell; the excess build up of metal ions in the epithelial cells causes death. It is suggested that mercury has a different mode of action.

More alkaline waters decrease solubility of heavy metals, and calcium ions reduce toxicity of heavy metal ions. Temperature decreases usually increase survival time. Toxicity increased with decreased dissolved oxygen. The combined action of Cu and Zn is additive, as the action of each is similar.

331. Lloyd, R. and W.R. White. 1967. Effect of high concentration of carbon dioxide on the ionic composition of rainbow trout blood. Nature 216:1341-1342.

Experiments to determine the changes in ionic components in the blood of rainbow trout subjected to high concentrations of carbon dioxide are reported. Serum from fish which were put into an environment of high carbon-dioxide concentration were analysed for sodium, bicarbonate, chloride and phosphate. Sodium and inorganic phosphate levels did not differ greatly from those of the control group of fish; the bicarbonate in the serum rose from the control level of 6·75 mequiv/l to 32·2 mequiv/l within 24 hours with 35 mg/l free carbon dioxide in the water; a corresponding decrease in the chloride levels, which fell from 152·5 mequiv/l to 114·6 mequiv/l was noted. The change in serum chloride content was 13 mequiv/l greater than the corresponding change in the bicarbonate level; the nature of the extra anionic component which compensates for this is not known. The serum bicarbonate and chloride levels returned towards normal after the free carbon dioxide was removed from the water but the pre-test values were not reached, further indicating the presence of an unknown anionic component.

332. Lodge, M. and P.C.G. Isaac. 1958. Control of algae in a reservoir. Univ. Durham, Kings Coll., Dept. Civ. Enging. Bull. 12:13.

In order to determine the best algicidal treatment for a reservoir in the northeast of England, weekly examinations were made in February-August, 1957, to determine the nature and the amount of algae present, and screening tests with various algicides were carried out. The effects of algicidal treatments on the algal populations are shown graphically. Copper sulphate was at first considered the most suitable algicide but chlorine later proved more valuable. Throughout the test period, the algal flora was predominantly chlorophycean, but an autumn peak of diatoms later replaced the green algae.

333. Lowman, F.G., R.A. Stevenson, R.M. Escalera, and S.L. Ufret. 1967. The effects of river outflows upon the distribution patterns of fallout radioisotopes in marine organisms. Proc. Int. Symp. Radioecol. Concent. Process., 1966, Stockholm: 735-752.

Further studies are reported on the distribution of radioisotopes in waters along the west and south coasts of Puerto Rico with special reference to the effects on algae, which derive their trace elements direct from solution in water, and sponges, which ingest particulate matter containing the trace elements. The ash content of organisms in water off the west coast (which receives the outflow of three major rivers) was 1½-2 times that in the same species collected off the south coast (where the streams are intermittent). The content of potassium-40 was inversely related to the ash content. The

distribution of radioactive isotopes in algae and sponges is compared in gamma spectra. Of the two biologically important fallout radionuclides (manganese and cobalt), soluble and particulate manganese could be studied individually by observations on algae and sponges respectively, owing to their different intake mechanisms (results suggest that manganese-54 enters the ocean in a different chemical form not fully in equilibrium with the stable manganese), and cobalt-60 was accumulated only by one species of sponge. Compared with manganese and cobalt, relatively large amounts of fission products (zirconium-95-niobium-95, ruthenium-106-rhodium-106, and cerium-144-praseodymium-144) were accumulated by algae, probably owing to surface adsorption; sponges also accumulated large amounts of ruthenium-106-rhodium-106, and some cerium-144-praseodymium-144, but no zirconium-95-niobium-95 could be detected. Comparing the distribution of radioactive isotopes in water and organisms off the south and west coasts, it is concluded that the lithogenic material carried into the sea by rivers causes an increase in the total amount of all fission products; an apparent increase in the amounts of soluble or colloidal zirconium-95-niobium-95 (4.7 times), ruthenium-106-rhodium-106 (2 times), and cerium-144-praesodymium-144 (3.6 times); and an apparent increase in the amounts of particulate ruthenium-106-rhodium-106 (about 3.6 times) and cerium-144-praesodymium-144 (1.2 times).

334. Lucas, H.F., Jr., D.N. Edgington, and P.J. Colby. 1970. Concentrations of trace elements in Great Lakes fishes. J. Fish. Res. Bd. Canada 27:677-684.

The concentration of 15 trace elements was determined by activation analysis of samples of whole fish and fish livers from three of the Great Lakes: Michigan, Superior, and Erie. The average concentrations of 7 elements in 19 whole fish from 3 species were as follows: uranium, 3 micrograms/1 (parts per billion); thorium, 6 ppb; cobalt, 28 ppb; cadmium, 94 ppb; arsenic, 16 ppb; chromium, 1,000 ppb; and copper, 1,300 ppb. The average concentrations of 8 elements in 40 liver samples from 10 species of fish were as follows: uranium, approximately 2 ppb; thorium, $\leq$2 ppb; cobalt, 40 ppb; copper, 9,000 ppb; zinc, 30,000 ppb; bromine, 400 ppb; arsenic, 30 ppb; and cadmium, 400 ppb. Other elements observed in most of the samples were: antimony, 5-100 ppb; gold, 2-5 ppb; lanthanum, 1-20 ppb; rhenium, 0.5-5 ppb; rubidium, 0.06-4 ppb; and selenium, 0.1-2 ppb.

Trace element concentrations varied with species and lake. Uranium and thorium varied with species, but not for the same species from different lakes. The level of copper, cobalt, zinc, and bromine varied little between species and lakes. The concentration of cadmium, arsenic, and chromium varied between species and with species between lakes.

335. Lucas, J.W. and D.C. Pickering. 1958. Direct absorption of dissolved strontium-90 and yttrium-90 by tadpoles of Rana temporaria. Nature 182:1242-1243.

A long-term investigation is in progress on the direct biological effects of radioactive isotopes on the life cycle of the frog, and preliminary results are given in tables and graphs on the absorption of radioactive strontium and yttrium by tadpoles of Rana temporaria. In about one week 100 tadpoles absorbed approximately 18% of the strontium-90 and 72% of the yttrium-90, which was equivalent to about 0.02 and 0.09 μC., respectively. The strontium-90 content of the tadpoles was not appreciably reduced by washing with water, even after 4 weeks; a 0.01% solution of ethylenediaminetetra-acetic acid increased the rate of decontamination. Preliminary studies suggest that the presence of calcium bicarbonate in the water reduces the uptake of strontium-90 by the tadpoles, although the curves obtained were similar to those for soft water. Histological changes and the effect on metamorphosis are being investigated.

336. Lucu, C. 1968. Sodium metabolism in crab Carcinus mediterraneus CRSN. Proceedings of the third international colloquium on medical oceanography. Fifth and sixth sessions:61-69.

Laboratory studies on the uptake and release of sodium-22 by Carcinus mediterraneus from natural, diluted, and concentrated sea water demonstrated the crab's ability to regulate the concentration of this element in its blood stream and the rate of accumulation and loss. Results, which proved similar to those obtained by others for C. maenas, were presented graphically.

337. Ludemann, D. 1953. The toxicity of manganese to fish, crabs, and animals forming the food of fish. Schr Reihe Ver. Wasserhyg. 7:18 p.

After a summary of information available in the literature on the toxic action of manganese on fish, the author describes experiments on fish, river crabs, and water animals on which fish feed. Solutions of manganese sulphate and manganese chloride were used and tests were made in glass aquaria or glass dishes in which the water was aerated. Using manganese sulphate it was found that manganese in concentrations such as are naturally found in water, even in water containing much iron, had no effect. The first effects became visible at concentrations of 0.5 g/l of manganese; a solution containing 1 g/l caused death of fish. With manganese chloride the first effects were visible at a concentration of 33 mg/l and death was caused at 40 mg/l. The symptoms were the same with both compounds. Experiments with lower water animals showed great resistance in some species especially Sphaerium,

dragonfly larvae, and Cambarus affinis Say, all of which were undamaged in solutions containing 1 g/l of manganese. The second part of the investigation was concerned with methods of detecting manganese in dead fish. Sections of the most important organs showed no histological alterations which could be regarded as due to uptake of manganese. Manganese could however be detected by chemical analysis of dead fish.

338. Mackenthum, K.M. 1958. The chemical control of aquatic nuisances. A report on the use of chemicals in lakes, ponds, and streams for the control of algae, weeds, and other aquatic nuisances. Committee on Water Pollution, Madison, Wis.: 64 p.

The author discusses the use of chemicals for the control of aquatic weeds and algae, including the calculation of the amount of chemical required, the equipment for duplication of the chemical, and precautions to be taken. The effects of treatment are described. Sodium arsenite is usually used for the control of aquatic weeds and copper sulphate for the control of algae. A section is also included on the nature and development of swimmers' itch and on chemical control of the snails which form the alternate host of the schistosome cercariae. Snails can be killed by treatment with copper sulphate and copper carbonate or with copper sulphate and fresh hydrated lime. Tables are given showing the lakes in Wisconsin which have received treatment with copper sulphate or sodium arsenite during the past 8 years.

339. Mackenthum, K.M. and H.L. Cooley. 1952. The biological effect of copper sulphate treatment on lake ecology. Trans Wis. Acad. Sci. Arts Lett. 11:177-187.

Laboratory experiments have shown that copper sulphate precipitated and accumulated on bottom muds of lakes is, at a concentration of about 9,000 mg per kg of mud (dry weight), toxic to Tendipes damosus and between 11,200 mg and 17,400 mg per kg of mud is toxic to Pisidium dahoense. In 2 lakes in Wisconsin, which had received repeated treatment with copper sulphate to control algal growths, it was found that the concentration of copper in mud was considerably lower (maximum of 480 mg per kg of mud) than the toxic concentrations. Differences in the density of the population of bottom organisms in treated and untreated lakes could not be attributed to copper.

340. Mackereth, F.J. and W.J.P. Smyly. 1951. Toxicity of copper in solution to the stone loach. Nature 168:1130.

Investigation of the cause of death of stone-loach, Nemacheilus barbatulus, in an aquarium indicated that the fish died of copper poisoning as a result of a change in the water supply. The fish had originally been kept alive in water containing 0.15 mg/l copper and died when the supply was replaced by lake water containing 0.28 mg/l copper. Studies showed that stone-loach could survive in water containing less than 0.20 mg/l copper but died within 24 hrs in water containing 0.20 mg/l or higher.

341. Maetz, J. 1969. Seawater teleosts: evidence for a sodium-potassium exchange in the branchial sodium-excreting pump. Science 166(3905):613-615.

The net sodium extrusion rate by the gill of a seawater-adapted euryhaline flounder is identical to the potassium influx. The excretion of sodium is blocked in K^+-free seawater solutions. The instantaneous sodium outflux readjustment pattern of flounders transferred from seawater to solutions of various sodium chloride or potassium chloride concentrations is consistent with the hypothesis of a linkage between Na^+ outflux and K^+ influx through a common exchange carrier. External Na^+ and K^+ compete for this common carrier. It is suggested that the exchange diffusion mechanism (linkage of sodium influx and outflux) and the high internal sodium turnover rate which characterizes all seawater teleosts are the results of this competitive process. The sodium-potassium dependent adensoine triphosphatase system occurring in the gill of the seawater teleosts may play a central role in this sodium-potassium exchange pump.

342. Malacea, I. 1966. Contributions to knowledge on the toxic effect of cyanides, ammonia, mercury, and arsenic on some species of fish and on Daphnia. Studii Prot. Epur. Apel., Buc. 7:751-792. (English summary).

Bio-assays were carried out to determine the effects of potassium cyanide, ammonium sulphate, mercuric chloride, and disodium hydrogen ortho-arsenate on common Romanian fishes (minnow, gudgeon, bitterling, and carp) over a period of 4 days and on Daphnia magna over a period of 2 days, and to establish the maximal permissible concentrations of these substances in surface waters. The minimal lethal concentrations of cyanide ion, expressed in mg/l were 0.47 for bitterling, 0.06 for gudgeon, 0.2 for minnow, and 1 for Daphnia. The cyanide affects the nervous system and respiration of fish to an extent depending on environmental factors, especially the pH value of the water. Fish which survived recovered completely on transfer to clean water, even after losing their equilibrium. The minimal lethal concentrations of ammonium sulphate, in mg/l, were 200 for carp, 300 for gudgeon, 160 for bitterling and minnow, and 73.4 for

Daphnia. The toxic effect on fish is due to hydrolysis of ammonium sulphate to free ammonia which acts on the nervous system and irritates the epithelium of the gills; after losing their equilibrium the fish will not recover on transfer to clean water. The toxic action of mercuric chloride is due to the mercury ions which destroy the epithelium of the gills, leading to asphyxia. Expressed in mg/l of mercury, the minimal lethal concentrations were 0.04 for bitterling, 0.05 for gudgeon, 0.3 for carp, 0.02 for minnow, and 0.15 for Daphnia. Fish cannot recover after beginning to lose their equilibrium. The toxic effect of arsenic compounds on aquatic organisms is attributed to the arsenic ion, which has a slow action, giving a prolonged latent phase. Trivalent arsenic compounds, such as arsenites, penetrate more quickly into animal tissues and for equivalent arsenic concentration they are more toxic than the pentavalent (arsenate) compounds. The minimal lethal concentrations of the sodium arsenate tested were, expressed in mg/l of arsenic, 100 for bitterling and minnow, 160 for carp, and 5 for Daphnia. Toxicity of sodium arsenate was affected by external factors, particularly the pH value, temperature, and oxygen concentration of the water.

343. Malacea, I. and E. Gruia. 1964. Contributions to the study of the toxic effect of heavy metals on some aquatic organisms. Inst. Hydrotech. Res., Sci. Sess., Bucharest, Sect. 4:47-49.

Bioassays were conducted with freshwater organisms including Daphnia magna and three cyprinid fish species: bitterling, carp, and minnow. Poisoning with heavy metals such as copper, zinc, lead and nickel is an additive process depending on metal concentration and duration of exposure. Water hardness has an important effect on toxicity since, in the presence of calcium, heavy metals (except nickel) form carbonates and hydroxides which are sparingly soluble and thus reduce the toxicity. It was concluded that the present value of 0.1 mg/l for the maximum permissible concentration of lead and nickel is adequate to protect aquatic organisms. However, it was recommended that the present thresholds of 0.1 and 5 mg/l, respectively, for copper and zinc be lowered.

344. Malacea, I. and E. Gruia. 1965. Contribution to the study of the toxic effect of copper, zinc, lead, nickel on some species of fish and on daphnia. Stud. Protect, Epurarea Apelor Inst. Stud. Cercetari Hidrotehnice 6:391-451.

The toxic effect of copper (Cu), zinc (Zn), Pb and nickel (Ni) was studied on three species of fish: bitterling (Rhodeus sericeus amarus), carp (Cyprinus carpio L.), and minnow (Phoxinus phoxinus), and on Daphnia magna. The town's water was used after previous dechlorination

for dilution. The experiments with the fish lasted four days and those with Daphnia two days. The results confirmed previous findings that the heavy metals have an irritating effect on the tegument and particularly on the gills of the fish, leading to death by asphyxiation; bitterlings and minnows also showed a noxious effect on their nervous system. It was demonstrated that the latent phase of intoxication lasts until the first signs of loss of equilibrium appear; thereafter the effects become irreversible. Factors influencing the toxicity were concentration and time and hardness of the water. With the exception of Cu, the metals reacted with calcium salts in the water to form slightly soluble carbonates and hydroxides, thus decreasing the toxicity of the solution. As hardness of water varies generally with season, so does the binding capacity of the metal ions, thus demonstrating that the toxicity of the metals is different for various aquatic basins and seasons. The present standards for Pb and Ni of 0.1 mg/l were considered as safe, but the existing standards of 0.1 and 0.5 mg/l for Cu and Zn, respectively, should be lowered.

345. Maloney, T.E. and C.M. Palmer. 1956. Toxicity of six chemicals to thirty cultures of algae. Wat. & Sewage Wks. 103:509-513.

Tests were carried out using six chemical compounds, which had previously shown promise as algicides, to determine the lowest concentration of each chemical which could control algae, whether it was selective or general in its algicidal effects, and its toxicity to fish. The chemical compounds used were copper sulphate, 2,3-dichloronaphthoquinone, dodecylacetamido dimethyl benzyl ammonium chloride, rosin amine D acetate, rosin amine D sulphate, and zinc demethyl dithiocarbamate. The toxicity of these compounds to 30 species or strains was determined.

346. Mandelli, E.F. 1969. The inhibitory effects of copper on marine phytoplankton. Marine Science 14:47-57.

The growth of several species of dinoflagellates and diatoms in batch cultures under continuous illumination was inhibited at 20°C by concentrations of copper between 0.055 and 0.265 mg/l. Coccochloris elabans failed to grow at 0.03 mg/l and 40°C, whereas Dunaliella tertiolecta survived 0.6 mg/l at 30°C. Skeletonema costatum in light-dark cultures with maintenance of constant number of cells and copper ions was inhibited at 0.05 microgram/ml. A positive correlation was found between the log of copper uptake: biomass of algae ratio and the temperature, and a negative correlation between the same ratio and salinity.

347. Marei, A.N., M.M. Saurov, and G.D. Lebedeva. 1958. On transmission of radio-strontium by nutritional chain from open water reservoirs into the human organism. Med. Radiol. U.S.S.R. 3:69-76; Nuclear Abstr. 12:1122.

Aquatic organisms such as plankton, aquatic plants, molluscs and fish, as well as domestic ducks, accumulate significant amounts of radioactive strontium in their tissues from the water, and the isotope may pass into the human organism when fish and poultry are eaten. In view of this, it is suggested that the maximum permissible concentration of radioactive strontium in reservoirs should be revised.

348. Marshall, J.S., A.M. Beeton, and D.C. Chandler. 1964. Role of zooplankton in the freshwater strontium cycle and influence of dissolved salts. Verh. Int. Ver. Limnol. 1962, 15:665-672.

Experiments on the uptake of strontium-85 by Daphnia magna showed that at equilibrium more than 95% of the strontium in the animal was concentrated in the exoskeleton and therefore lost on moulting. It was considered probable that dense populations of limnetic plankton species might account for a significant proportion of the total calcium and strontium (including strontium-90) removed from the epilimnion of a stratified lake, as a result of the continual shedding of exoskeletons by the living organisms rather than by settling of dead plankton. When the animals were transferred to an unlabelled medium before reaching equilibrium the rate of loss of strontium was negligible compared with the rate of uptake. As with recently-moulted crayfish uptake of strontium by Daphnia appeared to follow a first-order reaction. In predicting the biological fate of strontium-90 in terrestrial food chains, use has been made of the OR (or 'observed ratio') between the strontium-90: calcium ratios in the acceptor and the precursor, and in order to test the applicability of the OR equation for predicting the uptake of strontium-90 by an aquatic organism experiments were carried out with Daphnia magna in spring water (diluted with various proportions of distilled water to give different concentrations of calcium) and in natural waters from 11 different sources. The results, given graphically, suggest that the OR is a constant for a given species, and that calcium is concentrated to a much greater degree than is strontium. The OR can also be defined by the ratio of the concentration factors for strontium and calcium, and the average OR for Daphnia.

349. Martin, D. and E.D. Goldberg. 1962. Uptake and assimilation of radio-strontium by Pacific mackerel. Limnol. Ocean. 7 (supplement): LXXVI-LXXXII.

Pacific mackerel (Pneumatophorus diego) were fed with radioactive strontium-90, and the activity in various organs was measured over a period of 235 days. Ninety-five per cent of the radioactivity was excreted in 24 hours. The remaining 5% remained fixed in the body throughout the period of the experiment; of this fixed activity, 80% was located in the calcareous portions of the fish. The gills showed the greatest activity per unit weight in 1-3 days after feeding, indicating the isotope was being excreted by these organs.

350. Martin, S.C., W.T. Helm, and W.F. Sigler. 1969. Accumulation of radium-226 in two aquatic ecosystems. Proc. 2nd Natn. Symp. Radioecol. 1967, Ann Arbor, Mich: 307-318.

Details are given of research carried out in Colorado to assess the effects of waste waters from uranium mills on stream biota and to examine the accumulation of radium-226 in various biotic components. Over a period of three years, studies were made on water, sediment, algae, invertebrates, and fish in the Animas river, which, following diversion of waste waters from Durango uranium mill, was recovering from the effects of the previous pollution, and in the San Miguel and Dolores river system which was still receiving waste waters from the Uravan uranium mill. The Animas river is recovering from the previous pollution, as indicated by the abundance and diversity of biotic components, and the lower concentrations of radium-226 (only about 3 times background level in the last years of the study compared with up to 20 times background in earlier samples and several hundred times in still earlier studies). In the San Miguel-Dolores river system, the number and diversity of organisms were reduced below Uravan and the concentration of radium-226 in the biota showed an unexpected increase with increasing distance downstream, although the concentration in the water and sediments decreased with distance downstream; it is concluded that in the upper part of the pollution zone the organisms could not survive long enough to accumulate the amounts of radium-226 which might otherwise be found.

351. Marvin, K.J., L.M. Lansford, and R.S. Wheeler. 1961. Effects of copper ore on the ecology of a lagoon. U.S. Fish Wildl. Serv., Fish. Bull. 184:153-160.

An analysis of the biological and chemical data shows that copper concentration of a lagoon located off Galveston in the Gulf of Mexico was not increased to a level lethal to Gymnodinium breve after the addition of 55,000 kg of copper ore (highest Cu^{2+} concentration at any time = 0.45 μg atoms/l; concentration lethal to G. breve = 0.5). The flora and fauna of the lagoon and organisms placed

there in dialysis bags and live cars showed no significant effect attributable to the ore. The copper level, after the addition of the ore, increased to a maximum that was below the laboratory estimate of the level toxic to G. breve and then dropped to a lower level. These results show that the ore is not capable of maintaining a sufficiently high copper concentration to be considered as a means of controlling red tide outbreaks in waters similar in quality to that of the lagoon. "Results of this experiment indicate that copper ore does not have the desired characteristics of red tide controlling agent, and we recommend that it not be used."

352. Matida, Y. and H. Kumada. 1969. Distribution of mercury in water, bottom mud and aquatic organisms of Minamata Bay, the River Agano and other water bodies in Japan. Bull. Freshw. Fish. Res. Lab., Tokyo 19 (2):73-93.

Distributions of mercury and other heavy metals were examined in water, mud and aquatic organisms in Minamata Bay, the River Agano and other waters in Japan. Of the heavy metals, only mercury was very high in Minamata Bay and the River Agano where Minamata disease occurred. The distribution of mercury in Minamata Bay indicated that the origin of mercury was the Minamata factory of Shin-Nippon-Chisso Company. The content of total and organic mercury in aquatic organisms suggested that monitoring, background survey and study of the mechanism of accumulation of these substances are desirable.

353. Mauchline, J. and A.M. Taylor. 1964. The accumulation of radionuclides by the thornback ray, Raia clavata L., in the Irish Sea. Limnol. Ocean. 9:303-309.

The thornback ray is a non-migratory elasmobranch that occurs in the Irish sea near the point of discharge of atomic wastes from the Windscale Works of U.K. Atomic Energy Authority. Waste waters include the relatively-soluble strontium-90 and cesium-137 and the relatively insoluble (in sea water) ruthenium-106, cerium-144, zirconium-95 and niobium-95. It was found that Cs^{-137}, Ru^{-106}, and Ce^{-144} were accumulated to a greater extent than Sr^{-90} in flesh, stomach, and stomach contents; Sr^{-90} was concentrated to a greater extent in liver, and Sr^{-90} and Cs^{-137} were more important than Ru^{-106} and Ce^{-144} as contaminants of cartilage.

354. Mehran, A.R. and J.L. Tremblay. 1965. An aspect of zinc metabolism in Littorina obtusata L. and Fucus edentatus. Revue Can. Biol. 24:157-161.

The uptake of zinc-65 by the alga Fucus edentatus and the mollusc Littorina obtusata was studied in an apparatus designed to simulate the tidal cycle. Zinc disappeared from the sea water rapidly at first, 42% having been removed after one day, and after 10 days the water contained no more than 10% of the concentration initially present. Littorina took up the zinc rapidly during the first two days and reached equilibrium after three days; Fucus reached saturation after three to four days.

355. Merlini, M. 1967. The freshwater clam as a biological indicator of radiomanganese. Proc. Int. Symp. Radioecol. Concent. Process., 1966, Stockholm: 977-982.

Samples of the bivalve Unio mancus var. elongatus from lake Maggiore were compared with those from lake Varese, Italy, especailly with respect to their ability to concentrate stable manganese and manganese-54 from fallout. Water from lake Varese is comparatively rich in manganese (0.033 mg/l) and Unio from this lake incorporates more manganese into its shell and some parts of the soft tissues than the animals from lake Maggiore where the water contains less manganese (0.02 mg/l). However, since the stable manganese dilutes the radioactive manganese in the fallout accumulated by the animals, Unio from lake Varese have a lower specific activity, expressed as atoms of manganese-54:atoms of stable manganese, than those from lake Maggiore. Concentration factors for stable manganese in gills and mantles were more than 80,000 in lake Varese and more than 100,000 in lake Maggiore, while those for manganese-54 were 40,000 and 300,000, respectively, with corresponding concentrations of 0.0004 and 0.00015 pc in the water. In Unio from both lakes the soft tissues accumulated more manganese than the shells, the concentration of both stable and radioactive manganese decreasing in the order: gills, mantle, visceral sac, adductor muscles, and shell (this order was confirmed experimentally 10 minutes after immersion of Unio in water containing manganese-54 as the chloride). Although the shells do not accumulate such high concentrations of manganese as the soft tissues, they are, nevertheless, excellent indicators of contamination of the environment with manganese-54.

356. Miles, H.M. and L.S. Smith. 1968. Ionic regulation in migrating juvenile coho salmon, Oncorhynchus kisutch. Comp. Biochem. Physiol. 26:381-398.

The mean levels for hematocrit (37.8%) percentage of total dissolved solids (4.77%), and sodium (146.7 mequiv./l), potassium (8.58 mequiv./l), calcium (6.73 mequiv./l), magnesium (1.08 mequiv./l) and chloride (117.3 mequiv./l) concentrations in blood plasma were determined for juvenile coho salmon in fresh water.

Observations suggest a correlation between hematocrit and temperature during the winter and spring residence in fresh water.

No premigratory change in electrolyte composition was observed.

Migrating juvenile coho salmon were transferred into sea water to observe changes in blood parameters during the adjustive phase.

The adjustive phase was apparently completed in about 36 hr and was characterized by transient increases in plasma concentrations of sodium, chloride and magnesium.

357. Miller, M.A. 1946. Toxic effects of copper on attachment and growth of Bugula neritina. Biol. Bull. 90:122-140.

Critical concentrations of copper to early life stages of Bugula >0.2 mg/l kill larvae and completely inhibit growth of attached fauna; 0.2-0.3 mg/l retard growth; <0.2 mg/l retard growth and interfere with enzyme function.

Bugula ancestrulae can recover and develop almost normally after seven days exposure to sublethal concentrations of copper. They can recover after repeated immersion in Cu solutions that practically prevent growth. Length of exposure has no effect on the ability to recover.

358. Miyake, Y., Y. Sugiura, and T. Nan'niti. 1962. Studies of radioactive contamination in local marine resources. Final Report. Int. Atom. Energ. Agency, 1 AEA-R-19: 138 p. Nuclear Science Abstracts 1965, 19:620.

A study was made in Suruga bay Japan, on the Pacific side of the island of Honshu. Observations were made on various oceanographic and chemical factors, and on the distribution of natural and artificial radionuclides. The vertical profile of strontium-90 suggests a faster rate of vertical mixing than previously supposed. Analyses of Sergestes lucens showed a concentration factor for strontium-90 of 11-17.

359. Moiseev, P.A. 1958. New data on the effect of thermonuclear explosions on aquatic organisms. Rybroe Khoz. 34 (1):22-24.

The author reviews the results of several investigations on the radioactivity of water and aquatic organisms from the Pacific

ocean after thermonuclear explosions, and gives tabulated data on the concentration of strontium-90 in sea water and the bones of various fishes collected at several sampling stations during 1956 and 1957. The data indicate that the testing of thermonuclear devices has resulted in high levels of radioactivity in practically all the water masses of the western Pacific.

