INVESTIGATION OF THE PROCESS FOR REGISTRATION OF SQUOXIN FOR SQUAWFISH CONTROL

Final Report

by

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Funded by

United States Department of Energy

Bonneville Power Administration

Division of Fish and Wildlife

December, 1984

Contract No. DE-AI83-BP13220
Project No. 83-428

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ABSTRACT

Squawfish are a predator on downstream migrant salmon and steelhead. Squoxin, 1,1'+nethylenedi-2-naphthol, is a specific toxin for squawfish. This report addresses the requirements and deficiences in data necessary for squoxin registration as a pesticide. It includes an annotated bibliography, keyword index from published and unpublished sources covering information on squawfish, squoxin, state and federal regulations for pesticide registration.

Pesticides must be registered for a specific use by the U.S. Environmental Protection Agency (EPA) under the Federal Fungicide, Insecticide, and Rodenticide Act (FIFRA). The process is a detailed, complex process and could take from 3-6 years to complete. An existing data base on squoxin will reduce cost and time for registration.

Squoxin is 100% lethal to squawfish at concentrations as low as 10 ppb for at least 2 hours. The recommended rate for field application is 100 ppb for 12 hours. At 100 ppb, the maximum LCO for the least squoxin tolerant salmonids is 7-17 times greater than the minimum LC_{100} for northern squawfish. The most sensitive salmonid is chinook salmon (300 ppb for 96 hours). Aquatic invertebrates are generally resistant to squoxin - LC_{50} for _Daphnia_ is 950 ug/l in 96 hours. One exception is the blackfly _Simulidae_ - LC_{50} is 60 ug/l in 48 hours.

Squoxin is excreted in aquatic biota and mammals primarily via the bile. Squoxin shows little tendency to accumulate in animal tissues. Over 90% of accumulated squoxin was excreted from rainbow trout tissues in 48 hours. There are two principal oxidative degradation products in river water: 1,2-napthoquinone and l(hydroxymethyl)2 naphthol.

A petition to register squoxin was submitted to EPA in 1977. EPA noted deficiences in data including testing for residues in meat, milk, poultry, eggs, potable water, and irrigated crops; aquatic metabolism; mutagenicity; avian oral LD_{50}; acute LD_{50} for freshwater invertebrates; freshwater fish LC_{50}; and acute LC_{50} for marine organisms. Cost estimates for conducting the squoxin data research range from $436,600 to 52,070,000.

Squawfish control with squoxin would represent an annual savings to the commercial and sports fishing industry of $20-25 million based on the value of the Columbia River salmon and steelhead lost to predation. The cost for registration of squoxin and initial treatment of the Columbia is far less than the value of returning adults from the smolts lost to predation in one year.

Cost estimates in 1984 dollars to treat the Columbia River with squoxin are: 300,000 cfs of water in a single application - $412,920; treatment at 10-mile intervals from McNary Dam to Bonneville Dam - $4,129,200; a single treatment at 25,000 cfs - $34,410. The latter is a practical approach to treat at minimum flows, high temperatures where squawfish concentrate.

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EXECUTIVE SUMMARY

The Investigation of the Process for Registration of Squoxin for Squawfish Control is one of the studies funded by Bonneville Power Administration under provisions of the Northwest Power Planning Council and Conservation Act. Squawfish are a predator on juvenile downstream migrant salmon and steelhead that become stunned and disoriented after passage through turbines at hydro-electric dams. The use of the pesticide squoxin, which is a specific toxin for squawfish, has been proposed to control the numbers of squawfish. This report addresses the requirements and deficiences in data necessary for squoxin registration as a pesticide. It includes an annotated bibliography to bibliographic index from published and unpublished sources covering information on squawfish, squoxin, and EPA regulations.

Pesticides used in the United States must be registered for a specific use by the U.S. Environmental Protection Agency (EPA) under their regulations and provisions of the Federal Fungicide, Insecticide, and Rodenticide Act (FIFRA). The process is detailed, testing is expensive, and could take as long as 5-6 years to complete. An existing data base on squoxin will reduce the cost and time required for registration.

Attempts have been made to control squawfish populations since the early 1930's with varying degrees of success. Gillnets have been widely used where smaller salmonids were present. Electrical barriers were developed to keep squawfish from hatchery release areas of the Columbia River. Spawning populations have been poisoned with rotenone and dynamited. Squoxin, 1,1'-methylenedi-2-naphthol, was discovered at the University of Idaho to be a specific toxin for the northern and Umpqua squawfish and has been extensively tested in field and laboratory applications. Some studies indicate that squawfish are only significant predators under highly localized, seasonal, or unusual circumstances. A study at Bonneville Dam estimates that 11% of the downstream migrant salmon and steelhead entering the Bonneville Pool were eaten by squawfish in one season. One author believes that predation is contributing to instability of upriver salmon and steelhead runs of the Columbia River and could lead to eventual extinction. Increased survival of salmonid populations has been demonstrated in several studies where large numbers of squawfish were removed.

The northern squawfish, *Ptychocheilus oregonensis,* is a member of the family, Cyprinidae, and is the only species of that group known to be a significant salmonid predator. They spawn between May and August depending on water temperature in streams or lakes. Spawning takes place over coarse rubble in shallow water. The young rear in shallow, backwater areas. Males mature in 5-6 years of age with females maturing at 6-7 years. Some females have been aged to 17 years. Insects are the principal food of squawfish less than 19 cm. At lengths greater than 36 cm fish are the principal food. They are opportunistic feeders.

The toxicity to squawfish of the chemical 1,1'-methylenedi-2-naphthol was discovered at the University of Idaho in a screening program to find chemicals that are selectively lethal to squawfish. It was named squoxin by Dr. Craig MacPhee who patented its use as a squawfish piscicide in the United States and Canada. The patent was given to the governments of the respective countries. The compound is a white crystaline powder formulated for field use as the monosodium salt and dissolved in ethyl alcohol. A period of laboratory testing determined that squoxin is 100% lethal to squawfish at concentrations as low as 10 ppb for at least 2 hours. The recommended rate for field application is 100 ppb for 12 hours. At a concentration of 100 ppb, the maximum LCO for the least tolerant salmonid species is 7-17 times greater than the minimum LC_{100} for northern squawfish.

An experimental use permit was granted to the Northwest fishery agencies to collect data to be used for registration of squoxin. The data are discussed in the order of EPA data requirements. Analytical methods were developed for detection of squoxin in fish tissues using gas chromatography. The analytical method for water uses colorimetry. High pressure liquid chromatography and scintillation counting were other techniques used. Residue chemistry field studies found 2.38 ppm squoxin in dead squawfish. Edible tissues of live trout immediately after exposure contained less than 0.1 ppm squoxin.

The early degradation studies determined the half life of squoxin under field conditions in a stream to be about 2 hours. Later laboratory studies with radio-labeled squoxin showed a half life of 40 minutes for ring-labeled squoxin and 80 minutes for methylene-labeled squoxin. As many as 12 degradation products were suspected in the early analytical work. The more recent work determined two principal oxidative degradation products in river water: 1,2-napthoquinone and 1(hydroxymethyl)2-naphthol. The oxidative pathway is given.

Squoxin was found to be readily excreted in aquatic biota and mammals. Both rainbow trout and rats excreted squoxin primarily via the bile. The primary means of excretion in aquatic invertebrates appears to be desorption-diffusion mechanisms through the exoskeleton. Exactly what proportion of detoxification is by biochemical means in aquatic invertebrates has not been determined. Squoxin has demonstrated little tendency to adsorb to inorganic solids. However, a strong sorption/desorption reaction was found from dissolved and suspended organic compounds.

Unlike the chlorinated hydrocarbons, squoxin shows little tendency to accumulate in animal tissues. Over 90% of accumulated radio-labeled squoxin was excreted from rainbow trout tissues in 48 hours. Less than 0.01 ppm remained in all tissues (except brain) after 92 hours. Experiments with Daphnia gave the same type of results with over 90% of accumulated squoxin excreted in 96 hours.

Several toxicological studies were conducted with squoxin. No tissue abnormalities were found in chronic tests with dogs or rats fed squoxin at 100 and 250 mg/kg and 100 and 1,000 mg/kg respectively for 90 days, and none of the animals died. The LC_{50} of squoxin fed to mallard ducks and Coturnix quail was greater than 20,000 ppm. Many toxicity tests of squoxin were conducted with salmonids and other nontarget species of fish. The Cyprinids, dace, and shiners had a lower LC_{50} than the salmonids. The most sensitive salmonid appears to be the chinook salmon (300 pph). The LC_{50} of squoxin for squawfish is 10 ppb.

Aquatic invertebrates are generally resistant to squoxin - LC_{50} for Daphnia is 950 ug/l in 96 hours. One exception is the blackfly Simulidae - LC_{50} is 60 ug/l in 48 hours. No mortalities of aquatic invertebrates or amphibians were observed in the many field tests of squoxin. Registration of pesticides is administered by the EPA under their regulations and the FIFRA. The steps in the registration process are given. Briefly, they include consultation with EPA on data requirements for a specified use of the pesticide, design the research protocol , conduct the chemistry and toxicological tests, prepare and submit data to EPA, EPA review of test results and response to EPA's comments by the applicant. An experimental use permit is required for the testing. All research must be done in accordance with Good Laboratory Practice Rules. Registration of a compound with EPA will generally satisfy state requirements for data, although a separate permit is required for pesticide use in each state.

The process for pesticide registration is difficult because the regulations have evolved over several years, and the data requirements have changed somewhat since previous studies were conducted. EPA's data requirements are detailed, often difficult to achieve, and expensive to produce. Squoxin is a minor-use product but is treated by EPA the same as a major-use product.

A petition was submitted to EPA in 1977 containing all the results of research that had been done at that time. EPA was critical of the data submitted and noted deficiences in data required in a letter dated February 10, 1982. The remaining data requirements are discussed and outlined. The requirements include testing for residue chemistry in meat, milk, poultry, eggs, potable water, and irrigated crops; aquatic metabolism; mutagenicity; avian oral LD_{50}; acute LD_{50} for freshwater invertebrates; freshwater fish LC_{50}; and acute LC_{50} for marine organisms.

The registration of a pesticide is a detailed, complex network of regulations and requirements. To assure success of a program to register squoxin, a program manager is highly recommended. His duties would he overall coordination, development of a research program specifically to meet EPA data requirements, communication with EPA data reviewers on protocol, and conduct of studies and preparation of submittals to EPA. Cost estimates for conducting the squoxin data research range from $436,600 to $2,070,000.

Columbia River studies of juvenile chinook and steelhead mortalities from squawfish predation show that 20% may be lost at each dam. The projected loss in 1973 from Little Goose Dam to Bonneville Dam was 8.3 million smolts. The cost for registration of squoxin and initial treatment of the Columbia River is far less than the value of returning adults from the smolts lost to predation in 1 year.

The value of the salmon and steelhead of the Columbia River and tributaries that are lost to predation and the cost of producing these fish in hatcheries was estimated by National Marine Fisheries Service. Control of squawfish numbers with squoxin would represent an annual savings to the commercial and sports fishing industry of $20-25 million.

Estimates of the cost of treating the Columbia River with squoxin are given. Based on the estimated 1984 cost of squoxin ($620/33 gal. barrel), the cost to treat 300,000 cfs of water in a single application would be $412,920. Treatment at 10-mile intervals from McNary Dam to Bonneville Dam would cost $4,129,2DO. A more practical approach would be to treat at minimum flows and high temperatures at points where squawfish are known to concentrate such as the tailrace of dams. A single treatment at 25,000 cfs would cost $34,410.

SECTION 1
INTRODUCTION

PURPOSE

The Pacific Northwest Electric Power Planning and Conservation Act of 1980, 16 U.S.C. 839 et seq. (the Northwest Power Act) directed the Northwest Power Planning Council (Council) to develop a Fish and Wildlife Program to protect, mitigate, and enhance fish and wildlife on the Columbia River and its tributaries. Bonneville Power Administration's (BPA) authority was expanded to include the funding of research on fish and wildlife resources affected hy hydroelectric projects on the Columbia River and its tributaries.

The Fish and Wildlife Program (Program) was adopted by the Council November 15, 1982. The Program includes many elements: upstream and downstream migration of anadromous fish; wild, natural and hatchery propagation; resident fish; ocean survival; and coordination of river operations. Section 404 (6) (1) of the Program deals with the problems of juvenile salmonid downstream passage at hydroelectric dams on the Columbia River. Young salmon and steelhead become stunned, disoriented and are vulnerable to predation after passage through turbines. Predators, especially squawfish, are abundant at the base of the dams and feed on the disoriented juvenile salmonids.

In order to control the squawfish and reduce losses to predators, squoxin, a pesticide that is a specific toxin for squawfish, has been proposed. The purpose of this report is to describe the process for registration of a pesticide with the Environmental Protection Agency (EPA) and define specifically the remaining requirements for registration of the piscicide, squoxin. An annotated bibliography and bibliographic index are a part of this report. Subject material from published and unpublished sources concerning squawfish, squoxin, and EPA regulations are included in the references. Pesticides are regulated by the U.S. EPA under the Federal Fungicide, Insecticide, and Rodenticide Act (FIFRA) and a series of regulations and guidelines. A pesticide must be registered with EPA before it can be shipped or used in the United States. Squoxin is a piscicide and is classified as a pesticide for use on an aquatic food (eg. fish).

The pesticide registration process is not a simple matter. EPA's regulations are detailed for each specific use group. Data requirements to support a petition to EPA for registration are difficult to meet, must he developed according to specific guidelines, and take substantial amount of time and money to develop. The process for registration of a new pesticide could take as long as 5-6 years and cost up to 18 million. Testing to meet EPA data requirements may take 2 years plus another 2 years for technical review and processing by EPA and the applicant. The time and money required to register squoxin will be substantially less because of an existing data base.

Field evaluations on a stream and a reservoir in Idaho have shown that the chemical control of squawfish numbers greatly increases the survival and abundance of desirable fishes (MacPhee 1969, Ortman 1972).

Control of the numbers of squawfish which congregate in the tailrace and forebays of the mainstem Columbia River dams has been largely unsuccessful using nets and traps.

Squawfish are opportunistic feeders and are known to prey heavily on juvenile salmon and steelhead during the downstream migration season from May to August. One study at Bonneville Dam estimates that 3.8 million downstream migrant salmon and steelhead were eaten by squawfish in one season. This represents 11% of the total migration through the Bonneville reservoir. It is estimated that control of squawfish numbers by the use of squoxin would represent an annual savings of $20-25 million to the commercial and sports fishing industry in the states of Oregon, Washington, and Idaho.

The feasibility of treating the Snake River with squoxin at two of its lower dams has been developed in a proposal that was not implemented. Cost of the Snake River treatment, which included a research study, would have been $46,000 in 1977 (Ebel 1975).

Data requirements for registration of a pesticide include product chemistry, residue chemistry, environmental fate, mammalian toxicology, reentry protection, and effects on fish and wildlife. Product chemistry requirements include a complete analysis of ingredients and impurities and all the physical and chemical characteristics. Residue chemistry deals with the nature and magnitude of the residue in plants and livestock including irrigated crops, water, and milk and includes a proposed tolerance. Mammalian toxicology tests determine the acute, subacute, and chronic toxic effects of a pesticide. Dncogenicity, teratogenicity, and mutagenicity tests are required in mammals. Environmental fate studies are required to determine degradation products, dissipation, and accumulation in fish and nontarget organisms. Reentry testing includes studies of plant and soil dissipation. The toxicology tests determine the LC_{50} or LD_{50} of a pesticide. LC_{50} or LD_{50} is the lethal concentration or letha? dose of a toxicant that kills 50% of the test organisms in a specified time (usually 96 hours).

The protocol for conducting the individual tests is contained in EPA guidelines (Appendix D). Criteria for the various tests are included in the guidelines. The number and species of animals, concentration of chemicals, time of exposure to the toxicant, presentation of test results, and record keeping requirements are specified. The criteria for fish and wildlife tests are detailed while those for residue chemistry are not.

Acceptable laboratory practices required for conducting studies to obtain data to support a pesticide registration application are explained in detail in The Good Laboratory Practices Rule (Appendix G). Sections of the regulations discuss personnel, facilities, equipment, operations, test and control substances, record keeping requirements, and reports.

An agreement between EPA and the Food and Drug Administration (FDA) has made the testing requirements and the laboratory practices of the two agencies consistent (Appendix F).

The pesticide registration process involves consultation with EPA to determine data needs and study design requirements, subsequent testing, preparation of test results, EPA review and satisfactory responses by the applicant. If all requirements are satisfactorily met, EPA will register the compound for a specific use. A review by EPA and reregistration is required every five years.

SECTION 2
BACKGROUND

A considerable amount of research work has been done on squawfish since the early 1930's. Research has centered on its life history and the development of methods for control of large populations of this predaceous fish. A part of this study was to review the literature on squawfish and the pesticide squoxin and then prepare a bibliographic index.

HISTORY OF THE SALMONID PREDATION PROBLEM

Low survival of salmonids from fry to smolt stage has been attributed in part to predation by squawfish, char, and coho salmon (Foerster 1931, 1937a, 1937b; Foerster and Ricker 1941). An indication of the magnitude of the effect of predation on salmonid survival is demonstrated by Foerster and Ricker (1941). The removal of 90% of the predaceous fishes from Cultus Lake, B.C. resulted in increased young sockeye survival of 3-1/3 times over average conditions prior to control (Foerster and Ricker 1941).

Snake River studies in 1976 by the National Marine Fisheries Service estimated the squawfish population in the upper one-half of the Lower Monumental Resevoir was 133,000 fish (Sims, Bently and Johnsen 1977). Twenty-one percent of squawfish collected below Lower Granite Dam contained salmonid remains. Long et al. (1968) showed that turbine related mortalities of coho salmon passing through turbines at Ice Harbor and Lower Monumental Dams was as high as 30% when indirect mortality from predation was included. Direct turbine mortality was 10-11%. In 1973, a low flow year in which almost all of the young migrants had to pass through turbines, a 95% loss of both chinook salmon and steelhead populations was measured from the Salmon River to the Oalles Dam (Raymond 1974). It is reasonable to assume that predation will be as high as direct turbine mortality at Columbia and Snake River Dams in low flow years (Personal Communication Dr. W. Ebel).

Hamilton et al. (1970) found that low survival of coho in Lake Merwin, Washington, was due to predation by rainbow trout and squawfish. The Oregon Department of Fish and Wildlife conducted a study in the forebay at Bonneville Dam in 1980 to determine the amount of predation by squawfish on downstream migrant salmon and steelhead, (Uremovich et al. 1980). They estimated that 3.8 million juvenile salmonids may have been consumed by squawfish in the forebay (powerhouse and spillway) between April 13 and August 30, 1980. This represents 11% of the 34 million juvenile salmonids estimated to have entered the Bonneville pool in 1980. Twenty percent of 4 million sockeye fingerlings rearing in Lake Washington are eaten by squawfish (Bryant 1976).

Not all research results have indicated that squawfish are significant salmonid predators under natural conditions in streams. Brown and Moyle (1981) concluded that squawfish do not appear to be significant predators of salmon and trout in streams except under highly localized, seasonal, or unusual circumstances. In a study on the Willamette River, Oregon, Buchanan et al. (1981) found only 2% of squawfish stomachs contained salmonids. They believe that reports of squawfish predation in flowing waters were misleading because they were based on studies conducted in artificial situations (below dams or downstream of hatchery releases) which could have inflated predation values. Mullan (1980), in discussion of the Columbia River, makes the observation that . . . "a reasonahly logical case can be made, largely based on theoretical and circumstantial considerations, that predation is contributing to instability of upriver salmonid runs and could contribute to eventual extinction."

In conclusion, the effects of squawfish predation on salmonids in the mainstem Columbia River centers around the dam impacts. Squawfish are opportunistic predators taking advantage of the large numbers of downstream migrant salmon and steelhead smolts passing each of the dams on the Columbia and Snake Rivers during the spring and summer. The predation is significant and is considered by the State and Federal Fishery Agencies to be one of the limiting factors in maintaining upriver runs of salmon and steelhead trout in the Columbia River system.

COMPETITION

Squawfish are one of a number of species competing for a common food base. They probably consume the preferred food items of other species when they are availahle because of their opportunistic feeding habits (Heun 1983). Pollard (1972) observed that differential habitat preference in Anderson Ranch Reservoir probably minimizes interaction between Kokanee and squawfish during much of the year. A number of studies have shown that squawfish feed on aquatic insects that are known to be part of the diet of salmonids (Beamsderfer 1983), (Falter 1969), (Reid 1971) (MacPhee and Reid 1971). MacPhee and Reid (1971) believe that any reduction in the number of squawfish probably would increase the abundance of these organisms and provide additional food for trout and other fishes in the treated area.

SQUAWFISH LIFE HISTORY

There are two species of squawfish, the Northern squawfish (Ptychocheilus oregonensis), and Umpqua squawfish (P. umpquae), in the Northwest. A third species, the Sacramento squawfish, P. grandis, is found in northern California. They all are indigenous and have similar life histories. Squawfish are members of the family Cyprinidae. Spawning takes place between May and early August. Spawning time is dependent on temperature and stream velocity. Spawning grounds have low velocities (0.2 to 1.4 feet per second) with gravel and cobble substrates free of fine particles (Beamsderfer 1983, Heun 1983, Olney 1975, Patten and Rodman 1969, Reid 1971, and Taft and Murphy 1950).

