Research on Effects of Chemical Contaminants

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PRIOR TO 1970

Only a limited amount of research on the effects of chemical contaminants on marine animals was carried out at the Seattle and Alaska laboratories prior to 1970. A few investigations were started in the 1960s, including work to determine what effects water which had been supersaturated with gases had on salmon as they passed over Columbia River dams. Robert Clark began a project in 1969 to monitor the accumulation of petroleum hydrocarbons by intertidal organisms in Puget Sound. Ray Anas investigated accumulation of DDT in fur seals in the Pribilof Islands. The Technology Laboratory was able to measure the amounts of DDT and mercury in the edible flesh of commercial fish and shellfish of the Pacific Coast and Alaska. However, none of this early work definitively

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answered the question of whether the presence of man-introduced contaminants affected marine animals or the ecological systems.

Organization of EC Division

Research at Seattle on the effects of pollution was first conducted by the Food Science Pioneer Research Laboratory (FSPRL) under Maurice Stansby. Research planning began in the spring of 1970. After the Northwest Fisheries Center (later Northwest and Alaska Fisheries Center) began operations in October 1970, members of the FSPRL started exploring the effects of chlorinated hydrocarbons on salmon. This work was soon extended to include the effects of petroleum hydrocarbons. Much of this early work was carried out by Dr. Edward Gruger, Neva Karrick, and Dr. T. Roubal.

On 18 January 1972, the FSPRL was disbanded and the Environmental Conservation (EC) Division was established. This division absorbed the FSPRL staff of Stansby, Dr. Gruger, Karrick, Dr. Roubal, Dr. Donald Malins, Nell Nickels, and Paul Robisch. Maurice Stansby was named Director. In July 1972 a number of other Center scientists with pertinent backgrounds or experience were transferred to the new EC Division. These included: Leonard Fulton; Robert Clark and John Finley, who had worked previously on petroleum hydrocarbons in the environment; Ray Anas, who had worked on contaminants in seals; Dr. Harold Hodgins, Dr. Fred Utter, William Gronlund, Douglas Weber, and Ethel Blood, all of whom had been doing physiological, behavioral, and genetic research on salmon; Dr. George Snyder and employees from the field stations at Mukilteo, Washington, and Prescott and Hammond, Oregon. Fulltime permanent employees in these groups included Warren Ames, Donovan Craddock, Richard Hughes, Benjamin Patten, and George Slusser (from Mukilteo); Dr. Theodore Blahm, Larry Davis, Maurice Laird, and Robert McConnell (from Prescott); and Joseph Durkin, Roy Pettit, and Carl Sims (from Hammond).

In addition to these permanent positions there were 17 fulltime temporary positions, a total of 46 fulltime positions in the new EC Division. Of these positions, 15 were in the Pioneer Research Unit at Seattle, 12 were in the physiological unit under Dr. Harold Hodgins at Seattle, and 19 were under Dr. George Snyder (15 in field stations and 4 in Seattle).

The functions of the new division were to study the nature and extent of chemical pollution in marine environments and to relate these findings to possible alterations in the health of marine organisms. The EC Division adopted an interdisciplinary approach to these complex issues, and utilized specialists in the fields of analytical chemistry, biochemistry, vertebrate and invertebrate pathology, electron microscopy, immunology, and behavioral marine biology.

RESEARCH 1970 THROUGH 1974

From 1970 through 1974, in addition to organization of the EC Division, other efforts were carried out.

Research was carried out by the chemists who had been transferred from the discontinued Food Science Pioneer Laboratory. This research actually began as a portion of the program of that laboratory even before it became a

part of the EC Division. Techniques were devised starting in 1970 to adapt some of the methodology, formerly used for the research on oxidation of fish oils, to problems of effects of environmental contaminants on fish. For example, Dr. Roubal devised ways of utilizing spin labeling, a technique using electron paramagnetic resonance, on which Dr. Roubal had done pioneering research relating to the oxidation program. He used this technique so that it could be used to study the fate of fat soluble contaminants assimilated into fat depots of salmon. This spin labeling procedure proved to be a valuable tool, and the basis for several papers describing its application to fish.