360. Moiseev, P.A. and A.V. Kardashev. 1964. Radioactivity of some hydrobionts in seas in the Soviet Far East in 1958 after the USA had tested atomic weapons in the central part of the Pacific Ocean. In Radioactive contamination of seas and oceans, Moscow, 1964: 126-135; Biological Abstracts 1967, 48:1977.

Following the nuclear weapons tests in the Pacific Ocean in 1958, the radioactivity of marine organisms from the east of U.S.S.R. was determined, using a method with potassium chloride as standard. The radioactivity of plankton was found to be high and was due mainly to short-lived isotopes; the concentration factors for plankton ranged from 30 to 900. In the fish which were studied, the gills, viscera, and bone marrow were highly radioactive. The various organs had accumulated the isotopes selectively, and the bones, scales, and gill covering were found to have accumulated strontium, zinc, barium, lanthanum, and zirconium. Laminaria, which is used as food, had accumulated 37-58 μμc of beta activity per g of dry weight.

361. Morgan, F. 1964. The uptake of radioactivity by fish and shellfish. I. Cesium-134 by whole animals. J. Mar. Biol. Assn. U.K. 44:259-271.

Studies on the uptake of cesium-134 by 36 species of fish and shellfish showed that the time taken for the concentration in the fish to reach the water concentration was 0.5-4 days for marine pelagic species and most shellfish except scallops and freshwater mussels, 6-17 days for marine demersal species and bottom-feeding species, and 30-120 days for freshwater fish and rays. Experiments on selected species indicated that uptake of cesium-134 is proportional to a power of the weight. For plaice, lobster and eel over a wide range of weights uptake varies as $W^{.78}$ and the times taken to reach half-equilibrium concentrations vary as a value between $W^{.25}$ and $W^{.29}$.

362. Mount, D.I. 1964. An autopsy-technique for zinc-caused fish mortality. Trans. Amer. Fish. Soc. 93:174-182.

It is shown that the relative zinc content of the gills and opercular bone in fish can indicate whether death of the fish was caused by toxic levels of zinc in the water. The ratio of zinc in the gills to zinc in the bone remains reasonably constant when fish are held in water containing sub-lethal concentrations of zinc, but at toxic levels, the metal accumulates more rapidly in the gills and the ratio shows a marked increase. In carp, however, the zinc content of the gills is more variable and may be high under non-toxic conditions, making diagnosis more difficult. The ratio was not affected by the presence of five other metals, the combined toxicity of which was equivalent to that of the zinc. Tests with freshwater species showed that zinc is not absorbed after death, and so immediate removal of the fish for autopsy is not necessary. The gill/bone ratios of zinc in 22 species from polluted and unpolluted waters, and the effects of zinc content of the water on this ratio in five species are discussed.

363. Mount, D.I. 1968. Chronic toxicity of copper to fathead minnows (Pimephales promelas, Rafinesque). Water Research 2:215-223.

The effects of continuous chronic exposure of fathead minnows (Pisces: cyprinidae) to copper was studied for a year. Concentrations of approximately 99, 33, 11, and 3.7 μg/l of copper were used in the test tanks and data on the physical and chemical characteristics of the water used are presented. The percentage survival of fish for the test period, the sex ratios and sexual maturity; growth rate measured over two periods of 60 days; and the mean final weight of fish from each tank were recorded together with the number and viability of the eggs produced. Effects of copper on the growth rate of fry were observed at 96 μg/l of copper. The 96-hour TL_m concentration of copper for adult minnows was 430 μg/l in static test and 470 μg/l in a flow-through system. Histological examination of tissues revealed no damage even in fish from high concentrations of copper which were sexually retarded and showed a stunted growth rate. It was found that there is a range of concentrations of copper in water at which indefinite and apparently healthy survival is possible but at which reproduction is inhibited. This effect cannot be detected by growth or histopathological examination. The experimentally determined maximal acceptable concentration was divided by the 96-hour TL_m to give an 'application factor' that could be used to estimate safe copper concentrations for other species and other types of water; this factor was found to be between three and seven % of the TL_m value.

364. Mount, D.I. and C.E. Stephan. 1967. A method for detecting cadmium poisoning in fish. J. Wildlife Management 31: 168-172.

Bluegills (Centrarchidae) exposed to various non-toxic concentrations of cadmium sulphate for periods up to 90 days accumulated amounts of cadmium in their gill tissues which in the live fish never exceeded 130 μg per g of tissue. Brown bullheads (Ictaluridae) and bluegills exposed to lethal concentrations of cadmium sulphate accumulated a minimum of 150 μg cadmium per g of gill tissue. It is suggested that acute cadmium poisoning can be detected by measuring the amount of cadmium in gill tissue.

365. Mount, D.I. and C.E. Stephan. 1969. Chronic toxicity of copper to the fathead minnow (Pimephales promelas) in soft water. J. Fish. Res. Bd. Can. 26:2449-2457.

The toxicity of copper to fathead minnows in a soft water was determined under continuous-flow and static conditions. An application factor of 0.13-0.22 was calculated for the 96-hour static tests, compared with limiting values of 0.03-0.08 found during the hard-water tests. Growth and reproduction data are tabulated. The results suggest that the degree of water hardness could affect the application factor, but this was not conclusive and other variables could be responsible for the differences in the ranges found.

366. McKee, J.E. and H.W. Wolf. 1963. Water quality Criteria, 2nd edition. Resources Agency of California, State Water Quality Control Board, Sacramento, California. Publ. No. 3A: 548 p.

This volume satisfactorily summarizes the major literature on toxicity of heavy metals and other pollutants to aquatic biota especially freshwater organisms. A bibliography of 3,827 references is appended, many of which deal exclusively with heavy metals.

367. Nagabushanam, R. 1961. The effect of low salinity on the larvae of Martesia striata. J. Sci. Industrial Research, 20 C:102-103.

The results are given of experiments to determine the effect of changes in the salinity of sea water on larvae of the wood-boring mollusc, Martesia striata. It was found that a sudden change in salinity from 33 to 15 o/oo had no effect. Movement of the larvae ceased during the first 24 hours in sea water with a salinity of 9 o/oo, but later they were observed swimming. At a salinity of 6 o/oo, movement ceased completely within 24 hours and death occurred within 36 hours, and at a salinity of 3 o/oo the larvae died within 12 hours. These results indicate that the larvae can tolerate salinities in the range 9-30 parts per thousand.

368. Nakatani, R.E. and R.F. Foster. 1963. Effect of chronic feeding of Sr-90-Y-90 on rainbow trout. U.S. Atom. Ener. Comm. HW-SA-2255: 14 p.

Results are given of experiments on prolonged feeding of yearling rainbow trout with strontium-90-yttrium-90. Growth depressions and significant mortalities occurred in fish fed 0.5 μc per g of fish daily for 21 weeks, but other groups receiving lower concentrations (0.05 and .005 μc per g) did not differ from the control fish. A pronounced leukopenia was observed for the high-level treatment group at the end of the test. All treatment groups retained about 25% of the administered dose; the total body burden of a 309 g fish in the highest group was in the order of 2200 μc. At the end of the test no obvious damage was observed in the low and medium groups, but six months post-treatment leukopenia was indicated in the medium group. Effects observed in the high-dose group included anorexia, loss of weight, listlessness, and a diminished response to external stimuli.

369. Nehring, D. 1962. Experiments on the toxicological effect of thallium ions on fish and fish-food organisms. Z. Fisch. 11:557-562.

Experiments on the toxicity of thallium to fish and other aquatic organisms showed that concentrations causing damage within three days were, per liter, 10-15 mg for rainbow trout, 60 mg for perch, 40-60 mg for roach, 2-4 mg for Daphnia, and 4 mg for Gammarus. Harmful effects were also observed when fish were exposed to low concentrations for prolonged periods. The effect of thallium is to increase the blood pressure.

370. Nelson, D.J. 1963. Role of bottom organisms. In Transport of radionuclides in freshwater systems. Report of a working meeting held at Univ. of Texas, January 30-February 1, 1963. U.S. Atom. Ener. Comm. Div. Tech. Inf. TID-7664: 193-207.

The author discusses the respective roles of tubificid worms, clams, and aquatic insects in the distribution or redistribution of radioactive material in an aquatic environment, emphasizing the need to consider rate processes rather than the standing crop. Tubificid worms were the most abundant organisms in the bottom of the Clinch river and a laboratory model study was made to determine the movement of sediment downstream by these worms, taking into account their unique feeding habit in which they burrow with their heads in the sediments and tails up in the flowing stream, defecating upwards into the liquid so that faecal pellets fall back. The transport

of sediment in this way by tubificid worms was found to be insignificant in the Clinch river but it would probably be significant, as compared with transport by water, when the population of worms reached about 100 per cm^2. Studies on clams in the Tennessee river showed that although these organisms can concentrate radioactivity by about $4x10^3$ times they cannot adsorb sufficient to alter the whole distribution pattern in the river. The harvest of clams removes about 64 mc of strontium-90 from the river annually, compared with a discharge of 1-2 c per week from Oak Ridge National Laboratory. Emergent insects caught in light traps on the bank of the Clinch river were found to have significant concentration factors for strontium-90 and cesium-137 but not for total rare earths. Comparative data are tabulated for the insects (almost exclusively chironomids) and for sediments taken from the same part of the river at about the same time. In view of the difficulty of representative sampling of bottom deposits, it is suggested that for some radionuclides, such as strontium-90, insects might be regarded as integrating samplers over the surface area of the mud and thus used in monitoring this radioactivity. The removal of strontium-90 by chironomids in Clinch river is calculated to be about $3.55x10^{-5}$ μc per m^2 year, which is only about 1/45th of that contributed to the river by fallout, and it is therefore concluded that the apparent dispersal of radioactivity by emerging aquatic insects is of little significance.

371. Nelson, D.J. 1967. The prediction of strontium-90 uptake in fish using data on specific activities and biological half-lives. Proc. Int. Symp. Radioecol. Concent. Process., 1966, Stockholm: 843-851.

White crappie (Pomoxis annularis) and other fish from the Clinch river, Tenn., which are subjected to chronic exposure to controlled releases of strontium-90 and other radio-isotopes from the Oak Ridge National Laboratory, were collected monthly and analysed chemically and radiochemically. In this paper data for calcium and strontium are tabulated and discussed. Good agreement was observed between the specific activity of strontium-90 and water and white crappie bone, indicating that the concentration of strontium-90 in fish can be predicted when the specific activity of the water is known. This method of prediction is considered superior to the method using the strontium-90 stable calcium ratio since in five species of Clinch river fish differences in the concentration of either calcium or strontium would affect the accuracy of predictions based on calcium concentrations. The biological half-life of strontium in white crappie flesh ranged from 12 to 48 minutes, showing that fish flesh will reflect quickly changes in the environmental concentration of strontium-90.

372. Nelson, D.J. 1969. Cesium, cesium-137, and potassium concentrations in white crappie and other Clinch river fish. Proc. 2nd Nat. Symp. on Radioecology. USAEC Conf. 670503: 240-248.

Potassium concentrations in white crappie were relatively constant throughout the year and the average of all specimens was 3.48 mg/g fresh weight. Other species -- including drum, white bass, channel catfish and bluegill -- contained similar K concentrations, and the K content of fish was considered a conservative property. Cesium concentrations in the white crappie flesh were about 0.8×10^{-2} μg/g fresh wt from May through July, and during the remainder of the year varied from 1.0×10^{-2} to 1.6×10^{-2} μg/g. In addition to varying seasonally, the Cs content of different species ranged from 0.344×10^{-2} μg/g in bluegill to 1.60×10^{-2} in white bass. Concentration factors for K were from 2500 to 2700, while those for Cs were from 140 to 640.

The average specific activity of ^{137}Cs in white crappie flesh was about the same as the average specific activity in Clinch river water. These results showed that specific activities of ^{137}Cs may be used to predict ^{137}Cs concentrations in fish for chronic releases of ^{137}Cs to surface streams. The variable Cs content and the constant K content of fish vitiates application of ^{137}Cs to K ratios for predictive purposes.

373. Nelson, W.C. and F.W. Whicker. 1969. Cesium-137 in some Colorado game fish, 1965-66. Proc. 2nd Nat. Symp. on Radioecology. U.S.A.E.C. 670503: 258-265.

In 1965 and 1966 the ^{137}Cs concentration in muscle tissue of 132 fish representing eight game fish species from 23 Colorado waters varied from non-detectable (50 pCi/kg) to 5800 pCi/kg. Waters sampled included 3 plains, 2 foothills, 5 montane and 12 alpine reservoirs and lakes as well as one plains stream. Elevation of these waters varied from 1538 to 3498 meters. Lake depths varied from 1-45 meters, lake areas from 1.4 to 230 hectares and lake watershed areas, where measured, from 53-2480 hectares. Conductivity of waters varied from 8-1700 micromhos and potassium concentration from 0.1-10.3 mg/1. Based on six samples, ^{137}Cs concentrations were from 2-7 times greater in 1965 than 1966. In general sunfish, crappies and trout sampled from plains and foothills reservoirs and lakes and the river contained little or no ^{137}Cs. Trout from alpine lakes and reservoirs contained moderate to high concentrations of ^{137}Cs. Variations in ^{137}Cs concentrations in fish from diffirent types of waters were ascribed to differences in ^{137}Cs input and availability due chiefly to differing climatic, edaphic and limnological conditions. Variations in ^{137}Cs concentrations between species were ascribed to differences in the biology and physiology of the species.

374. Neustroev, G.V. and V.N. Podymakhin. 1966. Respiration of Salmo salar L. spawn in radioactively contaminated waters. Radiobiologiya 6:115-116. Nuclear Science Abstracts 1966, 20:5226.

Salmon roe were kept in aquaria in water containing $1x10^{-6}$ cesium-136/l. Respiration was measured and compared with that of control roe kept in uncontaminated water. In both aquaria oxygen consumption increased gradually, but oxygen consumption of roe in the contaminated water was always higher than that of the controls. After hatching, control larvae consumed 50% more oxygen than had the roe, while larvae in the contaminated water consumed twice as much oxygen as the roe. The results indicate that irradiation increases the intensity of respiration of both roe and larvae.

375. Nishikawa, K. and K. Tabata. 1969. Studies on the toxicity of heavy metals to aquatic animals and the factors to decrease the toxicity. III. On the low toxicity of some heavy metal complexes to aquatic animals. Bull. Tokai Fish. Res. Lab., Tokyo, No. 58:233-241. (In Japanese with English abstract).

The toxicity of heavy metal ions decreased considerably with the addition of sodium thiosulfate or sodium citrate. With addition of EDTA the toxicity of such highly toxic heavy metals as Cu^{2+} or Hg^{2+} decreased remarkably, but the toxicity of lowly-toxic Ni^{2+} or Co^{2+} increased. It was considered that the toxicity might be attributable to EDTA. Carp grew well in a complex solution containing Cu^{2+} equivalent to 10-fold TL_m concentration and sodium thiosulfate. Thus, one should take complexing substances into account in certain instances when one discusses the toxicity of heavy metals in environmental water.

376. Nishiwaki, Y., H. Kawai, H. Honda, Y. Kimura, H. Morishima, T. Koga, and R. Ono. 1965. Studies on the behavior and distribution of radionuclides in the suspended matter in sea water. I. On the accumulation and distribution of some radionuclides in the suspended matter in sea water. Radio-Isotopes, Tokyo, 14:368-373.

Results are given of studies on the accumulation and distribution of the radioactive isotopes iron-55 and -59, cobalt-60 and strontium-89 in suspended matter in surface sea water from Osaka bay, Japan. It was found that accumulation of the nuclides by the suspended matter reached equilibrium in about 7-10 days. The greatest concentration factors occurred with the larger particles of solids. More cobalt-60 was taken up by the larger particles and more iron-55 by the smaller particles.

377. Nolan, M.O. 1950. Laboratory tests on the rapidity of molluscacidal action of copper sulphate in high concentration. Publ. Hlth. Rep., Wash. 65:1481-1485.

Laboratory experiments were made to determine the effect of copper sulphate at a concentration of 20 mg/l on the planorbid snails Australorbis glabratus, Biomphalaria boissyi, and Bulinus contortus. The snails were immersed for periods of 1, 2, 3, 4, 5, and 24 hours. In half the experiments the water was aerated and in half unaerated but results were not significantly different. After immersion the snails were placed in fresh water and observed until they either died or recovered. All snails immersed for 24 hours were killed within that period. Australorbis and Biomphalaria were not killed during immersion periods of 1-5 hours but the numbers of Australorbis that died subsequently ranged from 55% of those immersed for 1 hour to 96% of those immersed for five hours. The numbers of Biomphalaria that died later varied irregularly between 58 and 78%. Bulinus was more susceptible; these snails survived periods of immersion of 1 and 2 hours but most died within the next 24 hours. It is thought that the copper inactivates certain enzymes, and studies are at present being made on the physiological effect of toxic agents on snails.

378. Okun, D.A., et al. 1966. A review of the literature of 1965 on wastewater and water pollution control. J. Water Poll. Cont. Fed. 38:1049-1137.

Permissible concentrations of copper, zinc, lead and nickel to aquatic organisms was determined in bioassays with Daphnia and 3 species of cyprinids. Poisoning with heavy metals was found to be an additive process which depended on concentration of the toxicants and length of exposure.

379. Ophel, I.L. and J.M. Judd. 1962. Absorption of radiostrontium by the gills of freshwater fish. Nature 194:1187-1188.

In experiments to determine the site of direct absorption of radioactive strontium by fish, the accumulation of the isotope by goldfish (Carassius auratus) with only the head and gills exposed to a solution of strontium-90 was compared with that accumulated by goldfish with the whole body exposed. Each fish was placed in a tube, with its head resting on an open grid at the lower end, and suspended vertically in distilled water containing strontium-90; precautions were taken to prevent dessication of the partially-immersed fish, and the solution was aerated continuously. Various immersion periods and concentrations of isotope were used. The concentration of strontium-90 accumulated was determined by weighing each fish, wet-ashing

it with concentrated nitric acid and hydrogen peroxide, evaporating the resulting solution and counting the residue. The results showed no significant difference between the concentrations of strontium-90 accumulated by the partially-and totally-immersed fish under the same experimental conditions.

380. Ophel, I.L. and J.M. Judd. 1967. Experimental studies of radiostrontium accumulation by freshwater fish from food and water. Proc. Int. Symp. Radioecol. Concent. Process., 1966, Stockholm: 859-865.

Aquarium experiments are described in which goldfish (Carassius auratus), acclimated to the experimental temperature, were fed known amounts of strontium-90 in a maintenance diet of 'commercial' food (which contained both calcium and strontium), or basic 'synthetic' food (containing negligible concentrations of alkaline-earth cations), or diets prepared from the synthetic food by adding 500 m. equiv. per kg of magnesium, calcium, or strontium. Results show that the presence of Ca, Sr, or Mg in the diet caused a great reduction in the retention of strontium-90 by the fish. Compared with a retention of about 27% from the basic diet, diets containing Ca or Sr gave retentions of about 5% and that containing Mg gave a retention of about 8%. To compare the uptake of strontium-90 from water and food, the concentration of strontium-90 in the water was kept constant by daily changes, a maintenance diet of non-radioactive food was supplied, and the fish were withdrawn daily for force-feeding with equal amounts of either radioactive or non-radioactive food. From the results of two experiments it was calculated that the water contributed 8 and 30% and the food contributed 92 and 70%, respectively, of the retained Sr. The difference in the two experiments was not directly attributable to the size of the fish since data on the direct uptake of strontium-90 from the water did not reflect this difference, but it is considered attributable to differences in the amount of non-radioactive food fed to the fish, since this was based on the body weight and therefore resulted in different concentration factors for strontium-90 in the food. Further experiments, in which the non-radioactive food was given either immediately or 48 hours after the force-fed dose of radioactive food, showed that the retention of strontium-90 was greater when the highly concentrated force-fed food passed through the gastro-intestinal tract undiluted by non-radioactive food. It is therefore concluded that the uptake and retention of strontium-90 from food by fish will be affected by the composition and specific activity of the food, and by the feeding habits of the fish; and therefore prediction of the body burden of strontium-90 in fish, and the relative contributions of food and water, should take into account the influence of these factors.

381. Ophel, I.L. and J.M. Judd. 1967. Strontium-calcium relationships in aquatic food chains. Proc. 2nd Natn. Symp. Radioecol., Ann Arbor, 1969: 221-225.

In waters contaminated with strontium-90, there is a direct relation between the amount of nuclide incorporated into fish tissue and the concentration of stable strontium in the tissue. Studies were therefore made using flame emission spectrophotometry to determine the strontium content of fish from two lakes in Ontario. Results show marked differences in the concentration of stable strontium in different species of fish from the same lake and in the same species of fish from different lakes. The differences in stable strontium are accompanied by corresponding differences in radioactive strontium, resulting in essentially identical specific activities in the different species of fish. However, the calcium concentration is similar for all species and therefore the strontium-calcium ratios are very different from the different species. Data are also tabulated on the strontium:calcium ratio in various aquatic plants. There is a marked correlation between the strontium:calcium ratios in fish and in fish-food organisms.

382. Osterberg, C. 1962. Zn-65 content of salps and euphausids. Limnol. Ocean. 7:478-479.

Samples of herbivorous filter-feeding pelagic plankton, Salpa spp. and Euphausia pacifica, collected in the Pacific Ocean off the Oregon coast, were found to contain zinc-65. Although the presence of other fission products after the 1961 Russian test series suggested that some of the zinc may have been deposited as a result of fallout, the concentration of zinc in both salps, collected before the 1961 test series, and euhpausiids, collected after the tests, gradually decreased with distance from the mouth of the Columbia river, suggesting that the river is the major source of this isotope.

383. Osterberg, C., W.G. Pearcy, and H.J. Curl. 1964. Radioactivity and its relationship to oceanic food chains. J. Marine Res. 22:2-12.

Gamma-ray spectra were prepared for some primary producers, filter-feeding herbivores and carnivores, representing different trophic levels obtained from the Pacific Ocean off the coast of Oregon; these organisms had been exposed in their natural environment to radioactive fallout and to neutron-induced radionuclides from Columbia river water. The results indicated that zirconium-95, niobium-95 and cerium-144 were concentrated by primary producers and herbivores but not by carnivores; chromium-51 was abundant only in primary producers; manganese-54, cobalt-60 and cesium-137 were found only in herbivores and carnivores; and zinc-

65 was present in every organism examined. The authors conclude that particulate radioactive fallout, although concentrated at the second trophic level by filter-feeding plankton, does not occur to any great extent in animals used for human consumption; neutron-induced zinc-65 is more likely to enter the human food chain, but this is relatively innocuous isotope since it emits few ionizing particles. In the event of high levels of radioactive fallout, therefore, the higher trophic levels of the marine food chain should be considered as a good source of food.

384. Ozretic, B. and M. Krajnovic. 1968. The turnover of zinc-65 during the early embryonal development of the sea urchin, Paracentrotus lividus Lam. Proceedings of the Third International Colloquim on Medical Oceanography. Fifth and Sixth Sessions: 101-106.

Laboratory tests showed that whereas the uptake of zinc-65 by unfertilized sea urchin eggs is low, a rapid increase occurs on fertilization and during the early stages of development, excepting the phase immediately following hatching.

385. Pahl, G. 1969. Radioactive and stable strontium analysis of upper Mississippi river clamshells. Proc. 2nd Nat. Symp. on Radioecology. U.S.A.E.C. Conf. 670503:234-239.

The freshwater clam forms a significant portion of the benthic fauna of the Upper Mississippi River biological community. Evidence indicates that it may serve as an ideal biological monitor of the ^{90}Sr concentration not only in the Upper Mississippi River but also of the worldwide fallout of this radionuclide. Advantage was taken of the fact that the shells of the long-lived clams of this area are composed of distinct annual layers and chemically are composed almost exclusively of calcium and/or strontium carbonate. The shells of live clams of the genus Lampsilis collected at the end of the 1962-4 growing seasons were analyzed for both stable and radioactive strontium. Shell layers formed over the ten-year period of 1955-64 showed stable strontium to be consistently 10 orders of magnitude greater than that of radioactive strontium. During this time the stable strontium increased by a factor of only 2, while the ^{90}Sr increased by a factor of 8. This rise of radiostrontium over the 1955-64 period, while not corresponding with the overall strontium increase, did correlate closely with the fallout pattern associated with nuclear weapon testing carried out during this period.

386. Palmer, H.E. and T.M. Beasley. 1967. Fe-55 in the marine environment and in people who consume ocean fish. Proc. Int. Symp. Radioecol. Concent. Process., 1966, Stockholm:259-262.

Tabulated data are given from measurements of iron-55 in various species of marine fish and other marine organisms. The concentrations of iron-55 were about 1000 times higher than those reported for cesium-137, cobalt-60, and silver-110, but the differences in concentration in fish from different geographical locations (including both the northern and southern Atlantic and Pacific Oceans) were consistent for all the isotopes. The high concentrations of iron-55 in marine species are attributed largely to the low concentration of stable iron in sea water. The implications of these results are discussed as regards the body burden of iron-55 in individuals consuming large quantities of marine fish.

387. Parchevskii, V.P., G.G. Polikarpov, and I.S. Zabarunova. 1965. Certain regularities in the accumulation of yttrium and strontium by marine organisms. Dokl. Akad. Nauk SSSR 164: 913-916.

Results are given of studies to determine the probable relation between accumulation of radioactive isotopes by marine plants and animals and the activity of the isotopes in the water. The accumulation of yttrium-90 was found to be independent of the activity in the water. With strontium the accumulations of stable strontium and strontium-90 were found to be similar in the case of plants, but were markedly different in the case of molluscs because accumulation is a function of their growth.

388. Parry, G. 1960. The development of salinity tolerance in the salmon, Salmo salar (L.) and some related species. J. Exp. Biol. 37:425-434.

A study has been made of the survival and osmotic regulation of young salmonid fishes following transfer from fresh water to various dilutions of sea water. Survival is in the order: Salmo salar > S. gairdnerii > S. trutta and is generally better the larger the fish. The survival pattern of alevins differs from that of the older stages.

Hypo-osmotic regulation is first seen in parr and becomes fully effective in smolts.

389. Parry, G. 1961. Osmotic and ionic changes in blood and muscle of migrating salmonids. J. Exp. Biol. 38:411-427.

Osmoregulation of the Atlantic salmon in fresh water and sea water, and during transfers from one salinity to another, has been studied by measuring the freezing-point and the levels of some inorganic ions in the blood plasma, and water content and ions in

whole muscle. An increase in blood concentration of about 12% follows the transfer of juvenile fish from fresh water to sea water; and a fall of concentrations of about 5% follows the transfer of the adult fish from sea water to fresh water. Some changes in analyses of whole muscle indicate changes in the extracellular compartment during transfers from one salinity to another. Osmoregulatory powers of juvenile salmon and fresh-run adults are good, but spent fish returning from fresh water to sea water, osmoregulate with difficulty or not at all.

390. Parsons, J.D. 1968. The effects of acid strip-mine effluents on the ecology of a stream. Arch. Hydrobiol. 65:25-50.

The complete oxidation of iron sulfide occurs on spill piles. Strip-mine lakes act as holding areas of oxidated sulfuritic material. Cedar Creek, in Missouri, was affected by both continuous and periodic flows of acid-mine effluents. The longitudinal succession associated with a stream of this type has been modified in biotic response to the continuous atypical aquatic environment as a function of effluent ions. The greatest deviation from the expected pattern was found in fishes, and the least in the benthos with its great dependency upon the abiotic substrate, and of intermediate response the zooplankters with both inhabitable volume as well as water quality being a factor. In both zooplankton and benthic populations in the continuously polluted area, the number of species was small compared to the total number of individuals. This was in direct contrast to the biotic structure in the downstream area. The populations of fishes in the periodically polluted area were typical of streams in the surrounding area. In the final analysis, not only the initiation of an excess acid flow, the maintenance of such a flow, the concentration of effluent ions, and the distance travelled by such a flow, but also the rate of recovery of the downstream area were dependent upon a delicate, ever-changing balance in the amount, distribution, and intensity of rainfall, and to some extent, upon the time interval between rains. The effects of acid effluents upon the abiotic environment were the a) precipitation of the normal silt load, b) destruction of the bicarbonate buffer system, c) increase in the titratable acidity and hydrogen-ion concentration, d) introduction of various metal ions, and e) reduction of the oxygen concentration in the downstream stations. The acidity of the strip-mine effluent as measured by titratable acidity and hydrogen-ion concentrations was responsible for the destruction of animal populations of the downstream communities. The response of the community structure to the abiotic environment during the a) normal, b) pollution, and c) recovery conditions was studied comparatively. A complete picture of the biotic response to abiotic environment has been ascertained based on community response. The repopulation of the ecosystem was dependent upon a) water quality, b) type of life cycle, and c) season of high water.