Squawfish residing in lakes may spawn in the lake or move into tributary streams for spawning. Following spawning most adults move back to the lake, hut some remain in the streams throughout the summer (Reid 1971). Large concentrations of squawfish from several hundred to a few thousand fish gather for spawning. Males exhibit sexual dimorphism in the form of small tubercles on the dorsal surface of the head (Patten and Rodman 1969). Both sexes have a dark lateral band from the snout to the base of the tail. Pectoral and ventral fins are bright orange (Patten and Rodman 1969).

Spawning takes place with several males and a single female. The eggs are about 1 mm in diameter, adhesive, and are driven into the interstices of the substrate. A female will spawn several times in a season (Patten and Rodman 1969). Females produce from 2,000 to 75,000 eggs per spawning season (Reid 1971). The eggs hatch in seven to eleven days depending on water temperature (Jeppson and Platts 1959). Young squawfish rear in shallow, slow-moving waters. Gravel removal, dredging, and hank stabilization provide the nitches for juvenile squawfish rearing (Reid 1971).

In the St. Joe River squawfish growth averaged 30 mm per year over a 5-year period (Reid 1971). Male squawfish mature when they are 5 or 6 years of age, females at 6 and 7 years (Reid 1971). Growth slows in both sexes after maturing. Some females attain lengths of over 500 mm and ages up to 17 years (Reid 1971).

Squawfish are opportunistic feeders. Their diet varies with their size. The diet of squawfish <19 cm consists primarily of insects, oligochaetes, and plant materials. The diet for fish from 21-35 cm consists of a high proportion of fish in summer months. The diet of squawfish >36 cm consists primarily of fish and crayfish (Falter 1969). Although Falter (1969) did not find trout in squawfish stomachs his study did not exclude trout as food. The ratio of squawfish to trout biomass in the river system is so large that if only a small fraction of squawfish utilize trout for food they could have a significant effect on trout populations. MacPhee (1969) found six times as many rainbow trout fingerlings after removal of squawfish from the St. Joe River as compared to the control year.

METHODS OF SQUAW FISH CONTROL

Several different methods have been used to control squawfish with varying degrees of success. Foerster and Ricker (1941) reduced squawfish populations of Cultus Lake to 1/8 of its pre-control abundance by intensive gillnetting over three years. The rainbow trout catch index doubled over six years as a result of squawfish gillnetting in Hayden Lake, Idaho, by Jeppson (1957) and Jeppson and Platts (1959).

Several other means of squawfish control have proven to be successful. Hamilton et al. (1970) demonstrated by recovery of marked fish that trapping had reduced the squawfish population of Lake Merwin in three years by 90%. Dynamite has been used successfully to disperse and eradicate concentrations of spawning squawfish (Jeppson 1957, Keating 1958). Electrical barriers were used to protect large hatchery releases of salmon on the Columbia River (Maxfield et al. 1959, 1969, 1970). Rapid drawdown of a reservoir during squawfish spawning can dry out and kill the eggs. An entire year class was destroyed at Anderson Ranch Reservoir (Pollard 1972).

Chemicals have been used for control of undesirable fish populations for many years (Cumming 1975). Some of the difficulties with use of toxicants are inadequate knowledge of the biology of the target species and lack of or inadequate pre and post-treatment surveys (Lennon et al. 1971). Rotenone has been extensively used but is expensive and nonspecific. It has been successfully used to kill spawning populations and concentrations of juvenile squawfish (Pollard 1972). Squoxin (1,1'-methylenedi-2-naphthol) has been successfully demonstrated to kill squawfish without harm to nontarget organisms (MacPhee 1967, 1969, 1971b; MacPhee and Bailey 1973; MacPhee and Reid 1971; MacPhee and Ruelle 1968, 1969b, 1971).

Many applications were successfully made in Idaho, Oregon, and Washington under an experimental use permit (Beach 1974; Keating et al. 1972; MacPhee 1971a; MacPhee and Reid 1971; Swan 1972a, 1972b, 1973; Watson 1973; Welsh 1975; Whitworth and Collins 1973). Lake Phinetta was also treated in British Columbia (Cartwright 1977). Applications made at 30 ppb killed squawfish for 5 miles downstream. When applied at 100 ppb squawfish were killed for 10 miles without harming gamefish and with only few mortalities of other minnows and sculpin (Keating 1972). There was no indication of harm to insects, crayfish, freshwater mussels, or tadpoles (Keating 1972).

Increased survival of gamefish and improved fishing success resulted from removal of squawfish by squoxin from Cascade Reservoir and the St. Joe River (Keating 1972). There is no avoidance response to squoxin as with some other fish toxicants. It kills all sizes of squawfish, and the first sign of response is loss of equilibrium. Once equilibrium is lost, the fish invariably dies, even when removed from the treated water and placed in fresh water (MacPhee and Ruelle, 1969a). They found the toxicity of squoxin to squawfish is inversely related to temperature. The concentration of squoxin required for 100% kill dropped by a factor of 10 from 0.10 ppm at 4.4°C to 0.01 ppm at 12.8°C. Mean time to death also descreased with increasing temperatures ranging from 11.4 hours at 10.0°C to 2.4 hours at 18°C with an equal concentration.

SECTION 3
SOUOX IN

A research effort was conducted by the U.S. Fish and Wildlife Service to locate chemicals which would be acutely toxic to larval sea lampreys at extremely low concentrations and which, at the same concentrations, would be nontoxic to other fishes inhabitating the same natural environment (Applegate et al. 1957). MacPhee used the same approach for squawfish in studies at the University of Idaho (MacPhee 1963, 1971b; MacPhee and Bailey 1973; MacPhee and Ruel le 1964; 1965a, 1965b, 1969a). Screening tests were made on 188 chemicals as larvacides and 2,570 as piscicides in 1963 and 1964 (MacPhee and Ruelle 1965a).

Twenty-two chemicals of a total of 488 tested gave an indication of being a squawfish larvacide; 24 chemicals out of 535 were selectively lethal to squawfish (MacPhee and Ruelle 1964). Selectivity indices were calculated for a number of chemicals by dividing the minimum concentration of chemical lethal to the pest fish by the minimum concentration lethal to the desired species (MacPhee and Ruelle 1964). The selectivity index was used to compare the relative toxicity of the chemicals tested to target and non-target species.

During the extensive screening tests, a chemical highly selective to the Northern squawfish, <u>Ptychocheilus oregonensis</u>, and the Unpqua squawfish, P. umpquae, was found (MacPhee 1966). The chemical is 1,1'-methylenedi-2-naphthol monosodium salt. Further discussion of the compound is found in the Chemistry section. A long period of laboratory and field development and testing was required to find the solvent and formulation of the parent compound that would be effective on squawfish, nonlethal to salmonid and other non-target species, and permit safe and easy handling in the field (MacPhee and Ruelle 1965a; MacPhee 1966; MacPhee 1967).

The formulation of squoxin tested is:

Compound	Molecular Wt.	Proportions
1,1-methylenedi-2-naphthol	300	30
ethanol		45
sodium hydroxide	40	4
water		8

(MacPhee and Ruelle 1969a)

Dye studies needed to develop application rate for squoxin in the field showed that stream dispersion is slow at low summer velocities and that at least 8 hours are required to reach a maximum concentration in the stream (MacPhee 1967). A 0.05 ppm dose for twice the length of time would be more effective than 0.1 ppm for half the length of time. In later studies, using Snake River water, Ebel (1975) recommended using 0.03 ppm for a 12-hour period. He found that it would be safe to treat with 0.2 ppm without harming chinook salmon that may be present during a treatment.

The cause of death of squawfish from squoxin treatment is thought to be interference of oxygen transport (MacPhee and Ruelle 1969b). Nakaue et al. (1972) demonstrated that squoxin is a weak uncoupler of oxidative phosphorylation as compared with the chlorinated bisphenols (e.g. hexachlorophene, pentachlorophenol). The mechanism for specificity of the toxin is unknown. However, the work of (Nakaue et al. 1972) shows that squoxin interferes with respiration at the cellular level. Squoxin was demonstrated to stimulate mitochondrial ATPase activity. The interaction of squoxin with mitochondrial proteins is the best hypothesis for the mechanism of squoxin toxicity. There is no biological evidence to show why squawfish are more susceptible to squoxin than other species.

Dr. Craig MacPhee at the University of Idaho, in 1960, conducted research with a chemical compound that he named squoxin. He discovered that it was a selective piscicide for squawfish. There was widespread interest in using squoxin for squawfish control. Squoxin needed to be registered for use as a piscicide. An experimental-use permit was granted by EPA to American Cyanamid Company for use by the Idaho Department of Fish and Game, the Oregon Game Commission, and the Washington Department of Game. Studies were conducted by these agencies to gather information on the efficacy of squoxin in field applications and determine its effect on non-target species of fish and other aquatic organisms. A large part of the work was done to develop data to support a petition to EPA for registration of squoxin. Results of these experimental studies are summarized in Section C, Part 1, of a petition to EPA dated February 14, 1977, for an exemption from a tolerance (Appendix A).

Data on squoxin from the petition and from other literature that specifically pertains to the EPA Part 158 Data Requirements are summarized in the following section. Many other studies are abstracted in the bibliographic index that do not pertain to EPA's requirements. The discussion in this report follows the same order of subjects as in the Part 158 Data Requirements such as metabolism, mobility, and dissipation studies. The complete text of Part 158 is in Appendix B. Laboratory studies were conducted at the University of Idaho College of Forestry, Wildlife and Range Sciences; Oregon State University Department of Agricultural Chemistry, and the University of British Columbia. A contract study was conducted by Cannon Laboratories, Reading, Pennsylvania.

The remainder of this section is organized in accordance with the outline of EPA Data Requirements (Appendix B).

PRODUCT CHEMISTRY

Analytical methods for the detection of squoxin in fish tissues were developed at Oregon State University (Burnard 1974; Burnard and Terriere 1974; Burnard et al. 1974; Kiigemagi et al. 1975; Terriere 1972; Terriere et al. 1970). The method for detection of squoxin and its degradation products in water involves coupling squoxin with a chromogenic agent and measurement by calorimetric procedure. Sensitivity is 0.1 ppm. Detection of squoxin in fish tissues makes use of electron capture gas chromatography and is sensitive to 2 ppb. Other methods of detection of squoxin include: high pressure liquid chromatography in work on degradation products (Burnard and Terriere 1973; and Oliver et al. 1983). Radioactive squoxin was used in several experiments and detected by scintillation counting (Burnard and Terriere 1974; Burnard et al. 1974; Oliver et al. 1983; Terriere 1974; Terriere and Burnard 1975). Squoxin, Figure 3.1, is prepared in a one-step process by combining beta naphthol and formaldehyde (Ogata et al. 1969).

Gabicia et al. (1976) demonstrated an analytical method by which petroleum ether - extracted, brominated squoxin can be quickly and easily detected in water and fish tissues by electron capture gas chromatography. Limits of detection are 100 picograms, or 85 parts per trillion, for a 200 ml sample of water and 600 picograms or 140 parts per billion, for a 1 gram fish tissue sample.

RESIDUE CHEMISTRY

Laboratory studies with trout and squawfish at squoxin concentrations of 50 ppb indicated little tendency for squoxin to be retained in live fish. Maximum residues, based on radioassays were 10.91 ppm in live trout and 3.77 ppm in dead squawfish (Terriere 1974). In field studies residues found were 1.48 ppm in live trout and from 0.84 to 2.38 ppm in dead squawfish. Squoxin concentration was 100 ppb. Immediately following exposure, "Residues in the edible tissues of the trout were less than 0.1 ppm," (Terriere and Burnard 1975). Staley (1977) reported that the invertebrate Daphnia pulex excreted over 90% of an accumulation of squoxin in 96 hours; Hyalella azteca required 275 hours. He concluded that . . . "because of Squoxin's water solubility, low partition coefficient, rapid degradation, and the ability of a wide variety of organisms to excrete it, the toxicant would not be biologically magnified to a significant degree in the aquatic ecosystem."

ENVIRONMENTAL FATE

Staley (1977) attempted to quantify the relative amounts of squoxin residue in components of a hypothetical ecosystem 24 hours after a 500 ug/l treatment, Figure 3.2. Data were derived from both microcosm data and independent

Chemical properties of squoxin are: chemical name - l,l'- methylenedi-2-naphthol, monosodium salt. Other designations - methylene-l,l'-di-2-naphthol, bis(E-hydroxy-I-naphthyl-methane) - SCAVENGER 300, Sonar 300.
Empirical formula - $C_{21}H_{16}O_2$.
Color: white
Physical state: solid powder
Odor: naphthol
Density: (specific gravity) 0.98/0.1 at 25°C
Solubility: 1.4 ppm
Molecular Wt.: 300
Octanol/water partition coef: 4.55

Structure -

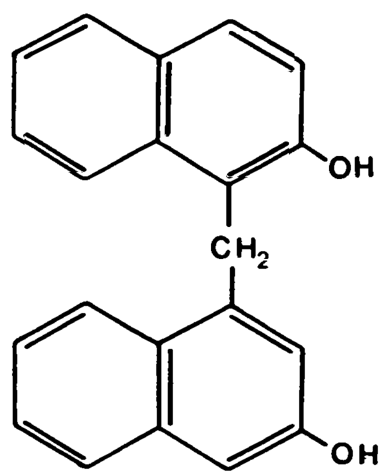

Figure 3.1. Chemical Properties and Structure of Squoxin.*

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Appendix B
Beilsteins Institute for Organic Literature (1923)
Beilsteins Institite for Literature of Organic Chemistry (1944)
Beilsteins Institute for Literature of Organic Chemistry (1969)
Ogata et al. (1969)
Shearing and Smiles (1937)

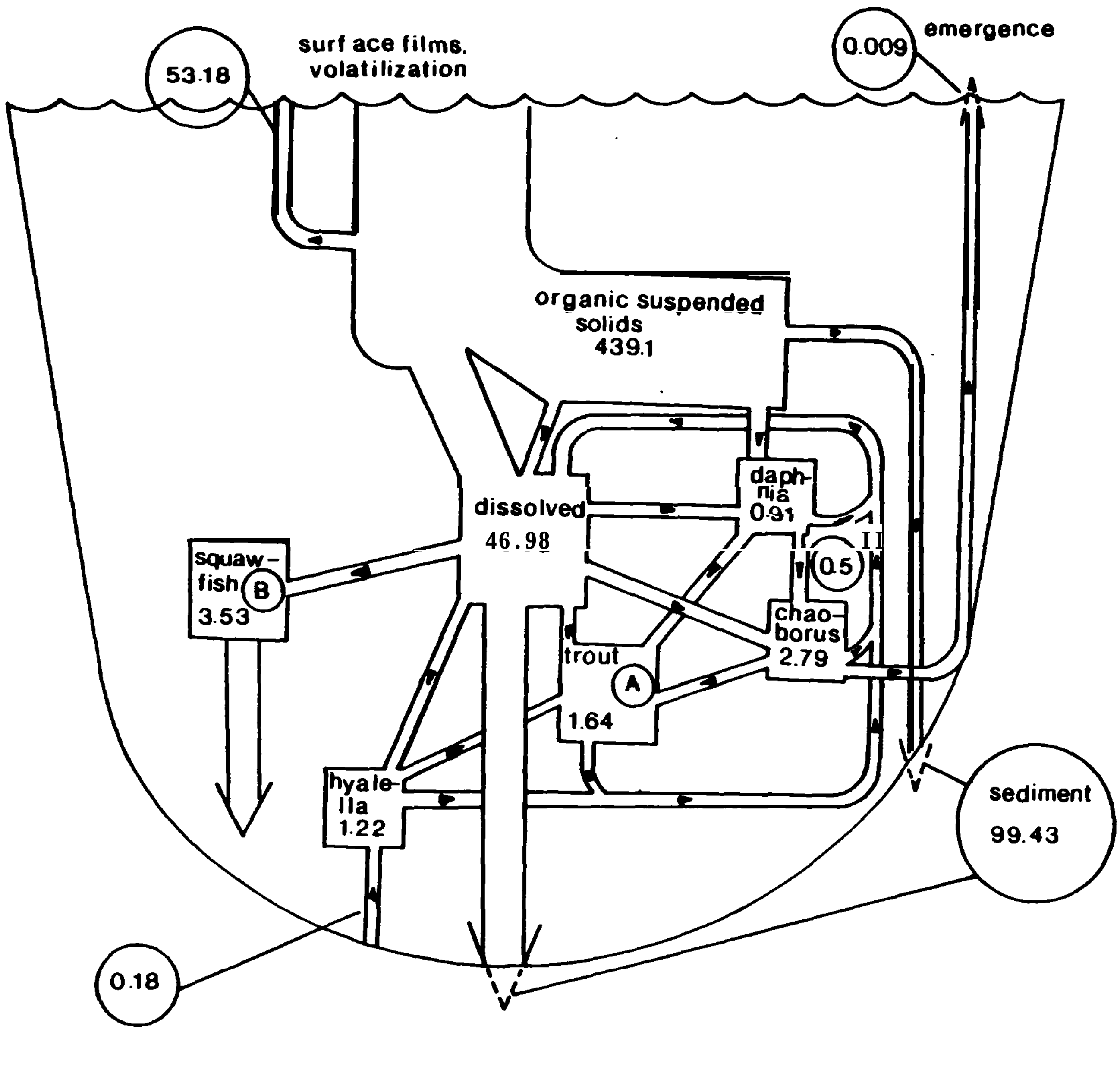

Figure 3.2. Partitioning of 500 ug/l Squoxin Residues in a Hypothetical Lentic Ecosystem 24 Hours after Treatment (Staley 1977). Numbers Indicate ug Squoxin in each Environmental Component Except: A.) Tissue Concentration in Trout (mg/kg) after a 50 ug/l Treatment for 24 Hours (Burnard and Terriere 1974); and B.) Tissue Concentration (mg/kg) in Squawfish after a lethal Dose (Ibid. 1974).

data so that the resultant concentrations in each compartment are more indicative of the proportion present rather than an absolute value.

Degradation Studies

The early work of Burnard and Terriere (1973) suggested as many as 12 degradation products from the oxidation of squoxin in water. Oliver et al. (1983) identified the oxidative degradation products as 1,2 napthoquinone, 1,2 napthoquinone 1-methide, 1-(hydroxymethyl)-2-naphthol, and formaldehyde. The oxidative pathway of squoxin and derivization of 1(hydroxymethyl)-2-naphthol is shown in Figure 3.3. The fate of squoxin and rates of degradation of ring-labeled and methylene-labeled squoxin are shown in Figures 3.4 and 3.5 respectively.

Burnard et al. (1974) showed by using ^{14}C labeled squoxin that after 48 hours in aerated distilled water over 90% of the squoxin was converted to other products. Field monitoring showed the squoxin degradation to be 90% in seven hours. There is a difference in research findings of the half life of squoxin. Keating et al. (1972) estimates that half life, under field conditions, is approximately 2 hours. Oliver et al. (1983) found the half life of ring-labeled squoxin to be about 40 minutes and methylene labeled about 80 minutes in river water. They speculate that, one degradation product, 1-(hydroxymethyl)-2-naphthol, could be the principal biologically active agent because it is detected by the colorimetric method along with squoxin.

Ebel (1975) determined degradation rate of squoxin by two methods: chemical analysis and bioassay. He found that in Snake River water squoxin degraded rapidly at 4, 10, 15, and 20°C, but most rapidly at 15 and 20°C. Chemical analysis showed squoxin degraded 93% in 24 hours at 15°C. Bioassay tests indicated 25 to 50% degradation in 48 hours at 15°C.

Metabolism

Staley (1977) with the Amphipod, *Hyalella azteca*, found that only a small amount of squoxin was transported by the consumption of contaminated food items. In the presence of contaminated organic sediment, *H. azteca* accumulated 7.40 ng squoxin residues/mg wet weight. *H. azteca* in the same vessel confined in a floating cage accumulated squoxin residues of 1.7 ng/mg wet weight, 23% of the concentration in those permitted to graze. The concentration of squoxin residues in the water was only 0.3% of that in the sediment. Thus, the concentration factor was 2-3 orders of magnitude greater than by ingestion. As a result of this and other evidence Staley concluded that the main route of uptake in *H. azteca* is through adsorption of the squoxin residues rather than digestion and assimilation.