Using more conventional approaches, Dr. Gruger and others within the group began with an investigation of pickup and release by fish of chlorinated hydrocarbon compounds, such as PCBs, from the water in which they lived. By 1973, attention began to be concentrated more on the pickup and release of hydrocarbons from petroleum discharged into waters inhabited by fish.

In some cases biologists and physiologists within the division worked on problems they had become engaged in before the Northwest Fisheries Center was organized. Some groups under Dr. Snyder at Prescott, Oregon, continued work on problems concerning water which, in passing over dams, had become supersaturated with nitrogen and caused gas-bubble disease in fish. At Dr. Snyder's station at Hammond, Oregon, work was carried out on pickup by fish of spray contaminants used for controlling forest fires. Later, problems at the mouth of the Columbia River in connection with dredging were undertaken. At Mukilteo, work was continued on effects of elevated water temperatures that might occur when nuclear power plants used water for cooling and then returned it to areas inhabited by fish. Also considerable effort was aimed at improving conditions for holding fish to bioassay various effects brought about by water pollution. Thus the Mukilteo station was transformed into a facility available to all of the EC programs where testing adverse effects upon fish could be studied.

In the group under Dr. Hodgins, various programs involved determining causes of skin tumors in fish and of other fish diseases, application of electrophysiology to possible disorientation of fish interfering with spawning migrations as a possible effect of pollution, and studies involving genetics. These were all areas in which Dr. Hodgins' staff had formerly been engaged, and research was undertaken which made use of the knowledge and skills of these staff members in pollution and other studies of importance to the goals of the EC Division.

In the late 1960s Robert Clark began surveying the levels of petroleum hydrocarbons at selected sampling stations around Puget Sound and in the Strait of Juan de Fuca. This work was continued and a new study was begun on the continuing pollution caused by oil escaping from tanks of a vessel wrecked on the northwestern coast of Washington.

RESEARCH FROM 1975 TO 1981

On 1 November 1974, Dr. Donald Malins was appointed Director of the EC Division following the retirement of Stansby. At that time the major effort

of the Division was directed toward investigations on the effects of petroleum in the environment on marine organisms. Other important investigations dealt with the effects environmental changes in the Columbia River had on salmon (carried out at the two Oregon field stations), and the effect of altered temperature on fish (carried out at Mukilteo).

The EC Divison presently consists of four major task units: Sublethal Biochemical Effects (Dr. U. Varanasi, Task Leader), Contaminant Effects of Life Processes (Dr. H. Hodgins, Task Leader), Invertebrate Pathology (Dr. A. Sparks, Task Leader),the National Analytical Facility (Dr. W. MacLeod, Task Leader).

An interdisciplinary approach, coupled with a staff able to conduct both field and laboratory research, led to cooperative research with other organizations also concerned with the effects of pollutants on marine animals. As a result of its collaborative efforts with other NOAA programs--specifically, the Marine Ecosystems Analysis (MESA) Program, Outer Continental Shelf Environmental Assessment Program (OCSEAP), and the Energy Resources Project III--and with the Environmental Protection Agency (EPA), the EC Division was able to broaden its scope of research to address more effectively the problems of environmental pollution. These efforts made possible biological and chemical field studies in such widespread geographical areas as Puget Sound, Washington; Prince William Sound, Alaska; the New York Bight; the Bering Sea; the Gulf of Alaska; and the Brittany coast of France.