391. Parsont, M.A. 1967. The distribution of radium-226 in an aquatic environment. Thesis, Colorado State University: 133 p.

Detailed results are given of studies on the distribution of radium-226 in a stream below a uranium mine. It was found that the concentration of radium in the sediment was directly related to particle size and showed no seasonal variations; the concentration in both large and small particles decreased exponentially with distance from the source of contamination. Filtered water samples showed lower concentrations of radium-226 than unfiltered samples, indicating that most of the radium was associated with the particulate material. In areas where the sediment contains high concentrations of radium-226, the root system of aquatic plants contained more radium than did the stems and leaves. The reverse was true in areas of lower sediment radium concentration. Aquatic insects concentrated large amounts of radium-226, but the concentration of radium accumulated by fish could not be related statistically to stomach contents.

392. Passow, H., A. Rothstein and T.W. Clarkson. 1961. The general pharmacology of the heavy metals. Pharmacological Reviews 13:185-224.

This article is devoted to a discussion of predominantly theoretical aspects of metal poisoning, with emphasis on chemical and physico-chemical modes by which chemicals can alter the functions of living cells. Topics discussed include chemical interactions between heavy metal ions and biochemical substances; the action of metals on enzyme systems, including inhibition kinetics, metal interactions with various components of enzyme systems, and relations between the chemical properties of heavy metals and enzyme inhibition; interactions with surface films; action of metals on cells; actions of metals on epithelial tissues; and the nature of the metal induced response. Numerous examples are cited with specific metals including mercury, silver, lead, cadmium, zinc, calcium, magnesium, uranium, manganese, barium, nickel, and cobalt. A bibliography of 130 references is appended.

393. Patin, S.A. and N.I. Popov. 1966. The absorption of artificial radionuclides by marine detritus under natural ocean conditions. Proc. Symp. Int. Atom. Energ. Agency: 443-449.

Sea water and suspended solids from the Indian Ocean were analysed for radionuclides. Although relatively large amounts of material were analysed, the activities of strontium-90 and cesium-137 in solids were below the limit of sensitivity of the analytical

methods used; the maximal possible concentrations of these isotopes did not exceed 0.1-0.3 pc per g dry weight, representing a concentration factor of less than 1000. The concentrations of cerium-144 and ruthenium-106 in the suspended matter were about 2 pc per g dry weight, representing concentration factors of 10,000-50,000. These results stress the great differences in the effectiveness of accumulation of fission products by marine detritus. Since the proportion of nuclides in the suspended material is, in general, not very large, most of the artificially produced radionuclides in sea water must exist in the ionic or colloidal state.

394. Patrick, R., J. Cairns, Jr., and A. Scheier. 1968. The relative sensitivity of diatoms, snails and fish to twenty constituents of industrial wastes. Prog. Fish-Cult. 30: 137-140.

Acute toxicity of salts of zinc, copper, chromium and other wastes were determined against various freshwater species; Physa heterostropha, a snail; Lepomis macrochirus, bluegill sunfish; and Nitzschia lineaus, a diatom.

Concentrations fatal to 50% of sunfish in 96 hours, in mg/l metal were: 113 for Cr^{3+}, 168 for Cr^{2+}, 1.25 for Cu^{2+} and 2.86-3.78 for Zn^{2+}. For snails these values were 17.3 for Cr^{3+}, 16.8 for Cr^{2+}, and 0.79-1.27 for Zn^{2+}. Concentrations that cause 50% reduction in number of cells of diatoms produced in 120 hours, in mg/l, were: 0.208 for Cr^{3+}, 7.8 for Cr^{2+}, 0.8 for Cu^{2+} and 4.3 for Zn^{2+}.

395. Pauley, G.B. and R.E. Nakatani. 1968. Metabolism of the radioisotope zinc-65 in the freshwater mussel, Anodonta californiensis. J. Fish. Res. Bd. Can. 25:2691-2694.

The distribution of zinc-65 in the freshwater mussel Anodonta californiensis after exposure to aerated Columbia river water spiked with the isotope, was investigated. The uptake by mussels after a 5-day exposure was proportional to the concentration of the zinc. The concentration of zinc-65 in various tissues is shown as a function of period of exposure to a concentration of 100 μc per liter; after 36 days of exposure, 75% of the isotope was in the gills, mantle, and palps, and this was distributed in a pattern similar to that of the stable zinc content. Autoradiographs showed some zinc-65 in all tissues except Leydig cells and the mucous cells of the epithelial layers, but little was adsorbed on the surfaces of the mussels.

396. Paulini, E. and J. Pellegrino. 1957. Influence of infection of Schistosoma mansoni on the susceptibility of Australorbis glabratus to copper sulphate. Trans. Roy. Soc. Trop. Med. Hyg. 51:283-284.

Infected snails were more susceptible to copper.

397. Pearcy, W.G. and C.L. Osterberg. 1967. Depth, diel, seasonal, and geographic variations in zinc-65 of midwater animals off Oregon. Int. J. Oceanol. Limnol. 1:103-116.

Macroplankton and micronekton at one station off the coast of Oregon were sampled over a 2-year period to obtain information on variations in the uptake of zinc-65. Animals collected in the upper 150 m showed marked seasonal variations in the content of zinc-65 per g of biomass, with summer maxima related to the seasonal occurrence of Columbia river 'plume' waters off Oregon; these variations were less noticeable in animals from depths of 150-550 m, and no seasonal variations were found in animals at greater depths. Although the concentration of zinc-65 in animals collected at all depths during winter was low, it was higher than in samples collected further offshore, indicating that even in winter more of the zinc activity originated from the Columbia river water than from fallout and that some of the river water is retained off Oregon throughout the year. The concentration of zinc-65 per g of sample was markedly higher at night than during the day in animals collected in the upper 150 m in summer indicating that vertical migrants may accumulate more radioactive isotopes than non-migratory epipelagic animals. A first approximation of the vertical movement of radioactive zinc suggests that about 40% of the zinc-65 incorporated in the animals moves twice daily through the base of the permanent halocline at 150 m, indicating that vertically migrating animals may play a major role in the movement of certain radioactive isotopes, and other materials, through density gradients in the open sea.

398. Pearcy, W.G. and C.L. Osterberg. 1968. Zinc-65 and manganese-54 in albacore Thunnus alalunga from the west coast of North America. Limnol. Oceanogr. 13:490-498.

A study was made to determine the major gamma-emitting radioisotopes found in the livers of albacore, Thunnus alalunga, taken from the coastal waters off northwest America during the summers of 1962-1966. Zinc-65 and manganese-54 were found to be the dominant artificial radionuclides and their concentration and specific activities changed considerably during the summer. Levels of zinc-65 content in albacore taken off Oregon and Washington increased during the summer and were directly related to their association with the Columbia river

plume; zinc-65 content of fish taken from Baja, California was only 10% of fish taken further north and showed no seasonal trends. There was no evidence of migration between the northern and southern fisheries The radioactivity and specific activity of manganese-54 during the summer, indicating that manganese-54 is more readily available in offshore waters than in coastal waters. The main source of manganese-54 is fallout from nuclear weapon tests.

399. Pendleton, R.C. 1958. Effects of some environmental factors on bioaccumulation of cesium-137 in an aquatic community. Hanford Biol. Res. Ann. Rep.; U.S. Atom. Energ. Comm. HW-59500:42-46.

The amount of cesium-137 taken up by algae, submerged water weeds, grass, fish, and amphibians was found to vary with temperature. Shading reduced uptake by submerged plants, and emergent plants rooted in gravel accumulated more cesium-137 than did those rooted in mud. Contamination of all organisms decreased because of loss to bottom mud.

400. Pendleton, R.C. and W.C. Hanson. 1958. Absorption of cesium-137 by components of an aquatic community. Proc. 2nd U.N. Int. Conf. Peaceful Uses Atom. Energ. 18:419-422.

Field studies and controlled experiments are reported which confirm the hypothesis that a marked difference exists in the availability of cesium-137 to ecologic chains originating in aquatic as compared with terrestrial environments. Numerical results are tabulated in terms of the concentration factor for various organisms in water containing mixed fission products from the Hanford chemical separations facilities, Wash.; the wide variation between different species is explained. Plants exposed to cesium-137 in an aquatic environment accumulate the isotope at least 500 times as much as previously reported for plants grown in soil, and animals feeding on these plants become proportionately more contaminated than those utilizing terrestrial food chains. For example, a carp may concentrate the isotope by a factor of 3000. The discharge to an aquatic environment of cesium-137 at the recognized maximum permissible concentration level for drinking water will produce hazardous levels of contamination in organisms which may be consumed by man. Based on these results, a probable route for the transfer of hazardous quantities of cesium-137 to man is shown diagrammatically.

401. Pendleton, R.C., R.D. Lloyd, C.W. Mays, D.R. Atherton, and N.V. Chamberlain. 1964. Radium contamination at the Jordan River delta of the Great Salt Lake. J. Water Pollut. Contr. Fed. 36:925-927.

Following on the accidental release of wastes from a uranium ore refining plant in Utah, a study was made to determine the extent of contamination in the Jordan river delta where it enters the Great Salt lake. High concentrations of radium and thorium were found in environmental samples and in muskrats living in the area, but carp appeared to contain relatively low levels. The contamination was limited to irrigated fields, water channels and impoundments, and there was evidence of high accumulation in localized areas, such as mats of blue-green algae where maximum deposition of silt occurs. Since much of the flow in the river is used for irrigation, the possibility of contamination of crops for human consumption is great, and the need for strict control to prevent future release of wastes is stressed.

402. Perkins, R.W. and J.M. Nielsen. 1960. Radioactivity in foods resulting from Columbia river water radioisotopes. U.S. Atom. Ener. Comm. HW-63824:25-32.

Water from the Columbia river is used for cooling the reactors at Hanford, Wash., and is then returned to the river. The used cooling water contains trace amounts of several radioactive isotopes, most of which have half-lives of up to only a few hours. However, the half-lives of some of the isotopes are sufficiently long for their distribution to be traced through the food chains of the aquatic life in the river, and some can be traced from irrigation water through farm produce to man. The results are given of a comprehensive study of the radioactive isotopes present in farm produce irrigated with water from the Columbia river. The isotopes present in sea foods harvested from waters near the mouth of the Columbia river were measured and compared with those present in sea foods from several other parts of the world.

403. Petkevich, T.A. 1967. Elemental composition of bony tissue of plankton-feeding and benthos-feeding fish from the Northwest part of the Black Sea. Dopovidi Akademii Nauk Ukrains'koi RSR, Ser. B 29, No. 2:142-146.

The content of certain trace elements in the bones of sprats, anchovy, mackerel and other fish was determined by spectral analysis. The bony tissue of plankton-feeding fish can concentrate manganese, nickel, chromium, vanadium, titanium, tin, lead and strontium to a greater extent than that of benthos-feeding fish.

404. Phelps, D.K. 1967. Partitioning of the stable elements Fe, Zn, Sc, and Sm within the benthic community, Anasco Bay, Puerto Rico. Proc. Int. Symp. Radioecol. Concent. Process., 1966, Stockholm: 721-734.

A preliminary report is given of studies on the partitioning of the stable elements iron, zinc, scandium and samarium between the predominant members of the benthic fauna and in the sediments at two points in Anasco Bay, Puerto Rico, at depths of 8 and 13 m directly in the mouth of the river, Anasco, which carries large quantities of sediment. Data, obtained by neutron activation analysis, are reported in tables and diagrams. The qualitative and quantitative structure of the faunal community has a direct effect on the distribution of the elements examined; a shift in predominance from polychaete annelids to pelycopod molluscs would result in a decrease in the amount of iron and zinc incorporated into the living community and conversely a change in predominance from pelycopods to polychaetes, particularly if Capitella or Paraprionospio were present, would result in increased concentrations of scandium and samarium. Among the polychaetes, at least, the composition of the community based on feeding-types is an important factor in the partitioning of the stable elements; the less dependent an organism is on the sediment as a source of food, the lower its concentration of these trace elements becomes. The polychaetes which feed primarily from the sediment water interface (selective deposit feeders) concentrate iron to the apparent exclusion of zinc, while the polychaetes which feed primarily below the sediment-water interface (non-selective deposit feeders, omnivores, carnivores) concentrate zinc to the apparent exclusion of iron. Scandium was concentrated to a high level by a few individual species but in general the concentrations of scandium and samarium in the organisms were similar to those in the sediments. There was a greater difference in the amounts of stable elements concentrated by different feeding types at the same location than there was between the same feeding types from different locations.

405. Phelps, D.K., R.J. Santiago, D. Luciano, and N. Irizarry. 1969. Trace element composition of inshore and offshore benthic populations. Proc. 2nd Nat. Symp. on Radioecology. U.S. A.E.C. Conf. 670503: 509-526.

Preliminary studies of stable element partitioning within shallow water assemblages of infauna have shown discrimination between Fe and Zn that follows feeding categories. Select deposit feeders concentrate Fe over ambient sedimentary levels while non-select deposit feeders and omnivores concentrate Zn. This study represents a further investigation of relationships between the distribution of Fe, Zn, Cu, Sc, and Sm and the ecology of benthic assemblages.

Levels of Cu and Sm in the fauna were found to be enhanced by proximity to the land mass. Iron and Sc were higher in fauna collected from silty clays than in fauna living in sands and gravelly sands with no apparent increase due to the influence of the land mass. Zinc levels in the animals showed no relationship to proximity of the land mass or to changes in substrate although there was a tendency for higher values to occur in organisms found in the offshore silts and clays.

406. Pickering, Q.H. 1968. Some effects of dissolved oxygen concentrations upon the toxicity of zinc to the bluegill, Lepomis macrochirus, Raf. Water Research 2:187-194.

The effects of three levels of dissolved oxygen on the non-lethal toxicity of zinc to bluegills in hard spring water under continuous-flow exposure was studied. The nominal dissolved-oxygen concentrations were 1.8, 3.2, and 5.6 mg/l; temperature was maintained at 25°C and pH value at 7.8. It was found that for the surviving fish at all three concentrations of oxygen, growth was greatest in fish exposed to 1 mg/l of zinc and least in those exposed to 4 mg/l, and that growth increased with increase in oxygen concentration. Statistical analysis indicated that the effect of zinc on growth was not significant but that the effect of dissolved oxygen was significant. It is thought that zinc has little cumulative toxicity for bluegills.

407. Pickering, Q.H. and C. Henderson. 1966. The acute toxicity of some heavy metals to different species of warm water fishes. Air and Water Pollution 10:453-463.

A comparative study was undertaken to determine the acute toxicity of the salts of copper (Cu), zinc (Zn), nickel (Ni), trivalent and hexavalent chromium (Cr), and lead (Pb) to four species of warm water fishes and the dependence of this toxicity on certain other water quality characteristics. The species used were fathead minnows, bluegills, goldfish, and guppies. Ten individuals of a species were used for each of the concentrations tested and in the control. The test solutions were prepared in a logarithmic series of numbers such as 10, 5.6, 3.2, 1.8 and 1.0 mg of the metal salt per liter of water, and from the mortalities at different concentrations the 24-, 48- and 96-hour median tolerance limits (TL_m) were computed. With all four species in soft water, Cu was the most, and Cr^{6+} the least toxic while with the other metals, relative toxicity varied with the test species. With Pb (as chloride and acetate), the mechanism of toxicity appeared to be different at high concentrations and short exposures than at low concentrations and long exposures. The 96-hour TL_m values in soft water for the fathead minnow (7.33 and 31.5 mg/l) and goldfish were significantly lower than the 24-hour values (11.5 and 45.4 mg), and the 96-hour TL_m in soft water was significantly lower for the fathead minnow than for the other species.

408. Pickering, Q.H. and W.N. Vigor. 1965. The acute toxicity of zinc to eggs and fry of the fathead minnow. Prog. Fish-Cult. 27:153-157.

It appears from bioassays with zinc that these fish (fry) exposed during the egg and embryo stages, as compared to fry not so exposed, develop a tolerance to zinc. One-day-old eggs exposed to 1.1 mg/l of zinc hatch, and the fry live at least three days. Newly-hatched fry not previously exposed to zinc died within 24 hours after exposure to 1.1 mg/l. TL_m value of Zn to eggs was greater than 3.98 mg/l but the TL_m value decreased to 1.69 mg/l after 12 days exposure. The survival at 1.06 mg/l or less of zinc was not significantly different from survival in controls.

409. Podubsky, V. and E. Stedronsky. 1948. Toxic effects of some metals on fish and river crabs. Ann. Acad. Tchecosl. Agric. 21:206-222; Chem. Abstr. 44:8008.

The toxic effect of several metals to fish and river crabs was investigated. Copper was most toxic followed by zinc, brass, iron, and nickel. Aluminum was toxic in waters containing little calcium. Copper coated with zinc, and tin and iron coated with zinc were slightly toxic, while stainless steel, iron coated with nickel and chromium, and lead were not toxic.

410. Podubsky, V. and E. Stedronsky. 1950. Toxic effects of some metals on both small and large water organisms. Ann. Acad. Tchecosl. Agric. 23:209-215; Chem. Abstr. 45:6309.

The effects of copper, zinc, and other metals on aquatic organisms are discussed. Copper and zinc are markedly toxic to Ephemerid larvae but Chironomid larvae are fairly resistant.

411. Podubsky, V. and E. Stedronsky. 1951. The toxic effects of some metals on the fry of the common pike (Esox lucius), the spawn of the great maraena (Corogonus maraena), and the spawn of the common trout (Salmo fario). Ann. Acad. Tchecosl. Agric. 23:295-301; Biol. Abstr. 27:1413.

For pike fry, and spawn of the great maraena and common trout the toxicity of metals increases in the order zinc, brass and copper. Zinc killed all spawn before hatching time. Iron was harmless to fry and spawn.

412. Podubsky, V. and E. Stedronsky. 1952. The effect of zinc on fish spawn and young fish and on Daphnia in water of different degrees of hardness. Ann. Acad. Tchecosl. Agric. 25:441-448.

Experiments with fish spawn, young fish, and Daphnia showed that zinc plate placed in hard well water did not form poisonous salts (chloride and sulphate) but such salts were formed in the soft water of fish ponds. Such water became toxic. Damage was caused to the plasma. The effect was even stronger with brass.

413. Polikarpov, G.G. 1961. Ability of some Black Sea organisms to accumulate fission products. Science 133:1127-1128.

The coefficients of accumulation of strontium-90, cesium-137, and cerium-144 in seaweeds, eelgrass, Actinia, molluscs and crustacea in the Black Sea were determined, and are given in a table. The discharge of strontium-90 into sea water from decomposing seaweed and the retention and additional absorption of cesium-137 and cerium-144 on organic debris are discussed. The results are discussed in relation to the effects of radioactive waste waters discharged into the Black Sea. It has been estimated that the time interval for the rise of bottom waters to the surface in the Black Sea is from 60 to 130 years, and during this period there would be a 5 to 30-fold decrease in the activity of strontium-90.

414. Polikarpov, G.G. 1961. The absorption of strontium-90 by marine organisms. Prirorda 2:83.

A study was made of the uptake of strontium-90 by actiniae, molluscs, shrimp, crab, and algae. The coefficients of accumulation, related to live weight, were actiniae 1, molluscs 6, shrimps 8, and crabs 3. The radioactivity of dying brown algae decreased, but in dying green and red algae the concentration of strontium-90 remained the same as in living algae. When animals or algae with a high absorption coefficient for strontium-90 die, a significant part of the activity passes out again into the surrounding water.

415. Polikarpov, G.G. 1961. The role of detritus formation in the migration of strontium-90, cesium-137, and cerium-144. Experiments with the seaweed Cystoseira barbata. C.R. Acad. Sci. URSS 136:921-923. Nuclear Sci. Abstr. 1961. 15:1872.

In the disposal of radioactive wastes at sea, a knowledge of the effect of decaying matter on the movement of fission products is important. Experiments were therefore carried out with strontium-90, cesium-137, and cerium-144 in the presence of Cystoseira barbata, a brown alga commonly found in the Black Sea. As the sea water was not circulated or aerated the alga began to die in four days and was completely decomposed at the end of the experiment (64 days). It was

found that strontium-90 was almost completely leached from the organic matter by the sea water, but that additional amounts of cesium-137 and cerium-144 were adsorbed from the sea water by the decayed organic matter.

416. Polikarpov, G.G. 1966. Radio-ecology of aquatic organisms. Reinhold Book Division, New York: 340 p.

In this translation of a book originally published in U.S.S.R., the author discusses the importance of marine radioecology in determining the effect of radioactive contamination of sea water on commercial fisheries, in predicting the risk to humans from contaminated sea food, and in developing measures for controlling radioactive contamination of seas and oceans. Factors affecting the accumulation of radionuclides by marine organisms are discussed and the effects of nuclear radiation on marine organisms are described. In drawing conclusions from the available data the author points out that strontium-90 accumulated during life is returned to the environment from dead marine plants; in addition to being more hazardous to man than other isotopes in food, strontium-90 is also more mobile in the sea.

417. Polikarpov, G.G., Y. P. Zaitsev, G.V. Barinov, and V.P. Parchevsky. 1967. General features of the concentration processes of radioactive substances by hydrobionts in different seas of the world ocean. Proc. Int. Symp. Radioecol. Concent. Process., 1966, Stockholm: 771-790.

Giving tabulated data and a list of 49 references the authors review and discuss the accumulation of radionuclides by marine organisms, with reference to isotope-exchange kinetics and their use to develop laws of uptake and loss of radionuclides by hydrobionts. Concentration factors are listed for individual radio-isotopes in similar and closely related species of hydrobiont in different seas, showing that, in general, concentration factors obtained in one sea are also valid for other seas. Distribution of strontium-90 in similar species in different oceans and seas demonstrate that geographical distribution of strontium-90 is very uneven; mathematical analysis of changes in concentration of strontium-90 in plankton, algae, and molluscs in the Black, Adriatic, and Ligurian seas, show a similar mathematical dependence.

418. Pomeroy, L.R., R.E. Johannes, E.P. Odum, and B. Roffman. 1969. The phosphorus and zinc cycles and productivity of a salt marsh. Proc. 2nd Nat. Symp. on Radioecology. U.S.A.E.C. Conf. 670503: 412-419.

By synthesizing the results of two field experiments using ^{32}P and ^{65}Zn with earlier work in Georgia salt marshes, the cycles of the elements P and Zn are described quantitatively. Marsh grass (Spartina alterniflora) and sediments dominate both cycles. The uppermost meter of sediments contains enough P to support Spartina production for 500 years and enough Zn for 5000 years. Spartina production removes P and Zn from the subsurface (reduced) sediments and introduces them into the water (via bacterial utilization of dead Spartina and subsequent utilization of the bacteria by detritus feeders) at a rate that replaces total water P in a month and total water Zn in a year. A significant part of the P is exported from the marsh in organisms and detritus. The P and Zn in the estuarine water are in equilibrium with plankton, bacteria, and surface (oxidized) sediments. The equilibrium strongly favors the sediments. Probably the subsurface-sediment compartment of P and Zn is replaced by the conversion of oxidized sediments to reduced sediments through the process of creek meandering. The oxidized sediments are in equilibrium with the water, which receives inputs of P and Zn from both land and sea. The transfer of P and Zn from the deep sediments to the water by Spartina explains the high concentration of these elements in the water of marshy estuaries.

419. Pomeroy, L.R., E.P. Odum, R.E. Johannes, and B. Roffman. 1966. Flux of phosphorus-32 and zinc-65 through a salt-marsh ecosystem. Proc. Symp. Int. Atom. Ener. Agency: 177-188.

Zinc-65 and phosphorus-32 were introduced simultaneously into the waters of a tidal creek flowing through a salt marsh on the east coast of U.S.A., and the distribution of radioactivity in the various components of the ecosystem was observed over a period of several months. It was found that the isotopes were taken up rapidly by the clay sediments and also by the bacteria in these sediments; higher plants in the marsh did not take up either of the isotopes, and populations of diatoms and algae did not become as radioactive as the sediments in which they lived, but a dinoflagellate bloom did accumulate appreciable amounts of radioactivity. The isotopes were removed from the sediments by animals which consumed the sediments either as their food or incidentally during feeding, and it is thought that digestion of bacteria from the sediments by sediment-feeding animals is an important step in the transport of radioactivity from sediments to biota.

420. Pooth, I.S. 1954. The effect of mine water on the diatomaceous flora in some oligotrophic lakes in Vasterbotten. Rep. Inst. Freshw. Res. Drottning, 35:184-209.

Investigations are described of three lakes in Sweden, the Hobäckstjäru, Gillervättnet, and Brutrasket, and their connecting

streams, carried out to find the effect of the discharge of waters from the Boliden mine and from an ore-concentration plant. The ores mined contain mainly iron and zinc with some copper, arsenic, and lead, and considerable amounts of sulphur. Analyses are given of the mine water, which is acid and contains free sulphate ions and metal salts. Examinations were made in 1950 before discharge of mine water began and in 1952 when the lakes had received mine water for a year, and shorter investigations were made in 1953 and 1954 when waste waters from the ore-concentration plant were being discharged. In 1950 the lakes in their natural condition were oligo-dystrophic in character with a low content of lime and nutrient matter and the plankton contained a more or less rich diatom population consisting of the pure water forms common in the northern forest districts. This population disappeared almost completely after mine water had been discharged for a year, being almost completely replaced in the first lakes and streams of the series by Eunotia exigua, whose occurrence and appearance are described. Discharge of warm water from the ore-concentration plant restored the reaction of the lake water to neutral and the effect on the biological conditions will be investigated later.

421. Portmann, J.E. 1968. Progress report on a programme of insecticide analysis and toxicity-testing in relation to the marine environment. Meeresuntersuchungen 17(1-4):247-256.

Static 48 hr bioassays were conducted in 10 liter perspax aquaria using aerated full-strength sea water and the following assay species: pink shrimp, Pandalus montagui; brown shrimp, Crangon crangon; shore crab, Carcinus maenus; and cockle (bivalve) Cardium edule. Animals were acclimated for three days then placed in sea water to which heavy metal solutions at a range of concentrations had been added and left for 48 hours. All studies were in the dark and temperature-regulated at 15°C. Four heavy metals were tested: mercury as $HgCl_2$, copper as $CuSO_4$, zinc as $ZnSO_4$ and nickel as $NiSO_4$.

Approx. 48 h TL-50 value - mg/l

	Mercury	Copper	Zinc	Nickel
Pink shrimp	0.1	0.2	10.0	200.0
Brown shrimp	∿6.0	∿30.0	∿100.0	∿150.0
Shore crab	∿1.0	∿100.0	∿12	∿300.0
Cockle	∿10.0	∿1.0	∿200.	∿500.0

Hg > Cu > Zn > Ni

This sequence follows the relative solubilities of four metals in sea water.

The effect of temperature on toxicity of Cu and Hg to brown shrimp and cockle was very pronounced. A reduction in temperature from 22° to 5°C was sufficient to increase the tolerance of brown shrimps to Cu and Hg by a factor of 5. With cockles, the effect was more pronounced, with increases in resistance of 80 for Cu and 130 for Hg.

Starving shrimp and cockles for two weeks prior to assay resulted in increased sensitivity to mercury for both species (Hg was only compound tested) by factors of approximately 2.

The age of brown shrimp is important in resistance to mercury. Larger (= older) shrimps were more resistant than smallest group by factor of about 2; it is possible to predict sensitivity of this species to Hg on basis of size.