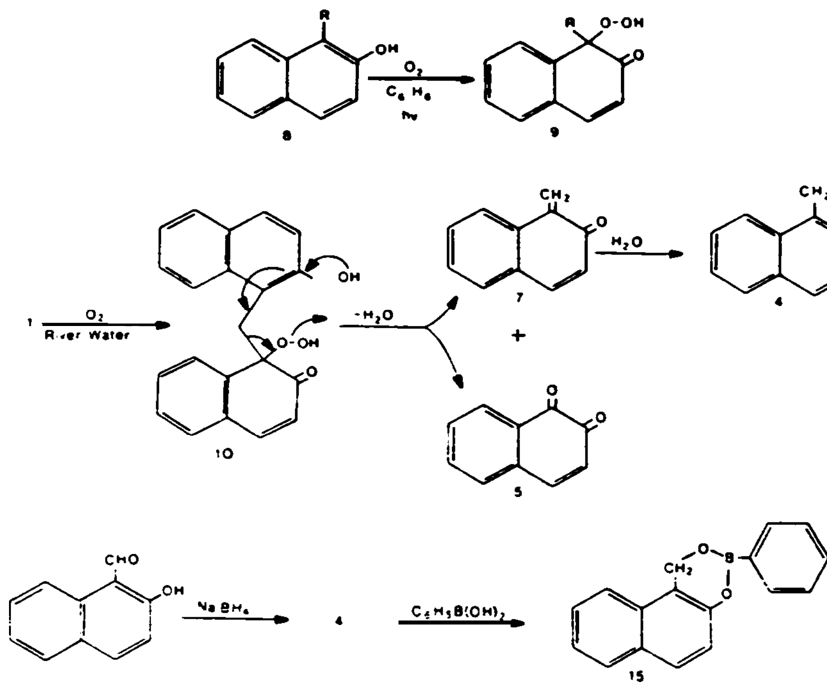

Figure 3.3. Oxidation Pathway of Squoxin and Derivatization of 1-(hydroxy-methyl)-**2-naphthol (Oliver et al.** 1983). **Legend** 1. **Squoxin** (1,1'-methylene-di-2-naphthol). **2. 2-naphthol. 3. Formaldehyde. 4. 1-(hydroxymethyl)-2-naphthol. 5. 1,2-naphtho-quinone. 6. Dehydrosquoxin. 7. 1,2-naphthoquinone** 1-methide. 8. 1-alkyl-2-naphthol. **9. Hydroperoxides.** 11. **2-hydroxy-1,4-naphthoquinone. 15. Phenylboronic ester.**

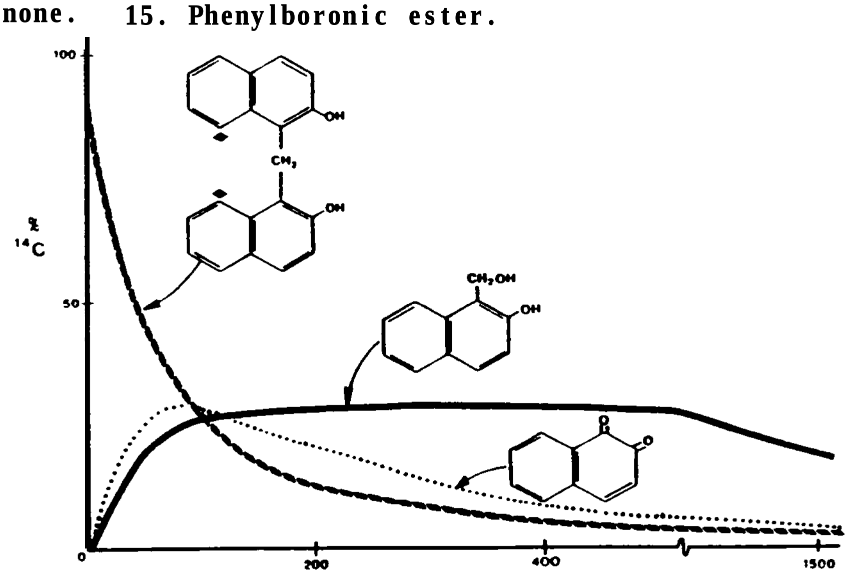

Figure 3.4. Decomposition of Ring-labeled Squoxin in River Water (Oliver et al. 1983).

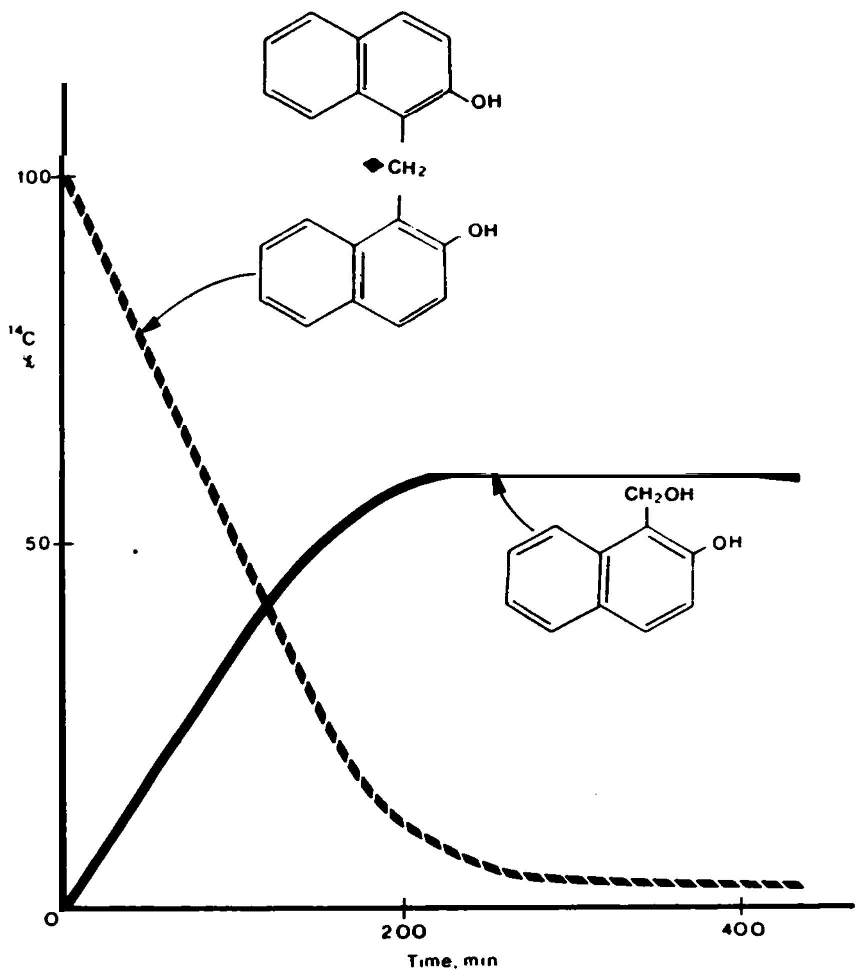

Figure 3.5. Decomposition of Methylene-labeled Squoxin in River Water.

Chaoborus trivittatus fed Daphnia pulex contaminated with squoxin (D. pulex were exposed to 500 ug ^{14}C squoxin/l of water for 24 hours prior to-ingestion) retained 5% of the total activity ingested (Staley 1977). The residues in C. trivittatus appeared to be retained longer than those from waterborne exposure to the labeled squoxin. D. pulex in a separate experiment but with similar exposure conditions were able to excrete 2/3 of the accumulated toxicant rapidly within 24 hours, in an uncontaminated environment, followed by a plateau with a further rapid loss of over 90% between 72-96 hours. H. azteca required 275 hours for a 90% reduction in squoxin concentration.

The principal mode of reduction in aquatic invertebrates of tissue concentrations of squoxin appears to be from desorption via the exoskeleton or loss via molting or pupation. The exoskeleton acts a sink for squoxin. D. pulex exhibited a significant reduction in toxicant after molting. In H. azteca concentrations decreased rapidly while in contact with organic sediments. C. trivittatus upon pupation exhibited a rapid loss of squoxin.

White rats fed ^{3}H and ^{14}C labeled squoxin did not exhibit a tendency to accumulate it in body tissues (Burnard and Terriere, 1974). Bile was the major route of excretion of squoxin and its metabolites. An average of 92% of the total body burden was recovered in the bile.

Squoxin was found to be readily excreted in aquatic biota and mammals. Both rainbow trout and rats excreted squoxin primarily via bile. The primary means of excretion in aquatic invertebrates appears to be desorption-diffusion mechanisms through the exoskeleton. Loss following molting by D. pulex, rapid loss by H. azteca in contact with organic sediment, and loss-upon pupation in C. trivittatus illustrate these mechanisms. Exactly what proportion of detoxification is by biochemical means in aquatic invertebrates has not been determined.

Mobility Studies

Adsorption/desorption. Squoxin has demonstrated little tendency to adsorb to inorganic suspended solids. Terriere et al. (1970) observed a slight depression of extractable squoxin from water containing 50 ug/l of Florisil (activated magnesium silicate), but there was no appreciable degradation due to 50 mg/l of Attaclay or magnesium oxide. Staley (1977) found a strong sorption reaction from dissolved organic compounds but concluded that in natural waters other degradation pathways proceeded at a faster rate. The presence of high concentrations of dissolved organic compounds may result in enhanced stability of squoxin by limiting the penetration of sunlight in water. Staley (1977) also found that squoxin desorbed readily from the surfaces of organic material. This may help to explain Terriere's findings of the persistence of squoxin in a pond 14 days after treatment (Swan 1972a). MacPhee and Cheng (1974) observed the measurable concentrations of squoxin in water containing phytoplankton persisted for 72 hours longer than in controls. Staley (1977) stated that it is not known whether the movement of squoxin from sediment and phytoplankton back into the water represents the enhanced solubility of degradation products or desorption of the parent compound.

The degradation of squoxin was faster in Takes with greater pH, dissolved inorganics and organic compounds (Staley 1977). Recoverable squoxin concentrations following treatment of natural lake waters ranged from 77% loss at 48 hours in a productive lake, to a loss of only 11% at 96 hours in pristine lakes with low alkalinities (4 mg as $CaCO_3/l$).

Tests by Staley (1977) of the partitioning of squoxin over time using microcosms all demonstrate similar curves of decreasing concentrations in sediment with increasing water concentrations.

Dissipation Studies - Field

Burnard et al. (1974) reported an experiment on the St. Joe River where the concentration of squoxin was measured hourly at several points downstream. Thirty ppb at the point of application dropped to 22 ppb at the 1/2 mile--point and 4 ppb at the 5-mile point. To be assured of a complete kill, squoxin is metered into a stream at about each 5-mile point.

The half life of squoxin varies in the uncirculated water of ponds and pools. In a 2,200 liter plastic swimming pool, squoxin's half life was 24 hours (Keating et al. 1972), while in a 1.8-acre-foot rearing pond it was less than 6 hours. A measureable concentration (3.6 ppb) persisted for 14 days in the pond, although laboratory studies have demonstrated a much shorter residual life (Swan 1972a).

Accumulation Studies

Fish. Metcalf et al. (1975) found that the uptake and concentration of organic compounds, eg. squoxin, was a function of their lipid/water partition coefficients and their resistance to degredation by enzymatic processes. Squoxin is rapidly excreted in the bile of trout (Staley 1977). The conclusions of Staley (1977) are pertinent: "Squoxin is probably less likely than many other pesticides to reach unacceptable levels in [non-target] organisms considering only its physical/chemical attributes. The distribution of 1.0 gram of squoxin in a binary solvent system of hexane/water would be 790 mg/210 mg (3.76). These values are very different from those reported for DDT: 999.99 mg/0.01 mg (99,999) in the same binary solvent system (Kenaga 1972). These values mean that DDT strongly sorbs to an organic or lipid compound and powerfully resists any movement into the aqueous solution. The ready desorption of squoxin or its degradation products from organic sediment in the microcosms illustrates the difference in these two compounds. The low stability of squoxin in aqueous solution insures that the compound will not be present in the environment, and hence available for uptake by organisms, for a long period."

Terriere (1975) exposed rainbow trout to four successive 6-hour exposures of ^{3}H squoxin at 50 ppb and then purged in fresh water. They monitored the loss of squoxin from individual tissues and found that over 90% of the accumulated labeled compound was excreted during the next 48 hours. Less than 0.1 ppm remained in edible tissues at 48 hours and less than 0.01 ppm in all tissues (except brain) after 92 hours. Therefore squoxin in trout depurates rapidly under natural conditions.

Aquatic Non-target Organisms. No evidence was found in the available literature of substantial accumulation of squoxin by non-target organisms. Staley (1977) found rapid excretion of squoxin in C. trivittatus and H. azteca. Total body burden declined to less than 10% within 144 hours and remained at this level for the next 24 hours. Daphnia pulex excreted over 90% of squoxin in 96 hours.

Squoxin was found to be highly toxic to blackfly larvae, 48 hr LC_{50} 60 ug/l (Staley 1977). The blackfly (Family Simulidae) is a vector for a fatal malaria-like protozoan disease (Leucocytozoon simondi) which infects young ducks, geese, and all waterfowl (Kudo 1960). The potential for the use of squoxin in blackfly control should he studied to determine the possible benefits of its use in aquatic environments where blackflies are a problem.

TOXICOLOGY DATA

Acute Testing

American Cyanamid Company made a series of acute toxicology tests on squoxin (Appendix A). These preliminary tests gave the following results:

Test	Result
Oral LC_5 (rat)	> 109 mg/kg.
Dermal L850	> 59 mg/kg.
Primary eye irritation	No adverse effects
Primary dermal irritation	No studies

Subchronic Testing

90-day feeding - (rodent)	No studies
21-day dermal	No studies
90-day dermal	No studies

Chronic Testing

Two simultaneous 13 week oral toxicity studies were conducted on dogs and rats by Cannon Laboratories (Ravert and Parke 1976, Terre11 and Parke 1976). Squoxin was administered orally to dogs by capsule (because the squoxin in feed was unpalatable) at rates of 100 mg/kg, 250 mg/kg and 0 mg/kg (control) for 90 days. No significant abnormalities were observed in any of the nine physical and physiological parameters examined. In a simultaneous experiment rats were fed squoxin (in the food) at the rates of 100 mg/kg and 1,000 mg/kg for 13 weeks. There was a significant decrease in body weight and food consumption in the high dose group (1,000 mg/kg). Hematocrit was reduced in all groups, including controls. Organ weights were reduced in test animals. There were no differences between test and control animals for the other parameters measured.

Oncogenicity Testing. The organ weight change in the chronic rat feeding study is the only indication of an abnormality from chronic or subchronic studies (Ravert and Parke 1976). This change is associated with reduction in body weight and food consumption and is not a morphologic effect (Ravert and Parke 1976).

Teratogenicity. No work has been done on this subject.

Reproduction. No work has been done on this subject.

Mutagenicity Testing

No work has been done on this subject.

Special Testing

No work has been done on this subject.

RE-ENTRY PROTECTION DATA REOUIREMENTS

No studies were conducted on this subject.

WILDLIFE AND AOUATIC ORGANISMS DATA REQUIREMENTS

Avian and Mammalian Testing

Avian Oral LD50. No studies were conducted on this subject.

Avian Dietary LC50. Two tests were conducted by Reinert and Parke (1976) using mallard ducks (Anus platyrhinchos) and Coturnix quail. Both animal groups were fed squoxin concentrations of between 5,000 ppm and 20,00@ ppm. None of the ducks or quail died or exhibited other pathological effects from the toxicant.

Wild Mammal Toxicity. The only wild mammals that would routinely come in direct contact with squoxin treated water would be rodents such as mice, rats, beaver, or muskrats. Due to the short half life of squoxin in streams (2 hours) and that treatment of streams is for only 12 hours, the period of possible-exposure would be no longer than 12 hours. None of the evidence from testing indicates any acute oral toxicity to mammals, e.g. rats at 1,000 mg/kg (Ravert and Parke 1976).

Avian Reproduction.
No studies were conducted on this subject.

Simulated and Actual Field Testing - Mammals and Birds
No studies were conducted on this subject.

Aquatic Organism Testing

Freshwater Fish LC50. The LC_{50} of squoxin for six species of freshwater are in Table 3.1 (MacPhee and Cheng 1974).

Toxicity tests of squoxin were conducted on seven species of fish by the U.S. Department of Interior, Bureau of Sport Fisheries and Wildlife (1969). The highest LC_{50} in 96 hours was for coho salmon at 0.110 ppm. Test results are in Table 3.2. The 96-hour LC_{50} from (MacPhee and Ruelle 1965b) is 0.30 ppm for chinook salmon, 2.0 ppm for coho salmon, and 0.006 ppm for squawfish. Table 3.3 gives the summary of LC_{50}s for freshwater fish.

MacPhee and Ruelle (1969b) calculated a selectivity index (the maximum concentration of squoxin that is lethal to 0% of a desirable fish divided by the minimum concentration lethal to 100% of a pest fish). Table 3.4 contains the approximate LC_0/LC_{100} selectivity indices for salmonids versus squawfish.

Table 3.1. LC_{50} Concentrations in ppb of Squoxin in 12, 24, and 96-hour Bioassays for Six Species of Freshwater Fishes. (LC_{50}s in Parentheses Were Derived by the Method of Litchfield and Wilcoxon 1949.) (MacPhee and Cheng 1974.)

Species	Temperature Degrees C.	12-hour	24-hour	96-hour
Oncorhynchus tshawytscha	10.0		700	(375)
	12.5		700	400
	18.5-20.0	950	650	400
		(900)	700	350
Acrocheilus alutaceus	10.2	(300)	80	(65)
	15.0-15.5	(50)	(50)	(65)
Rhinichthys cataractae	5.0			(250)
	7.0	1200	(1000)	400
	10.3-10.5	2000	(300)	(150)
	15.0-15.5	(250)	(80)	(80)
	18.8-20.5	(70)	(60)	50
Rhinichthys osculus	5.0	(1400)	(500)	
	10.2-10.6	1200	300	80
	15.0-15.6	(130)	(350)	50
	20.0	80	(60)	(60)
Richardsonius balteatus	4.4-5.0	(1400)	600	(150)
	10.2-10.6	350	350	(180)
	15.0-15.5	650	200	250
	20.0	(200)	200	(180)
Cottus rhotheus	5.0			(1100)
	10.2-10.6		1600	(900)
	15.0-15.3	1600	(800)	(600)
	20.0-20.5	(1300)	(900)	(900)

Table 3.2. Toxicity of Squoxin (1,1'-methylenedi-2-naphthol) to Fish (U.S. Department of Interior 1969).

Species	Temp. C.	Water hardness	LC50 (p.p.m.) and 95-percent confidence interval at 3 hours	6 hours	24 hours	48 hours	96 hours	Mean slope function
Coho salmon *Oncorhynchus kisutch*	7	standard	4.800 2.890-7.970	1.275 1.030-1.580	0.745 0.620-0.895	0.440 0.392-0.493	0.241 0.208-0.280	1.321
" "	12	"	2.260 1.683-3.036	2.000 1.545-2.545	0.666 0.574-0.774	0.270 0.226-0.323	0.182 0.162-0.205	1.267
" "	17	"	1.275 1.030-1.580	1.275 1.030-1.580	0.288 0.258-0.322	0.163 0.137-0.194	0.110 0.087-0.139	1.239
" "	12	soft	1.288 1.030-1.611	1.288 1.030-1.611	0.599 0.516-0.695	0.282 0.255-0.312	0.199 0.183-0.217	1.196
" "	12	medium	1.940 1.375-2.736	1.288 1.030-1.611	0.730 0.614-0.869	0.303 0.282-0.326	0.185 0.171-0.203	1.235
" "	12	hard	1.940 1.375-2.736	1.288 1.030-1.611	0.646 0.561-0.743	0.330 0.293-0.372	0.241 0.212-0.275	1.262
Rainbow trout *Salmo gairdneri*	7	standard	2.735 2.040-3.660	1.300 1.030-1.640	0.900 0.714-1.133	0.600 0.518-0.694	0.322 0.290-0.356	1.306
" "	12	"	1.300 1.030-1.650	1.300 1.030-1.650	0.647 0.610-0.686	0.400 0.364-0.440	0.225 0.184-0.274	1.225
" "	17	"	1.300 1.030-1.650	1.263 0.988-1.619	0.402 0.348-0.464	0.229 0.200-0.262	0.181 0.153-0.215	1.283
" "	12	soft	2.175 1.640-2.881	2.175 1.640-2.881	0.721 0.632-0.823	0.506 0.444-0.577	0.298 0.266-0.344	1.244

Table 3.2 continued:

Rainbow trout *S. gairdneri*	12	medium	2.250 1.678-3.020	2.190 1.650-2.910	0.820 0.715-0.942	0.400 0.369-0.434	0.272 0.249-0.297	1.244
"	12	hard	2.180 1.640-2.890	1.310 1.030-1.665	0.778 0.724-0.835	0.477 0.394-0.507	0.293 0.264-0.325	1.227
Brook trout *Salvelinus fontinalis*	12	standard	1.400 1.040-1.890	1.400 1.040-1.890	0.739 0.650-0.840	0.430 0.390-0.475	0.239 0.208-0.275	1.295
Goldfish *Carassius auratus*	12	"	---	6.580 5.660-7.640	1.345 0.994-1.822	0.782 0.685-0.891	0.779 0.729-0.881	1.258
Carp *Cyprinus carpio*	12	"	---	---	1.158 1.015-1.320	0.618 0.535-0.714	0.490 0.423-0.568	1.291
White sucker *Catostomus commersoni*	12	"	---	---	0.540 0.461-0.631	0.380 0.330-0.437	0.380 0.322-0.448	1.341
Black bullhead *Ictalurus melas*	12	"	11.200 9.120-14.190	4.940 3.798-6.420	1.310 1.030-1.663	1.310 1.030-1.663	0.708 0.534-0.938	1.438
Green sunfish *Lepomis cyancellus*	12	"	6.207 5.425-7.100	3.265 2.333-4.575	0.665 0.544-0.799	0.339 0.367-0.434	0.359 0.319-0.404	1.216
Bluegill *Lepomis macrochirus*	12	"	5.900 5.080-6.850	3.120 2.260-4.310	2.690 1.890-3.820	1.057 0.814-1.372	0.704 0.578-0.946	1.481

Table 3.3. Squoxin Toxicity to Several Species of Freshwater Fish and Test Conditions.