Contaminants

An important issue in the last half of the 1970s was the possible effects of drilling and oil spills in cold, northern waters. Chemical, physical, and biological reactions with almost infinite number of petroleum compounds create a dynamic environment. The EC Division planning broke the complex picture into workable segments of research. Initial laboratory impact studies were done on the water-soluble fraction of aromatic hydrocarbons and selected metals. Early studies provided basic information on uptake and discharge of the contaminants by marine organisms. As techniques were refined, both for chemical analyses and for exposure of fish and shellfish to components of oil, research progressed to include a determination of metabolites formed and the effects of these metabolites and of oxidized compounds. While laboratory and field studies that assess the impact of single contaminants are continuing, emphasis has been directed toward studies of the effects of multiple contaminants. Tasks on Sublethal Biochemical Effects and on Contaminant Effects of Life Processes are evaluating the potential for interactions among representative petroleum hydrocarbons, chlorinated hydrocarbons, and heavy metals.

Sublethal Biochemical Effects (SBE)

In studying the effects of petroleum hydrocarbons, Dr. Varanasi and her colleagues have shown that these are potentially toxic metabolites in marine organisms. Several aromatic hydrocarbons were studied in depth. Their conversion products were isolated from a variety of marine species and specific tissues, and were chemically identified. These conversion products

tend to remain in tissues and body fluids of marine organisms long after the parent hydrocarbons have disappeared.

Further work by the SBE group has shown that the liver enzymes of flatfish extensively metabolize the carcinogenic hydrocarbon, benzo[a]pyrene, to intermediates that interact with DNA. Such interactions are believed to be the starting point for tumor formation. Both parent aromatic hydrocarbon and metabolites have been shown to enter the reproductive system of flatfish. The presence of such pollutants in eggs and milt may interfere with the fertilization of eggs and the subsequent development of embryos. Studies are in progress to examine these issues.

Contaminant Effects on Life Processes (CELP)

Dr. Hodgins and his colleagues have undertaken a variety of laboratory and field studies designed to improve understanding of the effects of pollutants on physiological, pathological, and behavioral processes of marine biota. For example, laboratory studies have shown that flatfish exposed to sediments contaminated by crude oil take up a variety of petroleum hydrocarbons. Light- and electron-microscopic examination of exposed fish showed an enhanced accumulation of lipids in the liver, and clinical tests revealed altered hematocrit values and hemoglobin levels. Other laboratory studies have shown that exposure to the water-soluble fraction of crude oils can cause significant changes in predator-prey relationships resulting in decreased predation by adult coho salmon. Still other studies have revealed little or no effect of crude oil exposure on resistance to infectious disease by various salmonid and flatfish species.

Field studies undertaken by the CELP Task have addressed a number of critical questions including the possible relationship between enhanced incidence of disease (particularly those of noninfectious etiology) and high levels of environmental contaminants. In a continuing survey undertaken in collaboration with MESA, Dr. Bruce McCain and his coworkers have documented an increased incidence of certain liver tumors and hepatic lesions among fish collected in urban estuaries containing high levels of pollutants. The manifestations of these lesions in terms of organ dysfunction and fish health are presently under investigation in laboratory studies.

Additional field research was undertaken in collaboration with OCSEAP following the grounding of the tanker Amoco Cadiz off the coast of France. The research was aimed at gaining a better understanding of the impact of a major oil spill; Dr. Joyce Hawkes evaluated the effects of the petroleum hydrocarbons on mussels within the spill zone. Electron microscopic examination of exposed organisms revealed increased areas of lipid and increased numbers of lysosomal granules in cells of the digestive glands. In other OCSEAP-oriented field studies, Douglas Weber demonstrated that petroleum hydrocarbons can disrupt the normal migratory behavior of adult salmonids.

While the laboratory and field studies assessing the impact of single contaminants are continuing in both the SBE and CELP tasks, recently emphasis has been directed toward the study of the effects of multiple contaminants.

The EC Division scientists are presently evaluating the potential interactions among representative petroleum hydrocarbons, chlorinated hydrocarbons, and heavy metals.