422. Potts, W.T.W., M.A. Foster, P.P. Rudy, and G.P. Howells. 1967. Sodium and water balance in the cichlid teleost, Tilapia mossambica. J. Exp. Biol. 47:461-470.

The total body sodium increases from 10.6 mg/g fish in fresh water to 13.8 mg/g fish in 200% sea water. The rate of exchange of sodium increases from .046 mg/g/hr in fresh water to 13.8 mg/g/hr in 100% sea water. The rate of drinking increases from 0.26%/hr fresh water to 1.6%/hr in 400% sea water. Even in 200% sea water drinking accounts for only a quarter of the total sodium influx. The permeability to water, as measured by tritiated water, is highest in fresh water and lowest in 200% sea water. The permeabilities to water measured in this way are consistent with the drinking rates determined in sea water and 200% sea water.

423. Prasad, G. 1959. The toxicity of common salt to cyclops. Vijn. Parish Anusand, Patr. (Res. J. Hind. Sci. Acad.) 2:105-109. (English summary).

Experiments were made to determine the toxicity of sodium chloride in waste waters to Daphnia magna. A concentration of 0.83% sodium chloride killed 50% of the organisms in 24 hours at 25°C. The 72-hour TL_m at 25°C was 0.78% sodium chloride, but only 0.50% at a temperature of 50°C.

424. Preston, A. 1967. The concentration of zinc-65 in the flesh of oysters related to the discharge of cooling pond effluent from the C.E.G.B. nuclear power station at Bradwell-on-sea, Essex. Proc. Int. Symp. Radioecol. Concent. Process., 1966, Stockholm: 995-1004.

Before operation began at the Bradwell nuclear power station, Essex, the maximal permissible limits for discharge of waste waters from the fuel-element cooling ponds were calculated, using oyster flesh as the critical material and zinc-65 as the critical isotope. The radioactivity of the cooling-pond water is kept to acceptable levels by passing a small volume of the water regularly through ion-exchange columns; most of the zinc-65 activity is removed on a non-regenerable resin but the back-washing water from other regenerable resins is the principle source of zinc-65 discharge to the Blackwater estuary. The calculated maximal rate of discharge is compared with that based on subsequent operational data; and graphical and tabulated data are also given on the concentration of zinc in sea water and oyster flesh and the corresponding concentration factors in oyster flesh, including the variations with zinc concentration and with distance from the cooling-water outfall. Results support the view that radioactivity is transported to the oysters on particles associated with the water close to the sea bed. Since the power station began operation the concentrations of stable zinc in the estuarine water and in the oysters have also increased, but the increase is probably too small to have influenced the accumulation of zinc-65 by the oysters. The zinc content of oysters was related to their dry weight; oysters of good quality should have minimal zinc contents.

425. Price, T.J. 1965. Accumulation of radionuclides and the effects of radiation on molluscs. In Biological Problems in Water Pollution Third Seminar August 13-17, 1962. U.S. Public Health Service 999WP-25:202-210.

A report, with graphical results, is given of laboratory experiments on the accumulation and retention of cesium-137, cerium-144, zinc-65, and gold-199 by the hard clam, *Mercenaria mercenaria*, oyster, *Crassostrea virginica*, and bay scallop, *Aequipecten irradians*, and on the lethal effects of ionizing radiations on these organisms. All three organisms concentrated cesium-137 from the water. After 10 days scallops showed a concentration factor of 10 in muscle, with the concentration rate still increasing; visceral mass had a concentration factor of 8 but equilibrium with the medium was near. Clams showed a lower rate of accumulation with a concentration factor of 6 in the soft tissues after 20 days (the uptake of cesium-137 was still continuing). With oysters, the concentration of cesium was reaching equilibrium after 12 days with a concentration factor of only 5. Both uptake and subsequent biological elimination of the isotope show an initial rapid phase, attributed to the visceral mass, followed by a longer continuous uptake or loss attributed to the muscle tissue. In tests on biological elimination of cesium, the oysters retained 4% and the clams 12% of the activity after 28 days probably owing to the formation of chemical complexes within the tissues. Cerium-144

was made available to the organisms as particles in the medium or associated with known populations of Nitzschia closterium cells, and the experiments showed that accumulation of this isotope was affected by the physical (particulate) state. Uptake of cerium was slow and continuous for 10 days, after which it fluctuated, the maximum concentrations being reached after 20 days. Most of the activity was in the shell owing to surface adsorption, with less in the meats and still less in the liquid. The activity in the meats was possibly due to particles adhering to tissue surface and present in organs and structures connected with the digestive tract. Only a small percentage could be assimilated, since the particle size would limit absorption through the walls of the intestinal tract. The initial loss of cerium-144 from clams and scallops placed in rapidly-flowing sea water was rapid, and was followed by loss at a very reduced rate. After 195 days, clams retained 20% of the original cerium-144 while with scallops, after 35 days, the shells had lost 55% of the original activity, the muscle 62%, and the visceral mass 89%, and it appeared that any further loss of activity would be small. Molluscs have a higher zinc content than other invertebrate groups and are important in the transfer of zinc-65 through food chains to man; however, oysters concentrate zinc-65 to higher levels than clams. The uptake of gold-199 by both clams and separated shells was rapid for the first 14 days, after which it was much slower; live clams removed 3.6 times more gold-199 than the separated shells, apparently owing to absorption of the nuclide on body surfaces and to some contribution from metabolic processes. Clams which burrowed in montmorillonite clay on the bottom of the tank were prevented from absorbing gold-199 and after 23 days contained 38% less activity than the clams in the water.

426. Pringle, B.H., D.E. Hissong, E.L. Katz, and S.T. Mulawka. 1968. Trace metal accumulation by estuarine mollusks. J. Sanitary Engineer. Div. 94 SA3:455-475.

In view of the relative paucity of information on trace metal distribution in marine animals, a series of studies were initiated in order to investigate the mechanics of concentration of these materials. Data were obtained on a number of mollusk species. There is a wide variation in species ability to take up and concentrate zinc, lead, nickel, cobalt, iron, manganese, copper, cadmium, and chromium within their natural (estuarine) environment. Uptake rates in a controlled, simulated-environment system using various concentrations of lead, copper, cadmium, and zinc indicate that all of the species studied varied in their selectivity for the particular metal taken up. The rate of uptake, and the tissue level attained, were found to vary with time, and the particular metal concentration used. Using various lead concentrations it was observed that of the

various anatomical areas, the muscle, mantle edge, mantle, remainder, gill, gonad, and digestive gland accumulated increasing tissue levels in that order. Depletion is a relatively slow process in most cases; it varies from species to species as to rate and final tissue concentration. Species used were quahaug clam, Mercenaria mercenaria; soft shell clam, Mya arenaria; and the oysters Crassostrea gigas and C. virginica. Copper was especially toxic to Mya. Concentrations >0.02 mg/l were toxic over a continuous exposure of several weeks. Copper is selectively concentrated over zinc by Mya. Mya concentrates cadmium at a lower rate than do either copper or zinc under identical experimental conditions. Lead is also picked up and concentrated.

427. Pshenin, L.P. 1960. The accumulation of U-UX, by nitrogen-fixing microorganisms of the Black sea. C.R. Acad. Sci. U.R.S.S. 133:1448-1450; Nuclear Sci. Abstr. 15:1090-1091.

The ability of nitrogen-fixing bacteria and yeasts from the Black Sea to accumulate uranium from sea water was investigated. Yeasts were found to be more active than bacteria in taking up uranium.

428. Pulley, T.E. 1950. Effect of aluminum chloride in small concentrations on various marine organisms. Texas J. Sci. 2: 405-411.

Experiments were made on the effects of aluminum chloride in sea water on various marine organisms. Results showed that in concentrations of 44 mg/l aluminum chloride did not kill adult fish, shrimps, or oysters. At 88 mg/l young redfish died quickly and other species more slowly; 132 mg/l killed most fish in a few hours and all in a few days; 176 mg/l killed all test fish in a few hours. The solution of the salt in sea water was strongly acid, but by the action of natural buffering agents neutrality was restored in 1-2 days with concentrations up to 88 mg/l and in 3-5 days with concentrations of 132-176 mg/l. The importance of bacterial action as an agency in restoring neutrality is greater with high concentrations of aluminum chloride than with low. Oysters were found to be more resistant than fish to the action of aluminum chloride, for a few days at least. It is considered that the toxic effect of aluminum chloride was not the result of a decrease in pH value of the sea water.

429. Pyefinch, K.A. and J.C. Mott. 1948. The sensitivity of barnacles and their larvae to copper and mercury. J. Exp. Biol. 25:296-298.

Precipitation of copper from the medium occurred at concentrations of 6-7 mg Cu/l. Authors suggest that heavy metals penetrate tissues and act intracellulary as enzyme poisoners or protein precipitants. Authors observed a decrease in dissolved oxygen uptake of a marine amphipod following exposure to copper suggesting that Cu acts on respiratory enzymes. Dilute sea water markedly reduced the toxicity of copper and mercury to barnacle larvae. Hypertonic seawater also reduced toxicity of copper. TL_m values at 6 hours in mg Cu/l for Balanus balanoides and B. crenatus ranged from 0.23 to 0.46 for 5 and 6 hour larval stages.

430. Rachlin, J.W. and A. Perlmutter. 1968. Fish cells in culture for study of aquatic toxicants. Water Research 2:409-414.

The effect of zinc in various concentrations on tissue cultures of cells of the fathead minnow was compared with its effect on the intact animal as found by previous work. The cultures were exposed to concentrations of zinc representing the 96-hour TL_m (7.5 mg/l), one-tenth of TL_m (0.75 mg/l), ten times the TL_m (75 mg/l), and the calculated safe value (1.8 mg/l), all derived from the intact animal study. The cells were more sensitive than the whole animals, and the safe value of zinc concentration for the latter reduced the mitotic index of the cells to 50% of the control value, while the 75 mg/l concentration had no effect. It is concluded that safe concentrations based on toxicity studies of cell systems, and not the mature animal, should be used as starting levels for studying the effects of toxic substances on the test animal in various stages of its development.

431. Rachlin, J.W. and A. Perlmutter. 1968. Response of an inbred strain of platyfish and the fathead minnow to zinc. Prog. Fish-Cult. 30:203-207.

The toxicities of zinc to an inbred strain of platyfish (Xiphophorus maculatus) and the fathead minnow (Pimephales promelas) over concentration ranges of 10-100 mg/l and 1-10 mg/l respectively, were determined, under identical conditions of water quality and temperature (23°C). Concentrations fatal to 50% in 96 hours were 12.0 mg/l for platyfish and 7.6 mg/l for minnow; the latter exhibited a relatively high female threshold level of about 10 mg/l zinc.

432. Rachlin, J. and A. Perlmutter. 1969. Response of rainbow trout cells in culture to selected concentrations of zinc sulfate. Prog. Fish-Cult. 31:94-98.

The response of rainbow trout (Salmo gairdneri) gonadal cells in culture to various concentrations of zinc was studied. A

concentration of 18.0 mg/l zinc reduced the mitotic index of these cells by approximately 70%. Concentrations of zinc between 1.8 mg/l and 10.0 mg/l had no effect on the mitotic index of the cultures, whereas 32.0 mg/l zinc completely inhibited mitosis. The relation between these values and previously determined values for fathead minnow (Pimephales promelas) cells in culture is discussed.

433. Ray, P. and A. David. 1962. A case of fish mortality caused by precipitation of ferric iron in the river Daha at Siwan (North Bihar). Indian J. Fish., Sect. A 9:117-122.

The river Daha, Bihar, India, is polluted with waste waters from sugar refineries and distilleries, and in September 1959 a heavy fish mortality occurred in the river at a period when the distillery waste waters were being discharged into the river which was at its lowest summer flow. Investigations showed that the gills of the affected fish were covered with fine brown suspended matter, and the water also contained a brown suspended floc. It was concluded that the distillery waste waters, which had a high content of organic matter, while moving slowly in the river had dissolved iron salts from the bottom deposits, and further downstream the presence of bicarbonates had resulted in precipitation of ferric hydroxide which caused physical damage to the gills of the fish. In addition, the local villagers had entered the water to catch the distressed fish, thus stirring up the muddy bottom and causing a reduction in the dissolved oxygen concentrations and an increase in the carbon-dioxide concentration of the water.

434. Raymont, J.E.G. and J. Shields. 1963. Toxicity of copper and chromium in the marine environment. Int. J. Air Water Pollution 7:435-443.

Results are given of experiments on the toxicity of copper and chromium to certain marine animals. Most of the experiments were carried out on the polychaete worm, Nereis virens, but some tests were also made with the shore crab, Carcinus maenas, and small prawns, Leander squilla. Since the solubility of copper in sea water is low and most inorganic salts precipitate readily, most of the experiments on copper were carried out with copper sodium citrate; in the tests on chromium, sodium chromate was used. The results indicate that with Nereis a toxic threshold exists for copper at a level of about 0.1 ppm copper, but chromium is less poisonous, the toxic threshold approaching 10 times this value. The experiments with the crab Carcinus indicate that copper is at least 10 times, and possibly nearer 20 times, more toxic than chromium, and copper also appears to be more toxic than chromium for Leander. Carcinus was found to be much more resistant than Nereis to both copper and chromium. This is attributed to specific

differences in the physiology of the two animals, such as permeability of the gut and body wall, composition of the body tissues, and rates of excretion; size may also have some effect.

435. Reed, J.R. and D.J. Nelson. 1969. Radiostrontium uptake in blood and flesh in bluegills (Lepomis macrochirus). Proc. 2nd Nat. Symp. on Radioecology. U.S.A.E.C. Conf. 670503: 226-233.

The rapid initial uptake of radiostrontium by bluegill sunfish (L. macrochirus)was attributed to a quickly exchanged Sr pool in flesh and blood. Two percent of the Sr pool in blood consisted of a component having a biological half-life of two hours. Another 1% of the blood Sr exchanged in 35 days and 97% was contained in a component with a long, undetermined biological half-life. Strontium in blood contributed less than 0.09% to the Sr in flesh. At least three compartments of Sr metabolism were identified in flesh. One percent of the Sr in flesh was turned over with a biological half-life of about two hours while 9% was turned over with a half-life of nine days. The remaining 90% of Sr in flesh had a long but undetermined half-life.

Uptake of Sr in the quickly exchanged Sr pool was directly proportional to the Sr concentration in test solutions in the range from 0.3 to 300 mg/l Sr. At 3,000 and 30,000 mg/l Sr, bluegills took up more Sr than at the lower concentrations indicating to authors an inability to discriminate against Sr at abnormally high environmental concentrations.

436. Regnier, J.E. 1965. Zinc-65 uptake in a two-step marine food chain. Thesis, Univ. of Florida, Gainesville, Fla: 175 p. Dissertation Abstracts 1966, 27:B848.

To evaluate the validity of the maximal permissible concentration of zinc-65 in sea water, laboratory experiments were carried out using a two-step food chain comprising two species of microscopic marine algae (Nitzschia closterium and Carteria sp.) and a bottom-feeding fish, mullet, (Mugil sp.). It was found that the concentration factor for zinc-65 was slightly greater for Carteria than for Nitzschia, but the size of these factors appeared to be limited by the available zinc-65 rather than by species characteristics. Uptake of zinc-65 by mullet from the algae could be described by a mathematical model, and the apparent maximal concentrations were reached in 55-60 days; the maximal concentrations decreased with increasing size of fish. There was evidence that the mullet tended to discriminate against zinc-65. The differences in uptake of zinc-65 from the two algae were significant, but appeared to be due to variations

in the concentrations of zinc-65 and total zinc in the fish food rather than to differences in the mode of uptake from the two species of algae. It was concluded that mullet are useful indicators of contamination of marine environments with zinc-65. From the results of these experiments it appears that the maximal permissible concentration of zinc-65 in sea water could be five times greater than the currently value of 7×10^{-6} μc per ml, but further work on other marine food chains is required to confirm this.

437. Renfro, W.C. 1968. Radio-ecology of zinc-65 in an arm of the Columbia river estuary. Thesis, Oregon State University.

Results of a one year study of the concentrations of zinc-65 in water, bottom deposits, plants, and animals in Alder Slough, a small ecosystem in the Columbia River estuary, indicated temporary fluctuations in the activities of zinc-65 and in the concentrations of total zinc in all components of the ecosystem. There were also variations between individual fish. In general, individuals with high zinc-65 activities also had high total zinc concentrations. Following the shut-down of the nuclear reactors at Hanford for 45 days it was found that the rates of decrease in zinc-65 activity in several organisms varied with the trophic level of the organism and with changes in prevailing ecological conditions.

438. Renfro, W.C. and C. Osterberg. 1969. Radiozinc decline in starry flounders after temporary shutdown of Hanford reactors. Proc. 2nd Nat. Symp. on Radioecology. U.S.A.E.C. Conf. 670503:372-379.

Concentrations of ^{65}Zn and total Zn were measured in starry flounders collected periodically over a one-year period from Alder Slough, a small arm of the Columbia River estuary. The nuclear reactors of Hanford, Washington, which supply most of the ^{65}Zn in the river were shut down for 45 days during this period and, as a result, the input of radioactivity to the study area was greatly reduced and specific activity (^{65}Zn/g total Zn) in the flounders declined. The time required to reduce the ^{65}Zn specific activity by one-half under these conditions in which the flounders continued to obtain ^{65}Zn from their food web and water is termed "ecological half-life". The "ecological half-life" for ^{65}Zn in juvenile starry flounders was 139 days under the conditions prevailing in this study. The effective half-lifes of ^{65}Zn in three flounders held in the laboratory were 56, 91, and 162 days, depending on the initial concentration of ^{65}Zn in each test fish.

439. Rice, T.R., J.P. Baptist, and T.J. Price. 1965. Accumulation of mixed fission products by marine organisms. Proc. 2nd Int. Conf. Wat. Pollut. Res. Tokyo, 1964. 3:263-286.

Phytoplankton(Nitzschia) closterium and Carteria sp.), scallops (Aequipecten irradians), shrimps (Penaeus setiferus) and croaker (Micropogon undulatus) were exposed to sea water containing mixed fission products, including Ce^{144}/Pr^{144} and Sr^{90}/Y^{90}, and oysters were fed on Carteria cells grown in such water. Uptake and subsequent losses of β- and γ-activity were measured. Much of the β-activity became associated with phytoplankton cells by non-metabolic processes, probably adsorption and exchange. Carteria cells appeared to remove a greater percentage of cerium-144/praseodymium-144 than of other radioactive isotopes with weaker energies. There appeared to be a rapid uptake of isotopes of short half-life, with the uptake of isotopes with longer half-lives proceeding more slowly; it required about 144 hours for the cells to take up enough of the different isotopes to give a decay rate similar to that of the mixtures of isotopes initially present in the sea water. The radioactivity accumulated by phytoplankton was not lost readily; the individual isotopes accumulated were examined by ion exchange. In the feeding tests with oysters, the γ-activity reached a slightly higher concentration than the β-activity, giving a β:γ ratio similar to that in the Carteria cells, with about 0.3% of the available activity accumulated in the soft tissues. When the oysters were transferred to flowing sea water, there was a rapid initial loss of 76% of both β- and γ-activity, which was attributed to elimination of non-assimilated activity from the gastro-intestinal tract, but subsequent losses were small. In the scallop, more β-than γ- activity was accumulated, the uptake in each case decreased in the order visceral mass, shell, and muscle; concentration factors calculated for these tissues were, respectively, 35, 29, and 11 for β-activity and 26, 23, and 20 for γ-activity. In shrimps the ratio of β-:γ-activity was also changed as compared with the sea water; concentration factors for the head and viscera, muscle, and shell were, respectively, 3.5, 0.6, and 10.2 for β-activity and 7.7, 1.8, and 19.4 for γ-activity. In the croaker, concentration of fission products was greatest in the internal organs, reaching about 5 times the initial concentration in sea water, while muscle accumulated the least amount of radioactivity. The internal organs contained a β-emitter with energy corresponding to that of praseodymium-144 and accounting for about 26% of the activity. Bone contained an emitter with energy corresponding to yttrium-90 and accounting for 37 per cent of the total activity; this indicated that the parent strontium-90 was also present, and strontium-90/yttrium-90 would account for 74% of the total activity if the two isotopes were in equilibrium.

In the discussion that followed Ophel, I.L., emphasized the difficulties of interpreting the results of experiments on the accumulation of radionuclides and summarized experiments on the effects of

environmental factors on the accumulation of radioactive strontium by fish. Ophel's results showed that the rate of accumulation of strontium-90 was approximately doubled for each 10°C increase in temperature (within the tolerable range), and it was depressed by starvation or by the presence of magnesium or inactive strontium, but not by sodium or potassium; the course of the uptake in rapidly-growing fish differed from that in fish maintained at constant weight. It was shown that there is no constant concentration factor even for a single species of fish and one particular isotope, but that each concentration factor determined experimentally relates to those particular experimental conditions. The relation of the experimental concentration factors to the "true" concentration factor was discussed. Saiki, M. and Umezu, T., stressed that induced radioactive material, such as zinc-65 and iron-55 (rarely found in fission products) is also important in the radioactive contamination of marine organisms, as indicated by analytical data on fish caught in the Pacific Ocean where it is affected by nuclear tests. It was concluded that most of the colloidal and particulate matter consists of minute chlorophyll-free particles and the remainder of phytoplankton with only a small percentage of micro-organisms; and that the most effective accumulators of radionuclides in the ocean are the mucous, ciliary, and pseudopodial filtering zooplankton.

440. Rice, T.R. and V.M. Willis. 1959. Uptake, accumulation and loss of radioactive cerium-144 by marine planktonic algae. Limnol. Oceanogr. 4:277-290.

The uptake of radioactive cerium-144 by 6 species of marine planktonic algae was studied. In these experiments the cerium occurred mostly in the particulate state when added to sea water. Different species of algae concentrated the cerium from 300-3000 times over the amount in the medium within 30 min, and after 24 hours all 6 species tested had concentrated cerium from about 2000-4500 times. A culture of Nitzschia closterium containing dividing cells removed all the cerium-144 originally added to the medium. Non-dividing cells of Nitzschia kept in the dark continued to take up radioactive cerium for as long as 3 days. The amount of cerium taken up by cells of Nitzschia as the concentration of cerium in the medium was increased. Particulate cerium became associated with the cells more rapidly than did ionic cerium. The uptake of cerium by Nitzschia was reduced by the addition to the medium of a chelating compound. When radioactive cells of Nitzschia were resuspended in non-active medium, they lost about 25% of their contained cerium-144 in 5 hours. More cerium-144 was lost from cells resuspended in 4 successive portions of non-active medium than from cells remaining in the first portion. When the medium contained a chelating compound, a greater amount of cerium-144 was lost from the cells. The greatest loss of cerium-144 per unit of protoplasm in cells in nonactive medium was from "biological dilution" as a result of cell division; this loss amounted to one-half of the contained activity of the cells at each division.

441. Roberts, H. 1963. Cadmium toxic to rainbow trout. Prog. Fish-Cult. 25:216.

During testing of a closed-system plastic tank at Darran Springs Hatchery, Calif., the small cadmium-plated metal screen being used was found to be lethal to rainbow trout (Salmo gairdneri) under certain conditions. Small numbers of rainbow trout were placed in the tank and each group of fish died within 24 hours. Since the cadmium screen has been replaced, however, normal mortality has occurred in the tank. Cadmium-plated bolts are in common and extensive use today and the utmost caution should therefore be exercised in their use in construction of fish planting tanks and hatchery facilities.

442. Rodgers, E.O., B.H. Hazen, S.B. Friddle, and S.F. Sneiszko. 1951. The toxicity of pyridylmercuric acetate technical (PMA) to rainbow trout (Salmo gairdnerii). Progr. Fish-Cult. 13:71-73.

Experiments on the toxicity of pyridylmercuric acetate (PMA) to trout showed that PMA at a concentration of 10 mg/l was more toxic to rainbow trout fingerlings than to fingerlings of brown and brook trout and that its toxicity increased with increases in temperature of the water. Experiments using rainbow trout fingerlings of an average size of 60 mm showed that treatment with PMA reduced the appetite of the trout for almost a day, but regardless of the toxic effect of PMA, it is still considered to be a useful disinfectant in controlling gill diseases and external parasitic infestation.

443. Rosenthal, H.L. 1957. The metabolism of strontium-90 and calcium-45 by Lebistes. Biol. Bull. 113:442-450.

Experiments have shown that the uptake of strontium-90 by male guppies from the water in which they swim is linear with time for the total carcass and the tissues studied. Tissues containing high concentrations of calcium accumulate more strontium-90 than do soft tissues. The rate of turnover of the nuclide varied from very fast to very low according to the type of tissue; the whole body, head and spine retain strontium-90 for long periods, while viscera loses the isotope rapidly when the fish is transferred to fresh water. It was found that the uptake and turnover of strontium-90 and calcium-45 by male fish are qualitatively similar, but significant quantitative differences are apparent.

444. Rosenthal, H.L. 1957. Uptake of calcium-45 and strontium-90 from water by fresh-water fishes. Science 126:699-700.

Experiments using three species of freshwater fish: guppies, zebra fish, and white cloud mountain fish, have shown that these fish take up calcium-45 and strontium-90 from the water at similar rates, the uptake being directly proportional to the period of exposure. This is in contrast to the results of other workers using marine fish, which were found to discriminate against strontium in favor of calcium. It is suggested that the apparent lack of discrimination of strontium-90 by freshwater fish reflects differences between freshwater and marine fish in absorption of the isotope by the gills, skin and intestinal tract, rather than fundamental alterations in the metabolism of mineral elements of bone.

445. Rosenthal, H.L. 1963. Uptake, turnover, and transport of bone-seeking elements in fishes. Ann. N.Y. Acad. Sci. 109:278-293.

The rate of uptake of calcium-45, strontium-90 and sulphur-35 from water by the male guppy (Lebistes) is linear with time; similar results were obtained from uptake of calcium-45 and strontium-90 by white cloud mountain fish (Tanichthys and zebra fish (Danio) of both sexes. The rate of incorporation of the nuclides is also linear with time for various tissues of the body. The rate of uptake was found to be related to the concentration of the nuclides in the water at constant ionic concentration. A series of double tracer experiments, using calcium-45 and strontium-90, indicated that freshwater fish have little ability to discriminate between strontium and calcium when the isotopes are taken up from the surrounding water.

446. Rounsefell, G.A. and J.E. Evans. 1958. Large-scale experimental test of copper sulphate as a control for the Florida red tide. USFWS Spec. Sci. Rept-Fisheries No. 270: 57 p.

Large-scale experiments were carried out in 1957 on the use of copper sulphate for the control of red tide on the coast of Florida. The chemical was sprayed from the air at the rate of about 20 lb. per surface acre (22.5 kg per surface hectare). This treatment rapidly reduced the numbers of Gymnodinium breve from several million per liter to almost none, but in two out of five areas the numbers of organisms increased again after 10-14 days to concentrations lethal to fish. This method is not recommended for general control, but can be used to give temporary relief from the air-borne toxin in local situations.

447. Rucker, R.R. and W.J. Shipple. 1951. Effect of bactericides on steelhead trout fry. Prog. Fish-Cult. 13:43-44.

Experiments were made to control the growth of a fluorescent species of Pseudomonas which had infected yearling blueback salmon

(Oncorhynchus nerka). Neither Roccal nor malachite green would control the bacterium at concentrations tolerated by the fish, but pyridylmercuric acetate successfully controlled the pathogen when the fish were immersed for one hour in a solution containing 10 mg/l.

448. Rucker, R.R. and D.F. Amend. 1969. Absorption and retention of organic mercurials by rainbow trout and chinook and sockeye salmon. Prog. Fish-Cult. 31:197-201.

The Food and Drug Administration has established zero tolerance for mercury in foodstuffs because of its potential hazard to human health. This limit may be modified if further studies indicate permissible levels.

These experiments indicate that mercurials used as therapeutics and prophylactics for fish diseases can be absorbed and retained by fish for prolonged periods, and that legal-size wild fish may ingest enough mercury-contaminated fingerlings to accumulate relatively high levels of mercury. Therefore, legal-size hatchery fish treated with mercurials or wild fish that have eaten mercury-contaminated fingerlings may be a public health hazard.