Species	Temp. C.	Water hardness	pH	LC_{50} (ppm) conf. interval at 96 hours	Reference
Coho salmon *Oncorhynchus kisutch*	7	standard		0.241	U.S. Dept. Interior 1969
"	12	"		0.182 0.162-0.205	"
" "	17	"		0.110 0.087-0.139	"
" "	12	soft		0.199 0.183-0.217	"
" "	12	medium		0.185 0.171-0.203	"
" "	12	hard		0.241 0.212-0.275	"
" "	12.8F	4 ppm	7.9	1.70	"
Chinook salmon *Oncorhynchus tshawytscha*	12.8F	4 ppm	7.9	0.300	"
"	10.0	28	7.5	(0.375)	MacPhee & Cheng, 1974
	12.5	"	"	0.400	"
	18.5-20.0	"	"	0.400	"

Table 3.3 continued:

Species	Temp. C.	Water hardness	pH	LC_{50} (ppm) conf. interval at 96 hours	Reference
Steelhead trout Salmo gairdneri	12.8F	4 ppm	7.9	2.20	"
Rainbow trout Salmo gairdneri	7	standard		0.322 0.290-0.356	"
" "	12	"		0.225 0.184-0.274	"
" "	17	"		0.181 0.153-0.215	"
" "	12	soft		0.298 0.266-0.344	"
" "	12	medium		0.272 0.249-0.297	U.S. Dept. Interior 1969
" "	12	hard		0.293 0.264-0.325	"
Brook trout Salvelinus fontinalis	12	standard		0.239 0.208-0.275	"
Goldfish Carassius auratus	12	"		0.779 0.729-0.881	"

Table 3.3 continued:

Species	Temp. C.	Water hardness	pH	LC_{50} (ppm) conf. interval at 96 hours	Reference
Carp *Cyprinus carpio*	12	"		0.490 0.423-0.568	"
White sucker *Catostomus commersoni*	12	"		0.380 0.322-0.448	"
Black bullhead *Ictalurus melas*	12	"		0.708 0.534-0.938	"
Green sunfish *Lepomis cyanellus*	12	"		0.359 0.319-0.404	"
Bluegill *Lepomis macrochirus*	12	"		0.704 0.578-0.946	"
Chiselmouth *Acrocheilus alutaceus*	10.2	28	7.5	(0.065)	
	15.0-15.5	"	"	(0.065)	
Longnose dace *Rhinichthys cataractae*	14.8	"	"	(0.050)	MacPhee & Bailey, 1973
	5.0	"	"	(0.250)	"
	7.0	"	"	0.400	"
	10.3-10.5	"	"	(0.150)	"
	15.0-15.5	"	"	(0.080)	"
	18.8-20.5	"	"	0.050	"
Speckled dace *Rhinichthys osculus*	5.0	28	7.5		
	10.2-10.6	"	"	0.080	"
	15.0-15.6	"	"	0.050	"
	20.0	"	"	(0.060)	"

Table 3.3 continued:

Species	Temp. C.	Water hardness	pH	LC_{50} (ppm) conf. interval at 96 hours	Reference
Redside shiner					
Richardsonius	4.4-5.0			(0.150)	"
balteatus	10.2-10.6			(0.180)	"
	15.0-15.5			0.250	"
	20.0			(0.180)	"
	4.0-6.7	180	8.2	(0.170)	"
	9.7-9.8	"	"	(0.120)	"
	14.8-15.3	"	"	(0.130)	"
	17.5	"	"	(0.150)	"
	18.8-19.7	"	"	(0.90)	"
Torrent sculpin					
Cottus	5.0			(1.100)	"
rhotheus	10.2-10.6			(0.900)	"
	15.0-15.3			(0.600)	"
	20.0-20.5			(0.900)	"
	3.5	180	8.2	--	
	13.8	"	"	(0.350)	MacPhee & Bailey, 1973
	19.5-19.8	"	"	(0.220)	"
Squawfish	18.5	4 ppm	7.9	0.0026	MacPhee & Ruelle, 1965b
Ptychocheilus	16.0			0.0029	1969b
oregonensis	12.8			0.006	"
	10.0			0.0076	"

Table 3.4. Selectivity Index of Squoxin for Salmonids Versus Squawfish (MacPhee and Ruelle 1969b).

Squawfish	Temperature Degrees C.	Salmon Coho	Salmon Chinook	Trout Steelhead	Trout Brook
Northern	10.0	87	7 10	87	20
	12.8	100		100	30
	15.6	100	12	100	37
	18.3	100	17	100	50
Umpqua	10.0	43	3	43	10
	12.8	50	5	50	15
	15.6	53	7	53	20
	18.3	60	10	60	30

At a concentration of 0.1 ppm squoxin, the maximum LCO for the least tolerant salmonid species is 7 to 17 times greater than the minimum LC_{100} for Northern squawfish and 3 to 10 times greater than that for Umpqua squawfish depending on the temperature.

Acute LC_{50} Freshwater Invertebrates. Staley (1977) conducted a series of experiments to determine the effect of squoxin on aquatic invertebrates. He found a gross difference in LC_{50} between-two specie; of Diptera larvae Simulium canadense, and Chaoborus trivittatus (180 ug/l and 10,000 ug/l respectively). Chaoborus can live for days an in oxygen depleted environment while Simulidae live in flowing, oxygen rich water. Both have the same mode of oxygen uptake by simple diffu sion of gases through the cuticle. The precise mechanism of toxicity for squoxin is not fully known, but it is believed to interfere with oxygen transport.

Vaso-dialation is observed in squawfish and uncoupling oxidative phosphorylation is reported for squoxin. Staley (1977) hypothesized that an organism capable of living through anaerobic periods (Chaoborus) would be best able to weather a chemical severance of the available oxygen supply and thus the difference in toxic reaction to squoxin.

Studies by Staley (1977) gave the following LC_{50} values, Table 3.5, for aquatic invertebrates.

No significant increase in insect drift was observed on the St. Joe River during a 72-hour observation following a 13-hour treatment with 100 ug/l of squoxin. (Brusven and MacPhee 1974). Eight species of insects from the orders Tricoptera and Ephemoptera made up 87% of the insects collected.

There is a potential use of squoxin that could benefit the production of waterfowl. The blackfly (Family Simulidae) is a vector for a fatal malaria-

Table 3.5. Toxicity of Squoxin to Invertebrates - Summary of LC_{50} Values (Staley 1977).

Organism	Time 48 Hours	96 Hours
Simulium canadense	60 ug/l	- - - - -
Chaoborus tribittatus	resistant	resistant
Hyalella azteca	"	3250 ug/l
Anisogammarus ramellus	"	690 ug/l
Daphnia pulex (adult)	1620 ug/l	950 ug/l
Daphnia pulex (juvenile)	2490 ug/l	- - - - -

like protozoan disease (Leucocytozoon simondi) which infects young ducks, geese, and all waterfowl. The etiology is given in (Kudo 1960). The U.S. Fish and Wildlife Service considered closing down the Semay Wildlife Refuge in Michigan because of high mortalities of waterfowl from this disease (Personal Communication Dr. Richard Kocan 1984). Squoxin was found to be highly toxic to blackfly larvae, 48hr LC_{50} 60 ug/l (Staley 1977). The potential for the use of squoxin in blackfly control should be studied to determine the possible benefits of its use in aquatic environments where blackflies are a problem.

Acute LC50 Estuarine and Marine. Bioassay screening tests by the Bureau of Commerical Fisheries at Gulf Breeze, Florida, showed a 50% decrease in shell deposition of Crassostrea virginica compared to controls after 96 hours with a squoxin concentration of 0.19 ppm. The EC_{50} of the pinfish Lagodon rhomboides occurred at a concentration of 0.52 ppm squoxin in 48 hours (pp. 338-342 of Appendix A).

Fish Early Life Stage and Aquatic Invertebrate Life Cycle. Studies were done by the International Pacific Salmon Fisheries Commission on early life stages of sockeye salmon for toxicity to squoxin (Johnston 1972). A selectivity index is in Table 3.6 along with results of a 96-hour bioassay in Table 3.7.

The results show that newly hatched sockeye salmon alevins would be subjected to lethal concentrations of squoxin if squawfish eradication were attempted when newly hatched sockeye alevins were present at water temperatures of 4.4°C. or less. This situation is denoted by a selectivity index (LC0/LC100) value of 0.9 in Table 3.6. Only when an index is equal to or larger than 1 (and preferably higher for field application) will squoxin be lethal to 100 percent of the northern squawfish and 0 percent of the sockeye. This concentration is 10 times the amount recommended for eradication of squawfish. The tests also show that sockeye infected with costiasis would also be more susceptible to squoxin. Zooplankton exposed to squoxin ranging from 0.008 to 0.10 ppm at a temperature of 12.8°C. suffered no mortalities. Field applications would not be made at temperatures below 12°C. because of the larger concentration required to kill squawfish and the greater cost. The possible detrimental effect on non-target organisms would also be considered.

Table 3.6. Selectivity Indices (LC_0/LC_{100}) for Sockeye Salmon Versus Northern Squawfish (Johnston 1972).

Sockeye Developmental Stage	Selectivity Index At--			
	. ° .	. 0 .	10°C.	12.8°C.
Alevins just hatched	0.9	1.5	6.0	9.0
Alevins with 50 percent yolk	1.0	1.7	6.7	10.0
Fry with no yolk	7.0	11.7	53.3	90.0
Fingerlings:				
Precostiasis	7.0	11.7	53.3	90.0
With costiasis	8.0	5.0	--	--
Post costiasis	7.0	11.7	--	--

Fish Life Cycle. The recommended rate for application of squoxin is 100 ppb. Johnston's (1972) studies with sockeye show that newly hatched fry could be damaged at squoxin concentrations of 900 ppb. However, the no-effect level rises to 9,000 ppb upon absorption of the yolk sac. In the natural environment, sockeye salmon (and other salmonids) eggs would hatch in the early spring months when stream temperatures would not exceed 12°C. Squoxin would not be applied at this time for reasons given above. A restriction would he placed on the label to prevent application in salmonid spawning areas when yolk-sac fry were present and when the temperature was less than 12°C. Applications of squoxin would be made only by fishery biologists with an intimate knowledge of the watersheds and the species present.

Aquatic Organism Accumulation. There is a linear relationship between the partition coefficient and bioconcentration of organic chemicals (Neely et al. 1974). Kenaga (1972) proposed guidelines to determine bioconcentration potential of pesticides. He observed that some of the important properties of pesticides resulting in high bioaccumulation are high fat solubility, low water solubility, high partitioning coefficients from water to environmental components, and high stability under various hydrolytic, light, heat, and microbiological conditions. The n-octanol/water partition coefficient of squoxin was calculated to be 4.55 (Schmedding, personal communication). Nakaue et al. (1972) calculated the partition coefficient of squoxin in hexane/buffered water at 3.8. A partition coefficient is the ratio of the equilibrium concentrations of a chemical in a non-polar, and a polar solvent, i.e. n-octanol and water, or hexane and water (Neely et al. 1974). Squoxin has a comparatively low n-octanol/water partition coefficient of 4.55 when compared with that of chlorinated organic pesticides such as p,p'DDT=1.55×10^6 (Chiou et al. 1977).

Table 3.7. Maximum Concentrations of Squoxin Lethal to 0 Percent of Sockeye and Minimum Concentrations Lethal to 100 Percent of the Squawfish in 96-hour Bioassays at Four Temperatures (Johnson 1972).

	Average weight (grams)		Percent mortality	Squoxin concentrations (ppm) at--			
				4.4°C.	7.2°C.	10°C.	.8°C.
Sockeye alevins:							
Just hatched	0.127	(120)	0	0.09	0.09	0.09	0.09
Yolk 50 percent	.156	(120)	0	.10	.10	.10	.10
Sockeye fry:							
No yolk	.210	(120)	0	.70	.70	.80	.90
Sockeye fingerlings:							
Precostiasis	1.6-13.6	(120)	0	.70	.70	.80	.90
With costiasis	1.6-13.6	(60)	0	.30	.30	--	--
Post costiasis	1.6-13.6	(60)	0	.70	.70	--	--
Northern squawfish	56.0	(24)	100	.10	.06	.015	.01

1974). Kenaga (1972) proposed guidelines to determine bioconcentration potential of pesticides. We observed that some of the important properties of pesticides resulting in high bioaccumulation are high fat solubility, low water solubility, high partitioning coefficients from water to environmental components, and high stability under various hydrolytic, light, heat, and microbiological conditions. The n-octanol/water partition coefficient of squoxin was calculated to be 4.55 (Schmedding, personal communication). Nakaue et al. (1972) calculated the partition coefficient of squoxin in hexane/buffered water at 3.8. A partition coefficient is the ratio of the equilibrium concentrations of a chemical in a non-polar, and a polar solvent, i.e. n-octanol and water, or hexane and water (Neely et al. 1974). Squoxin has a comparatively low n-octanol/water partition coefficient of 4.55 when compared with that of chlorinated organic pesticides such as p,p'DDT=1.55×10^6 (Chiou et al. 1977).

Black et al. (1983) observed a close correlation between toxicity of organic contaminants and n-octanol/water partition coefficient. A direct correlation was observed between acute toxicity of several classes of organic compounds and bioconcentration potential (Birge and Cassidy 1983; Chiou et al. 1977). Squoxin has a low partition coefficient, is relatively unstable in oxygenated water, and has a low tendency to bioaccumulate in aquatic organisms (Staley 1977). Further information on bioaccumulation in fish can be found under a previous heading, "Accumulation Studies."

Terriere and Burnard (1975) exposed squawfish and rainbow trout to radiolabeled squoxin in the laboratory. Maximum residues in trout were 9.45 ppm from as many as four exposures at a concentration of 50 ppb. Squawfish killed by a single exposure had maximum residues of 3.5 ppm. Trout exhibited an ability to metabolize and excrete squoxin. Trout excreted over 90% of the accumulated dose during the next 48 hours in clean water. Bile was the primary route of squoxin excretion. Surviving trout from a field exposure of 100 ppb had residues as high as 1.48 ppm (whole body), while squawfish contained residues ranging from 0.84 to 2.38 ppm. Edible trout tissues contained less than 0.1 ppm. Therefore, it appears that bioaccumulation of squoxin in edible portions of trout is not a serious problem.

Simulated or Actual Field Testing. Thirty-six field applications of squoxin were made by the fishery agencies of Idaho, Oregon, Washington, and British Columbia (IR-4 1979). The number of squawfish killed ranged from 2,000 to 200,000 over stream reaches from 1-1/2 miles to 33 miles. Concentrations of squoxin ranged from 33 ppb to 150 ppb. Almost 100% kill of squawfish occurred in the treated stream reaches with only a few dead shiners, chubs, and sculpins noted in the mixing zone below the point of application. No dead salmonids or invertebrates were observed in the streams.

SECTION 4
REGISTRATION REQUIREMENTS

The law and regulations for the registration and use of pesticides in the United States have evolved over several years. The Federal Insecticide, Fungicide, and Rodenticide Act was passed by Congress in 1972 giving the Environmental Protection Agency the authority to prescribe regulations to carry out the provisions of the Act. EPA has developed proposed regulations for registration of pesticides and guidelines for data requirements. They prescribe laboratory practices for testing. A specific set of rules, guidelines, and procedures must be followed to issue the registration of a pesticide. A flow chart of the steps is outlined in Figure 4.1.

FEDERAL INSECTICIDE, FUNGICIDE, AND RODENTICIDE ACT (FIFRA)

The basic provisions of the FIFRA (Appendix C) are outlined in Table 4.1. The Act states that no person may distribute, sell, or transport any pesticide which is not registered with EPA. Procedure and requirements for registration are stated, including data in support of an application. EPA is required to publish guidelines specifying the kinds of information required to support the registration. Other administrative and legal provisions are covered in the Act which are not pertinent to this review.

Guidelines have been published by EPA for each section of the Part 158 Data Requirements for Registration (Appendix D). Guidelines are nonregulatory and are intended to standardize the methods, species tested, and data treatment. The director of each part of a testing program should develop a protocol for his study such as mutagenicity and consult with EPA prior to commencing the work to be certain the results will be acceptable.

A flow chart is given in Figure 4.1 showing the steps in the process for registration of a pesticide. An important aspect of the process is the need for continuing communication with the EPA Product Manager assigned to the compound being tested.

40 CFR PART 158 - DATA REOUIREMENTS FOR REGISTRATION (PROPOSED)

The Part 158 data requirements are divided into sub part A - General Provisions and sub part B - Registration Data Requirements. Appendix B contains the entire regulation which supercedes all former drafts designated as parts 163 and 181.

Part 158 encompasses the full range of data requirements pertaining to the registration/reregistration or experimental use of each pesticide product under the FIFRA. An applicant should determine the data required for the

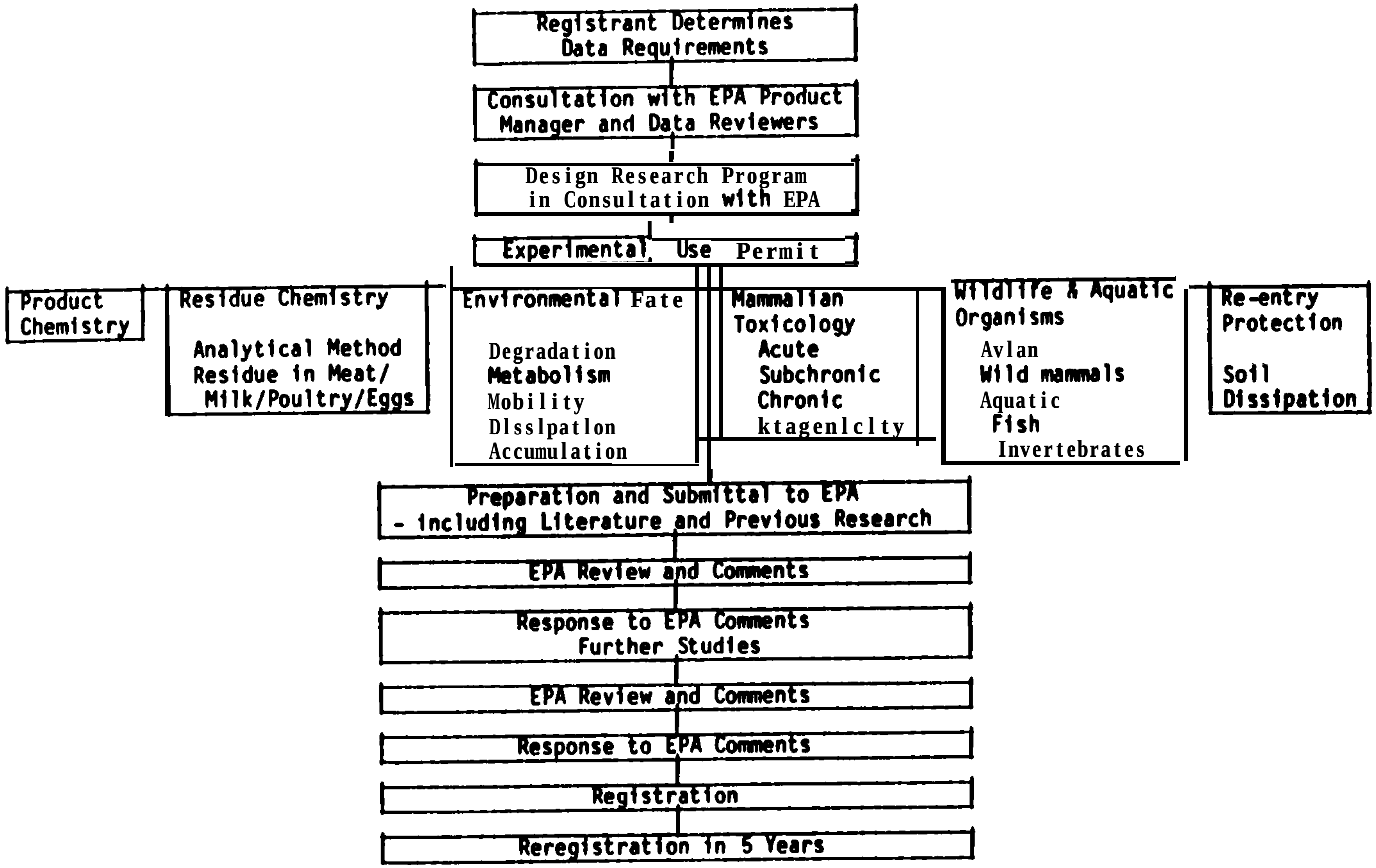

Figure 4.1. Flow Chart of Steps Required for Pestlclde Reglstratlon by the Environmental Protection Agency.

FIFRA Requlrements - See text page 4-3.
Endangered Species Requirements - See text page 5-1.
NEPA Requirements - See text page 5-1.

Table 4.1. Provfsions of the Federal Insecticide, Fungicide, and Rodenticide Act as Amended.

Sec. 1. Title and Table of Contents
sec. 2. Definitions
Sec. 3. Registration of Pesticides
- a. Registration with EPA is required for distribution, shipment or sale of pesticides.
- b. Exemption - experimental use permit
- c. Procedure for registration
  - (1) Statement of applicant
    - A. Name and address of applicant
    - B. Name of pesticide
    - C. Copy of label - including claims and directions for use
    - D. Description of tests and results
      Including an offer to compensate original data submitters - within a 15-year period from date of submittal
    - E. Formula
    - F. Request for classification for general or restricted use
  - (2) A. Data in support of petition
  - (4) Notice of application - published in FR by EPA
  - (5) Approval of registration
    Waive data requirements pertaining to efficacy if a state determines efficacy under Sec. 24c.
  - (6) Denial - if provisions of paragraph 5 are not met - EPA will publish denial with the factual basis in the FR.
  - (7) Registration under special circumstances
    - A. - if similar to an existing registered pesticide
    - 8. - will permit additional uses
    - C. - contains an active ingredient not contained in any currently registered pesticide for a period reasonably sufficient for generation and submission of data; conditional registration if EPA determines that the use will not cause unreasonable adverse effect on the environment and the use is in the public interest

sec. 4 Use of Restricted Use Pesiticides; Certified Applicators

Sec. 5 Experimental Use Permit
- a. Permit to accumulate data for registration - action required by EPA withing 120 days
- b. Temporary residue tolerance
- c. Subject to terms and conditions of EPA
- d. Studies - results reported to EPA
- e. Revocation
- f. State authorization - EPA may authorize state issuance of experimental use permits

9. Exemption for Agricultural Research Agencies - can be issued to any public or private agricultural research agency or educational institution for 1 year or other time specified for experimentation

Sec. 6 Administration Review; supervision; cancellation after 5 years, automatic unless an extension is requested

Sec. 7 Registration of manufacturer

Sec. 8 Books and records

Sec. 18 Federal agencies are exempt if an emergency exists

Sec. 24 c. A state may provide for local use of registered pesticides for 90 days

Sec. 26 States have the primary enforcement responsibility - by a cooperative agreement with EPA

general use pattern intended and consult with EPA prior to commencing a testing program.