Auke Bay Laboratory

In addition to the work on effects of chemical pollutants on marine organisms being carried out by the Environmental Conservation Division at Seattle, an effort within the Environmental Program is being carried out by the Center's Auke Bay Laboratory. This program emphasizes problems specific to Alaska. Considerable work has been conducted on problems caused by the wood products industry where substances toxic to fish have leached from trees into streams. Considerable emphasis, especially in recent years, has been placed on problems connected with the petroleum industry in Alaska. Long-term monitoring studies have been made both in marine waters near oil pipelines where oil is transferred to ships and at oil-drilling sites. A recent study at Port Valdez investigated effects of dumping billions of gallons of ballast water used by tankers on their northern runs.

In addition to this field study, laboratory investigations are also conducted at Auke Bay. Many of these studies relate to aspects such as pick-up and discharge of petroleum and petroleum compounds by fish and shellfish, and the effects of these contaminants. Both short-term acute-toxicity studies and long-term sublethal-effects studies are being made, but most emphasis is on the former. Unlike the EC Division at Seattle, a majority of the staff with the Auke Bay program has a background in biology or fisheries, although most have had experience or other training in physiology or other disciplines.

This physiological project is headed by John Karinen. Other scientists in the program include: Patricia Arasmith, Malin Babcock, Sidney Korn, Stephen Lindsay, and Dr. Stanley Rice. Theodore Merrell has overall charge of the Environmental Program, including the physiology-bioassay project, and of the watershed and estuarine ecosystems projects which include work in effects of the trans-Alaskan pipeline. In these latter two projects, workers include: Dr. K. Koski, L. Barr, R. Walters, and R. Myren.

Electron Microscope Unit

The research on early biological effects of pollutants required definition of the early structural changes in tissues and organs. Consequently an electron microscope unit was formed in 1976 when the Northwest and Alaska Fisheries Center and the Environmental Protection Agency purchased transmission and scanning electron microscopes. Dr. Joyce Hawkes is in charge of the studies performed on the scopes; other personnel in the unit are Carla Stehr, Paul Olson, and William Paine.

Invertebrate Pathology (IP)

The capabilities of the EC Division were expanded in 1977 when Dr. Albert Sparks transferred from Washington, D.C., to set up a Task on Invertebrate Pathology. The IP task focuses on research to better define and characterize the diseases of marine invertebrates. To date, Dr. Sparks and Jolly Hibbits have identified a number of previously unrecognized disease syndromes and are studying their pathological manifestations. In

particular, they have demonstrated the highly invasive nature of the fungus causing black mat disease which previously was believed to colonize only on the external surfaces of the snow (Tanner) crab. This observation, along with the documentation of a high incidence of black mat disease in Alaskan waters, suggests a possible relationship between this disease and the recent decline of this commercially important species.

National Analytical Facility

The NOAA National Analytical Facility (NAF) provides NOAAs environmental programs with detailed information on the types and amounts of trace chemical contaminants in the marine environment. Many of NOAAs environmental programs must contend with extremely complex mixtures of chemical compounds which are challenging to isolate, identify, and measure. To deal effectively with such mixtures, highly trained analytical chemists and technicians are needed to operate the modern, sophisticated instrumentation required for these trace chemical analyses. This need presents difficulties for many research projects which have neither the resources nor the volume of analyses to justify the undertaking. Chemists on the staff of the facility include: Task Leader Dr. William MacLeod, Donald Brown, Douglas Burrows, Victor Henry, Dr. Margaret Krahn, and Patty Prohaska.

The NAF operates with state-of-the-art equipment, such as glass-capillary gas chromatography coupled with mass spectrometry, and high-performance liquid chromatography using ultraviolet and ultra-violet-fluorescence on-line detection systems. In addition to providing analytical services for laboratory studies, the staff is studying new ways to analyze marine pollutants and their toxic conversion products. Their research has provided new procedures for analyses of environmental samples.

Using the combined expertise of many different disciplines, scientists in the EC Division are providing important information to state and federal agencies and other groups, on the possible impact of man-made chemicals and other stresses on marine life.