449. Rudakov, N.I. 1961. Accumulation, distribution, and exchange of calcium-45, strontium-90, cerium-144, and cesium-137 in fish and methods of marking fish fry. Izv. gosud. nauchno-issled. Ozern. Rechn. Ryb. Khoz. 51:165-254. Nuclear Science Abstracts 1965. 19:4462.

Experiments with five species of fish (Cyprinus carpio, Carassius carassius, Salmo salar, Salmo irideus, and Coregonus autumnalis migratorius) show that young fish can accumulate considerable amounts of radioactive isotopes from radioactive and stable isotopes in solution. Calcium-45 and strontium-90 accumulate first in organs and tissues in contact with the solution (gills, scales, fins, and skin), and more slowly in the bones, internal organs, and muscles, but after 15 days both isotopes are almost entirely localized in bone tissue. Cerium-144 and cesium-137 do not accumulate in the gills to the same extent, but enter the blood rapidly; cerium is then concentrated in the liver and bony elements, while cesium is distributed throughout all the organs and tissues. Owing to exchange processes, however, the radioactivity of all the organs and tissues decreases more rapidly than would occur by natural decay alone.

450. Ruf, M. 1965. Radioactivity in freshwater fish. Zentbl. Vet. Med. 12:605-612. Nuclear Science Abstracts 1967. 21:51.

In view of increasing contamination of surface waters with artificially produced radioactivity, it is important to assess degree of contamination of freshwater fish which could be eaten by man. It was found that total beta-activity in muscle (mostly due to potassium-40) ranged from 2 to 3.7 pc per g of freshweight for cyprinid fish and from 2.7 to 3.8 pc per g for salmonids. Most the gamma activity found in fish muscle consisted of potassium-40, cesium-137 and barium-133; the activity due to cesium-137 amounted to about 3150 pc per kg. Cyprinid fish muscle contained 1-12 pc of strontium-90 per kg, but higher concentrations were found in bones. There was also evidence of the presence of strontium-89. The degree of uptake of the various isotopes depended on several factors that could not be predicted. In addition to intake with food, absorption of radioactive strontium through the body surface appeared to be important.

451. Salo, E.O. and W.L. Leet. 1969. The concentration of zinc-65 by oysters maintained in the discharge canal of a nuclear power plant. Proc. 2nd Natn. Symp. Radioecol., Ann Arbor, 1967: 363-371.

Cooling water and low-level radioactive waste waters from Humboldt Bay Nuclear Power Plant, near Eureka, Calif., are discharged into a short canal leading into Humboldt Bay. Pacific oysters, Crassostrea gigas, were reared for periods up to 13 months on trays suspended on a raft in the discharge canal (the canal bed is not suitable for oysters owing to heavy siltation) and the uptake of zinc-65 (which is the dominant radionuclide in the discharge from the standpoint of biological concentration) was studied by removing oyster samples as fresh groups were added. The monthly average concentration of zinc-65 in the canal waters ranged from 0.104×10^{-2} to 1.963×10^{-2} pc per ml, and changes in the concentration in the water were reflected in changes in the concentration in the oysters; it is therefore concluded that oysters maintained on rafts can be used as long-term indicators for zinc-65. The concentration of zinc-65 in oysters reached 175 pc per g after exposure for 13 months; concentration factors ranged from 5.6×10^3 to 1.2×10^4 for the 1962 brood and from 8.6×10^3 to 1.1×10^4 for the 1964 brood. As regards public health, the maximal body burden that could be derived from eating the oysters is well within the maximal permissible concentration, and considerable dilution of the discharge occurs before it enters Humboldt Bay.

452. Sanborn, N.H. 1945. The lethal effect of certain chemicals on fresh-water fish. Science 101:13.

Studies are described of the toxicity of chemicals for treating waste waters from canneries to goldfish (Carassius auratus) 50-75 mm long, to large-mouth bass (Micropterus salmoides) 75-100 mm and to bluegill

sunfish (Lepomis macrochirus) 40 to 65 mm in length. Tests were made with water which had a pH value of 7.2 to 7.6 and a total hardness of 64 to 80 mg/l, of which 28 to 36 mg/l were non-carbonate hardness. In one series of experiments a solution of the chemical being tested was introduced continuously into the bottom of the tank containing the fish at a rate which maintained a solution of constant composition in the tank, as judged by the pH value. Two fish of each species were used in each tank which was continued for 7 days. All 3 species survived in water containing 50 mg/l sodium hydroxide but died within 2 to 5 hours in water containing 100 mg/l sodium hydroxide. Goldfish survived in water containing 500 mg/l sodium carbonate but bass died within 7 to 9 hours and sunfish within 4.5 to 11 hours. Sunfish withstood 100 mg/l ferrous sulphate ($FeSO_4 \cdot 7H_2O$) but bass died within 4 to 7 days and sunfish within 2.5 to 3.5 days; bass and sunfish survived in water containing 50 mg/l ferrous sulphate; ferrous sulphate was precipitated as ferric hydroxide and death appeared to be due to accumulation of ferric hydroxide on the gills. All 3 species survived water containing 100 mg/l aluminum sulphate ($Al_2(SO_4)_3 \cdot 18H_2O$). Neither species of fish was able to withstand 250 mg/l of aluminum sulphate. The concentrations of lime, ferrous sulphate, and aluminum sulphate discharged in waste waters from canneries are small. In one sample obtained from a cannery treated with 68 kg of lime and 34 kg of ferrous sulphate, the concentration was equivalent to 7 mg/l ferrous sulphate. The concentration of sodium nitrate in waste waters from canneries is less than 1,000 mg/l and this sodium nitrate is normally decomposed in lagoons before the waste waters are discharged to streams. Sodium carbonate is sometimes used to reduce the acidity of waste waters which are to be treated in percolating filters; the concentrations of sodium carbonate in effluent from the filters is small.

453. Sather, B.T. 1967. Chromium absorption and metabolism by the crab, Podophthalmus vigil. Proc. Int. Symp. Radioecol. Concent. Process, 1966, Stockholm: 943-976.

Literature on the toxicity of chromium to freshwater and marine organisms is reviewed (a bibliography of 54 references is appended), and experiments are reported on the accumulation and metabolism of chromium in the portunid crab Podophthalmus vigil. After exposure to sea water containing 1 μc/l of chromium-51, as chromic chloride, for 16 days, the radioactivity in the tissues was highest in gills, then muscle, mid-gut gland, carapace, and blood in that order. Gills and muscle reached equilibrium in 2-3 days but the mid-gut and haemolymph required 4-5 days. After 16 days the crabs had removed 90% of the radioactivity from the medium (which had contained 936 times the amount found in natural sea water). When the crabs were subsequently transferred to non-radioactive sea water, the medium and the blood were not enriched with chromium-51 but the gills lost chromium probably owing to transportation to other tissues. After

intrapericardial injection of 5.3 μc of chromium 51 and exposure to non-radioactive sea water, the radioactivity of the medium did not increase but radioactivity was transported and deposited in the gills. When the injection was accompanied by an equal dose of iron-59, all the tissues discriminated against the iron, but the iron also affected the metabolism of chromium; with injection of both elements the gills and other tissues lost radioactivity, both as chromium and iron, and the medium became enriched with both elements. Incubation of gills with chromium-51, with or without addition of potassium cyanide, to inhibit phosphorylation, and Diamox (acetazolamide), to inhibit carbonic anhydrase, showed that the control gills could regulate the amount of chromium absorbed (the regulatory mechanism was much better for hexavalent chromium than for the trivalent form), and that this regulation tended to be dependent on oxidative phosphorylation and partially dependent on the zinc containing carbonic anhydrase. Iso-electric precipitation and electrophoresis of blood showed that most of the radioactivity of the blood was probably in the saline portion of the haemolymph.

454. Saunders, R.L. and J.B. Sprague. 1967. Effects of copper-zinc mining pollution on a spawning migration of Atlantic salmon. Water Research 1:419-432.

Studies on the effects of pollution by copper and zinc in the Northwest Miramichi River, N.B., have included observations in the avoidance reactions of migrating Atlantic salmon (Salmo salar). Results, showed that metal concentrations of less than half the lethal threshold value caused a considerable reduction in the number of salmon reaching the spawning grounds above the polluted zone and a marked increase in the number returning downstream without spawning.

455. Saurov, M.M. 1957. Radioactive contamination of fish in waters containing strontium. Trud. Vses. Konf. Med. Radiol., Vopr. Gig. Dozimetr., 66-73; Chem. Abstr. 52:16657.

Experiments were carried out on the uptake of radioactive strontium by four species of fish kept in water containing different concentrations of strontium-90. It was found that considerable amounts of strontium-90 were taken up over prolonged periods, and there was a direct relationship between the concentration of strontium-90 in the tissues, the activity of the water, and the period of exposure. The uptake of strontium was inversely proportional to the concentration of calcium in the water. Greater amounts of strontium were accumulated in the scales and bones than in the muscles and internal organs. Maximum permissible concentrations for radioactive strontium in open water reservoirs was established.

456. Sautet, J., H. Olliver, and J. Quicke. 1964. Contribution to the study of the biological fixation and elimination of arsenic by Mytilus edulis. Second Note. Annls. Méd. lég. Crimin. Police scient. 44:466-471.

Tabulated and graphical results are given of experiments on the uptake of arsenic by mussels. It was found that neither the flesh nor the shells retained more than traces of arsenic (4-10 μg and 0.5-2 μg respectively) when exposed to a dose of 100 g/l of arsenic; these concentrations are much less than the toxic concentration for humans (100 mg). By contrast, the byssus accumulated 250-500 μg, and the excreta contained 550-800 μg in an insoluble organic form.

457. Schelske, C.L. 1965. Ecological implications of fallout radioactivity accumulated by molluscs. Paper presented at 131st Annual meeting of Amer. Assn. for Adv. Sci., Montreal: 21 p. Nuclear Science Abstracts 1965. 19:5444.

To obtain data for future comparisons of radioactivity in estuarine organisms, measurements were made of gamma-emitting isotopes in four species of molluscs collected near Beaufort, N.C. It was found that both clams (Mercenaria mercenaria) and marsh mussels (Modiolus demissus) contained relatively large amounts of cerium-144 and ruthenium-106 and were, therefore, suitable as biological indicators of these isotopes. Oysters (Crassostrea virginica) also accumulated these isotopes, but were more suitable as biological indicators for zinc-65. The gamma-activity of scallops (Aequipecten irradians) was greater than that of the other molluscs, and these organisms were found to be indicators of manganese-54. The differences in the isotopes taken up by the different organisms are attributed to selective feeding and it is suggested that the distribution of environmental radioactivity in marine organisms may be used to distinguish ecological niches among organisms with similar feeding mechanisms.

458. Schiffman, R.H. 1961. The uptake of strontium from diet and water by rainbow trout. U.S. Atom. Ener. Comm. HW-72107: 12 p.

The results of experiments on the uptake of radioactive strontium from food and water by trout are discussed. In three weeks the concentration of strontium-90 in the fish approached about 1.5 times the concentration in the surrounding water. When the isotope was administered in gelatine capsules about 21% of the isotope was retained, but retention was only about 7% when the isotope was incorporated into natural food. Under the conditions of the experiments, uptake from the water was greater than uptake through the food chain.

459. Schiffman, R.H. 1965. Strontium-calcium transport across the gill of rainbow trout (Salmo gairdnerii). J. Cell. Comp. Physiol. 65:1-5.

It was found that there can be two rates of uptake for strontium, a passive rate and a higher energy-dependent rate; the passive uptake of strontium is not affected by the presence of calcium, but calcium in concentrations greater than 4 mg/l does inhibit uptake of strontium by the energy-dependent system.

460. Schiffman, R.H. and P.O. Fromm. 1959. Chromium-induced changes in the blood of rainbow trout, Salmo gairdnerii. Sewage Industr. Wastes, 31:205-211.

Experiments were made on the effect of exposure to high sublethal levels of chromium on the physiology of the blood of rainbow trout. The percentages of red blood cells (hematocrits) on both splenectomized and intact fish exposed to 20 mg/l of chromium were significantly higher than for control fish in clean tap water. Exposure of fish to concentrations as low as 2-4 mg/l was found to raise the hematocrit to its maximum value. The presence of the spleen was found to have no effect on the rise in hematocrit under chromium stress. The potential influence of the potassium ion in the potassium dichromate on the experimental results is discussed.

461. Schmitz, W., W. Besch, and I. Kneissl. 1967. Salinity tolerance of Gammarus pulex pulex, Gammarus tigrinus, and Asellus aquaticus depending on the relative concentrations of the sodium, magnesium, potassium, and calcium cations. Int. Revue ges. Hydrobiol. 52:589-616.

Using the 24-hour and 48-hour TL_m values as criteria of salt tolerance, experiments were carried out with Gammarus pulex, G. tigrinus, and Asellus aquaticus exposed to various solutions of mixed salts covering a wide range of variations in the concentrations of potassium and calcium, and also in the ratio of the ionic concentrations of sodium and magnesium. The survival of the test species depended principally on their cyto-osmotically-determined tolerance to the concentration of total salts, even when the relative concentrations of ions differed from those in sea water; but variations in relative ionic concentrations modified the salt tolerance, generally in the same direction for all three species. Increases in the ratio of magnesium:sodium decreased the salt tolerance, with an optimal tolerance at the ionic proportions in sea water; the tolerance was also decreased slightly when all the magnesium ions were replaced by sodium. In solutions of mixed salts, the tolerance decreased considerably with increasing concentrations of potassium above a certain level (195-390 mg/l for Asellus and Gammarus pulex, but higher for G. tigrinus), and the tolerance increased

with increasing concentrations of calcium up to 20 mg/l for Asellus and G. pulex and up to 400 mg/l for G. tigrinus. Observations on the distribution of the test species in the rivers Werra, Weser, and Innerste corresponded with the results of the experiments.

462. Schmitz, W. and K. Müller. 1949. Death of fish in the Werra. Jber. Limnol. Prussia. Freudenthal:3-10.

The authors describe an investigation of serious destruction of fish which occurred in the river Werra, Germany, in July 1949. The content of salt in the Werra is high because of the discharge of waste waters from the potash industry; the concentration of chloride varies during the year from several hundred to more than 1,000 mg/l and is highest in late summer and autumn. The alterations caused in the population of streams by variations in content of salt are discussed. Mass development of plankton occurred in the Werra in July 1949; the dominant organism was Thalassiosira fluviatilis. As a result the water became hypersaturated with oxygen and the pH value increased to about 10. No observations were made at night but it is possible that absorption of oxygen during respiration led to an oxygen deficiency, arrested development of the algae which decomposed and caused further pollution. The factors important in the destruction of fish were the increase in pH value and the decrease in oxygen. Experiments on the effect of gradually increasing the pH value of water showed that the increase observed in the Werra was sufficient to kill or damage the more sensitive types of fish. Damage was done to the fish, causing difficulty in respiration and even if the fish were not killed they were more sensitive to lack of oxygen.

463. Schofield, C.L. 1965. Water quality in relation to survival of brook trout, Salvelinus fontinalis (Micthill). Trans. Amer. Fish. Soc. 94:227-235.

Studies on the survival of groups of test fish in Honnedaga lake, New York, have shown that there is a relation between survival of brook trout and water quality. Heavy mortality of trout from a hard-water and a soft-water hatchery coincided with periods of high acidity and high concentrations of heavy metals in the lake water during the summer, but trout from another hard-water hatchery, where the water supply contained traces of zinc, survived transfer to the lake. Water from 30 other lakes in the Adirondack mountains was analysed for comparison, but none showed a similar combination of a very low salinity, high acidity and relatively high concentration of metals.

464. Schott, W. 1951. Sensitivity of trout to zinc. Dtsch. Lebinsmittrdsch. 48:62-63.

Trout kept in fish tanks died when the water supply contained 0.15 mg/l of zinc. Zinc in toxic concentrations was dissolved from newly galvanized pipes when the concentration of free carbon dioxide in the water increased to 16.5 mg/l.

465. Schreiber, B. 1963. Acantharia as "scavengers" for strontium and their role in the sedimentation of radioactive debris. In Nuclear detonations and marine radioactivity. The report of a symposium held at the Norwegian Defense Research Establishment, 16-20 September 1963: 113-126.

The marine planktonic protozoan Acantharia has an absolute and specific capacity for absorbing strontium from the medium and can presumably accumulate radioactive strontium from fallout and radioactive wastes. Since pure cultures of Acantharia could not be obtained for experimental purposes, the author is carrying out experiments on the concentration factor for strontium-90 in total marine plankton, using plankton from the Tyrrhenian sea which contains 10-20% of Acantharia and plankton from the Adriatic which contains almost no Acantharia. Preliminary results indicate that the concentration factor is about 5 times greater for plankton samples containing Acantharia.

466. Schreiber, B. 1967. Radionuclides in marine plankton and in coastal sediments. Proc. Int. Symp. Radioecol. Concent. Process., 1966, Stockholm: 753-770.

Studies are reported, with detailed tabulated and graphical results, on the uptake of fallout radio-isotopes by marine plankton in the Ligurian-Tyrrhenian and upper Adriatic seas. In addition to analyses of plankton and sea water, to permit determination of concentration factors, cuttlebone samples were also analysed, using this animal, equally present in both seas, as a "biological comparator". While cuttle-fish shows slow fixation of natural strontium contaminated by strontium-90 and averages the specific activity all over its bone, without exceeding the average temporal value of the environment, plankton is submitted more rapidly to fallout contamination and much higher values of strontium-90 can be found in plankton than in the surrounding sea water. Comparison of concentration factors confirms that in the plankton of the Tyrrhenian sea there is a component, Acantharia, capable of selective concentration of both natural strontium and its radio-isotopes. Other radionuclides were also determined and from May 1961 to September 1963 significant increases were recorded for the plankton and in the concentrations of strontium-90-yttrium-90, cerium-144-praseodymium-144, and zirconium-95-niobium-95; and other

fallout nuclides (antimony-125, promethium-147, europium-155, and manganese-54) and the natural nuclides radium-226 and potassium-40 were identified in ash from plankton caught in the Ligurian-Tyrrhenian sea in the period of maximal contamination, summer 1963. Radionuclides are also being studied in coastal sediments of the Ligurian sea; further results are given for 1965, and the data are discussed as regards the fate of individual fallout nuclides, and their vertical movements in oceanic waters. The distribution of beta activity along the depth of the sediment cores were also examined and interpreted in relation to the recent deposition of radionuclides and the residual radioactivity of previous depositions of fallout. On the basis of the results, a method is formulated for evaluating the rate of sedimentation on the basis of the "absolute age" of the different layers of the sediments.

467. Schurr, J.M. and M.N. Starnper. 1962. Model for the accumulation of strontium and calcium by recently moulted crayfish (Cambarus longulus longerorostus Ort.). Limnol. Ocean. 7: 474-477.

The effect of crayfish in concentrating radioactive strontium may be important in waters contaminated with radioactivity, particularly as crayfish lose major reserves of elements such as calcium and strontium by moulting of the exoskeleton. Crayfish which had recently moulted were placed in water containing calcium and strontium tagged with strontium-85. The initial absorption of strontium-85 was rapid, but the rates of uptake decreased exponentially as an upper limit was reached. A simple mathematical model was developed which attributes this limit to the number of sites available for deposition in the exoskeleton. Deposited ions are relatively immobile until 2-4 days before the next moult when some are redistributed to the calcareous gastroliths prior to re-use. There is therefore a striking structural fluctuation in the strontium burden of contaminated crayfish.

468. Schweiger, G. 1957. The toxic action of heavy metals salts on fish and organisms on which fish feed. Arch. Fischereiwiss. 8:54-78.

The author describes and gives the results of investigations into the toxicity of mercury, cadmium, nickel, cobalt, and manganese salts to one- and two-year-old tench, carp, rainbow trout, and char, and to crustacea, worms, and insect larvae forming the food of fish. The results show that concentrations of 0.2 mg of mercury, 0.03 mg of cadmium, 1 mg of cobalt, or 15 mg of manganese per liter were not harmful to any of the fish or animals tested. The toxic action in 7-day experiments was that of acute poisoning and was similar in its effects on all the animals. Fish showed symptoms of slow suffocation and

paralysis and the food organisms showed signs of increasing exhaustion and paralysis. After a considerable period of difficulty in respiration, fish did not recover in fresh water. Examination of skin and gills showed that suffocation was caused by deposition of dead cell matter on the gills and surface of the body; cells were loosened from the gill epithelium and from the body surface. Chemical analysis and spectrographic examination showed the presence of the metals in the slime and deposited cells covering the body and accumulation of manganese and cadmium in the organs. Injection of much larger amounts than were found in poisoned fish showed that the toxic action was due to the destruction of the gill epithelium causing respiration difficulty and final suffocation.

469. Serbanescu, O. and P. Jitaru. 1965. On phosphorus-32 uptake in the body of some Black Sea fishes. Anal. stiint. Univ. Al. 1. Cuza, Sect. II A, 11(1):7-12; Nuclear Science Abstracts 1967, 21:4083.

In experiments on the uptake of phosphorus-32 by fish from the Black Sea (Gobius cephalarges and Sprattus sprattus phalericus), some of the fish were kept in aquaria containing sea water with added radioactive sodium phosphate, while other fish received intramusclar injections of phosphorus-32. Preliminary results indicate the uptake of phosphorus-32 from sea water is affected by the natural environmental conditions of the fish.

470. Serfaty, A. and R. Labat. 1960. Cardiac irregularities and sudden changes in salinity in the case of marine teleostean fish. Hydrobiologia 15:293-308.

An electrocardiographic technique was used to study the effects of sudden changes in salinity on the cardiac rhythm of mullets and sea bream. Sudden changes from sea water to fresh water caused a number of distinct changes in the electrocardiograms. The first stage involved tachycardia, and at the same time an accumulation of carbon dioxide in the blood. In the second stage tachycardia was gradually reduced and bradycardia occurred accompanied by a significant diminution in the amplitude and frequency of diaphragm movement. In the final stages, severe abnormalities occurred in the electrocardiogram, and diaphragm movements ceased, after which death followed rapidly. Death occurred about 1½ hours after exposure to fresh water with sea bream (Cantharus cantharus), a stenohaline species, and 4 or 9½ hours after exposure in the case of the more euryhaline mullets, Mugil auratus and Mugil capito, respectively. Consideration was given to the relation between the electrocardiograph abnormalities and the osmotic regulation and anoxaemia.

471. Seymour, A.H. 1959. The distribution of radioisotopes among marine organisms in the western central Pacific. Pubbl. Staz. Zool. Napoli 31, Suppl.:25-33.

In the western central Pacific Ocean, cerium-144 was the only long-lived fission product found in significant amounts in marine organisms. Of the induced radioactive isotopes, iron-55 and -59, zinc-65, cobalt-57, -58, and -60, and manganese-54 contributed up to 100% of the radioactivity in marine animals but almost none of the activity in algae. Zinc-65 was the isotope found most often in ocean fish, and iron-55 in reef fish. Plankton had greater amounts of cobalt-60 and less iron-55 than fish. The distribution of radioactive isotopes in terrestrial plants and animals from the same geographical area differed greatly from the distribution in marine organisms.

472. Shabalina, A.A. 1964. The effect of cobalt on the growth of young carp and filamentous green algae. Izv. gosud. nauchno-issled. Inst. Ozerm rechn. ryb, Khoz. 57:290-294. Biological Abstracts, 1966. 47:6901.

A three-month experiment on growth of young carp in static water containing 0.05, 0.5, and 5 mg of cobalt chloride per liter showed that initially the growth of the test fish was slower than that of control fish, but towards the end of the first month the weight gain of the test fish equalled that of the controls; the initial lag period increased with increasing concentration of cobalt. Cobalt was also observed to inhibit growth of Spirogyra, Oedogonium, and Volvox, and a concentration of 5 mg/l suppressed growth of Saprolegnia.

473. Shabalina, A.A. 1968. Effects of cobalt chloride on physiological indices in rainbow trout (Salmo irideus gibbons). Problems of Ichthyology (Voprosy Ikhtiologii) Amer. Fish. Soc. 8:741-747.

Cobalt chloride was added to the diet of young and two-year old rainbow trout. The tolerance of the young trout to increased water temperatures was not affected, but the tolerance of the two-year olds was increased by 1.6°C. Hemoglobin content of the blood was unchanged. The distribution of body fat was changed. In toxic doses cobalt produced gastro-intestinal hemorrhages in both groups of fish.

474. Shekhanova, I.A. and V.L. Pechkurenkov. 1968. Accumulation of strontium-90 and yttrium-90, dissolved in the water and its effect on the embryonic development of loach. Problems of Ichthyology (Voprosy Ikhtiologii) Amer. Fish. Soc. 8:551-561.

The dynamics of accumulation of loach (fish) eggs differed for strontium and yttrium-90. There are grounds for believing that yttrium-90 accumulates mainly on the surface of the egg membrane, whereas from 1/3-1/4 of the accumulated strontium-90 passes through the membrane into the embryo. The accumulation of strontium-90 and yttrium-90 by loach eggs proceeded differently in solutions with different activities. The coefficients of accumulation in solutions with activities of 1.75×10^{-6} and 1.5×10^{-8} Ci/liter were of the same order, while those for the 3.11×10^{-10} Ci/liter solution were an order higher. The radiation dose, calculated very approximately from the graphs for the disintegration energy of accumulated strontium-90 and yttrium-90, was several orders less than the X-ray dosage which increases the incidence of malformations among larvae.

475. Shuster, C.N., Jr. and B.H. Pringle. 1969. Trace metal accumulation by the American oyster, Crassostrea virginica. 1968 Proc. Nat. Shellfish. Assoc. 59:91-103.

A 20-week study was conducted early in 1968 to corroborate an earlier experiment on uptake by Crassostrea virginica. About 200 November-harvested oysters were placed in each of eighteen 120-liter tanks making use of a flow-through sea water system. During the acclimation and experimental periods the sea water was maintained at a flow rate of 2.5 l/min and a 20 $\pm$ 1°C temperature with salinity variable but usually 30 $\pm$ 2 o/oo. Beginning in January, the oysters were subjected to continuous levels of the nitrate salts of zinc (0.1 and 0.2 mg/l),copper (0.025 and 0.05 mg/l),cadmium (0.1 and 0.2 mg/l)and chromium (0.05 and 0.1 mg/l). Each week oysters were removed for analyses.

Information was obtained on trace metal accumulation rates, on mortalities, shell growth and on the general appearance of the oysters. The most obvious effects were observed in the copper- and the cadmium-exposed oysters. The bodies of the oysters exposed to copper became bluish-green in color and their shells showed excellent growth, mantle edge pigmentation increased and mortalities were slightly higher than in the controls. Cadmium-exposed specimens were emaciated, showed very little shell growth, lost pigmentation of the mantle edge and coloration of the digestive diverticulae and suffered high mortalities. Noteworthy is the observation that mortality of cadmium-subjected (0.2 mg/l)osyters commenced between the 4th and 8th week of exposure and was essentially complete (100%) between the 13th and 17th week.

476. Sigler, W.F. 1966. Some effects of accumulated radium on the productivity of algae. Final progress report U.S. Atom. Ener. Comm. TID-22322: 31 p. Nuclear Science Abstracts 1966 20:4.

Laboratory experiments on the effect of accumulation of radium on the productivity of benthic algae (Vaucheria and Cladophora) from Logan

river, Utah, showed that the accumulated radium had some effect on the algae, but it was not possible to distinguish between radiation and chemical effects. The amount of radium accumulated depended on the algal genus, the concentration of radium in the medium and the period of exposure.

477. Skauen, D.M. 1963. Radioactive zinc-65 in marine organisms in Fisher's Island Sound and its estuaries. Final Report December 1, 1959 through November 30, 1963. U.S. Atomic Energy Comm. TID-19922:52 p.

Results are given of studies on the concentrations of total zinc and zinc-65 in marine organisms from the Thames river, New Haven harbor and the Pawcatuck River, Conn., in 1961, 1962, and 1963. The methods developed for determining trace amounts of zinc, zinc-65, copper and cadmium in marine organisms and sediments are described. Particular attention was paid to the uptake of zinc-65 by oysters (Crassostrea virginica) and limpets (Acmoea t. testudinalis) under natural and laboratory conditions. The effects of environmental factors such as current velocity, temperature, salinity, turbidity and dissolved-oxygen concentration on uptake of zinc-65 were investigated.