40 CFR PART 162 - REGULATIONS FOR THE ENFORCEMENT OF FIFRA SUB PART A - REGISTRATION, REREGISTRATION, AND CLASSIFICATION PROCEDURES (INTERIM FINAL RULE)

EPA's summary states, "This interim final regulation expands the pesticide registration program of the Environmental Protection Agency (EPA or Agency) to authorize the conditional registration of pesticide products which are identical or substantially similar to those currently registered. It also authorizes the registration of new uses of existing pesticides. This regulation sets forth the applicable definitions, the data requirements for obtaining conditional registration, the conditions under which such applications will be approved or denied, and the mechanism for cancellation of conditional registrations." Part 162 is found in Appendix E.

40 CFR PART 160 - TOXIC SUBSTANCES CONTROL; GOOD LABORATORY PRACTICES STANDARDS

The Good Laboratory Practice Standards are a final rule of EPA regulations and apply to all testing to develop data for support of a petition for registration of a pesticide by EPA. The Federal Register section containing the final rule is the subject of Appendix F.

Sub part A of the regulation contains definitions and administrative provisions such as inspection of testing facilities by an authorized EPA or FDA employee. Sub part B specifies the qualifications of laboratory personnel including the study director and provides instructions for a quality control unit. Sub part C discusses facility requirements for handling animals and test materials. Sub part D concerns equipment design, maintenance, and calibration. Sub part E requires standard operating procedures to insure the quality and integrity of the data quality control unit. Sub part C discusses facility requirements for handling animals and test materials. Sub part D concerns equipment design, maintenance, and calibration. Sub part E requires standard operating procedures to insure the quality and integrity of the data generated in the course of a study. Requirements for test and control substances are the subject of sub part F. Protocol and conduct of a study are outlined in sub part G. Records to be kept and stored are described in sub part H.

40 CFR PART 172 - EXPERIMENTAL USE PERMITS

An experimental use permit is generally required for a field application of a pesticide not registered with EPA. A permit is not required for laboratory use to gather data to support a petition for registration or in certain limited field applications. In the case of an aquatic use, the limit is one surface acre, and the water or aquatic life may not be used for food unless a tolerance has been established.

Data required to support an application for an experimental use permit include: a description of the proposed testing program; name, address, and qualifications of all participants in the program; results of prior testing; and a petition proposing establishment of a tolerance or exemption from the requirement of a tolerance. Other requirements are: a lable providing directions for use, warnings, ingredients, etc.; a surveillance program; and reporting of test data. Further details or application for an experimental use permit can be found in Appendix G.

SECTION 5
OTHER STATUTORY REQUIREMENTS

ENDANGERED SPECIES ACT

The Endangered Species Act, Section 7(a)(2), requires consultations between each federal agency and the appropriate Secretaries of Commerce or Interior to insure that any endangered or threatened species is not adversely affected (Appendix H). This action is required if an applicant for a permit or license . . . "has reason to believe that an endangered species or a threatened species may be present in the area affected by his project and that implementation of such action will likely affect such species." In the case of squoxin, the consultation between the federal agencies and the Secretaries of Commerce and Interior would be no more than an administrative action due to the low toxicity of squoxin to non-target organisms.

NATIONAL ENVIRONMENTAL POLICY ACT

The purpose of the National Environmental Policy Act (Appendix I) is to provide public officials and citizens with information for protection of the environment. It directs federal agencies to provide the information before decisions are made and actions taken. NEPA does not place any responsibility on the applicant for a pesticide registration. EPA does not have any guidelines at this time for complying with NEPA.

In order to comply with NEPA, the use of pesticides by a federal agency would require an environmental review and dissemination of information.

STATE REGISTRATION

Northern and/or Umpquae squawfish are found in Oregon, Idaho, Montana, and Washington. These states each have pesticide control laws and regulations that are supplementary to the FIFRA. A flow chart of steps required for state pesticide registration are shown in Figure 5.1. The regulations for pesticide registration in Idaho, Oregon, Montana, and Washington are given in Appendix J. Use of squoxin in any of the Northwest states requires an experimental use permit or registration by EPA and an annual permit from the state.

In FIFRA there are two exceptions that are available to the states to the regular registration process. Special local need registration under Section 24(c) of FIFRA can be issued by a state only if all ingredients in the product are registered by EPA in some other formulation. This does not appear to apply to squoxin. An emergency need for control of a pest outbreak is another mechanism available to a state or a federal agency under Section 18

Phase I

Obtain EPA Experimental Use Permit (OR, ID, MT, WA).

Develop Data Requirements for EPA Registration (OR, ID, MT, WA).

EPA Registration (OR, ID, MT, WA).

Application to State for Pesticide Registration:
Pay Annual Fee;
Provide EPA Food and Food Products Tolerances;
Provide EPA Registered Label.
State Registration (OR, ID, MT, WA).

Phase II

State Use Authorization under FIFRA Section 24(c) if all product ingredients are registered with EPA (OR, ID, MT, WA).

Phase III

State Applies to EPA for Emergency Exemption under FIFRA Section 18 to Solve Emergency Outbreaks for One Season.
EPA Waives Data Requirements (OR, ID, MT, WA).

Figure 5.1. Flow Chart of Steps Required for State Pesticide Registration.

Footnote: All squoxin ingredients are not currently registered with the EPA. Hence, Phase II will not apply to squoxin.

Phases I, II, or III are independent in state pesticide registration.

References: Appendix K. - Personal Correspondence OR, ID, MT, WA.

of the FIFRA. This exempts the product from registration for one year. Again, this does not appear to be a viable alternative to registration of squoxin.

The Part 158 is used by the EPA review staff as criteria for determining the adequacy of data submitted for registration. Data that doesn't completely conform to current EPA protocols in the Guidelines is given consideration.

Data that was previously lacking is now available. One missing element, the degradation by-products of squoxin in water, is now available. Another missing piece of data, the individual organ weights in the Cannon toxicological study, is readily available but has not been given to EPA.

One of the issues in registration of squoxin is the inability to accurately determine what portion of previously submitted data is acceptable to EPA. The way the regulations are written places the burden of proof on the applicant. A petition to EPA that does not satisfy their reviewers will be rejected, and a test may have to be repeated or a deficiency corrected. Further communication with the EPA reviewers may resolve some of the issues.

PROJECT MANAGER

Close contact with the several data reviewers on the EPA staff is essential to all stages of a pesticide testing program. This should apply during preparation of the protocol for a given test, any necessary changes in procedure during the test, and follow up after submittal of the data.

The successful registration of squoxin will require a project manager who will have the responsibility of negotiating a data testing program with the EPA review staff, overseeing the research program and preparation of the data submitted to EPA. He will have to cooperate with the research supervisor(s) in preparation of protocols and design of the format for research to be certain the research results are in conformance with EPA requirements. It will also be his responsibility to respond to EPA comments on submittals and coordinate the correction of deficiencies.

Communication is so important to a successful program to register squoxin with EPA that a project manager is highly recommended. The essential elements of a job description for this person would be as follows: (Refer to flow chart for registration, Figure 4.1)

1. Serve as overall project manager to coordinate the several phases of the research program.
2. Act as a representative of the applicant for a pesticide registration with EPA.
3. Develop a research program to meet EPA's data requirements for registration of squoxin.
4. Communicate with EPA on all phases of the project from development of a research program to the final registration of squoxin.
5. Receive research data reports from the contracted testing laboratories and prepare submittals to EPA.

A partial alternative to a project manager is to enlist the services of IR-4 to assemble data and submit a petition to EPA.

DATA REQUIREMENTS FOR SQUOXIN REGISTRATION

The missing data requirements for registration of squoxin (See Table 7.1) were identified in a letter from EPA dated February 10, 1982 (Appendix K). Further information is in Table 7.1 in the discussion of Part 158. Part 158 remaining research needs for squoxin are:

Product Chemistry - product identity and composition with trace impurities;

Physical and Chemical Characteristics.

Residue Chemistry
Nature and magnitude of the residue in meat, milk, poultry, eggs, plants, soil, water, and fish identified to degradation product.

Environmental Fate
Confirm the-pathway of the degradation products of squoxin with aerobic and anaerobic metabolism studies, and field dissipation studies with sediment.

Toxicology

1. Conduct mammalian acute testing.
2. Conduct subchronic mammalian testing.
3. Upgrade the chronic tests of Cannon Labs to satisfy EPA requirements for organ weights (available from files).
4. Conduct studies on teratogenicity and avian reproduction if the mutagenicity tests show evidence of mutagenicity.

Mutagenicity

1. Conduct the battery of tests required by EPA.

Wildlife and Aquatic Organisms

1. Conduct an avian LD_{50} test.
2. Satisfy EPA regarding the dietary LC_{50} test with Coturnix quail.
3. Conduct avian reproduction test if required.
4. Conduct the simulated and actual field tests with mammals and birds if required.
5. Determine if the degradation products of squoxin (1,2-naphthoquinone, 1-(hydroxymethyl)-2-naphthol are the toxic agents of squoxin.
6. Consult with EPA to determine if freshwater fish LC_{50} test will have to be re-done.

7. Consult with EPA on adequacy of invertebrate LD_{50} tests.
8. Conduct LC_{50} tests with estuarine and marine organisms.
9. Conduct life cycle tests with fish and aquatic invertebrates if required.
10. Determine if previous accumulation tests with fish and invertebrates are adequate.
11. Determine if further field testing is required.

MAJOR ISSUES ASSOCIATED WITH SQUOXIN REGISTRATION

The major issues associated with squoxin registration are significant deficiencies in data required by EPA and the cost of conducting those studies. Data deficiencies include: the lack of adequate residue chemistry, aquatic metabolism research, a battery of mutagenicity tests, and some toxicology data on fish and wildlife. A further discussion and evaluation of EPA data requirements is in Section 7. A cost analysis for developing the necessary data is in this section including a costbenefit discussion for squoxin treatment of a major stream and the potential value of salmon and steelhead saved from squawfish predation.

The possibility that a chemical may be mutagenic or carcinogenic is always a major concern. No evidence of mutagenicity or carcinogenicity of squoxin or of its principal degradation by-products, 1-(hydroxymethyl)-2-naphthol and 1,2-napthoquinone, has been found in searches of the literature data banks, Medline, Toxline or, Cancerline (personal communication Dr. Donald Buhler). The unchlorinated structure of squoxin and its low bioaccumulation ability are factors which tend to indicate that it may not have carcinogenic or mutagenic characteristics. The acute, chronic, and subchronic test results to date show no evidence of neoplastic tissues as a result from squoxin exposure.

EPA required testing to meet regulatory data requirements is expensive, but necessary. While there is an opportunity for negotiation with EPA on specific requirements, they must follow established guidelines. Failure to meet their requirements will probably result in denial of a petition.

COST ANALYSIS

Research for Data Needs

A considerable amount of money has been spent in developing data to meet EPA's requirements for squoxin registration. Unfortunately, the data were not adequate to satisfy EPA's requirements. If squoxin is to be used for squawfish control, a substantial sum of money will be required to conduct the tests specified by EPA in their Feb. 10, 1982, letter (see Appendix K). When one considers the potential benefits in terms of the millions of downstream migrant salmon and steelhead smolts that could be saved annually and their value to sport and commercial fisheries, the cost of testing may be minor. An added potential monetary benefit as a result of squoxin use is the control of blackflies in waterfowl rearing and recreational areas. (See p. 3-7.)

The following discussion indicates the range of estimated costs for conducting the required squoxin studies. Figures below are for each research topic:

Data Subject	Estimated Cost Range (in 1,000s ot dollars) Min.	Max.
Product chemistry	20 -	40
Residue chemistry	250 -	420
Environmental fate	20 -	125
Aquatic aerobic & anaerobic		
Aquatic sediment dissipation	20	
Accumulation - non-target	30	
Toxicology		650
Acute	5.3	
Subchronic	?	
Chronic - teratogenicity		100 - 425
Mutagenicity	315	-160
Wildlife & aquatic		
Avian oral LD_{50}	1.5	
Avian dietary LC_{50}	8.0	
Wild mammal toxicity	2.0	
Freshwater fish LC_{50}	4.0	
Freshwater invertebrates acute LD_{50}	0.5	
Estuarine & marine acute LC_{50}	1.8	
Fish early life stages & aquatic Invertebrates life cycle	30.0	
Fish life cycle	40.0	
Simulated & actual field testing	?	
TOTAL	436.6	-2,070

These cost estimates were received from the following sources:

Bio Med Research Laboratories, Inc., Seattle, WA.
Springborn Bionomics, Inc ., Wareham, MA.
U.S Fish and Wildlife Service, La Crosse, WI.
Dr. Richard Kocan, Seattle, WA.

Closer estimates of the cost of conducting studies are difficult to obtain, at this time, without development of detailed research plans. Some of EPA's requirements are tentative depending on results of other tests (i.e. mutagenicity). The cost could be reduced substantially if some of the studies were done at universities or smaller laboratories with lower overhead. On the other hand, cost could increase considerably if squoxin were found to he mutagenic. This would result in the requirement of additional tests for carcinogenicity. Although EPA does not require it at this time, they could require a test for teratogenicity. One estimate on tests of the effect of squoxin on teratogenicity and avian reproduction is $100,000 to $125,000. Other useful research is not complete but was not specifically required by EPA to be repeated.

Cost of Major Stream Treatment

MacPhee and Ebel (1969) calculated the cost for treatment of the tailwaters of Ice Harbor Dam on the Snake River. For a time interval of 12 hours with a 100 ppb concentration of squoxin, the cost of squoxin would be $400. Squoxin cost was $200 per 30-gal barrel. A subsequent proposal for a pilot study was made that included treatment of the pool area 1.6 km below Lower Granite and Little Goose Dams (Ebel 1976). Treatment would be for 9 hours at a concentration of 100 ppb squoxin. Total cost of squoxin was calculated at $21,000 at a price of $350 per 30-gal barrel. Based on the U.S. Government Consumer Price Index, the 1984 cost would be 310% of 1969 dollars.

Tables 6.1-6.4 (MacPhee and Ebel 1969) were used to calculate the cost for a single treatment of 300,000 cfs of water for 9 hours at a concentration of 100 ppb squoxin. At 7.40 gals per hour per 1,000 cfs and a cost of $200 per 30-gal barrel ($620 in 1984 dollars), the totals are 666 barrels for a cost of 1133,200 ($412,920 in 1984 dollars). If it were possible to reduce the flow for a treatment period, a more realistic approach might be to calculate the cost at 25,000 cfs for 9 hours. This figure is $11,100 (634,410 in 1984 dollars). If similar treatments were made at each of the four dams from McNary to Bonneville, the cost would be $532,800 ($1,651,680 in 1984 dollars) at 300,000 cfs of flow and $44,400 ($137,640 in 1984 dollars) at 25,000 cfs flow.

If squoxin were introduced at each 10-mile point between McNary Dam and Bonneville Dam, the cost would be $1,332,000 ($4,129,200 in 1984 dollars) assuming a 100-mile distance between the two dams and the same cost for material. This is entirely impractical.

Lake Phinetta, a 68-acre lake in British Columbia, was treated with squoxin in August, 1972 at a cost for squoxin at $800 delivered. It is thought that the cost could be reduced to $200. This is comparable to a cost of $1,700 for rotenone treatment of the same volume of water (IR-4 1979). The lake was restocked with rainbow trout in September, 1972.

Table 6.1. Quantity of Squoxin (Liquid) Added Per Hour to Make a Maximum Concentration of 0.1 ppm of 1,1'-methylene-di-2-naphthol at the Point of Application* (MacPhee and Ebel, 1969).

Stream Flow cfs	Pounds per hour	Gallons per hour	Kilograms per hour	Liters per hour
1000	60.66	7.40	27.52	28.00
900	54.59	6.66	24.76	25.19
800	48.53	5.92	22.01	22.39
700	42.46	5.18	19.26	19.59
600	36.40	4.44	16.51	16.80
500	30.33	3.70	13.76	14.00
400	24.26	2.96	11.00	11.19
300	18.20	2.22	8.26	8.40
200	12.13	1.48	5.50	5.60
100	6.067	0.740	2.752	2.800
90	5.459	0.666	2.476	2.519
80	4.853	0.592	2.201	2.239
70	4.246	0.518	1.926	1.959
60	3.640	0.444	1.651	1.680
50	3.033	0.370	1.376	1.400
40	2.426	0.296	1.100	1.119
30	1.820	0.222	0.826	0.840
20	1.213	0.148	0.550	0.560
10	0.607	0.074	0.275	0.280
8	0.546	0.067	0.248	0.252
7	0.425 0.485	0.059	0.220	0.224
		0.052	0.193	0.196
6	0.364	0.044	0.165	0.168
5		0.037	0.138	0.140
4	0.303 0.243	0.030	0.010	0.112
3	0.182	0.022	0.083	0.084
2	0.121	0.015	0.055	0.056
1	0.061	0.007	0.028	0.028

*This table is based on liquid squoxin having a formulation as follows:

Component	Theoretical Composition
1,1'-methylene-di-2-naphthol, monosodium salt	39.8%
Ethyl alcohol	52.9%
Methyl alcohol	2.8%
Water	4.5%
Excess NaOH	trace

Specific gravity 0.983

Table 6.2. Quantity of Squoxin (Liquid) Added Per Acre-Foot (43,560 Cubic Feet) of Water to Provide the Following Theoretical Concentrations in Parts Per Million of Crystalline 1,1'-methylene-di-2-naphthol* (MacPhee and Ebel, 1969).

Concentration parts per million	Liters (liquid)	Gallons (liquid)	Pounds (crystalline 1,1'-methylene-di-2-naphthol)
1.0	3.387	0.895	2.72
0.9	3.050	0.806	2.45
0.8	2.713	0.717	2.18
0.7	2.365	0.625	1.90
0.6	2.028	0.536	1.63
0.5	1.691	0.447	1.36
0.4	1.358	0.359	1.09
0.3	1.014	0.268	0.816
0.2	0.667	0.179	0.544
0.1	0.339	0.089	0.272
0.09	0.305	0.081	0.245
0.08	0.271	0.072	0.218
0.07	0.237	0.062	0.190
0.06	0.203	0.054	0.163
0.05	0.169	0.045	0.136
0.04	0.136	0.036	0.109
0.03	0.101	0.027	0.082
0.02	0.068	0.018	0.054
0.01	0.034	0.007	0.027

*This table is based on liquid squoxin having a formulation as follows:

Component	Theoretical composition
1,1'-methylene-di-2-naphthol, monosodium salt	39.8%
Ethyl alcohol	52.9%
Methyl alcohol	2.8%
Water	4.5%
Excess NaOH	trace

Specific gravity is 0.983

Equivalents

1 gallon	= 3.785 liters
1 liter	= 1.057 quarts = 0.264 gallons
1 cubic foot	= 7.48 gallons = 62.4 pounds
1 pound	= 0.4536 kilograms
1 kilogram	= 2.205 pounds

Table 6.3. Quantity of Squoxin (Liquid) to Be Added to Various Sized Bodies of Standing Water to Provide a Theoretical Concentration of 0.1 Parts Per Million of 1,1'-methylene-di-2-naphthol* (MacPhee and Ebel, 1969).

Volume of water, cubic feet	Volume of squoxin, milliliters
100,000	777
90,000	699
80,000	621
70,000	544
60,000	466
50,000	388
40,000	311
30,000	233
20,000	155
10,000	78
9,000	70
8,000	62
7,000	54
6,000	47
5,000	39
4,000	31
3,000	23
2,000	16
1,000	8
900	7
800	6
700	5
600	5
500	4
400	3
300	2
200	2
100	1

*This table is based on liquid squoxin having a formulation as follows:

Component	Theoretical Composition
1,1'-methylene-di-2-naphthol, monosodium salt	39.8%
Ethyl alcohol	52.9%
Methyl alcohol	2.89.
Water	4.5%
Excess NaOH	trace

Specific gravity 0.983

Table 6.4. Flow Meter Calibrations for Squoxin Containing about 40% Naphthol Salt, 57% Ethanol and 3% Methanol (MacPhee and Ebel, 1969).

Flow meter scale centimeters	Volume of Flow				
	Flow meter #603*			Flow meter #605*	
	Glass ball	Steel ball		Steel ball	
	ml/min	ml/min	ml/hrs	ml/min	liters/hr
1	.	.	39	.	0.
2	0.5	2.75	165	21.5	1.3
3	1.3	5.50	330	52.0	3.1
4	2.2	9.0	540	92.0	5.5
5	3.5	12.0	720	150.0	9.0
6	4.7	17.0	1,020	223.0	13.4
7	5.5	21.0	1,260	288.0	17.3
8	6.8	26.5	1,590	350.0	21.0
9	8.0	32.0	1,920	438.0	26.3
10	9.3	37.5	2,250	508.b	30.5
11	10.5	43.0	2,580	575.0	34.5
12	11.7	48.0	2,880	660.0**	39.6**
13	13.1	53.0	3,180	740.0**	44.4**
14	14.0	58.5	3,510	820.9**	49.2**
15	15.0	64.0	3,040	900.0**	54.0**

Note: The above calibrations were obtained rather crudely in the laboratory and therefore can only be considered approximately correct.