478. Skauen, D.M. 1964. The effects of tritium oxide on aquatic organisms. U.S. Atom. Ener. Comm. NYO-3039-1: 18 p. Nuclear Science Abstracts 1965, 19:4-5.

When guppies were kept in tritiated water, no toxic effects were observed; some fish lived in the tritiated water for 10 months and no long-term effects caused by build-up of tritium in the fish were apparent, nor were there any genetic changes in the third generation of fish living in tritiated water. It appeared that the amount of tritium in the fish reached equilibrium with that in the surrounding water. About 90% of the tritium in the fish was in the body water and only 10% was actually incorporated in the body tissues. It is thought that the turn-over of tritium in the fish may have been rapid. Fish living for the longest period in tritiated water contained less tritium than fish in some of the other experiments; in this case, the amount of tritium in the water was lower as a result of evaporation losses over a prolonged period.

479. Skidmore, J.F. 1964. Toxicity of zinc compounds to aquatic animals, with special reference to fish. Quarterly Rev. Biology 29:227-248.

The toxicity of zinc compounds to aquatic animals is modified by several environmental factors: hardness, D.O., and temperature.

Resistance of aquatic animals to zinc varies with species. It is modified by acclimatization and possibly age. Survival time is inversely proportional to concentration of zinc. For these reasons concentrations reported as lethal vary widely. The author feels the action of zinc differs at different concentrations, and with age at development. A bibliography of 75 references is included.

480. Skidmore, J.F. 1965. Resistance of zinc sulfate to the zebra fish (Brachydanio rerio Hamilton-Buchanan) at different phases of its life history. Annals of Applied Biology 56: 47-53.

Eleven age groups of zebra fish were exposed to four concentrations of $ZnSO_4$, (5, 10, 20 and 40 mg/l) in soft water ($CaCO_3$ 10 mg/l) at 25°C. In all Zn concentrations newly-laid eggs survived longest. Survival decreased with age until hatching on fourth day. Fish 4-13 days old had short survival; 40-day-old fish, and adults (100 days old) survived slightly longer in highest concentrations. Many adults survived indefinitely. Threshold concentration of Zn was approximately 10 mg/l for adults and 1.3 mg/l for 40-day-old fish.

481. Skidmore, J.F. 1967. Oxygen uptake by zebra fish (Brachydanio rerio) of different ages in relation to zinc sulphate resistance. J. Fish. Res. Bd. Can. 24:1253-1267.

The routine rates of oxygen uptake in tap water of zebra fish of 11 age groups were measured using a Warburg constant-volume respirometer, and comparison of the rates of uptake per dry weight of fish with the survival periods for zebra fish of similar age groups exposed to zinc sulphate in a previous experiment showed a curvilinear relation between rate of uptake and the reciprocal of survival period. However, on dividing survival periods into minimal survival periods independent of uptake rate, and reaction periods, a rectilinear relation between rate of oxygen uptake and the reciprocal of reaction period was found for a minimal survival period of 1.3 hours. Disregarding data for fish aged less than 5 days, survival periods for a given concentration of zinc were related to the dry weights of the fish.

482. Skidmore, J.F. 1970. Respiration and osmoregulation in rainbow trout, with gills damaged by zinc sulphate. J. Exp. Biol. 52:481-494.

Damage to the gill epithelium occurs when hatched fish are killed rapidly by solutions of zinc sulphate. The rate of routine

oxygen uptake by lightly sedated rainbow trout did not alter on exposure to a rapidly toxic solution of zinc sulphate. However, oxygen utilization decreased seven-fold, gill ventilation volume increased six-fold, heart rate was halved, "coughing rate" increased 18-fold and the PO_2 of dorsal aortic blood declined. Unsedated trout usually struggled on exposure to zinc. The survival time of struggling fish was reduced and oxygen uptake increased, but other physiological changes were similar to those in quiet fish. The respiratory changes in poisoned trout were generally similar to changes observed earlier in the same fish under hypoxia. The osmotic concentration and the blood were largely unaffected by immobilization in zinc sulphate solution. Trout survived a four-fold increase in zinc concentration in the blood by injection. The results suggest that epithelial damage decreased the permeability of the gills to oxygen, and did not increase their permeability to cations. Zinc was not a rapid internal poison. Death was probably caused by tissue hypoxia, when maximum gill ventilation was no longer sufficient to supply the oxygen needs of the fish.

483. Slowey, J.F., D. Hayes, B. Dixon, and D.W. Hood. 1965. Distribution of gamma-emitting radionuclides in the Gulf of Mexico. Occ. Publs. Narragansett Marine Lab., Univ. of Rhode Island, Kingston, R.I. 3:109-129.

Results are given of preliminary studies on distribution of some gamma-emitting isotopes in the Gulf of Mexico. Manganese-54, which is produced from neutron activation of iron, was found in all samples of water examined and its concentration factor in algae was higher than that of other isotopes. Particulate matter contained higher concentrations of manganese-54 than of stable manganese-55, suggesting that the chemical form in which manganese-54 reaches the sea is different from that of stable manganese; it is probable that some of the manganese-54 enters as manganese dioxide which is relatively insoluble in sea water and would tend to form a colloid or precipitate out as particulate matter. The studies also showed that 50% of zirconium-95-niobium-95, 66% of ruthenium-106, and 33% of cerium-144 occur in the soluble (including collodial) form even 18 months after the last nuclear test. Antimony-125 was found for the first time in surface sea water, the concentration being higher near the shore than in the open Gulf, but it was not found in organisms or in particulate matter; it is thought that antimony may be washed down from land surfaces and concentrated in the surface waters of the ocean.

484. Smith, M.W. 1939. Copper sulphate and rotenone as fish poisons. Trans. Amer. Fish. Soc. 69:141.

Experiments on the destruction of fish in lakes in Nova Scotia preparatory to stocking with trout are described. The toxicity of copper sulphate to fish varies with the species, the temperature and hardness of the water, and the content of organic matter. A concentration of 3 mg/l copper sulphate proved effective for killing fish, though some eels (Anguilla rostrata) and some killifish (Fundulus diaphanus) survived. Most of the plankton and bottom fauna were destroyed, but higher plants such as Nymphaea, Juncus, etc. were not affected. The algal populations were almost entirely destroyed. It was about a year before plankton and aquatic insect larvae and nymphs repopulated the lakes; molluscs did not reappear. Much of the copper is apparently removed from solution in acid waters by combination with organic matter. A considerable quantity of copper remains in the water for some time but much of it probably combined and is not in a toxic ionic form. In experiments on the toxicity of rotenone, derris and cube powders containing 5% rotenone killed yearling trout in a concentration of 0.2 mg/l at 5° and 20°C. When applied to a small acid lake 0.25 mg/l of derris containing 5% rotenone killed most fish, though a few eels, lake chubs, and sticklebacks survived. Storage of derris and cube powders in dry conditions for three years did not affect their toxicity. The toxic action of rotenone increased with increasing temperature. Concentrations of rotenone sufficient to kill fish destroyed crustacea and may have affected some amphipods, but other forms of plant and animal life appeared to be unaffected under natural conditions. Caddis larvae were killed by prolonged exposure to 0.5 and 1.0 mg/l derris under experimental conditions. After a small lake had been treated with 1.33 mg/l derris the water remained toxic to fish for about 1 month.

485. Soyer, J. 1963. Contribution to the study of the biological effects of mercury and silver in sea water. Vie et Milieu 14 (1):1-36.

Analyses have shown that low concentrations (0.15 μg/l) of silver are present in the surface waters of the Mediterranean. Experiments on the effects of silver on the development of Echinoid larvae showed that low concentrations, similar to those found in sea water, are much more toxic than corresponding concentrations of other heavy metals such as copper, zinc and mercury. However, the sensitivity of different species to silver varied considerably. Copper and silver appeared to act synergistically when both were present. The importance of the effect of heavy metals in bottom deposits on the benthic fauna is considered. It is possible that silver also affects the development of plankton.

486. Sparling, A.B. 1968. Interactions between blue-green algae and heavy metals. Thesis, Washington University: 168 p. Diss. Abstr. 1969, 29B: 2921-2922.

Laboratory studies on the effect of certain heavy metals (copper, zinc, cadmium, and nickel) in concentrations of 0.5-10 mg/l on four genera of blue-green algae showed that low concentrations of some metals stimulated growth, and serious growth inhibition occurred only at concentrations higher than those usually used in algal control programs. Each of the metals was adsorbed to a significant extent by at least one species of alga, and in most cases where high levels of adsorption occurred high growth inhibition was noted. The adsorption of metals was too low to be of value in the treatment of industrial waste waters, but was high enough to affect the overall metal balance in natural waters, and it is pointed out that the application of heavy metals such as copper sulphate may actually stimulate predominance of blue-green algae over more desirable forms.

487. Sprague, J.B. 1962. Effects of sublethal concentrations of zinc and copper on migration of Atlantic salmon. U.S. Pub. Health Serv., Publ. No. 999-WP-25: 332-333.

By using a counting fence in the Northwest Miramichi River a consistant correlation was established between salmon movements and the combined effects of Zn and Cu pollution and H_2O hardness. Migration behavior was affected by concentrations of Zn and Cu below incipient lethal levels. The toxicity indexes (actual concentration of Zn or Cu as a fraction of the incipient lethal concentration) were combined to give a single index. An index value of approximately 0.15 is the maximum safe level of Zn and Cu for the undisturbed migration of salmon.

488. Sprague, J.B. 1964. Avoidance of copper-zinc solutions by young salmon in the laboratory. J. Water Poll. Cont. Feder. 36:990-1004.

Laboratory tests have been made on the avoidance reactions of Atlantic salmon parr to copper and zinc sulphates. The apparatus used consisted of a plastic trough with water flowing into each end and draining from the center; successively higher concentrations of copper or zinc sulphate, or both, were produced periodically in randomly chosen halves of the trough. Strength of avoidance was measured by the relative length of periods spent by the fish in ordinary and modified water, and by determining whether individual 'visits' in the metal solutions were significantly shorter than those in ordinary water. Threshold concentrations at which avoidance occurred were estimated to be 2.3 μg of copper and 53 μg/l of zinc; for a mixture, the threshold concentrations were 0.42 μg/l of copper plus 6.1 μg/l of zinc. Expressed as fractions of the incipient level these avoidance thresholds correspond to 0.052 incipient lethal level for copper, 0.092 for zinc, and 0.021 for mixtures. However, the soft laboratory water used had a

natural metal content of 2 μg copper and 3 μg zinc, so the actual avoidance thresholds were slightly higher than these values. When both metals were present, they exerted a slight synergistic effect in causing avoidance. It was also found that when fish were retested immediately, they did not avoid a significantly lower concentration of zinc in the second test. It is pointed out that although these experiments show the minimum concentrations of copper and zinc which young salmon avoid, in nature higher concentrations might be tolerated without showing an avoidance response, since the fish would be holding territories and pollution might extend over a large section of water, giving the fish little choice of unpolluted water.

489. Sprague, J.B. 1964. Lethal concentrations of copper and zinc for young Atlantic salmon. J. Fish. Res. Bd. Canada 21: 17-26.

The toxicity of copper and zinc was tested using young Atlantic salmon in soft water. When metal concentrations were plotted against resistance times on logarithmic paper, a straight-line relation was demonstrated, but a sharp break indicated the incipient lethal level (approximately 48 μg/l for copper and 600 μg/l for zinc), below which the fish could survive indefinitely. Mixtures of copper and zinc were twice as toxic as would be expected if the effects were additive. Resistance times for zinc increased between pH 7.9 and 9.3, probably owing to the decreased solubility of zinc; it is thought that only dissolved zinc is toxic and suspended zinc is without effect. The incipient lethal level was considerably raised in tests on zinc carried out at 5°C.

490. Sprague, J.B. 1968. Avoidance reactions of rainbow trout to zinc sulphate solutions. Water Research 2:367-372.

Rainbow trout (Salmo gairdneri Richardson) showed strong avoidance reactions to sublethal concentrations of zinc sulphate. The threshold avoidance level was 5.6 μg/l of zinc added to laboratory water. This is only 0.01 of the lethal threshold concentration. There were no significant differences in threshold avoidance levels at 9.5° and 18°C, nor when background of zinc in the water was increased during acclimation and/or testing, from 3 μg/l to 13 μg/l.

491. Sprague, J.B. and D.E. Drury. 1969. Avoidance reactions of salmonid fishes to representative pollutants. Proc. 4th Int. Conf. Water Pollut. Res., Prague: 169-179 and 181-186.

Studies are reported on the avoidance response of rainbow trout and Atlantic salmon to alkylbenzene sulfonate (ABS) (in a commercial detergent), phenol, chlorine, and effluents from kraft pulp mills and their bleacheries. Results, given graphically, are discussed individually for each pollutant and compared with those for zinc sulphate on the basis of "toxic units" (that is fractions of the lethal threshold concentration). There were, however, no common patterns of reaction and no common relations between the lethal level and the avoidance response. For ABS, trout showed a threshold avoidance level of 0.37 mg/l but at an almost lethal concentration of 10 mg/l the fish were confused and unable to show avoidance. Phenol was not avoided at any concentration from 0.001 mg/l which is almost lethal. Chlorine was avoided in concentrations of 0.01 mg/l, lethal in 12 days, and 1.0 mg/l, rapidly lethal, but an intermediate lethal concentration of 0.1 mg/l was preferred by the fish. Salmon showed strong avoidance of kraft mill effluents at a lethal concentration of 56% and moderate avoidance at concentrations from 10% dose to 10 mg/l, with no avoidance below this level. Similar avoidance response to both types of kraft mill effluent suggests that the response depends on products of the kraft cooking process rather than the bleaching process. Only zinc sulphate produced a sharp and consistent avoidance reaction at sub-lethal concentrations. The results are discussed in relation to field situations.

492. Sprague, J.B., P.F. Elson, and R.L. Saunders. 1965. Sub-lethal copper-zinc pollution in a salmon river -- a field and laboratory study. Int. J. Air Water Pollut. 9:531-543.

The authors summarize laboratory and field studies on the effect of copper and zinc pollution of the Northwest Miramichi River, N.B. on salmon. Observations on the river have shown that each year young salmon populations are severely depressed downstream from the entry of the polluted tributary; this is attributed to a combination of two factors: the low numbers of eggs brought in by adults, and the poor survival to underyearlings and parr. Lethal or near-lethal periods of pollution have occurred most years, while young salmon must live successfully in the river for three successive years. The invertebrate fauna in the river also show evidence of pollution, and their sensitivity to copper and zinc has been used as an index of the degree of pollution.

493. Sprague, J.B., P.F. Elson, and R.L. Saunders. 1965. Sublethal copper-zinc pollution in a salmon river -- a field and laboratory study. 2nd International Conference on Water Pollution Research, Tokyo, 1964. 1:61-82 and 99-102.

A summary of studies on the effect of copper-zinc pollution on salmon was given. Similar studies on aquatic macro-invertebrates

suggest that mayflies, which are approximately equal to salmon in their sensitivity to copper-zinc pollution, could be used to monitor the severity of such pollution, but caddisflies and certain midges are at least 1.5 times more resistant than mayflies and salmon.

In discussion that followed, it was noted that copper and zinc caused a green color in oysters (the minimal concentration of copper causing this phenomenon was concluded to be about 20 μg/l); that self-purification was inhibited by concentrations exceeding 0.05 m/gl cuprous copper and 0.05 mg/l zinc, and nitrification was inhibited by 1.0 mg/l cuprous copper and 5.6 mg/l zinc. The lethal levels were found to be 250 mg/l copper and 200 mg/l zinc for Escherichia coli, 0.04 mg/l copper and 12.0 mg/l zinc for Daphnia and 0.15 mg/l copper and 15 mg/l zinc for minnows. The benthic fauna was almost completely destroyed when concentrations of 0.03 mg/l cuprous copper and 1.1 mg/l zinc were present at the same time. Also, when copper and zinc (or cadmium) were present together the lethal effect on salmon, trout, and roach was increased fivefold, but other heavy metal salts showed only an additive lethal effect. It was concluded that the maximal permissible concentration of cuprous copper in streams ranges between 0.1 mg/l and 0.25 mg/l at a temperature of 10°C; in stagnant waters, a concentration of 0.03 mg/l cuprous copper may cause damage. The maximal permissible concentration of zinc depends on the hardness of the water, but for fish in water of average hardness it is 3-4 mg/l; lower organisms are less sensitive and many insect larvae, including Diptera, can tolerate zinc in concentrations up to 60 mg/l. Tests with Daphnia showed that the simultaneous presence of copper, zinc, and nickel salts does not necessarily increase the lethal effect, but is partly compensatory. Tables are included summarizing the results of this work and also the data (including some not widely known) obtained by previous workers on the toxic concentrations of copper and zinc for fish and other aquatic organisms.

494. Sprague, J.B. and B.A. Ramsey. 1965. Lethal levels of mixed copper-zinc solutions for juvenile salmon. J. Fish. Res. Bd. Canada 22:425-432.

Observations are reported on the threshold or incipient lethal levels of mixtures of copper and zinc (as their sulphates). With salmon in very soft water (total hardness 14 mg/l) the incipient lethal levels were 32 μg/l for copper and 420 μg/l for zinc. The concentration of the toxic substance was expressed in "toxic units" by calculating the chemical concentration as a proportion of the incipient lethal level and assigning a value of one toxic unit to the incipient lethal level. Experiments showed that the incipient lethal level of a mixture was reached when the sum of the toxic units for the individual metals reached unity, confirming that the effects of copper and zinc are additive. When the concentrations

of the metals were plotted as toxic units the resistance times of young salmon were almost identical when the fish were exposed to lethal concentrations of copper and zinc separately, but lethal concentrations of mixtures of these two metals acted two or three times more rapidly than the individual metals.

495. Sprague, J.B. and R.L. Saunders. 1963. Avoidance of sub-lethal mining pollution by Atlantic salmon. Proc. 10th Ontario Ind. Waste Conf.: 221-236.

Studies were carried out on the effects of copper-zinc pollution on the movement of salmon in the Northwest Miramichi river. Results were compared with data obtained in laboratory studies, and confirm that Atlantic salmon can detect copper and zinc at very low concentrations, of less than 10% of the incipient lethal levels. The two metals are at least additive in their effects on fish, and there may be a synergistic effect under some circumstances. The degree of pollution by copper and zinc, as regards their effects on fish, can be expressed as a single number which can be easily calculated. The migration of Atlantic salmon may be disturbed if the copper-zinc pollution exceeds 35-45% of the incipient lethal level.

496. Sreenivasan, A. and R.S. Raj. 1963. Toxicity of zinc to fish. Curr. Sci. 32:363.

As effluents from the manufacture of viscose rayon contain zinc sulphate, experiments were carried out to determine the effect of zinc salts on fish, using as test animals the Bangkok and Ooty strains of Cyprinus carpio, Tilapia mossambica, and Danio sp. For the Bangkok strain of Cyprinus, in water of pH 7.0-7.2, with a methyl-orange alkalinity of 46 mg/l, temperature of 28°-30°C, and a dissolved oxygen concentration of 8.8 mg/l, the 48-hour lethal concentration (LC_{100}) of zinc sulphate was 12-15 mg/l, and the TL_m was 10-12 mg/l. For Danio sp., the TL_m of zinc sulphate was 10 mg/l. Addition of 200 mg/l calcium chloride reduced the toxicity of zinc sulphate considerably, but 200 mg/l zinc sulphate had no toxic effect on the Ooty strain of Cyprinus. At pH 5.0 a 60% mortality occurred, and similar effects were observed with the Bangkok strain. In experiments with zinc chloride, the TL_m for Tilapia was 10-15 mg/l and the LC_{100} was 20-22 mg/l when the pH value of the water was 7.1-7.5, the alkalinity 33.6-48.8 mg/l, temperature 25.8°-28.5°C, and the dissolved-oyxgen concentration of 5.6-8.2 mg/l. Calcium carbonate in concentrations of 100-200 mg/l did not reduce the toxicity of zinc chloride to Tilapia, but 200 ppm calcium chloride reduced the toxicity by 75%. An increase in dissolved-oxygen concentration to 12.5 mg/l also reduced the mortality due to zinc chloride by 60%.

497. Starr, T.J. and M.E. Jones. 1957. The effect of copper on the growth of bacteria isolated from marine environments. Limnol. Oceanogr. 2:33-36.

The use of copper may be practical to prevent heavy fish mortalities associated with blooms of Gymnodinium brevis. However this type of control requires some knowledge of the effect that relatively high concentrations of copper may have on the marine community as a whole. Experiments were therefore made on the effect of copper on 145 marine bacteria. All the bacteria grew in a medium containing copper in concentrations of 0.25 mg/l. This concentration was compared with the in vivo (0.2 mg/l) and in vitro (0.1 mg/l) lethal doses of copper for Gymnodinium brevis. In addition, the growth of about 4% of the bacteria was stimulated by this concentration of copper, probably because of increased pigment production.

498. Strogonov, A.A. and E.P. Lisachenko. 1969. Accumulation of caesium-137 in hyponeuston of the Black sea. Radiobiologiya 9:604-607. Biol. Abstr., 1970, 51:2314.

It was found that there were marked seasonal variations in the coefficients of accumulation and concentration of cesium-137 by hyponeuston from the Black Sea. The greatest accumulation coefficients (up to 2000) were observed in samples containing a large amount of organic detritus and with a predominance of planktohyponeuston. Comparison of the coefficients for stable and ratioactive cesium showed that there is complete exchange between the two isotopes in the sea water and in the hyponeuston.

499. Stubbings, H.G. 1959. Abnormal development of the basis in Balanus amphitrite var. stutsburi Darwin. Nature 183: 1282.

Scalloped bases were developed when barnacles attached to a toxic metal surface, such as copper sheathing on ships. There were large amounts of copper salts in the deformed shells.

500. Stundl, K. 1955. The effects of waste waters from the iron industry and mining on Styrian waters. Öst. Wasserw. 7: 75-82.

The rivers Mur and Mürz and their tributaries in Styria are heavily polluted with industrial waste waters, with most of the industrial plants of the district situated in the valleys of these rivers. The author deals with two types of waste waters, those from the iron industry and those from mining. Figures are given for the

suspended matter and iron added to a tributary of the Mur by foundry waste waters. The most damaging constituent is fine slag which does not settle in the settling pits and whose sharp grains cause damage in the turbines of power works down-stream. Where suspended matter settles in the stream, the banks and bed are rendered almost sterile. Pickling waste waters also render the stream more or less sterile and at low flow may cause death of fish; this is due less to the acidity than to precipitation of iron hydroxide on eggs and gills of fish. Phenol in gas works waste waters may also cause death of fish; evaporation of such waste waters is practised in some works. The iron industry has increased rapidly in the valley of the Mürz. The effect of deposition of iron on the fauna of various tributaries is described and an account is given of biological and chemical examination of the water of the Mürz in 1953. With the stoppage of industry after the war the streams rapidly regained their natural condition and the subsequent deterioration was slower than the recovery. Methods of treatment of pickling waste waters are briefly described. Waste waters from mining also play a large part in the pollution. Waste waters from treatment of iron ore have a high content of suspended matter and cause turbidity over long stretches. Sedimentation before discharge would remove a large proportion of this matter. The effect of coal mining waste waters, especially coal washing water with its high content of suspended matter, on some of the streams is described.

501. Summerfelt, T.C. and W.M. Lewis. 1967. Repulsion of green sunfish by certain chemicals. J. Wat. Poll. Cont. Fed. 39:2030-2038.

The repelling ability of 40 different chemicals for fish was studied. The green sunfish was used as test fish because it is not a schooling species. Five fish were used for each trial. Most of the chemicals were screened at a concentration of 20 mg/l. Of the 40 chemicals screened, 32 failed to repel test fish at the concentrations used; among these was lead nitrate at test concentrations of 10, 20 and 40 mg/l, but it was avoided by fish.

502. Surber, E.W. 1959. Cricotopus bicinctus, a midge fly resistant to electroplating wastes. Trans. Amer. Fish Soc. 88:111-116.

In polluted stretches of Michigan rivers, larvae of the midge fly Cricotopus bicinctus have been found to be resistant to plating waste waters containing hexavalent chromium, cyanide and copper, and to low concentrations of oxygen. This insect survived in the Clinton River, and matured in the presence of concentrations of 25 mg/l chromium, 2.2 mg/l copper, and 3.2 mg/l cyanide. In streams receiving such plating wastes, the only other common bottom

invertebrates were the annelids, Limnodrilus and Tubifex, and a midge tentatively identified as a species of Pentapedilum.

503. Swift, E. and W.R. Taylor. 1960. Uptake and release of calcium-45 by Fucus vesiculosus. Biol. Bull. 119:342. Abstract of paper presented at a meeting of the Marine Biological Laboratory, Woods Hole, Mass., August-September, 1960.

Experiments were conducted on uptake of calcium-45 by whole young thalli of Fucus vesiculosus incubated in sea water at 22°C and under constant illumination. The algae took up radio-calcium rapidly, most of the uptake occurring in the first hour. The isotope did not appear to be concentrated, as the amount of isotope taken up was of the order of magnitude that would be expected if the radio-calcium in the sea water came into equilibrium with the calcium in the algae. Subsequently the algae were transferred to sea water to which no isotope had been added, and 90% of the radio-calcium was released from the algae in the first two hours. These results indicate that there is a rapid turnover of calcium by Fucus vesiculosus.

504. Syazuki, K. 1964. Studies on the toxic effects of industrial wastes on fish and shellfish. J. Schimonoseki Coll. Fish. 13:157-211.

Laboratory experiments have been carried out on the effects of various pollutants on marine fish (goby, crescent perch, and gray mullet) and shellfish kept in running water in a gradient tank, which is described. It was found that lethal concentrations were lower under these conditions than in static water. With the exception of phenol and potassium cyanide, the "avoidance concentrations" for the test fish were lower than the toxic concentrations. Over the temperature range 10°-26°C the relation between oxygen consumption and temperature was linear, but above 27°C oxygen consumption increased markedly and became unstable. When the concentrations of dissolved oxygen exceeded 6 ppm the rate of uptake of oxygen was constant, but increased with decrease in oxygen concentration to about 2 mg/l, below which the rate of oxygen uptake fell sharply. With the goby the rate of oxygen uptake decreased in the presence of certain concentrations of pollutants but increased again rapidly when the fish were transferred to clean water; exposure to pollutants also reduced the appetite of the goby. With shellfish the rate of oxygen uptake increased linearly with increase in water temperature from 12° to 26°C but decreased at a temperature of 30°C; oxygen uptake was reduced in diluted sea water and increased again when the shellfish were transferred to full-strength sea water. In the presence of pollutants the shellfish either closed their shells or else the rate of oxygen uptake became abnormal, decreasing in the presence of sulphuric acid, sodium

hydroxide, copper sulphate and zinc sulphate, and increasing in the presence of potassium cyanide, sodium sulphide, and phenol.

505. Sylvester, R.O., R.T. Oglesby, D.A. Carlson, and R.F. Christman. 1967. Factors involved in the location and operation of an aluminum reduction plant. Proc. 22nd Ind. Waste Conf. Purdue Univ., Engng. Extn. Ser. No/29:441-454.

Before and after the aluminum ore processing plant of Intalco Aluminum Corporation on the coast of Washington began operation, a study was made of conditions in Georgia Strait to which the waste waters are discharged. The sources and general characteristics of the waste waters were determined. It was found that strong tidal currents occur in the area, usually flowing parallel to the shore. The waste waters had a relatively high content of non-filterable solids and a high fluoride content; the size of the suspended particles varied considerably so that some samples of the waste waters showed significant sedimentation in sea water while the settling characteristics of other samples were poor. The simulated effluent was not found to be toxic to indigenous marine organisms in the concentrations anticipated in the vicinity of the outfall.

506. Tabata, K. 1969. Studies on the toxicity of heavy metals to aquatic animals and the factors to decrease the toxicity -- I. On the formation and the toxicity of precipitate of heavy metals. Bull. Tokai Fish. Res. Lab., Tokyo, No. 58:203-214. (In Japanese with English abstract).

Some experiments were done with regard to solubility of Zn^{2+} added to environmental water, the factors controlling it, and the toxicity of fine precipitates of heavy metals. If heavy metals precipitate in environmental water, they will not harm aquatic animals. However, Zn precipitate in sea water was toxic to Mytilus edulis. While metals were toxic in solution, the amount of CO_3^{2-} or OH^-, in the water affected the toxicity significantly. Dissolved Sn^{4+}, Cr^{3+}, Al^{3+}, and Fe^{3+} were not acutely toxic to aquatic animals within the pH range shown in water quality criteria.

507. Tabata, K. 1969. Studies on the toxicity of heavy metals to aquatic animals and the factors to decrease the toxicity -- II. The antagonistic action of hardness components in water on the toxicity of heavy metal ions. Bull. Tokai Fish. Res. Lab., Tokyo, No. 58:215-232. (In Japanese with English abstract).

The TL_m of metal ions increased almost 2.8 ± 0.6 fold when hardness in water increased eight fold by addition of $CaCl_2$ and $MgSO_4$.

This applies to Zn^{2+}, Cu^{2+}, Ni^{2+}, Co^{2+}, or Cd^{2+} as heavy metal ions, with Japanese killifish, carp, rainbow trout or daphnia as test animals and more than 24 hours test duration. The toxicity of Hg^{2+} or Cu^{2+} was not affected by hardness. The toxicity of heavy metal ions was affected slightly by sodium ions.

508. Tabata, K. 1969. Studies on the toxicity of heavy metals to aquatic animals and the factors to decrease the toxicity -- IV. On the relation between the toxicity of heavy metals and the quality of environmental water. Bull. Tokai Fish. Res. Lab., No. 58:243-253. (In Japanese with English abstract).

The 24 hr TL_m of Zn^{2+} to daphnia in water samples collected from 8 freshwater areas was determined. It was found that there is generally a relationship between the toxicity of heavy metals and water quality. The difference in the toxicity of heavy metal ions in various freshwater areas of the world was calculated on the basis of this relationship. The toxicity of heavy metal ions exhibited in the average quality of Japanese freshwater increased about 2.5 fold in comparison with that in North America. Fifty important rivers and lakes in Japan were classified into 6 groups according to hardness, and the difference in the toxicity of heavy metal ions among these groups was estimated.

509. Tabata, K. and K. Nishikawa. 1969. Studies on the toxicity of heavy metals to aquatic animals and the factors to decrease the toxicity -- V. A trial to decrease the toxicity of heavy metal ions by the addition of complexing agents. Bull. Tokai Fish. Res. Lab., Tokyo, No. 58:255-264. (In Japanese with English abstract).

Investigation was made to determine whether the counteraction of complexing agents on the toxicity of heavy metal ions could be applied to decrease the toxicity of industrial wastes. The addition of sodium citrate or EDTA to copper mine waste, and sodium thiosulfate to mercury pesticide resulted in reduction of toxicity. Cu-EDTA complex was more stable against bacterial decomposition than was Cu-citrate. Cu complexed with thiosulfate or citrate accumulated in the body of aquatic animals, while Cu complexed with EDTA accumulated only slightly. Such removal of toxicity might be suited to the secondary purification of industrial wastes in which a small quantity ot toxic heavy metals remained after customary purification. A disadvantage of EDTA as a complexing agent is its high cost. The addition of EDTA to waste in which a small quantity of Cu^{2+} remained might be effective for the prevention of green color in oyster.

510. Tagatz, M.E. 1961. Tolerance of striped bass and American shad to changes of temperature and salinity. USFWS Spec. Sci. Rept. 388: 8 p.

Abrupt transfer was made between fresh and salt water of different temperatures on adult and juvenile shad and bass. Gradual changes were also made. Temperatures ranged from 7 to 27°C and salinity from 0 o/oo to 35 o/oo. Adult bass were tolerant to abrupt changes between salt and fresh water at differences in temperature between 7 and 27°C. Juvenile bass survived abrupt transfers between salt and fresh in 13 to 21°C range but were not tolerant to transfers from fresh water at these temperatures to salt water of 7°C. Adult shad survived abrupt changes from fresh to salt water up to 9°C difference in temperature. They displayed some tolerance to abrupt transfers from salt to fresh water up to 5.5°C difference, but showed no tolerance at a 14°C temperature change. Juvenile shad survived abrupt changes from salt to fresh water at temperature differences over the range 7 to 21°C. They were not tolerant to abrupt changes from fresh to salt water at temperature differences over the 7 to 21°C range. In transfers conducted within fresh water, juvenile bass mortality occurred only in changes from water of 21°C or 13°C to water of 7°C. Juvenile shad mortality occurred in all tests where temperature decrease was more than 3.9°C. However, mortality was less in tests conducted within fresh water than in tests conducted from fresh to salt water over identical temperature differences, for both species. No mortality of either species (juveniles) resulted from fresh water transfers at an increase in temperature over the 7 to 21°C range. Juvenile bass and shad were able to acclimate under certain conditions to gradual changes in temperature or salinity over most ranges not tolerated in abrupt transfers.

511. Tagatz, M.E. 1969. Some relations of temperature acclimation and salinity to thermal tolerance of the blue crab, *Callinectes sapidus*. Trans. Amer. Fish. Soc. 98:713-716.

Crabs were less tolerant to temperature extremes at low salinity, and at both low (6.8 o/oo) and high (34 o/oo) salinities the upper and lower tolerance limits increased as the acclimation temperature increased. Limits for adults and juveniles were similar.

512. Tarzwell, C.M. and C. Henderson. 1960. Toxicity of less common metals to fishes. Industr. Wastes 5:12.

Data are tabulated showing the toxicity of fish to several of the less common metals, expressed as the 96-hour TL_m value. Beryllium was found to be the most toxic of the less common metals studied, having a 96-hour TL_m value as low as 0.2 mg/l in very soft water;

uranium was also relatively toxic with a 96-hour TL_m value of about 3 mg/l in soft water; and the TL_m values of the other less common metals tested ranged from 5-15 mg/l. For all these metals, the TL_m values in hard water were 10-100 times greater than those obtained on soft water, this lower toxicity probably being due to a lower solubility. It has been found that the toxicity to fish of many trade waste waters depends largely on the pH value, alkalinity, and hardness of the receiving water, and preliminary studies have indicated that a useful graphical relationship can be established satisfactorily for some materials.

513. Taylor, W.R. and E.P. Odum. 1960. Uptake of iron-59 by marine benthic algae. Biol. Bull. 119:343. Abstract of paper presented at a meeting of the Marine Biological Laboratory, Woods Hole, Mass., August-September, 1960.

Preliminary experiments have been made on the uptake of iron-59 from sea water by marine benthic algae. The isotope was taken up rapidly by Ceramium rubrum and Enteromorpha intestinalis, and there was little loss of the isotope when the algae were removed from the radioactive medium and placed in fresh sea water. The concentration factor was estimated roughly to be 100-300. To prevent adsorption of the isotope in the walls of the container, the chelating agent ethylenediaminetetra-acetic acid was added to the medium; in experiments lasting 3-4 hours both the amount and rate of uptake were less in the presence of EDTA. In an experiment with Fucus it was found that the radioactivity in the medium decreased at a rate less than that in a blank containing no algae, it is suggested that Fucus may release a chelating substance into the medium.

514. Telitchenko, M.M. 1961. Accumulation of radioactive isotopes of strontium and yttrium by mirror carp. Rybn. Khozy. 5: 40-43.

Results are given of studies on the uptake of radioactive strontium-yttrium by various tissues and organs of mirror carp. The isotopes were found to accumulate in tissues, such as bones and scales, which contain a large amount of calcium. Since the muscles and intermuscular bones are used as food, the radioactivity of the edible portion of the fish is considerably increased. Saturation of the organs and tissues with strontium-yttrium occurs after about three months if the contamination of the water does not exceed the natural strontium concentration of fresh water (0.1 mg/l); at this time the radioactivity of the carp meat approaches the activity of the surrounding medium.

515. Templeton, W.L. 1965. Ecological aspects of the disposal of radioactive wastes to the sea. In Ecology and the Industrial Society. A symposium of the British Ecological Society, Swansea, 13-16, April 1964: 65-97.

From the literature, the author reviews various aspects of marine disposal of radioactive wastes, with reference to the various sources of radioactivity in sea water, behavior of radionuclides in the sea, uptake of radionuclides by marine organisms, estimation of maximum permissible concentrations, effects of radiation on marine organisms, and studies on the distribution of effluent from Windscale discharged to the Irish Sea.

516. Teresi, J.D. and C.L. Newcombe. 1966. An evaluation of hazards from immersion of plutonium in the marine environment. Proc. 1st Int. Congr. Radiat. Prot: 673-680.

Studies were made to evaluate the potential hazards from the examination of the Californian coastal environment with plutonium following an instantaneous release upon immersion. The analysis considered the ocean environment at those distances from shore where the depth was about 10 m; at greater depths the hazard is expected to be less. The hazards were evaluated on the basis of the possible incorporation of plutonium into marine food chains. Using published concentration factors for fish and marine algae, the expected body burdens resulting from ingestion of fish, agar, algin, and Porphyra were calculated, on the basis of conservative assumptions, and compared with the recommended permissible body-burden for large populations. Using various mathematical diffusion models, details of which are given in an appendix, the diffusion parameters were calculated for instantaneous release of plutonium and were used to predict the area of the sea which would become contaminated with a hazardous concentration of plutonium and the duration of the hazardous concentration.

517. Teulon, F. and C. Simeon. 1966. Toxicological tests of chemical products on freshwater fish. Comm. Energie At. (France) Rappt. CeaR2938: 42 p.

Two species of carp (C. carassius and C. auratus) were placed in water containing various concentrations of lead (Pb). The tolerated concentration was 9.6 g/l.

518. Thomas, M.L.H. and G.N. White. 1969. Mass mortality of estuarine fauna at Bideford, P.E.I. associated with abnormally low salinities. J. Fish. Res. Bd. Can. 26:701-704.

Following a gale in May 1967, a deep layer of fresh water occurred in the Bideford River, Prince Edward Island, and salinities of less than one part per thousand were found at depths of 3 m in the inner part of the estuary. The reduced salinity caused extensive mortality of a variety of fauna, including Anguilla rostrata, Asterias vulgaris, Macoma balthica, Tellina agilis, and Yoldia limatula. Mortalities of A. rostrata and M. balthica, which are typical of brackish waters, could not be easily explained. A rising temperature, increasing the activities of species, as well as lack of time for acclimation to lower salinities, may have contributed to many cases of mortality.

519. Thomas, W.H., D.W. Lear and F.T. Haxo. 1962. Uptake by the marine dinoflagellate, Gonyaulax polyedra, of radioactivity formed during an underwater nuclear test. Limnol. Oceanog. 7 (Supplement): LXVI-LXXI.

After explosion of the test device, samples of radioactive sea water were collected near the test site at a depth of 125 m, and used for the culture of the coastal dinoflagellate, Gonyaulax polyedra. It was found that appreciable amounts of radioactivity were taken up by the organism: such activity could be transferred to the next trophic level and might eventually be incorporated into fish or other marine resources important to man. It is stressed however, that this organism is not an oceanic but a coastal species, and represents only part of the marine phytoplankton; other representative species of diatoms or nannoplankton might behave differently. Gamma-energy spectra suggested that Gonyaulax fractionated the mixture of radioactive isotopes, not all the isotopes being taken up to the same extent. Formation of precipitate in the samples may have been the result of the addition of phosphate to the solution. If this is the case similar precipitates might be formed when radioactive materials in surface water containing low amounts of phosphate diffuse into deeper water containing more phosphate; such a process might transfer some radioactivity to bottom sediments.

520. Thumann, M.E. 1941. The effect of waste waters containing arsenic on fish and crabs. Angew. Chem. 54:499.

Author reports on the effect of waste waters containing arsenic on several kinds of fish and on crabs. The animals were placed in waste waters diluted to give concentrations of arsenic varying from 0.35 to 3.1 mg/l. The affected fish sometimes became agitated, lost their equilibrium and overturned. Many died in concentrations greater than 1.1 mg/l. The effect of arsenic did not appear to be influenced by changes in temperature. The sensitivity to arsenic decreased in the order: perch, roach, carp, and eels,

crabs, though there was much variation in the behavior of individuals of each species. The content of arsenic in dead fish was determined; the concentrations of arsenic per kg wet weight were higher in less sensitive genera than in more sensitive genera. The contents of arsenic were not sufficiently great to make the fish poisonous if used for human consumption.

521. Ting, R.Y. and R. deVega. 1969. The nature of the distribution of trace elements in longnose anchovy (Anchoa lamprotaenia Hildebrand), Atlantic thread herring (Opisthonema oglinum LaSueur), and alga (Udontea flabellum Lamouroux). Proc. 2nd Nat. Symp. on Radioecology U.S.A.E.C. Conf. 670503: 527-534.

Trace amounts of the elements copper, iron, and zinc were determined in longnose anchovy (Anchoa lamprotaenia) and in alga (Udotea flabellum) from La Parguers and Joyuda, Peurto Rico. Levels of cobalt, copper, iron, manganese, nickel, and zinc in Atlantic thread herring (Opisthonema oglinum) from La Parguera, Puerto Rico, were also determined. Analyses were accomplished with atomic absorption spectroscopy. Concentrations of the elements in individuals of the same species sampled within the same locality at the same time did not approximate a normal distribution. However, the distributions of the log-transformed concentrations closely approximated a normal curve in most cases.

522. Tiniofeeva, N.A. and N.V. Kulikov. 1967. The role of freshwater plants in accumulation of strontium-90 and its distribution over the components of reservoir. Proc. Int. Symp. Radioecol. Concent. Process, 1966, Stockholm: 835-841.

The accumulation of strontium-90 (supplied as the chloride) was studied in freshwater plants found frequently in lakes of the southern and middle Ural, using a laboratory aquaria containing water and washed sand from the B. Miassova lake. Coefficients of accumulation are tabulated for 32 species of plant, the highest values being 1,910 for Cladophora fracta and 1,070 for Potamogeton compressus. The coefficients of accumulation were much greater for the 12 other isotopes which were studied. In some species of plants which had been killed by heating, the coefficient of accumulation of strontium-90 was considerably higher than that for the living plants, thus indicating the essential role of detritus in determining the fate of radioactive strontium in a reservoir. Other experiments showed that the coefficients of accumulation of strontium-90 were inversely related to the concentrations of stable isotopes of strontium, calcium, and magnesium in the water but were independent of a specific radioactivity of the solution, over a wide range. Experiments with

Elodea canadensis as the test plant and different concentrations of stable calcium in the water confirmed that with increasing concentrations of calcium there was a considerable reduction in the amounts of strontium-90 accumulated by the plants and the sand, while increased concentrations remained in the water. It is concluded that there may be at least two probable processes involved in the accumulation of strontium-90 in freshwater plants, one being reversible, of the ion-exchange type, and the other irreversible, based on the co-deposition of strontium and calcium carbonates.

523. Todd, M.E. and P.A. Dehnel. 1960. Effect of temperature and salinity on heat tolerance in two grapsoid crabs, Hemigrapsus nudus and Hemigrapsus oregonesis. Biol. Bull. 118:150-172.

Experiments were made on the effect of acclimatization to various combinations of temperature and salinity on the tolerance to heat of two species of grapsoid crabs. Acclimatization to a high temperature generally increased the resistance to lethal temperatures, while acclimatization to low salinities generally decreased it. The greatest resistance to high temperatures occurred in crabs acclimatized to high temperature and high salinity. The tolerance of crabs to high temperatures was adversely affected by moulting during the experiment, and by crowding. Smaller animals appeared to be slightly more resistant.

524. Townsley, S.J. 1967. The concentration of strontium-90 and other nuclides of strontium in fish. Proc. Int. Symp. Radioecol. Concent. Process, 1966, Stockholm: 867-878.

Experiments were carried out in aquaria to determine the rates of accumulation of three nuclides of strontium (strontium-85, -89, and -90) by the euryhaline, cichlid, teleost Tilapia mossambica, after acclimation to fresh or sea water. Results obtained during chronic exposure periods, with sampling at intervals of 1, 2, 4, 8, and 16 weeks, are given graphically in terms of concentration ratios. In fresh water, with concentrations of up to 100 μc/l of isotope, there was no significant difference in the concentration ratios relative to the medium, and the accumulation and deposition of strontium isotopes by Tilapia was therefore proportional to the concentration in the medium, but at concentrations higher than 200 μc, the concentration ratios were reduced significantly for all three isotopes. Mortalities of Tilapia were recorded for all three nuclides at concentrations in the fresh water ranging from 65 to 240 μc/l, with a significant increase in mortality rates at concentrations above 100 μc/l; 50% mortality occurred when the body burden was 0.8-1.0 μc per g fresh weight. No such radio-sensitivity or mortality

was observed with sea-water-adapted Tilapia. In sea water the concentration ratios were the same for all three nuclides and at all test concentrations; the body burden in sea water with concentrations up to 100 μc/l was 2-5 times less than that in fresh water with the same concentration and the same period of exposure. The concentration of radioactive strontium in the fish reached equilibrium with the medium after two weeks in sea water but only after more than 30 days in fresh water.

525. Townsley, S.J., R.E. Johannes, and B.T. Sather. 1962. The accumulation of radioactive isotopes by tropical marine organisms. Annual Report 1961-62. U.S. Atom. Ener. Comm. TID-19104: 52 p.

Results are given of studies on the uptake, tissue distribution, and elimination of radioactive isotopes by marine organisms. Specifically, the metabolism of strontium-85, -89, and -90, yttrium-90 and -91 and calcium-45 by tuna and Tilapia; the adsorption and excretion of chromium-51 by crabs; the effect of salinity on accumulation and loss of chromium-51 by various organisms; and the effect of the benthic amphipod Lembos intermedius, on the availability of phosphorus to the other trophic levels in an artificial marine ecological system, using inorganic phosphate labelled with phosphorus-32 as tracer.

526. Townsley, S.J., D.F. Reid, and W.T. Ego. 1962. The accumulation of radioactive isotopes by tropical marine organisms. Annual Report 1960-61. U.S. Atom. Ener. Comm. TID 14420: 36 p.

The results of studies on the uptake of radioactivity by different types of marine organisms are reported. The effect of light and enzyme inhibitors on the uptake of phosphorus-32 and zinc-65 by the mushroom coral, Fungia scutaria, was studied, and preliminary experiments were carried out on the ability of this coral to remove dissolved organic matter (glucose) labelled with carbon-14. The uptake of chromium-51 from sea water by the alga, Ulva lactuca, and the eggs of the ascidian, Pyura momus, was also investigated.

527. Trama, F.B. 1954. The acute toxicity of copper to the common bluegill (Lepomis macrochirus Rafinesque). Notulae Naturae 257:13 p.

The acute toxicity of copper depends on the amount of free copper present in the water. This amount is governed by the pH of

the water; i.e. below pH 5.3 all the copper is in solution; as the pH increases the copper salts precipitate.

Survival curves at 96 hours with respect to the concentration of copper were estimated at 0.74 mg/l (0.9 mg/l for 48 h TL_m). This is for a 50% kill on the basis of unprecipitated copper in solution.

The toxicity of copper salts is due to the amounts of Cu present and is independent of the anion (viz $CuCl_2 \cdot 2H_2O$; $CuSO_4 \cdot 5H_2O$).

In discussion that followed it was noted that 3.0 mg/l of $CuSO_4 \cdot 5H_2O$ (ca 0.75 mg/l Cu) produces almost 100% fish kill in four acid lakes in Nova Scotia and that 0.5 mg/l of $CuSO_4 \cdot 5H_2O$ is definitely toxic to growing trout (ca 0.125 mg/l Cu).

528. Trama, F.B. 1954. The acute toxicity of some common salts of sodium, potassium, and calcium to the common bluegill (*Lepomis macrochirus* Rafinesque). Proc. Acad. Nat. Sci. Philad. 106:185-205.

The effects of the chlorides, sulphates, and nitrates of sodium, potassium, and calcium upon the common bluegill were tested for a 96-hour period at 20°C. The 96-hour median toxicity level, in g/l, was 19.9 for sodium chloride, 13.5 for sodium sulphate, 12. for sodium nitrate, 2. for potassium chloride, 3.55 for potassium sulphate, 3. for potassium nitrate, 10.6 for calcium chloride and 10. for calcium nitrate. A saturated solution of calcium sulphate (2.980 g/l) did not produce significant mortalities.

529. Trama, F.B. and E.J. Benoit. 1960. Toxicity of hexavalent chromium to bluegills. J. Water Pollut. Cont. Fed. 32: 868-877.

Studies carried out by various workers on the toxicity of chromium to fish have given very variable results, largely because the tests have been carried out under a wide range of conditions. The authors describe experiments which they have carried out on the toxicity of chromate and dichromate. Experimental procedure is described. It was found that the 96-hour TL_m for bluegills in soft water is about 110 mg/l of chromium, as dichromate, and 170 mg/l as chromate, the reasons for this difference are discussed. The 24-hour TL_m in soft water is between 175 and 225 mg/l of chromium. The toxicity of chromium is considerably reduced by increase in alkalinity and hardness, and it is stressed that the alkalinity of the receiving water should be considered as well as the dilution when the disposal of waste waters containing hexavalent chromium is planned.

530. Turner, R.L. 1970. Quicklime: Effects on soft-bodied marine organisms. Science 168:606-607.

Authors suggest the possible use of quicklime to control the coral-eating sea star Acanthaster planci. This method of control has serious implications for other soft-bodied reef organisms. Quicklime has been used, since the mid-1930's, to eradicate sea stars in oyster beds and, more recently, sea urchins in kelp beds. The particulate lime spread over the surface waters falls upon and destroys the soft tissues of the body wall, causing eventual death. Quicklime is detrimental to numerous other marine organisms.

Effects of lime on the soft-shelled clam Mya arenaria and the sea cucumber Cucumaria frondosa were investigated. At concentrations used to eradicate sea stars, all ten lime-treated clams considerably reduced their filtering activity for a few hours after liming. The irritating lime particles, taken in through the inhalant siphon, interrupted "normal" feeding ability. However, the clams enveloped the particles in mucus and discharged the fouled mucus periodically via the siphons. The clams resumed "normal" filtering activity within one day.

Although the sea cucumbers secreted abundant mucus after liming, they developed wounds in the body wall, through which viscera protruded within 12 hours. Within 11 days, 20 of the 24 lime-treated C. frondosa died, and the remaining four were extremely deteriorated. Unlike Mya, the sea cucumbers were unable to dispose of the fouled mucus.

The use of quicklime for controlling Acanthaster must depend on the ability of coral polyps and other soft-bodied reef organisms to remove quicklime effectively from their bodies by mucus secretion or other mechanisms.

531. Ullmann, W.W., R.W. Schaefer, and W.W. Sanderson. 1961. Arsenic accumulation by fish in lakes treated with sodium arsenite. J. Wat. Pollut. Contr. Fed. 33:416-418.

Since 1956 sodium arsenite has been used for the control of weeds in Chautauqua and Findley lakes in New York State. In 1959 a study was made to determine the extent of accumulation of arsenic in fish from these lakes; the results were compared with fish from Cassadaga lake which has not been treated with the herbicides. In none of the fish examined was the amount of arsenic found equal to that present in edible salt water fish. The fish from Chautauqua lake contained less arsenic than those from Findley lake; this is attributable to the presence of residual arsenic in the water of Findley lake. It is concluded that longer contact periods are necessary for a significant accumulation of arsenic in fish under these conditions.

532. Umezu, T. and M. Saiki. 1967. Gross uptake of radionuclides by marine microorganisms in batch culture. Bull. Naikai Reg. Fish. Res. Lab. 24:1-9 (English Summary).

Relative values are given of the gross uptakes of radioactive isotopes from sea water by 15 species of micro-organisms (yeasts, bacteria, phytoplankton, and crustacean zooplankton) as suspensions of living or heat-killed organisms. Uptakes of cesium-134 and strontium-85 were only just measurable; phosphorus-32 was accumulated by living organisms, while zinc-65 was adsorbed more rapidly by dead organisms than by living ones.

533. Valee, B.L. 1959. Biochemistry, physiology and pathology of zinc. Physiological Reviews 39:443-490.

The article critically reviews the literature on zinc in view of the present knowledge of biochemical function of the metal. Physiological, pathological, and nutritional aspects are considered. Author also considers zinc in various species and tissues of marine molluscs and echinoderms.

534. Vecchio, P.V., A.M. Alasia, and G. Gualdi. 1962. Determination of arsenic in molluscs (Mytilus Linn.). Igiene San. Pubbl. 18:18-30.

As workers in other countries have reported high concentrations of arsenic in some aquatic animals, the authors determined the concentration of arsenic in mussels collected at three different places on the Italian coast. The arsenic concentrations found were about 3 mg per kg of edible flesh.

535. Vinogradov, A.P. 1953. The elementary chemical composition of marine organisms. Sears Foundation for Marine Research, Memoir 2, Yale Univ., New Haven, Conn.: 647 p.

This volume provides a summary and comprehensive presentation of most that was known about the elements found in marine organisms up to about 1950. Extensive data, including 327 tables, deal with elemental composition of marine algae, bacteria, higher aquatic plants, protozoa, porifera, coelenterata, bryazoa, brachiopoda, annelida, phoronidea, echinodermata, mollusca, crustacea, tunicata, and fishes -- including cyclostomes and sharks. Elements that are discussed include aluminum, iron, copper, zinc, titanium, molybdenum, tin, cobalt, nickel, mercury, silver, gold, vanadium, chromium, bismith, antimony, tungsten, gallium, germanium, cadmium, beryllium, praseodymium, samarium, cerium, lanthanum, yttrium, rubidium, cesium, lithium, strontium, barium, thallium, sodium, potassium, calcium, silicon, niobium, arsenic and neodymium.

536. Vogel, F.S. 1959. The deposition of exogenous copper under experimental conditions with observations on its neurotoxic and nephrotoxic properties in relation to Wilson's disease. J. Exp. Medicine 110:801-810.

Goldfish that were subjected to approximately 0.25 mg/l copper plus detergent (added to decrease coagulation of gill mucus) took in and retained copper in their brains, livers, and kidneys in concentrations comparable to those that occur naturally in Wilson's disease. After 25 weeks in copper-rich waters goldfish were sluggish, ate less, and exhibited a marked wasting when compared to controls.

Copper accumulated within the large neurons principally in those of telenecephalon and the anterior horn region of the spinal cord and in the tubular epithelial cells of the kidney, nuclei of the parenchymal cells of the liver, the sarcoplasm of the skeletal muscle and the epithelial covering of the gills. Cytologic damage include necrosis of renal epithelium and contraction and hyperchromaticity of the nerve cells. Author concludes that the similarity of the cytologic alterations induced in the central nervous system by copper and those that occur naturally in hepatolenticular degeneration in human beings provides evidence that copper itself plays an important role in the pathologic alterations of the brain in Wilson's disease.

537. Warnick, S.L. and H.L. Bell. 1969. The acute toxicity of some heavy metals to different species of aquatic insects. J. Wat. Poll. Cont. Fed. 41 (2, Part 1):280-284.

In static bioassays the acute toxicity of Cu, Zn, Cd, Pb, Cr, Hg, Co, Ni, and Fe salts on three species of stoneflies, mayflies and caddisflies was determined. The median tolerance limits of the metal salts for these organisms was determined. The mayfly was the most sensitive of the insects tested to all of the metals used. Insects seemed to be more tolerant than many species of fish. In the experimental procedures used, the dissolved oxygen, pH, and hardness remained fairly constant and these factors did not seem to influence mortalities.

538. Watson, D.G., C.E. Cushing, C.C. Coutant, and W.L. Templeton. 1969. Effects of Hanford reactor shutdown on Columbia River biota. Proc. 2nd Nat. Symp. on Radioecology. USAEC Conf. 670503: 291-299.