*Flowmeter catalogue numbers of the Matheson Co., Inc., P.O. Box 188, Newark, California 94560.

**These values were obtained by extrapolation.

Miscellaneous

Indian pack pumps under full pressure give about 1 liter per minute.

Squoxin cost: $6.11 per gallon in approximately 800 gallon lots
$6.63 per gallon in approximately 400 gallon lots

Value of Salmon and Steelhead Lost to Predation

Studies of squawfish predation on downstream migrant chinook and steelhead in the Bonneville Dam forebay found 11% mortality (Uremovich et al. 1980). Long's (1968) studies on turbine mortalities at Ice Harbor Dam found mortalities as high as 30% when indirect mortalities related to squawfish predation were included. Losses vary from dam to dam'and year to year depending on flow conditions (Collins et al. 1975). For this analysis we made the assumptions that predation in the tailrace is approximately equal to predation in the forebay and that predation is approximately equal at each of seven Columbia and Snake River Dams. In order to estimate the predation mortality at each dam, we used Raymond's (1974) figures for outmigration of chinook and steelhead smolts for 1973 at Little Goose and The Dalles Dams. We assumed a 20% loss to predation at each dam. The projected mortality (in millions of fish) at each dam from predation would be:

Dam	Little Goose	L. Monnumental	Ice Harbor	McNary
Fish arriving	10.5	8.4	6.72	5.37
Predation Loss	2.1	1.68	1.34	1.07
Remainder	8.4	6.72	5.37	4.3

Dam	John Day	The Dalles	Bonneville
Fish Arriving	4.3	3.44	2.75
Predation Loss	0.86	0.68	0.55
Remainder	3.44	2.75	2.20

The projected loss to predation in 1973 is 8.3 million smolts between Little Goose and Bonneville Dams. Collins et al. (1975) stated that there is a mean loss of 7% of salmonids from passage through Kaplan turbines in the Columbia River. A projected loss of 27% at each dam, results in an estimated loss of 8.9 million smolts from Little Goose through The Dalles or 1.59 million smolts remaining. The estimated survival is 338% greater than Raymond's (1974) estimate of 0.47 million smolts based on marked recoveries in 1973. Hence our projections of turbine and predation losses are conservative.

Trapping and hauling/barging has substantially reduced the number of smolts migrating from the Snake River. If the total number of migrating smolts was reduced by one half the predation mortality would still be 4.15 million fish. If a 6% adult return to the Snake River of the number of smolts passing the Dalles Dam (Raymond 1974) is assumed, the loss of 4.15 million smolts represents 249,000 adult chinook and steelhead. National Marine Fisheries Service estimated an annual savings of $20-25 million to the commercial and sport fisheries of Oregon, Washington and Idaho from the registration and use of squoxin (IR-4 1979).

A very conservative estimate of the benefits for one year to the commercial and sports fisheries from the control of squawfish predation would exceed the costs of registration of squoxin and initial treatment of the Columbia River.

The following economic assessment is part of a status summary resulting from a December 7, 1979 meeting (IR-4 1979) of the state and federal agencies involved in attempts to register squoxin:

> It has been estimated, based on data obtained from the Department of Fish and Wildlife (Oregon) that the present annual value of the fishing industry in the Columbia River and tributaries approximates $132 million. If the northern squawfish (*Ptychocheilus oregonensis*) was adequately controlled, the value of their industry would be increased to approximately $150 million, i.e. an annual benefit of some $18 million.
>
> Additionally, assuming that (1) hatchery trout and salmon are released from 50 hatcheries once annually (2) the cost of rearing to release is $17 million (3) in severe instances predatory squawfish consume about 30 per cent of the released juvenile salmonids, the use of squoxin could save some $5-6 million in annual hatchery expenses.
>
> It is estimated therefore that the registration of squoxin would represent an annual savings of $20-25 million to the commercial and sports fishing industry in the states of Oregon, Washington, and Idaho.

SECTION 7
DISCUSSION AND EVALUATION OF EPA DATA REOUIREMENTS FOR REGISTRATION OF SQUOXIN

An attempt to register squoxin was made in 1977. EPA responded to the squoxin registration request dated February 14, 1977, with two letters of comment dated January 17, 1978, and February 10, 1982, (Appendix K). The registration request (Pesticide Petition No. 7E 1928) was made on behalf of the IR-4 Technical Committee*; the Agricultural Experiment Stations of Washington, Oregon, and Idaho; biologists of the Washington Game Department; biologists of the Idaho Fish and Game Department; and the U.S. Department of Commerce. Bureau of Oceanic and Atmospheric Administration, National Marine Fisheries Service (Appendix A.) EPA's first response was severly critical of the data submitted because it was deficient in many areas such as residue chemistry and toxicology.

Following a meeting of supporters of the petition with EPA staff and resubmittal of responses to EPA, a second letter (2/10/82) was sent to IR-4 with much of the same major requirements but lacking the minor comments of the 1978 letter. In a meeting of the author with EPA staff on February 15, 1984, the requirements stated in the 1982 letter were confirmed. The remaining requirements required by EPA are shown in Table 7.1 which gives an outline of the EPA Part 158 Data Requirements and the respective Guideline.

The principal degradation by-products of squoxin as identified by Oliver et al. (1983) are 1,3 naphthoquinone, and I-(hydroxymethyl)-2-naphthol. No evidence of carcenogenicity or mutagenicity of these two compounds was found in the literature from a search of the data banks, Medline, Cancerline, or Toxline (Personal Communications Dr. Donald Buhler). The same lack of evidence was found for squoxin from a search of eight data bases including Cancerline (Personal communications Tom Moritz).

* IR-4 is an Interregional Research Group serving the Cooperative State Research Service of the U.S. Department of Agriculture in the registration of pesticides with EPA.

Table 7.1. Part 158 Data Requirements for Aquatic Food-Crop Use of Squoxin.

Section	Status	Remaining Required Work	Guideline
158.120 Product Chemistry			
Product Identity:			
Identity of Ingredients	c		61-1
Statement of Composition	c		61-2
Discussion of Formation of Ingredients	o		61-3
Analysis and Certification of Product Ingredients:			
Preliminary Analysis	o		62-1
Certification of Limits	o		62-2
Analytic Methods for Enforcement of Limits	c		62-3
Physical & Chemical Characteristics:			
Color	c		63-3
Physical State	c		63-3
Odor	c		63-4
Melting Point	o		63-5
Boiling Point	na		63-6
Density, or specific gravity	c		63-7
Solubility	c		63-8
Vapor Pressure	na		63-9
Dissociation Constant	o		63-10

Table 7.1 Continued

Section	Status	Remaining Required Work	Guideline
Product Chemistry con't.			
Octanol/water Partition Coefficient	c		63-11
pH	?		63-12
Stability	pc		63-13
Oxidizing or Reducing Action	c		63-14
Flammability	o		63-15
Explodability	o		63-16
Storage Stability	pc		63-17
Viscosity	?		63-18
Miscibility	?		63-19
Corrosion Characteristics	o		63-20
Dielectric Breakdown Voltage	o		63-21
Submittal of Samples	o		64-1
158.125. Residue Chemistrv			
Chemical Identity	c	x	171-2
Directions for Use	c	x	171-3
Nature of the Residue			
Plants	o	x	171-4
Livestock	o	x	171-4
Residue Analytical Method	pc	x	171-4
Magnitude of the Residue			
Meat/milk/poultry/eggs	o	x	171-4

Table 7.1 Continued

Section	Status	Remaining Required Work	Guideline
Residue Chemistry con't.			
Potable Water	o	x	171-4
Fish	pc	x	171-4
Irrigated Crops	o	x	171-4
Reduction of Residue	o	?	171-5
Proposed Tolerance	o	x	171-6
Reasonable Grounds in Support of the Petition	pc	x	171-7
158.130 Environmental Fate			
Degradation Studies - Lab Hydrolysis	c	x	161-1
Photodegradation in Water	pc	x	161-2
Metabolism Studies - Aquatic	pc	x	162-4
Mobility Studies Leaching (Adsorption/ Desorption	pc	x	163-1
Dissipation Studies - Field			
Soil	o		
Aquatic (Sediment)	pc	x	164-2
Accumulation Studies			
in Fish	c		165-4
in Aquatic Ron-Target Organisms	pc	x	165-5

Table 7.1 Continued

Section	Status	Remaining Required Work	Guideline
158.135 Toxicology			
Acute Testing			
Oral LD_{50} - Rat	pc		81-1
Dermal LD_{50}	pc		81-2
Inhalation LC_{50} - Rat	na		81-3
Primary Eye Irritation - Rabbit	pc	?	81-4
Primary Dermal Irritation	o	?	81-5
Dermal Sensitization	o		81-6
Subchronic Testing			
90-Day Feeding - Rodent, nonrodent	o	?	82-1
21-Day Dermal	o	?	82-2
90-Day Dermal	o	?	82-3
90-Day Inhalation - Rat	na		82-4
90-Day Neurotoxicity - Hen Mammal	na		82-5
Chronic Testing			
Chronic Feeding - 2 sp. Rodent and nonrodent	pc	?	83-1
Oncogenicity Study - 2 sp. Rat and Mouse	o	?	83-2
Teratogenicity - 2 sp.	o	?	83-3

Table 7.1 Continued

Section	Status	Remaining Required Work	Guideline
Reproduction - 2 Generation	o		83-4
Mutagenicity Testing			
Gene Mutation	o		84-2
Chromosomal Aberration	o		84-2
Other Mechanisms of Mutagenicity	o		84-4
Special Testing			
General Metabolism	o		85-1
Special Requirement			
Domestic Animal Safety	o		86-1.
158.140 Re-entry Protection			
Foliar Dissipation	na		132-1
Soil Dissipation	na		132-1
Dermal Exposure	na		133-3
Inhalation Exposure	na		133-4
158.145 Wildlife and Aquatic Organisms			
Avian and Mammalian Testing			
Avian Oral LD_{50}	o		71-1
Avian Dietary LC_{50}	pc		71-2
Wild Mammal Toxicity	o		71-3

Table 7.1 Continued

Section	Status	Remaining Required Work	Guideline
Avian Reproduction	o		71-4
Simulated and Actual Field Testing - Mammals and Birds	o	?	71-5
Aquatic Organism Testing			
Freshwater Fish LC_{50}	pc	x	72-1
Acute LD_{50} Freshwater Invertebrates	pc	x	72-2
Acute LC 0 Estuarine and Marine irganisms	pc	x	72-3
Fish Early Life Stage and Aquatic Invertebrate Life Cycle	pc	?	72-4
Fish - Life Cycle	o	?	72-5
Aquatic Organism Accumulation	pc	?	72-6
Simulated or Actual Field Testing- Aquatic Organisms	pc	?	72-7

c = complete
pc= partially complete
o = no work done
na= not applicable
? = tentative

Alphabetized list:

INVESTIGATION OF THE PROCESS FOR REGISTRATION OF SQUOXIN FOR SQUAWFISH CONTROL

ANNOTATED BIBLIOGRAPHY

1.
Applegate, V.C., J.H. Howell, A.E. Hall, Jr., and M.A. Smith. 1957. Toxicity of 4,346 chemicals to larval lampreys and fishes. United States Fish and Wildlife Service, Special Scientific Report Fisheries, Number 207.

Abstract: The objective of this investigation was to locate chemicals which would be acutely toxic to larval sea lampreys at extremely low concentrations and which, at the same concentrations, would be non-toxic to other fishes inhabitating the same natural environments. Screening tests of 4,346 compounds were conducted at 0.5 ppm of the formulated compounds on larval lampreys, rainbow trout and bluegill sunfish. Further tests at levels of 1.0 and 0.1 ppm were conducted on those compounds that killed larval lampreys in eight hours or less.

Keywords: lampreys, toxic chemicals, screening tests

2.
Beach, D.R. 1974. Squawfish control in Cascade Reservoir. Idaho Department of Fish and Game, Performance Report, Federal Aid Project F-53-R-9, Boise, Idaho, USA.

Abstract: Fisheries personnel dispensed squoxin into the North Fork Payette River above Cascade Reservoir for the sixth consecutive year. Application rate was 100 ppb at three drip stations for 12 hours; stream flow was 250 cfs. The squawfish kill in 1973 was 27,000 fish, more than that in the last 2 years but lower than the 5-year average. No significant squawfish runs developed in Gold Fork and Lake Fork Creeks, and they were not treated in 1973. No mortalities of game fish or invertebrates were noted.

Keywords: squawfish, squoxin, Cascade Reservoir

3.
Beamsderfer, R.C. 1983. Reproductive biology, early life history and microhabitat of northern squawfish, Ptychocheilus oregonensis, in the St. Joe River, Idaho. Master's thesis, University of Idaho, Moscow, Idaho, USA.

Abstract: Large concentrations of squawfish spawn in the St. Joe River in late June and July at specific sites having low velocity (0.2 to 1.4 feet per second) and a gravel and cobble substrate free of fine particles. Males mature at smaller sizes than females (250-285 mm in males, 265-380 mm in females) and ages (V-VI versus VII-VIII), growing less after sexual maturity and dying younger (oldest male IX, oldest female XII). Young squawfish vary in growth and average 49 mm in length in 1 year, Their diet varies but concentrates on a few aquatic insects. Habitat use of juveniles and adults is closely related to behavior.

Keywords: squawfish, St. Joe River, life history

4.
Beilsteins Institute for Literature of Organic Chemistry. 1923. Beilsteins Handbuch der Organische chemie, Vierte Auflage. Berlin, Verlag von Julius springer. pp. 1053-1054.

Abstract: Chemical formulation process information and chemical properties of the intermediates and final products in the formulation of bis-(2-hydroxy-1-naphthyl)-methane (squoxin).

Keywords: squoxi n, 1,1'-methylenedi-2-naphthol, bis-(2-hydroxy-1-naphthyl)-methane

5.
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Keywords: squoxi n, 1,1'-methylenedi-2-naphthol, bis-(2-hydroxy-1-naphthyl)-methane

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Beilsteins Institute for Literature of Organic Chemistry. 1969. Beilsteins Handbuch der Organische Chemie, Vierte Auflage, Springer-Verlag, Berlin, Heidelberg, New York. pp. 5882-5883.

Abstract: Chemical formulation process information and chemical properties of the intermediates and final products in the formulation of Bis-(2-hydroxy-1-naphthyl)-methane (squoxin).

Keywords: squoxin, 1,1'-methylenedi-2-naphthol, bis-(2-hydroxy-1-naphthyl)-methane

7.
Birge, W.J. and R.A. Cassidy. 1983. Structure-activity relationships in aquatic toxicology. Fundamental and Applied Toxicology 3:359-368.

Abstract: Relationships among chemical structure, aquatic toxicity, and bioconcentration potential were examined for several classes of organic compounds. Structure-toxicity correlations were based largely on median lethal concentrations (LC_{50}) and toxicant threshold concentrations (LC_1) determined in mini-chronic tests with early life stages of fish and amphibians. Exposure was initiated at fertilization and maintained through 4 days post hatching. Bioconcentration potential was assessed using n-octanol/ water partition coefficients (log P). In tests with polychlorinated biphenyls (PCB), acute and chronic toxicity generally increased with percent chlorination. In addition, toxicity of specific PCBs appeared to be affected by the ratio of less chlorinated to more highly chlorinated isomers. The toxicity of chlorinated methanes (i.e., methylene chloride, chloroform, carbon tetrachloride) also increased with chlorination. Concerning single ring aromatic compounds pyridine was much less toxic than benzene, and benzene was less toxic than its mono-substituted derivatives, including chlorobenzene, nitrobenzene, toluene, and phenol. However, no consistent order of toxicity was observed for the substituted compounds. Acute toxicity also increased with the number of aromatic rings in a series of nitrogen heterocyclic compounds, and the latter were less toxic than corresponding alicyclic compounds. Within most classes of compounds, a direct correlation was observed between acute toxicity and bioconcentration potential. As observed with PCB compounds, the mini-chronic test described in this study permitted evaluations of structure-activity relationships using both LC_{50} and LC_1 values determined with early life stages. The LC_1's compared well with results obtained in life-cycle studies, thus providing an economical and reliable means of estimating chronic values for reproductive impairment.

Keywords: chemical structure, lethal concentration, bioconcentratipn, mini-chronic, PCB

8.

Black, J.A., W.J. Birge, A.G. Westerman and P.C. Francis. 1983. Comparative aquatic toxicology of aromatic hydrocarbons. Fundamental and Applied Toxicology 3:353-358.

Abstract: Structure-toxicity relationships were investigated for six organic contaminants representative of three chemical classes likely to be found in coal conversion process waters and effluents. For each class of compounds, the chemical with the greater number of aromatic rings always exerted the greater toxicity. In tests with rainbow trout and largemouth bass, B-naphthol (2 rings) was about twice as toxic as phenol (1 ring), and phenanthrene (3 rings) was nearly three times more toxic than naphthalene (2 rings). Acridine (3 rings) was 7 times more toxic to bass and 34 times more toxic than quinoline (2 rings). This relationship between ring number and toxicity was in excellent agreement with results from

acute tests on the same compounds. Furthermore, a close correlation existed between toxicity and n-octanol:water partition coefficients within each class of compounds.

Keywords: structure-toxicity relationships, aromatic rings, toxicity, n-octanol

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Brinser, A., L.L. Smith, Jr., H.C. Frick and F.E.J. Fry. 1968. An economic evaluation of sea lamprey control and lake trout restoration in Lake Superior. Great Lakes Fishery Commission, Ann Arbor, Michigan, USA.

Abstract: An assumption is made that 85% of the pre-lamprey population of lake trout can be restored and that a stabilized fishery can be attained by 1976. Sport and commercial landings of trout will be 4,100,000 pounds after 1976. Cost of lamprey control for this level of production is estimated at $400,000 annually. Net annual benefits of the 85 % pre-lamprey level are projected at $1,499,300 for United States and $563,100 for Canada.

Keywords: sea lamprey, Lake Superior, lake trout, economic evaluation

10.
Brown, L.R. and P.B. Moyle. 1981. The impact of squawfish on salmonid populations: a review. North American Journal of Fisheries Management 1:104-111.

Abstract: Examination of the available literature on the effects of squawfish (Ptychocheilus sp.) predation and competition on salmonid populations indicates that: (1) squawfish may prey extensively on young salmon in lakes, but there is little evidence that this predation has much impact on the number of returning adults; (2) squawfish do not appear to be significant predators of salmon and trout in streams except under highly localized, seasonal and unusual circumstances; and (3) there is little evidence to indicate that squawfish compete strongly with salmonids. Areas of research are suggested that would clarify the role of squawfish in regulating salmonid populations and elucidate their position in the aquatic ecosystems of western North America.

Keywords: squawfish salmonid populations, predation

11.
Brusven, M.A. and C. MacPhee. 1974. An evaluation of squoxin on insect drift. Transactions of the American Fisheries Society 103:362-365.

Abstract: An analysis of 54 drift net samples obtained over a 72-hour period in riffle areas of the St. Joe River, Idaho, showed that a distributed concentration of 0.1 mg/liter (100 parts per billion) of 1,l'methylenedi-Z-naphthol for a 13-hour period caused no significant increase in insect drift during the sampling period. Eight species of insects in the orders Trichoptera and Ephemeroptera represented 87% of the total drift insects. All species drifted in greater abundance during the night.

Keywords: squoxin, 1,l'-methylenedi-2-naphthol, insect drift, St. Joe River

12.
Bryant, M.D. 1976. Lake Washington sockeye salmon: biological production; and a simulated harvest by three fisheries. Ph.D. thesis, University of Washington, Seattle, Washington, U.S.A.

Abstract: The productive capacity of the Lake Washington sockeye salmon system was examined using data from biological studies of the Lake Washington sockeye. Mortality rates during major life history stages were estimated and used in a series of spawner-recruit models. Mortality of juveniles during lake residence due to predation of squawfish was calculated at 20 percent.

Keywords: Lake Washington, sockeye, squawfish, predation

13.
Buchanan, D.V., R.M. Hooton and J.R. Moring. 1981. Northern squawfish (Ptychocheilus oregonensis) predation on juvenile salmonids in sections of the Willamette River, Oregon. Canadian Journal of Fisheries Aquatic Science 38:360-364.

Abstract: Predation by northern squawfish (Ptychocheilus oregonensis) on salmonids was studied in spring months in several lower, free-flowing areas of the Willamette River drainage, Oregon. During 1976 and 1977, 1,127 northern squawfish were collected by electrofishing and seining and examined for food contents. Almost 59% of the squawfish stomachs contained food items, but only 2% contained salmonids. Principal foods- were insects, crayfish, and sculpins (Cottidae), and the majority (over 90%) of squawfish had not consumed more than one principal food type. We suggest that previous reports of squawfish predation in flowing rivers were misleading because they were often based on artificial situations (below dams or in waters following hatchery releases) which could have inflated salmonid predation values. Further, the true predatory nature of squawfish is clouded because of their rapid digestion of food and the long lag time in examination of gut contents by previous researchers. Our sampling techniques avoided these shortcomings by sampling in free-flowing areas and by examining squawfish stomach contents immediately after capture.

Keywords: squawfish, Ptychocheilus oregonensis, predation, food habits, Oregon.

14.
Burnard, R.J. 1974. Studies of squoxin degradation products and residues and rates of decomposition. Idaho Department of Fish and Game Federal Aid Project F-64-R-3, Job Ib, Boise, Idaho, USA.