Closure of the Hanford reactors for an extended period caused a rapid and extensive decline in the concentration of radionuclides in Columbia River biota. Chromium-51 and ^{32}P decreased

two to three orders of magnitude in the lower trophic levels; declines in concentrations of ^{65}Zn, ^{54}Mn and ^{59}Fe were much less, suggesting a cycling of these nuclides from the sediments to the water during shutdown. In fish, ^{32}P was lost rapidly, ^{65}Zn slowly. Near equilibrium concentrations of radionuclides in most river organisms were approached within two or three weeks after the resumption of reactor operation.

539. Watson, D.G., J.J. Davis and W.C. Hanson. 1963. Interspecies differences in accumulation of gamma emitters by marine organisms near the Columbia River mouth. Limnol. Ocean. 8:305-309.

In 1959 and 1960 samples of marine plankton, sessile algae, molluscs, crustaceans and fish were collected near the mouth of the Columbia River and analysed for concentrations of gamma-emitting isotopes; the results for the various species are tabulated. The highest concentrations of most isotopes were found in plankton and the sessile alga Fucus furcatus; this is attributed to their position as primary producers in the food web, to their high surface-to-volume ratios making adsorption of greater significance, and to the inclusion of minute particles of sediments and organic debris with these samples. Comparison of results for the two years showed that zinc-65 appeared to have increased, ruthenium-103 and -106 and zirconium-95-niobium-95 decreased, and chromium-51, cerium-141 and -144, and manganese-54 showed no marked change. The levels of activity in plankton at the river mouth were markedly influenced by tidal direction and amplitude; greatest concentrations were found in samples collected at extreme low and ebbing tides, the periods when the river water was least diluted by ocean water.

540. Watson, D.G. and W.H. Richard. 1963. Gamma-emitting radionuclides in Alaskan fish and plants. U.S. Atom. Ener. Comm. HW-76000: 244-257.

Measurements have been made of amounts of gamma-emitting radioactive isotopes in fish from sea water, brackish water and fresh water bodies in Alaska. Naturally occurring potassium-40 exceeded the quantity of fallout isotopes by a factor of 10-100. Zinc-65 was present in all fish from lakes and in anadromous salmon, but was absent from stream fish. Highest levels of cesium-137 occurred in the freshwater lakes that collect run-off from the surrounding land.

541. Welander, A.D. 1969. Distribution of radionuclides in the environment of Eniwetok and Bikini Atolls, August 1964. Proc. 2nd Nat. Symp. on Radioecology. USAEC Conf. 670503: 346-354.

Radionuclide analyses were made of more than 2000 samples of animals, plants, water, bottom sediments and soils collected at Eniwetok and Bikini Atolls, the site of 59 nuclear tests between 1946 and 1958. Cobalt-60 was found in all samples but was dominant in the marine environment. Cesium-137 and ^{90}Sr, however, were predominant in the land environment. All samples contained traces of ^{54}Mn, although there were slightly larger amounts of this radionuclide in land plants and land invertebrates. Ruthenium-106 and ^{125}Sb were detected in significant amounts in groundwater and soil, with traces in animals and plants. Also, trace amounts of ^{207}Bi were found in most samples, and ^{144}Ce usually in algae, soils and land plants. There were comparatively large amounts of ^{55}Fe in a number of samples, especially in vertebrates. Plutonium-239 was found in soil and in the skins of rats and birds in the few samples analyzed. The soils contained the highest levels of radioactivity, followed by invertebrates, groundwater, shorebirds, plants, rats, plankton, algae, fish, bottom sediments, seawater and seabirds.

542. Westfall, B.A. 1945. Coagulation film anoxia in fishes. Ecology 26:283.

Previous workers have suggested that the lethal effect on fish of substances which coagulate the mucus on the gills is due to a decrease in the permeability of the mucus to dissolved oxygen. To test this hypothesis the author determined the effect of the concentration of dissolved oxygen on the toxicity of solutions of sulphuric acid and lead nitrate which caused coagulation of the mucus. It was found that goldfish were not harmed in a period of two hours in tap water containing only 0.9 mg/l dissolved oxygen. In concentrations of sulphuric acid sufficient to reduce the pH value to 2.8 the mucus on the gills was coagulated; when the concentration of dissolved oxygen was 5.7 mg/l 10 fish lived an average of 96 min. in this solution, but when the concentration of dissolved oxygen was only 1.2 mg/l the average period of survival was 53 min. Concentrations of sulphuric acid sufficient to give a pH value of 4.5 did not coagulate the mucus and did not cause death of fish even when the concentration of dissolved oxygen was 1.0 mg/l. Solutions of lead nitrate caused precipitation of the mucus without reducing the pH value to below 4.9. In solutions containing 5 gm/l of lead nitrate, 10 goldfish survived for the 2 hours of the experiment when the content of dissolved oxygen was maintained at 6.2 mg/l, but when the content of dissolved oxygen was 1.4 mg/l the average period of survival of the fish was 93 min. It is concluded from these results that precipitation of the mucus of the gills does decrease the permeability of the gills to dissolved oxygen. The content of dissolved oxygen had no effect on the toxicity of solutions of lactic acid which coagulate the mucus to only a very slight extent; it is considered that the lactic acid has a direct action on the fish.

543. Westoo, G. 1969. Methylmercury compounds in animal foods. In Miller, M.W. and G.G. Berg (eds.) Chemical Fallout-Current research on persistent pesticides. Chas. C. Thomas Publisher, Springfield, Ill. 111:75-90.

A method for determining methylmercury compounds in fish by gas-liquid chromatography and thin-layer chromatography was developed in 1965. In 1966 and 1967 the procedure was improved and can now be used also for other animal foodstuffs. Methylmercury compounds were found, e.g., in eggs, meat, liver (average values 0.06 mg of Hg/kg), and fish. The substitution of methoxyethylmercury for methylmercury compound as a seed disinfectant in Sweden in 1966 caused a decrease in the methylmercury content of eggs, meat, and liver in 1967 and 1968 to approximately 1/3 of the average values found earlier. Marine fish caught near the shore and freshwater fish often show high methylmercury levels. Frequently more than 0.4 mg of Hg/kg (very infrequently, as much as 5-10 mg/kg) in fish muscles has been found in Sweden. Levels above 1 mg of Hg/kg are usually caused by industrial discharge of mercury compounds. Regardless of the nature of the mercury pollutant, methylmercury has been found in the fish. When hens were fed with seed disinfected with different mercury compounds, part of the mercury in the eggs was in the methylated form.

544. White, G.F. and A.J. Thomas. 1912. Studies on the absorption of metallic salts by fish in their natural habitat. I. Absorption of copper by *Fundulus heteroclitus*. J. Biol. Chem. 11:381-386.

With *F. heteroclitus*, greatest absorption takes place in the first part of a period of exposure to copper, and a following gradual increase which then affects the fishes life. As much absorption may occur in dilute solutions as in the concentrated solutions if enough time is allowed. In two fish species (*Tautoga onitis* and *F. heteroclitus*) the largest amount of copper was found in the blood system. Authors concluded that Cu entered the system through gills. Visible evidence of Cu was found in microscopic sections of treated fish and not in controls.

545. Whitley, L.S. 1968. The resistance of tubificid worms to three common pollutants. Hydrobiologia 32:193-205.

Median tolerance limits for 24-hour periods are given for tubificid worms in solutions of various pH values, containing zinc, lead, and sodium pentachlorophenate; these ranged from 1.4 mg/l at pH 9.5 for sodium pentachlorophenate to 49.0 mg/l at pH 6.5 for lead. The 24-hour TL_m for zinc was 46.0 mg/l at pH 7.5. In the modified

Knop solution used, without the addition of toxic substances, survival levels were highest for pH values between 7.0 and 9.0. The results, the visual appearance of poisoned worms, and the various toxic mechanisms, are discussed in detail.

546. Wilder, D.G. 1952. The relative toxicity of certain metals to lobsters. J. Fish. Res. Bd. Can. 8:486-487.

The toxicity of some common metals to lobsters was investigated, using wooden tanks with metal floors. Lobsters died within 1 day in tanks with copper floors, within 6 days with monel metal, 9 days with zinc, and 9 days with lead. In tanks with iron, stainless steel, or aluminum floors more than 80% of the lobsters survived for 2 months.

547. Williams, B.R., H. Perkins, E.J. Hinde, and J. Gorman. 1965. The biology of the Solway Firth in relation to the movement of radioactive materials. III. Fisheries and food chains. U.K. Atom. Energy Authority Prod. Gr. Rep. 611, H.M. Stationary Office, London: 88 p.

In connection with the detailed study of the Solway firth to assess its capacity for receiving discharges of radioactive waste waters, results are given of investigations on fisheries, on algae, and on accumulation of radioactivity in the fauna. Studies on the bottom fauna and food of fish, particularly flounder and plaice, showed that marked interspecific competition for food occurred, and it was concluded that no one food chain is limiting. Investigations on the uptake of ruthenium-106 by the brown algae in the fucoid belt showed that the quantity of insoluble ruthenium-106 by the brown algae in the fucoid belt showed that the quantity of insoluble ruthenium-106 associated with each species can vary according to its position in an estuary; of the 4 species observed, the greatest amounts of ruthenium-106 were usually associated with Fucus spiralis. In studies on the specific activity of potassium-40, strontium-90, and ruthenium-106 in representative fauna, it was found that at higher trophic levels the specific activity of ruthenium-106 decreases, while the reverse is true for strontium-90. Uptake of strontium-90 by the flounder is thought to be related to food intake.

548. Williams, L.G. 1960. Uptake of caesium-137 by cells and detritus of Euglena and Chlorella. Limnol. Ocean. 5:301-311.

Species of Euglena and Chlorella had previously been found to accumulate considerable amounts of cesium-137 and further experiments were carried out to obtain information on the factors affecting

the bio-accumulation, exchange, and cycling of the isotope. All the experimental cultures contained selected pollution bacteria since the accumulation of cesium-137 and the population density were significantly greater than in bacteria-free media. The presence of antibiotics affected both the growth of the algae and the uptake of cesium-137. Uni-algal cultures of Euglena and Chlorella grown in 3 concentrations of cesium-137 chloride showed that the uptake of cesium-137 is linear with concentration in the range 1-10 μc per liter, which might be encountered in natural aquatic habitats. Although there is bioaccumulation of the isotope during the exponential growth phase, the greatest uptake by Euglena is during the subsequent stationary phase. High concentrations of potassium express the uptake of cesium-137 by living cells, and considerably smaller concentrations of stable cesium carrier have an even greater effect; but potassium and cesium behave independently in killed cells of Chlorella. With Chlorella, both dead and alive, and at all ages, most of the cesium is bound to the cell wall and particles of cell inclusions; but with Euglena, most of the cesium in young and dividing cells is unbound, whereas in old cells and cell fragments (detritus) it is bound. During the investigations the highest removal of cesium-137 from the medium was 93% in 34 days by Euglena and its detritus; and Chlorella removed about 47% in about 13 days. The radioactive cesium removed from natural waters by algae is deposited on the bottom in bound form in the dead cells, and, subsequently the detritus.

549. Williams, L.G. and H.D. Swanson. 1958. Concentration of caesium-137 by algae. Science 127:187-188.

As cesium-137 is one of the critical fission products in reactor wastes and atomic explosion fall-outs, and as it has a fairly long half-life and is water-soluble, it may be expected to increase in the environment as more use is made of nuclear energy. Experiments were therefore carried out on the accumulation of cesium-137 by fresh-water algae, particularly Euglena intermedia and Chlorella pyrenoidosa. It was found that both these algae concentrate cesium to a considerable extent. Traces of potassium in the medium appear to have a slight depressant effect on the uptake of cesium. It was also found that dead cells of Chlorella show a high concentration factor for cesium, indicating that structural components persist in the dead cells which are capable of adsorbing cesium from very dilute solutions; this adsorption is not affected by the presence of potassium.

550. Williams, R.B. and M.B. Murdock. 1969. The potential importance of Spartina alterniflora, in conveying zinc, manganese, and iron into estuarine food chains. Proc. 2nd Nat. Symp. on Radioecology. USAEC Conf. 670503: 431-440.

The potential importance of cord grass, Spartina alterniflora, in conveying radioisotopes of zinc, manganese, and iron into estuarine food chains was evaluated on the basis of its annual production, its content of the three elements, and its annual cycle of growth and decay. The growth of Spartina was studied with harvest and other techniques in salt marshes near Beaufort, N.C. Standing crop at maturity (in the fall) and annual production were estimated to average 545 and 650 g dry wt/m^2, or 208 and 248 g C/m^2, respectively Spartina production approached one-third the total phytoplankton net production of adjacent estuaries, and was thus potentially important in estuarine food chains. Zinc, manganese, and iron all had markedly higher concentrations in dead Spartina than in live, and averaged 22, 200, and 5,000 mg/kg (dry weight), respectively, in the dead material. The unusually high iron content of the dead material suggested that Spartina detritus may be especially important in the movement of radioisotopes of iron from water and sediment into estuarine animal populations.

551. Wilson, P.D. 1968. Some aspects of the chemistry of ruthenium in sea water. U.K. Atom. Energy Auth., PG-Reg. 819: 10 p. Nuclear Science Abstracts 22:1283-1284.

The waste water discharged to the sea from the Windscale works, Cumberland, Great Britain, contains radioactive ruthenium both in solution and as a co-precipitate with ferric hydroxide. Laboratory experiments using synthetic ruthenium solutions showed that in sea water an equilibrium is established between cationic, anionic and perhaps neutral ruthenium complexes. Ruthenium is, therefore, taken up by both anionic and cationic exchange materials and by the polysaccharide porphyran, which is a major constituent of the edible seaweed Porphyra; it is also adsorbed strongly by particles of ferric hydroxide. In all cases the degree of sorption increases slowly with time. Ruthenium co-precipitated with ferric hydroxide is only superficially leached by sea water; since, after aging, the particles became resistant to acid, it is concluded that ruthenium in this form is not a serious source of contamination to marine organisms.

552. Winkler, L.R. and L.W. Chi. 1964. Defensive mechanisms of the schistosome snail host Oncomelania formosana against copper sulphate in adult and egg stages. Am. J. Trop. Med. Hyg. 13:897-902.

Copper is deposited in high concentrations in special cells in the digestive gland hemocoel, and in lower concentrations in special cells of the tissue surrounding the stomach area. Embryos still in the egg deposit copper in the stomach area. Eggs are protected by mucus in

the mud capsule and by a "protein bath" surrounding the embryo, both of these serve to bind the copper.

553. Wisely, B. and R.A.P. Blick. 1967. Mortality of marine invertebrate larvae in mercury, copper and zinc solutions. Australian J. of Marine and Freshwater Res. 18:63-72.

The toxicity of sea-water solutions of mercury, copper and zinc salts to the larvae of some species of bryozoans (Watersipora cucullata and Bugula neritina), tubeworms (Spirorbis lamellosa and Galeolaria caespitosa), bivalve molluscs (Mytilus edulis planulatus and Crassostrea commercialis), and the brine shrimp (Artemia salina), were studied. TL-50 values are reported for a range of concentrations and the effects of pH variations on mortality rates are discussed. The experiments which were designed to find a suitable organism for screening potential anti-fouling compounds, showed that Artemia larvae, which were highly resistant to mercury and copper and could tolerate a low pH value, would be most useful in testing compounds.

Death rate of Artemia larvae in copper concentrations between 256 and 1,800 mg/l Cu with a pH range of 3.2-4.5 was similar to that of larvae in comparable solutions not containing copper, but with a similar pH range.

TL-50 (2 hour) values for copper sodium citrate in mg/l Cu, in the pH range 7.0-8.2 were: 0.51 for Spirorbis, 0.57 for Watersipora, 2.9 for Galeolaria, 3.85 for Bugula, and 22.5 for Mytilus. TL-50 (2 hour) values for zinc chloride, in mg/l Zn, ranged between 32.5 and 4.6 for Watersipora, Bugula, and Spirorbis. TL-50 (2 hour) levels for mercuric chloride at pH 7.8 to 8.2 were quite variable and ranged between 0.1 and 1,800 mg/l Hg.

554. Wiser, C.W. and D.J. Nelson. 1964. Uptake and elimination of cobalt-60 by crayfish. Amer. Midland Natural. 72:181-202.

Studies on the uptake of cobalt-60 by living and dead crayfish (Cambarus longulus longerostris) indicated that about half of the accumulation was by adsorption and half by absorption. However, most of the adsorbed cobalt was deposited in the exoskeleton, and 95% of the body burden was lost at moulting. Large animals accumulated more cobalt-60 than smaller ones, but the uptake per g was greater in the smaller animals, indicating the importance of surface adsorption phenomena. Rates of accumulation, measured by biological half-times, were 70 hours for small animals and 66 hours for large animals in a continuously renewed medium, and 24 hours for small animals and 16.5 hours for large animals in a medium which was not renewed, indicating that higher percentages of total uptake occurred

more rapidly when the supply of the isotope was limiting, and with larger animals. Rates of elimination were much slower than accumulation.

555. Wlodek, S. 1966. Aquatic organisms as biological indicators of radioactive contamination in the surrounding medium. Verh. Int. Verein. Theor. Angew. Limnol., 1965. 16:985-995.

Continuing studies on the accumulation of radioactive isotopes by aquatic organisms were made in several freshwater bodies in Poland, the south of France, and also in model reservoirs contaminated artificially with cesium-137 in concentrations of 4, 0.43, and 0.046 μc/l. Studies on the freshwater weeds in tributaries of the river Isere, France, showed the existence of three groups differing in the levels of both total beta and total gamma activity, the lowest activity occurring in plants such as Cladophora where the leaves are rough and dissected but have a large total surface area, while the amount of activity found in amphibiotic plants is affected by the precipitation received directly by the emergent leaves. Both in France and Poland the radionuclides found in aquatic plants included cerium-144/promethium-144, ruthenium-106/rhenium-106, cesium-137, and manganese-54; zirconium-96/niobium-95 also occurred in Polish aquatic plants in 1963 but not in 1964. Under conditions in tributaries of the Isere where the level of radioactivity in the water and sediments is relatively stable, the coefficients of accumulation of β- and γ-activity in aquatic plants appear to be suitable indicators of the degree of contamination of a water body. In certain cases, it may be advantageous to consider individual species of plant rather than the total flora; problems involved in assessing the value of an organism as an indicator of contamination and in choosing a formula for the coefficient of accumulation are considered. Studies on the distribution of radioactive cesium in an aquatic ecosystem showed that the element occurred principally in the bottom deposits, the plant community playing only a secondary role and seldom an important role, while the water mass tended to give up the cesium rapidly at the expense of the other components of the ecosystem; the periphyton also appear to be involved in the distribution of cesium. The uptake of cesium-137 by aquatic plants, which was proportional to the degree of contamination in the water, was not uniform throughout the plants; the upper, younger parts contained much less cesium than the older, lower parts. In general, dense plant growths contained less than 1% of the total cesium introduced into the water but, immediately following the contamination, about 5-7% of the cesium is retained temporarily by growths of Lemna and Elodea and more than 60% by Ulothrix. Filamentous algae, particularly Ulothrix, are concluded to be the most promising organisms for use in decontamination of water by the plant-harvesting method; about 30% of the initial contamination could be removed in the period immediately following contamination.

556. Wobeser, G., N.O. Nielsen, R.H. Dunlop, and F.M. Atton. 1970. Mercury concentrations in tissues of fish from the Saskatchewan River. J. Fish. Res. Bd. Can. 27:830-834.

Muscle tissue of 81 fish from several locations in the Saskatchewan River system contained an average of more than 1.0 mg/l of mercury. Fish collected at two sites had much higher concentrations, with individual fish containing up to 11.2 mg/l. The concentrations found were higher than those reported for fish from uncontaminated environments, and corresponded to values reported for Scandinavian fish collected in areas of industrial pollution.

557. Wolfe, D.A. and C.L. Schelske. 1969. Accumulation of fallout radioisotopes by bivalve molluscs from the lower Trent and Neuse Rivers. Proc. 2nd Nat. Sympt. on Radioecology. USAEC Conf. 670503: 493-504.

Bivalve molluscs have proven useful indicators of the distribution of fallout radioisotopes in an aquatic environment. Three species of filter-feeding molluscs, Elliptio complanatus, Rangia cuneata, and Polymesoda caroliniana, were collected from stations in the Trent and Neuse Rivers in Eastern North Carolina at four to six week intervals for more than a year. The soft tissues of each species were ashed and analyzed for gamma radioactivity in a multichannel spectrometer and 10 x 10 cm NaI crystal. The concentrations of gamma-emitting fallout radioisotopes were monitored in Rangia over a 48.2 km stretch of river and a salinity range of <0.1 to >15 o/oo. Ruthenium-106, ^{144}Ce, ^{137}Cs, ^{54}Mn, and ^{65}Zn were present in all samples. After the Chinese nuclear tests in May and December 1966, the amounts of ^{141}Ce, ^{103}Ru, ^{95}Zr-^{95}Nb and ^{140}Ba-^{140}La rose suddenly in the samples. Ruthenium-106 and ^{103}Ru were more concentrated in Rangia from downstream stations (salinity range 6-15 o/oo), whereas ^{137}Cs was more abundant in the same species from fresher water (salinity range 0-8 o/oo). Zirconium-95-niobium-95 from the Chinese test in May remained in Rangia from freshwater stations after it was no longer detectable in the same species collected downstream.

558. Wood, R.A. 1955. Toxicity studies on one, thirty, sixty-day old and adult Stagnicola reflexa. Proc. Ind. Acad. Sci. 64:291-294.

The effects of copper and magnesium sulphates and carbonates and sodium chloride on the snail Stagnicola reflexa were compared. Snails of different ages were exposed to varied concentrations of the salts for different periods of time. Copper carbonate and copper sulphate were the most toxic, the latter particularly so in the case of the adult snail.

559. Yager, C.M. and H.W. Harry. 1964. The uptake of radioactive zinc, cadmium, and copper by the freshwater snail Taphius glabratus. Malacologica 1:339-353.

Freshwater snails (Taphius glabratus) were exposed to zinc-65, cadmium-115m, and copper-64 in concentrations which allowed normal behavior and in concentrations which caused the distress reaction (inability to retract into the shell), and it was found that the uptake patterns were similar for the three nuclides. In normal snails more radioactive ions were taken up by snails exposed to larger volumes of solution than by snails exposed to only 10 ml of solutions of the same concentration for the same period. Uptake by the shell decreased with increase in period of exposure. In normal snails the amounts of nuclides concentrated in the liver were 4 to 7 times the amounts in other tissues, but in distressed snails the amount in the liver was only twice that in other tissues, and the amounts in the tissues were often lower than in snails showing normal activity. It is concluded that distress depends on the concentration of nuclide rather than on the amount absorbed, and that the ions produce distress by disrupting membrane permeability rather than by interfering with some internal metabolic mechanism.

560. Yager, C.M. and H.W. Harry. 1966. Uptake of heavy metal ions by Taphius glabratus a snail host of Schistosoma mansoni. Exp. Parisotol. 19:174-182.

Radioisotopes of cadmium and zinc concentrate in liver, kidney, oviduct, and sections of the intestine. These metal ions cause a "distress syndrome" in affected snails.

561. Young, D.R. and T.R. Folson. 1963. Concentrations of zinc-65, manganese-54, and cobalt-60 observed recently in marine organisms of the east Pacific. Paper presented at International Symposium on Radioactive Contamination of the Human Environment. Hiroshima, 1963: 13 p. Nuclear Science Abstracts 1967, 21:50.

Owing to their ability to concentrate radionuclides, sessile mussels and barnacles are useful for studying distribution of radioactive fallout. Variations in the concentrations of manganese-54, zinc-65, and cobalt-60 in the mussel Mytilus californianus collected at various points along the Pacific coast of USA, shows that radioactivity decreases towards the south. The concentrations of zinc-65, manganese-54, and potassium-40 in Mytilus collected from Scripps pier on the open coast, from San Diego harbor, and from a land-locked boat harbor were measured, showing that the greatest activity occurred at Scripps pier. There were no differences in

the concentrations of the various isotopes in mussels of different size. Analyses of different organs showed that the kidneys contained 50 times as much zinc-65 as the muscles.

562. Young, D.R. and T.R. Folson. 1967. Loss of zinc-65 from the California sea mussel, Mytilus californianus. Biol. Bull. 133:438-447.

Colonies of the California mussel Mytilus californianus, collected near the mouth of the Columbia River, where they had taken up zinc-65, were transferred to coastal waters of southern California where much lower levels of zinc-65 occur, and were subsequently sampled at intervals for one year. During this period the concentration of zinc-65 in the soft tissues (after allowing for radioactive decay) decreased by more than 97%. This decrease appears to be described satisfactorily by a single exponential function, with a biological half-life for growing organisms of 76 $\pm$ 3.5 days; if radioactive decay is not excluded the observed rate of loss of zinc-65 is described by an effective half-life of 58 $\pm$ 2.7 days.

563. Yudkin, J. 1937. The effect of silver ions on some enzymes of Bacterium coli. Enzymologia 2:161.

The poisonous effect of metal ions on enzymes is known but, up to now, their effect on bacterial enzymes has not been investigated. The author examined the effect of silver ions on various enzymes of B. coli. It was shown that the glucose succinic acid, and lactic acid dehydrogenases, hydrogenases and hydrogenlyases are completely inhibited by about the same concentration of silver. The poisoning did not appear immediately after the silver was added but reached a maximum after 1-2 hours at a temperature of 20°C. Attempts to reactivate the poisoned enzymes with potassium cyanide, hydrogen sulphide, and other substances were without result; slight reactivation was only sporadically observed.

564. Zavodnov, S.S., E.E. Iobchenko, and N.G. Fesenko. 1965. Pollution with copper and zinc of the Armenian S.S.R. rivers and the processes of their self-purification. Gidrokhim. Mater. 40:149-155.

Studies on the concentrations of copper and zinc in surface waters in Armenia showed that unpolluted rivers contained 2-3 times the maximal permissible concentration for zinc and 20-30% of the permissible concentration for copper. Trout, which are known to be sensitive to the chemical composition of the water, thrive in these rivers. The concentrations of copper and zinc in polluted waters

were only slightly higher than in unpolluted waters, and it is suggested that the present maximal permissible concentrations are too low. Although the concentrations of copper and zinc in polluted rivers decrease rapidly with increasing distance from the source of pollution, it is pointed out that much of these metals may be associated with the bottom deposits, and a change in conditions, such as a reduction in pH value or an increase in mineral content of the water, could bring them back into solution.

565. Zesenko, A.Y. and G.G. Polikarpov. 1965. Coefficients of accumulation and distribution of ruthenium-106 in organs and tissues of sea molluscs. Radiobiologiya 5:320-322.

Studies on the distribution of ruthenium-106 in mussels showed that 65% was accumulated in the shell and 30% in the byssus. It is thought that these organisms may play a significant role in filtering ruthenium-106 from shallow sea water.

566. Zlobin, U.S. 1966. Accumulation of radioactive strontium by the brown seaweeds. Gig. Sanit. 31 (12):86-88. Nucl. Sci. Abs. 1967, 21:2349.

Uptake of strontium-89 by the brown seaweeds Fucus vesiculosis, F. serratus, and Ascophyllum nodosum reaches equilibrium within 5-7 days. An increase in stable strontium in sea water up to 0.16 g/l causes a threefold reduction in the uptake of strontium-89 by Fucus serratus.

567. Zlochevskaya, I.V. and I.L. Rabotnova. 1966. Toxicity of lead to Aspergillus niger. Mikrobiologiya 35:1044-1052.

The effect of lead (Pb) on A. niger was tested in growth media containing glycerol, cysteine hydrochloride and ammonium nitrate as sources of carbon, sulfur and nitrogen, by adding 1420 mg/l of lead nitrate at a pH of 2.5. Inclusion of Pb in the medium decreased the growth rate of A. niger to complete suppression after 3 transfers. However, A. niger grew well and formed conidia in the supernatant in which only traces of the Pb complex were dissolved.

SECTION III

INDEX

Two indices are presented: INDEX-METAL and INDEX-TAXA. In each case, reference numbers followed by an asterisk (*) denote that the subject organism is either strictly freshwater or anadromous with the major biological effect observed in freshwater. Reference numbers not followed by an asterisk indicate that the subject organism is marine, euryhaline or anadromous with the major effect occurring in saline waters.

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