Abstract: The major objective of this job was to further develop the analytical method for measuring residues of squoxin in fish tissues. Further development of the analytical method initiated by Dan Church and the author was undertaken. The Church method involved extraction of squoxin from fish tissue with benzene, methylation with diazomethane, column cleanup using Na_2SO_4 and charcoal followed by evaporation and electron capture gas chromatographic analysis. Fish tissue was homogenized at -78°C to a fine powder extracted with benzene, the extract methylated with diazomethane, cleaned up by acetonitrile transfer followed by column chromatography over Na_2SO_4 and florisil and analyzed by electron capture gas chromatography. Residues of 0.1 ppm could be detected.

Keywords: squoxi n, residues, gas chromatography

15.
Burnard, R.J., U. Kiigemagi, and L.C. Terriere. 1974. The stability of squoxin in water. In Terriere (1974). Chemical and biological studies of the selective piscixde, squoxi n (l,l'-methylenedi-2-naphthol), Department of Agricultural Chemistry, Oregon State University, Corvallis, Oregon, USA.

Abstract: Experiments were conducted with ^{14}C squoxin in the laboratory and in the field to determine degradation products. Over 90% of the squoxin was converted to other products after 48 hours in distilled water. Squoxin persisted for four days in the dark. The degradation was 90% in seven hours from field monitoring.

Keywords: squoxin, degradation products, ^{14}C

16.
Burnard, R.J. and L.C. Terriere. 1973. Chemical and toxicological studies of a selective fish toxicant. Final Progress Report to National Oceanic and Atmospheric Administration. Department of Agricultural Chemistry, Oregon State University, Corvallis, Oregon, USA.

Abstract: Studies were conducted on the identification of degradation products of squoxin and studies of the effects of squoxin on animals and plants. Efforts included the synthesis of radioactively labeled squoxin, squoxin metabolism by the rat, rainbow trout and northern squawfi sh and development of an analytical method fdr squoxin residues in fish tissue.

Keywords: squoxi n, degradation products, metabolism, residues

17.
Burnard, R.J. and L.C. Terriere. 1974. The metabolism and excretion of squoxin by rats. In Terriere (1974). Chemical and biological studies of the selective piscicide, squoxin (1,1'-methylenedi-2-naphthol), Department of Agricultural Chemistry, Oregon State University, Corvallis, Oregon, USA.

Abstract: Radioactive squoxin ^{14}C and ^{3}H was applied orally and intraperitonaelly to rats. Average recovery was 92% in 72 hours. There was little tendency for the radioactive degradation products or the parent compound to deposit in the major organs or tissues.

Keywords: squoxin, metabolism, radioactive tagging

18.
Cartwright, J.W. 1977. Experimental use of squoxin as Scavenger 300 or Sonar 300 (1,1'-methylenedi-2-naphthol, monosodium salt) in British Columbia. Prepared for the Workshop on Fish Population Control by College of Forestry, Wildlife and Range Sciences and Office of Continuing Education, University of Idaho, Moscow, Idaho, USA.

Abstract: The experience of treatment of Lake Phinetta in B.C. with squoxin is described. A complete kill of squawfish was achieved with no kill of non-target species. The results of a study at the University of British Columbia on effects of squoxin on invertebrates are outlined.

Keywords: squoxin, 1,1'-methylenedi-2-naphthol, British Columbia

19.
Chiou, G.T., V.H. Freed, D.W. Schmedding, and R.L. Kohnert. 1977. Partition coefficient and bioaccumulation of selected organic chemicals. Environmental Science and Technology 11(5):475-478.

Abstract: An empirical equation is established to relate the experimental n-octanol/water partition coefficients to the aqueous solubilities of a wide variety of chemicals including aliphatic and aromatic hydrocarbons, aromatic acids, organochlorine and organophosphate pesticides, and polychlorinated biphenyls. Such a correlation, covering more than eight orders of magnitude in solubility (from 10^{-3} to 10^{4} ppm) and six orders of magnitude in partition coefficient (from 10 to 10^{7}), allows an assessment of partition coefficient from solubility with a predicted error of less than one order of magnitude. A correlation is observed between the bioconcentration factors in rainbow trout and the aqueous solubilities for some stable organic compounds.

Keywords: partition coefficient, organic chemicals, solubility, bioconcentration

20.
Clemens, W.A. 1934. The predator and coarse fish problem in relation to fish culture. Transactions of the American Fisheries Society 64:318-322.

Abstract: The problem of coarse fish and predators is a complicated one. Information on the effect of removal of predators such as squawfish is lacking. It should be possible by scientific observation and experiment to determine accurately the conditions resulting from the removal of one or more species. It is proposed to rid Cultus Lake of squawfish and Dolly Varden char and determine if there will be a resultant increase in sockeye salmon yearling migrants.

Keywords: predator, squawfish, Cultus Lake

21.
Clemens, W.A. and J.A. Munro. 1934. The food of squawfish. Biological Board of Canada, Pacific Progress Report 19:3-4.

Abstract: Stomach contents of squawfish were collected from lakes in five locations in British Columbia. Of 119 squawfish collected, 67 had eaten fish and of this number 27 were salmon, kokanee, or trout.

Keywords: squawfish, British Columbia, food

22.
Collins, B.B., W.G. Ebel, E. Monan, H.L. Raymond, and G.K. Tanonaka. 1975. The Snake River salmon and steelhead crisis - it's relation to dams and the energy crisis. Processed report, Northwest Fisheries Center. Marine Fishery Service, Seattle, Washington, USA.

Abstract: An analysis is made of the serious decline in percentage of return of adult chinook salmon and steelhead trout since 1969 at a time when there were significant increases in numbers of smolts migrating downriver. The decline is apparently related to loss of smolts between Little Goose Dam and The Dalles Dam. Causes of the decline are examined. Turbine mortality including predation was as high as 30% at Ice Harbor and Lower Monumental Dams. In 1975, a low flow year, the measured loss of chinook salmon and steelhead populations was 95% between the Salmon River and The Dalles Dam. Supersaturation and delays in migration are also factors in the losses. Measures recommended for reducing losses are screening and bypass of turbines, reduction of supersaturation with flip lips and minimizing migration delays by collection and transportation of smolts. Predicted benefits from remedial action are presented.

Keywords: Snake River, Columbia River, chinook salmon, steelhead, supersaturated nitrogen, predation, dams

23.
Commercial Fisheries Review. 1970. Squoxin is a selective toxin for squawfish. Commercial Fisheries Review 32(3):6.

Abstract: Squoxin is a nonchlorinated hydrocarbon that kills squawfish and leaves trout and other desirable species unharmed. Squoxin was developed by Dr. Craig MacPhee at the University of Idaho after 4 years of searching and testing. Squoxin is a slow working but short- lived toxin that must be applied over a long period. In one test an estimated 200,000 squawfish were killed in an 8-mile section of stream.

Keywords: squoxin, Craig MacPhee, University of Idaho

24.
Cook, R.S. 1971. Leucocytozoon Danilersky 1890. Pages 291-293. John W. Davis, Roy C. Anderson, Lars Karstad and Daniel O. Trainer, eds., in Infectious and parasitic diseases of wild birds, Iowa State Univ. Press, Ames, Iowa, USA.

Abstract: The life history of the protozoan of the genus Leucocytozoon is given. A disease fatal to young ducks and turkeys is caused by the organism which has a vector in the blackfly Simulidae. Apparently healthy ducks may become ill and die within 24 hours. Control of the disease depends on control of the blackfly vector. Successful raising of waterfowl now depends on screening them from flies or in confining operations to vector-free areas.

keywords: Leucocytozoon, blackfly, Simulidae, ducks, vector

25.
Crowley, G.J. 1973. Status report: squoxin. Unpublished report, Bureau of Sport Fisheries and Wildlife, Cook, Washington, USA.

Abstract: The piscicide squoxin is highly selective against two species of squawfish, Ptychocheilus oregonensis and P. umpquae. Extensive field testing in Idaho and Oregon has demonstrated the effectiveness of the chemical in controlling these squawfish while not harming sympatric fish species, especially salmonids, and invertebrates. The use of squoxin as an invention to promote fish culture by squawfish population eradication has been patented in the United States and Canada. The compound is not yet registered. However, efforts toward this end are underway as part of the Squoxin Development Project. Collaborators in this project are presently compiling available information for application to EPA, anticipated in February 1974.

Keywords: squoxin, summary

26.
Crowley, G.J. 1974. A review of the literature on the use of squoxin in fisheries. Report FWL/LR-74/17 Western Fish Nutrition Laboratory, Bureau of Sport Fisheries and Wildlife, Cook, Washington, USA.

Abstract: The piscicide Squoxin is highly selective against two species of squawfish, Ptychocheilus oregonensis and P. umpquae. Extensive field testing in Idaho and Oregon has demonstrated-the effectiveness of the chemical in controlling these squawfish while not harming sympatric fish species, especially salmonids and invertebrates. The use of squoxin as an invention to promote fish culture by squawfish population eradication has been patented in the United States and Canada. The compound is not yet registered. However, efforts toward this end are under way as part of the Squoxin Development Project. Collaborators in this project are presently compiling available information for application to EPA, anticipated in February 1974.

Keywords: squoxin, Ptychocheilus oregonensis, piscicide, literature review

27.
Cumming, K.B. 1975. History of fish toxicants in the United States. Pages 5-21 in P.H. Eschmeyer, editor. Rehabilitation of fish populations with toxicants: a symposium. Special Publication Number 4, North Central Division, American Fisheries Society.

Abstract: Many bodies of water have become overrun with undesirable fish species. The number and volume of waters being reclaimed have increased, but the trend may change because of restrictive environmental laws. Only four piscicides are presently registered for non-food use application.

Keywords: piscicide, registered pesticides

28.
Ebel, W.J. 1975. Degradation rate of the selective piscicide, squoxin, in Snake River water. Paper FWR 599 College of Forestry, Wildlife and Range Sciences, University of Idaho, Moscow, Idaho, USA.

Abstract: The degradation rate of squoxin (1,l'-methylenedi-2naphthol) in Snake River water was determine by two methods: chemical analysis and bioassay. Squoxin degraded rapidly at 4, 10, 15 and 20°C. in Snake River water, but most rapidly at 15 and 20°C. Degradation rate as determined by chemical analysis indicated squoxin was degraded about 93% in 24 hours at 15°C., whereas degradation rate determined by bioassay indicated the level of degradation was 25 to 50% in 48 hours at 15 C. Thirty parts per billion for a 12-hour period would be required for eradication of squawfish

in Snake River water; a level of 250 ppb was safe for spring chinook in 96-hour bioassays.

Keywords: squoxin, degradation rate , chemical analysis, bioassay, Snake River

29.
Ebel, W.J. 1976. A proposal for research on the effect of squawfish eradication on the smolt survival below a main stem hydroelectric dam. A proposal to the United States Army Corps of Engineers from the University of Idaho College of Forestry, Wildlife and Range Sciences, Moscow, Idaho, USA.

Abstract: Field application of squoxin has proved successful in increasing survival of desirable species of fish. Objectives of this proposal are to make relative estimates of pre-treatment and post-treatment numbers of squawfish in pool areas below Lower Granite and little Goose Dams to determine survival of chinook salmon smolts before and after eradication of squawfish and to supplement data on turbine mortality and juvenile salmon. Details of methods, logistics and scope are given.

Keywords: squawfish, U.S. Army Corps of Engineers, squoxin

30.
Eggers, D.M., N.W Bartoo, N.A. Rickard, R.E. Nelson, R.C. Wissmar, R.L. Burgner, and A.H. Devol. 1978. The Lake Washington ecosystem: the perspective from the fish community production and forage base. Journal of Fisheries Research Board of Canada 35:1553-1571.

Abstract: In Lake Washington, fish production through detritus-based food chains is substantially greater than fish production through the grazing food chain. The lack of significant grazing by fish on the zooplankton is a consequence of both piscivore predation and conditions in the planktivore spawning environment. At low planktivore abundance, squawfish may switch to benthos feeding, expioiting the abundant prickly sculpin. At high planktivore abundance, squawfish feed more heavily on planktivores. Thus, even when reproductive success of planktivores is good, swamping of the squawfish does not occur and depensatory mortality due to squawfish predation prevents planktivore abundance from increasing to the point where zooplankton resource depletion would occur. Benthic-littoral species are vulnerable to predation essentially only as larva and juveniles. They avoid predation by occupying littoral and epibenthic refugia. Recruitment to the adult population from these refugia may be sufficient to account for the greater rate of benthos exploitation by fish relative to the rate of zooplankton exploitation by fish. Neomysis is an important component of the Lake Washington fish production, since potentially Neomysis is a regulating agent on the zooplankton, and reducation in Neomysis predation on zooplankton, due to decreasing abundance and a deeper vertical distribution, may be partly responsible for the recent reappearance of

Daphnia. The response of the fish community to trophic changes in Lake Washington has been slight. No consistent trends in the growth of fish utilizing zooplankton were observed. However, annual growth increments of consumers utilizing the benthic detrital food chain have declined with sewage diversion. The insights gained from analyzing the Lake Washington fish community structure and the Lake Washington carbon budget corroborate the above response of the fish community to trophic changes. Planktivores are predator-controlled and not able to deplete zooplankton resources, and thus would be insensitive to alterations in standing crop of zooplankton. On the other hand, benthic-littoral fish are more resource-limited and would be expected to respond to alterations in their forage base.

Keywords: ecosystem, fish production, Lake Washington, eutrophication, predation

31.
Falter, M. 1969. Digestive rates and daily rations of northern squawfish in the St. Joe River, Idaho. Doctoral Dissertation, University of Idaho, Moscow, Idaho, USA.

Abstract: Experimentally determined digestive rates of squawfish from the St. Joe River were used to assess daily rations for squawfish. Digestive rates varied as temperature and were inversely proportional to squawfish size. Prior feeding or starvation had no significant effects on digestive rates. There was a marked size-related difference in food preference: (1) small squawfish (19 cm) fed primarily on insects, oligochaetes and plant material; (2) medium squawfish (21-36 cm) had a similar diet but with a high proportion of fish in summer months; (3) large squawfish (36 cm) fed primarily on fish and crayfish.

Keywords: squawfish, digestive rates, food preferences

32.
Foerster, R.E. 1931. A comparison of the natural and artificial propagation of salmon. Transactions of the American Fisheries Society 61:121-130.

Abstract: An experiment was planned at Cultus Lake, B.C., for a 12-year period from 1925-1935 to compare the results of five methods of propagation of sockeye salmon. A progress report shows survival from egg disposition to out-migrant as follows: natural propagation - 1%; eyed egg plants - under 2%; distribution of free swimming fry - nearly 4%; 5-months-old fingerlings - 10.6%; yearlings - 63.1%. The later two methods do not include losses between fry and fingerlings and fry and yearling stages. Survival from natural propagation varied widely. Disease was a problem in rearing fingerlings.

Keywords: Cultus Lake, sockeye, natural propagation, artificial propagation, survival

33.
Foerster, R.E. 1937a. Discussing the problems of propagation of pacific salmon. Progressive Fish Culturist 26:1-6.

Abstract: The results of a study of the natural and artificial propagation of sockeye slamon in British Columbia are reported. The percentage efficiency, as indicated by the number of seaward-migrating young, was not significantly different for natural propagation, artificial propagation involving fry distribution, or eyed egg planting. The mortality of sockeye in Cultus Lake between fry and seaward migrant is 95%. Research indicates that predatory fish are largely responsible for this loss.

Keywords: Cultus Lake, sockeye salmon, Dolly Varden, squawfish, predation

34.
Foerster, R.E. 1937b. Removal of predatory fishes to save young sockeye salmon. Pacific Fisherman 35(12):31.

Abstract: The mortality of young sockeye salmon in Cultus Lake is about 96%. This is believed to be largely the result of predation by squawfish, char and coho salmon. A total of 3,199 predators was removed from the lake in 1935. The resulting out-migration of sockeye in 1936 increased from 4% to 16.7%. In 1937, 6,120 predatory fishes were removed. The out-migration in 1937 was 3,000,000, an increase of 750% over pre-control years.

Keywords: sockeye salmon, Cultus Lake, predators, squawfish, char, coho

35.
Foerster, R.E. and W.E. Ricker. 1941. The effect of reduction of predaceous fish on survival of young sockeye salmon in Cultus Lake. Journal of the Fisheries Research Board of Canada 5:315-336.

Abstract: Predaceous fishes which feed on young sockeye salmon in Cultus Lake were reduced to about 1/10 of their original numbers. In the three years which have been tested, the mean survival rate of young sockeye salmon was increased 3-1/3 times over average conditions prior to control. This represents 3,800,000 migrants saved, which are expected to yield 380,000 adult sockeye.

Keywords: Cultus Lake, sockeye salmon, squawfish, char

36.
Follett, W.I. 1928. A note on the squawfish and one of its relatives. California Fish and Game 14(4):282-285.

Abstract: A relative of the squawfish, Mylopharodon conocephalus "hardhead," is found in the Feather River, California, along with the squawfish. Its appearance is similar and may be confused with squawfish by the casual observer. It is partly herbivorous and not thought to be harmful to trout.

Keywords: Mylopharodon conocephalus, squawfish, Feather River

37.
Gabicia, J., W.W. Benson, and M. Watson. 1976. A rapid and sensitive method for gas chromatogaphic analysis of the selective piscicide, "squoxin." Bulletin of Environmental Contamination and Toxicology 15(2) by Springer-Verlag, New York, Incorporated.

Abstract: An analytical method is reported by which petroleum ether-extracted, brominated squoxin can be quickly and easily detected in water and fish tissue by electron capture gas chromatography. Limits of detection are 100 picograms, or 85 parts per trillion for a 200 ml sample of water and 600 picograms or 140 parts per billion for a 1 gram fish tissue sample.

Keywords: squoxin, gas chromatography, detection

38.
Goodnight, N.H. 1975. Squawfish studies, St. Joe River. Federal Aid Project F-60-R-6, Idaho Fish and Game Department, Boise, Idaho, USA.

Abstract: The objective of this job was to evaluate a squoxin (selective squawfish toxicant) treatment and to improve techniques for application. Plans called for treating the lower 30 miles of the St. Joe River with squoxin at a concentration of approximately 70-100 ppb in late June or early July, 1974. Efficiency of treatment is greatest during that period when peak numbers of migratory squawfish occur in the river.
Flows at Calder on the St. Joe River during early July were running very high (3,000-4,000 cfs) due to a heavy spring runoff. Treatment at these flows would have been cost prohibitive since concentrations of 80 ppb would have required an application rate of 20 gallons per hour. A postponed treatment in late July would have been inefficient since post-spawning emigration of adults would have occurred by that time. We therefore cancelled treatment plans for 1974.

Keywords: squoxin, St. Joe River

39.
Guyman, M. 1966. Selective fish toxin kills squawfish. Oregon Game Commission News Release, July 18, 1966.

Abstract: The squawfish killing toxin, "squoxin," was developed at the University of Idaho by Dr. Craig MacPhee under sponsorship of the Bureau of Commercial Fisheries Columbia Fisheries Program Office. Initial field trials were done on the John Day River, Oregon. In the first tests 100% of the squawfish were killed for 1/2 mile below each drip station. Squawfish, trout, young salmon and steelhead were unharmed. Because of squoxin's selectivity, complete chemical control would be necessary to rid a lake of suckers and carp.

Keywords: squoxin, squawfish, chemical control, John Day River

40.
Hamilton, J.A.R., L.O. Rothfus, M.W. Erho, and J.D. Remington. 1970. Use of a hydroelectric reservoir for the rearing of coho salmon. Washington Department of Fisheries Research Bulletin Number 9.

Abstract: The feasibility of using Lake Merwin, a hydroelectric reservoir in the North Fork of the Lewis River in Washington, for rearing of coho salmon was examined. Other conditions were found to be favorable, but low survival was found to be due to predation by rainbow trout and squawfish. Squawfish control measures resulted in no increase in coho survival. It was concluded that certain conditions, principally predation, precluded the use of Lake Merwin as a rearing area for coho salmon.

Keywords: Lake Merwin, coho, squawfish, predation

41.
Heun, R. 1983. Lake Washington northern squawfish: life history, control methods, and impact on other species with an emphasis on salmonids. Final review paper, Fisheries Cooperative Research Unit, University of Washington, Seattle, Washington, USA.

Abstract: A review of the literature on squawfish life history in Lake Washington and elsewhere is given. Several conclusions are given. The removal of squawfish predation from Lake Washington may cause other predators to compensate for the increased number of sockeye. Assumptions would have to be made that the increased surviving sockeye would utilize the increased food supply, and the carrying capacity of the lake was otherwise high enough to support the increased sockeye population. Squawfish are one of a number of species competing for a common food base. The several methods for control of squawfish are reviewed ranging from dynamiting spawning populations to use of electric barriers and the toxin, squoxin. A theoretical model is presented for calculation of cost-benefit of squawfish control by the various methods.

Keywords: Lake Washington, squawfish, life history, control

42.
IR-4 Project. 1979. Squoxin registration progress review meeting, Portland, Oregon, December 7, 1979. IR-4 Project, Rutgers University, New Brunswick, New Jersey, USA.

Abstract: The status of registration of squoxin with the Environmental Protection Agency is outlined. Subjects include experimental studies, EPA petition review, comments on incomplete portions of petition, economic impact of squawfish control in Columbia River and studies in progress.

Keywords: squoxin, Environmental Protection Agency, petition IR-4, registration

43.
Jeppson, P. 1957. The control of squawfish by use of dynamite, spot treatment and reduction of lake levels. Progressive Fish Culturist 19(4):168-171.

Abstract: Provision of an adequate control of squawfish appeared to depend upon understanding the ecology of squawfish in each body of water and attacking the fish in the spawning and incubation period. Dynamite was selected from a number of devices as a relatively efficient method of dispersing or eradicating spawning schools of squawfish. Ditching dynamite was preferred because it sank and was resistant to moisture. In Hayden Lake, Idaho, squawfish were observed to congregate and spawn over coarse, wave-washed rubble at depths of less than 1 ft. Slight reduction in lake level was observed to cause mortality of eggs.

Keywords: squawfish, dynamite, Hayden Lake

44.
Jeppson, P.W. and W.S. Platts. 1959. Ecology and Control of the Columbia Squawfish in northern Idaho lakes. Transactions of the American Fisheries Society 88: 197-202.

Abstract: Columbia squawfish, Ptychocheilus oregonensis, and trout were found to occupy similar niches, resulting in competition for food and space and predation on each other. Mature squawfish are piscivorous with food habits similar to Dolly Varden, Salvelinus malma, rainbow trout, Salmo gairdneri and brown bullhead, Ictalurus nebulosus. Age and growth data are presented. In northern Idaho lakes a 13-year-old female squawfish attains a maximum weight of approximately 9 lbs. Males grow slower, averaging less than 1/2 the size of females. Spawning by lake populations occurs in lakes and streams. Lake spawning is in schools during late May and early June over wave-washed rubble on clear, calm days. The number of eggs in mature females varies from 12,000 to 100,000, averaging 40,000. Eggs hatch in seven to eight days. In six years of squawfish control in 3,800-acre Hayden Lake by dynamiting and gill netting spawning schools, mature squawfish were reduced to about 1/10 of their original abundance and an increase in trout noted.

Keywords: Columbia squawfish, ecology, Idaho, Hayden Lake

45.
Johnston, J.M. 1972. Tolerance of juvenile sockeye salmon and zooplankton to the selective squawfish toxicant, 1,1'-methylenedi-2-naphthol. Progressive Fish Culturist 34(3):122-125.

Abstract: The toxicity of 1,1'-methylenedi-2-naphthol to northern squawfish, sockeye salmon and ten species of zooplankton was determined in bioassays. LCO for sockeye alevins prior to yolk absorption was 0.09 to 0.10 ppm and 0.70 to 0.90 ppm after yolk absorption. Thereafter, size of fish did not affect tolerance to squoxin. Temperature had no effect on tolerance of alevins prior to yolk absorption. The LC_{100} for squawfish decreased from 0.10 ppm at 4.4°C. to 0.01 ppm at 12.8°C. No mortalities occurred among the zooplankton test groups as a result of exposure for 7 days to concentrations of squoxin ranging from 0.008 to 0.10 ppm at a temperature of 12.8°C.

Keywords: bioassay, squoxin, squawfish, sockeye salmon, zooplankton

46.
Keating, J.F. 1958. An investigation of the spawning habits and movements of non-game fish species, particularly squawfish, and evaluation of the findings regarding possible methods of control; a study of applicable methods of controlling non-game fish species: the efficiency and economics involved. Federal Aid Project F-22-R-4, Idaho Fish and Game Department, Boise, Idaho, USA.

Abstract: Life history studies of squawfish were conducted on Cascade Reservoir, North Fork Payette River and the Payette Lakes. Observations included time and location of squawfish spawning, temperature and stomach contents. Control methods investigated included dynamite, rotenone and electric shock. The control of the squawfish population of Cascade Reservoir appears to be feasible by control of the spawning runs.

Keywords: Cascade Reservoir, Payette Lakes, life history, squawfish, dynamite, electric barrier

47.
Keating, J.F. 1972. Results of 1971 field studies of squoxin (Scavenger 300, Sonar 300), a piscicide selective to squawfish and related minnows in Idaho. Federal Aid Project F-64-R-1, Job 1A, Idaho Fish and Game Department, Boise, Idaho, USA.

Abstract: Squoxin treatments in Idaho in 1971 were evaluated by chemical analysis and observations of insect and fish mortalities. Squoxin effectively killed squawfish for 5 miles when applied at 30 ppb and for 10 miles when applied at 100 ppb without harming game fish and with only a few mortalities of other minnows and sculpin. We found no indication that squoxin harmed insects, crayfish, freshwater mussels, or tadpoles in three separate treatments. Preliminary results indicate that removal of squawfish from the St. Joe River and Cascade Reservoir tributaries has improved survival of game fish and improved fishing success.

Keywords: squawfish, squoxin, Cascade Reservoir, St. Joe River

48.
Keating, J.F., 0. Kiigemagi, L.C. Terriere, and R. Swan. 1972. Recent developments in the testing of squoxin, a piscicide selectively lethal to squawfish. Pages 609-623, Proceedings of Fifty Second Annual Conference of Western Association of State Game and Fish Commissioners, Portland, Oregon, July 16-19, 1972.

Abstract: A review of four years of field application of squoxin is given. A substantial decrease of squawfish is noted in Cascade Reservoir and St. Joe River, Idaho, with continued or improved fishing success for game fish. Ron-target species of fish, except some Cyprinids and invertebrates, are not harmed by concentrations less than 100 ppb over short time periods. More comprehensive tests are needed.

Keywords: squoxin, squawfish, half life, insects

49.
Kenaga, E.E. 1972. Guidelines for environmental studies of pesticides: determination of bioconcentration potential. Residue Reviews 44:73-113.

Abstract: Molecules such as DDT and its stable transformation products DDD or DDE have been shown to persist and become bioconcentrated. The degree of bioconcentration of DDT and other materials depends on (1) temperature equilibrium of residue concentration reached initially by adsorption on organisms in competition with the air, water, and soil segments of the environment and (2) the redistribution of these adsorbed pesticides in organisms and their tissues by ingestion, adsorption, metabolism, partitioning, storage, and elimination. Some of the important criteria for selecting test methods to measure bioconcentration discussed are the physical, chemical, and biochemical properties of the pesticide and its transformation products; surface- weight relationship of treated environmental objects; consumption rates of various organisms; and other biological and ecological responses of various organisms to pesticides as used in practice. Bioconcentration factors are highly variable for a compound such as DDT due to great variation in the parameters and test methods used as a

basis for the measurement and calculation of the factor. Standardization of environmental test methods is needed for comparative purposes. Serious ecological problems may arise from bioconcentration when the degree of partitioning of a substance or its transformation products from water results in translocation to and storage in critical tissues of the organisms. Bioconcentration in many species can result in high residues caused by constant exposure to widely distributed toxicants, and an intake exceeding the capacities of the organism to metabolize and eliminate them. Some of the important properties of pesticides resulting in high bioaccumulation are low water solubility, high fat solubility, high partitioning coefficients from water to environmental components, and high stability under various hydrolytic, light, heat, and microbiological conditions.

Keywords: bioconcentration, pesticides, partitioning

50.
Kiigemagi, U., R.J. Burnard, and L.C. Terriere. 1975. Analytical methods for the detection of the pesticide, 1,1'-methylenedi-2-naphthol (squoxin), in fish and water. Journal of Agricultural Food Chemistry 23(4):717-720.

Abstract: Procedures are given for the measurement of the piscicide 1,1'-methylenedi-2-naphthol (squoxin), in fish tissue using gas chromatography, and for its detection in water using a colorimetric method. For the GC method squoxin is converted to its dimethyl ether and detected by electron capture. The method is sensitive to 0.1 ppm squoxin in fish tissue. The colorimetric procedure, which can be used in the field for monitoring, involves coupling squoxin with the chromogenic agent, Diazo Blue B. By use of extraction and concentration steps the method is made sensitive to 2 ppb squoxin in water. This method has been used in several field experiments with squoxin. The GC method has been used to measure squoxin residues in trout and squawfish collected during such field tests.

Keywords: squoxin, 1,1'-methylenedi-2-naphthol, gas chromatography, residues

51.
Kudo, R.R. 1960. Protozoology, Charles C. Thomas Publ., Springfield, Il., p. 620-622.

Abstract: A description is given of the life cycle of the waterfowl disease caused by the protozoan Leucocytozoon. Known vectors are the blackflies Simulium venustrum and S. pernassum.

Keywords: waterfowl disease, Leucocytozoon, blackfly, Simulium

52.
Lennon, R.E., J.B. Hunn, R.A. Schnick, and R.M. Burress. 1971. Reclamation of ponds, lakes and streams with fish toxicants: A Review. FAO Fisheries Technical Paper 100.

Abstract: The reclamation of fish production, farm, and ranch ponds in many areas of the world with toxicants has become an established, successful, and economical practice. The problems of securing adequate distribution of toxicant, assessing fish kills, and evaluating the success of reclamation and subsequent management are relatively minor compared to reclamation of large lakes, reservoirs and streams. Some of the problems include: (1) the need for reclamation is not adequately demonstrated; (2) biology of the target species is not investigated and alternatives are not adequately considered; (3) crews are not large enough or experienced; (4) pre-treatment surveys on biology and chemistry of receiving waters are often lacking or inadequate; (5) posttreatment surveys and subsequent management are often lacking; (6) the toxicants may be wrong, improperly applied and economics may govern the program; (7) steps are not taken to prevent re-infestation-of reclaimed waters. . .

Keywords: reclamation, toxicants, target species, pre-treatment surveys, post-treatment surveys

53.
Lennon, R.E. and C.R. Walker. 1964. Investigations in fish control , laboratories and methods for screening fish-control chemicals. Bureau of Sport Fisheries and Wildlife Circular 185.

Abstract: This report describes the physical and technical facilities and the procedures of the Fish Control Laboratories at Lacrosse, Wisconsin, and Warm Springs, Georgia. The laboratories emphasize screening of chemicals to find a variety of fishery management tools. Preliminary screening ascertains whether a chemical in three concentrations has a desirable biological activity on eight species of fish in reconstituted water at 12" and 17°C. Delineative screening ascertains effective concentrations (EC100) on eight species in reconstituted water (the method for which is described) at 12°, 17°, 22°, and 27°C. Intensive screening of promising fish control agents ascertains effects on 24 species of fish and on other aquatic organisms at different temperatures and in waters of various qualities in the laboratory and in the field.

Keywords: preliminary screening, chemicals, fish control agents, Fish Control Laboratories

54.
Leo, A., C. Hansch, and D. Elkins. 1971. Partition coefficients and their uses. Chemical Reviews 71(6):525-555.

Abstract: A compilation and assembly of work in the field of partition coefficients. Theory and formulas are given.

Keywords: partition coefficient

55.
LesVeaux, J.F. 1959. Summary report of survey to evaluate the need for specific fish toxicants in sport fishing waters. Progressive Fish Culturist 21(3):99-110.

Abstract: A questionnaire to the states requested information on the need for chemicals, especially specific toxicants, in fishery management problems. Each region has specific problems; many states are interested in specific toxicants.

Keywords: fishery management problems, specific fish toxicants

56.
Lindland, R.L. 1973. Squawfish control in Cascade Reservoir, Federal Aid Project F-53-R-8 Job 2a, Idaho Fish and Game Department, Boise, Idaho, USA.

Abstract: The squawfish kill from treatment of the North Fork, Payette River over five years with squoxin has been: 200,000 in 1968, 100,000 in 1969, 65,000 in 1970, 20,000 in 1971, and 15,000 in 1972. This decline indicates a significant reduction in the squawfish in Cascade Reservoir.

Keywords: Cascade Reservoir, squawfish, squoxin, North Fork Payette River

57.
Long, C.W., R.F. Krema, and F.J. Ossiander. 1968. Research on fingerling mortality in Kaplin Turbines - 1968. Bureau of Commercial Fisheries Biological Laboratory, Seattle, Washington, USA.

Abstract: During Columbia River dam turbine tests seagulls and squawfish were feeding on the experimental fish. Thirty-seven percent of the squawfish taken by purse seine in the area of fish releases had identifiable coho salmon in their stomachs and 54% had fish in their stomachs.

Keywords: squawfish, predation, turbine tests

58.
Lyman, W.J., W.F. Reehl and D.H. Rosenhlatt. 1982. Environmental behavior of organic compounds. Handbook of Chemical Property Estimation Methods. McGraw-Hill Book Company.

Abstract: For this bibliography, table 2-3 gives Regression Equations for the Estimation of S (partition coefficient) and tahle 2-8 gives associated references.

Keywords: partition coefficient, organic compounds

59.
MacPhee, C. 1963. The determination and development of sperm toxins for the control of undesirable species of fish. Operational Studies Contract Number 221.2-BCF-4, Columbia River Fishery Development Program, College of Forestry, Wildlife and Range Sciences, University of Idaho, Moscow, Idaho, USA.

Abstract: Research was conducted to determine the minimum effective concentration of various chemicals lethal to fish sperm which are sublethal to young salmonids; to test the effectiveness of sperm toxins in suppressing a natural squawfish population; to explore any toxins noted to have detrimental effects on eggs or larvae or coarse-fish. A fourth objective was the determination of piscicides. Emphasis was placed on the screening of chemicals.

Keywords: sperm toxins, squawfish, salmonids, piscicide

60.
MacPhee, C. 1966. The determination and development of chemicals for the control of undesirable species of fish. Operational Studies Contract 14-17-0001-1356, Columbia River Fishery Development Program, College of Forestry, Wildlife, and Range Sciences, University of Idaho, Moscow, Idaho, USA.

Abstract: Delineating bioassays with several species of salmonid fish and three species of squawfish were conducted in 96-hour exposures to 1,1'-methylenedi-2-naphthol. The minimum LD_{100} for Sacramento squawfish is larger than 0.7 ppm, much greater than obtained for northern squawfish or Umpqua squawfish. Stoneflies, mayflies, and crayfish are not killed at 3.0 ppm. No visible ill effects resulted to ducks and sheep forced to drink 1 ppm and 10 ppm respectively for one week. Field applications in Idaho and Oregon showed the effectiveness of the chemical on squawfish without killing salmonids.

Keywords: 1,1'-methylenedi-2-naphthol, squawfish, delineating bioassays

61.
MacPhee, C. 1967. The determination and development of chemicals for the control of undesirable species of fish. Operational Studies Contract 14-17-0001-1564 Columbia River Fisheries Development Program, College

of Forestry, Wildlife and Range Sciences, University of Idaho, Moscow, Idaho, USA.

Abstract: Screening tests on squawfish and suckers were done on over 200 chemicals not screened previously. Additional assays were conducted with Chemical A, 1,1'-methylenedi-2-naphthol in acetone, and its monosodium and disodium salts. The monosodium salt will be the most satisfactory formulation. This was confirmed in field tests.

Keywords: 1,1'-methylenedi-2-naphthol (monosodium salt), squawfish, assays

62.
MacPhee, C. 1969. The effect of squawfish eradication on trout survival. Pages 209-218, Proceedings of the Forty-Ninth Annual Conference of Western Association of State Game and Fish Commissioners.

Abstract: A section of the St. Joe River was planted with fingerling rainbow trout in 1967 and 1968. In the second year planting followed treatment with squoxin for squawfish removal. The fingerling counts were over six times and creel-size counts over two times as great in the treatment year as in the control year.

Keywords: squawfish, rainbow, St. Joe River

63.
MacPhee, C. 1971a. Selective chemical control of undesirable fish. Agrichemical Age, June 1971.

Abstract: Squoxin could be used for partial poisoning of large reservoirs, the back roll below main stem dams and streams immediately below hatchery release points. Length of application is a function of water temperature and velocity. The cost for treating the St. Joe River in 1968 with squoxin was 53,170 at $1.75 per pound. Some general toxicants are moderately selective and seldom achieve a complete kill. Selective toxicants can be used where desirable fish are present. The horizon for the selective control of fish and other pests is limitless.

Keywords: squoxin, selective toxicant, cost

64.
MacPhee, C. 1971b. Selective chemicals to control undesirable fish. _In_ Pesticides, Ecology, and Natural Resources Management - A Symposium at Washington State University, March 2-4, 1971.

Abstract: Development of a selective toxicant includes its initial determination, laboratory delineation, field application, ecological evaluation and federal registration. Squoxin (1,1'-methylenedi-2naphthol)

which is selectively lethal to squawfish is used to exemplify the nature and scope of such phases of development.

Keywords: selective chemicals, 1,1'-methylenedi-2-naphthol, laboratory delineation, ecological evaluation

65.
MacPhee, C. and G.C. Bailey. 1973. Development of selective fish toxins: toxicity of squoxin to fish species other than squawfish, Federal Aid Project F-64-R-2, Job I-d, Idaho Department of fish and Game, Boise, Idaho, USA.

Abstract: The tolerance of small chiselmouth (Acrocheilus alutaceus), longnose dace (Rhinichthy cataractae), speckled dace (R osculus), redside shiner (Richardsonius balteatus), and torrent sculpin (Cottus rhotheus) to squoxin (1-1'-methylenedi-2-naphthol) was determined using standard bioassay techniques. Of the species tested the sculpin was most tolerant. Tolerance to squoxin varied with species, temperature, concentration and source of bioassay water. The LC_{50} of the chiselmouth and dace was less than 100 ppb at temperatures higher than 15°C, the concentration usually applied to streams to eradicate squawfish (Pthchocheilus oregonensis). At similar temperatures the LC_{50} of redside shiner varied between 40 and 80 ppb whereas that of the sculpin varied between 200 and 1,000 ppb.

Keywords: squoxin, tolerance, chiselmouth, dace, shiner, sculpin

66.
MacPhee, C. and F. Cheng. 1974. Factors affecting degradation of squoxin and toxicity of squoxin to six fish species. Idaho Department of Fish and Game, Federal Aid Project F-64-R-3, Job I-d, Boise, Idaho, USA.

Abstract: In static bioassays degradation of squoxin (1,1'methylenedi-2-naphthol) was inversely correlated with temperature, calcium concentration, algae density and time of exposure. On the basis of the LC_{50} of the 10 and 15°C assays, the order of tolerance of the test fish to squoxin from the least to the greatest is as follows: chiselmouth (Acrocheilus alutaceus), longnose dace (Rhinichthy cataractae), speckled dace (R. osculus), redside shiner (Rhinichthys balteatus), chinook salmon (Oncorhynchus tshawytscha), and torrent sculpin (Cottus rhotheus).

Keywords: bioassays, squoxin, degradation, chiselmouth, dace, shiner, chinook salmon, sculpin

67.
MacPhee, C. and W. Ebel. 1969. The feasibility of increasing salmon production by poisoning squawfish below main stem dams with 1,1'-methylenedi-2-naphthol. Unpublished proposal, College of Forestry, Range and Wildlife Sciences, University of Idaho, Moscow, Idaho, USA.

Abstract: Success in large-scale treatment of lakes and streams with squoxin makes it logistically possible to poison squawfish in the tailwater and spillway areas of main stem dams. The discharge would have to be stopped to make the treatment economically practical. A formula is given to calculate the storage capacity required under any given conditions of flow and temperature. Tables are given that show the dates in 1962 and 1967 that squoxin could have been used to poison squawfish in the tailwater area of Ice Harbor Dam. Cost estimates for treatment are given.

Keywords: squoxin, squawfish, main stem dams, treatment, Ice Harbor Dam

68.
MacPhee, C. and G.E. Reid. 1971. Impact of northern squawfish on survival of fingerling rainbow trout. Federal Aid Project F-60-R-2, Job 2, Part I, Idaho Fish and Game Department, Boise, Idaho, USA.

Abstract: The summer abundance and distribution of about 150,000 hatchery-reared fingerling rainbow trout were obtained in the presence and absence of wild populations of northern squawfish. A chemical, 1,1'-methylenedi-2-naphthol, was used to selectively kill squawfish during the second and fourth summers. Eradication of squawfish increased the abundance of fingerling rainbow 4.1 times. Fingerling abundance was 4.9 times greater in the mid-channel and pools where squawfish were most prevalent prior to poisoning.

Keywords: northern squawfish, rainbow trout, 1,1'-methylenedi-2-naphthol

69.
MacPhee, C. and R. Ruelle. 1964. The determination and development of sperm toxins for the control of undesirable species of fish. Federal Aid Project 14-17-0001-923, College of Forestry, Wildlife and Range Sciences, University of Idaho, Moscow, Idaho, USA.

Abstract: Results are reported of experiments to isolate a chemical lethal to squawfish during some or all stages of its life cycle. Twenty-two chemicals of a total of 535 tested gave indication of being a larvacide. Twenty-four chemicals out of 535 were selectively lethal to squawfish. Delineating tests were conducted with chemical A.

Keywords: squawfish, salmonids, chemical A, bioassays

70.
MacPhee, C. and R. Ruelle. 1965a. The determination and development of chemicals for the control of undesirable species of fish. Federal Aid Project 14-17-0001-1148, Idaho Cooperative Fishery Unit, College of Forestry, Wildlife and Range Sciences, University of Idaho, Moscow, Idaho, USA.

Abstract: Totals of 488 chemicals have been tested as larvacides and 2,570 as piscicides in 1963 and 1964. Work was begun on calculating standard selectivity indices for certain chemicals. The selective index is calculated by dividing the minimum concentration lethal to the pest fish by the minimum concentration lethal to the desired species.

Keywords: selectivity index, bioassay, larvacide, piscicide

71.
MacPhee, C. and R. Ruelle. 1965b. A method for controlling the northern and Umpqua squawfish by means of a selective piscicide, chemical B. Federal Aid Project 14-17-0001-1356, Special Report Number 1, College of Forestry, Wildlife and Range Sciences, University of Idaho, Moscow, Idaho, USA.

Abstract: Chemical B was used in 96-hour tests with two species of squawfish and four species of salmonids. A selectivity index was calculated for all salmonids at the four temperatures tested. In a second experiment squawfish were exposed to chemical B for 6 hours and then removed to fresh water. In the same experiment salmonids were exposed to the maximum sublethal concentration for 12 hours. Additional tests were conducted in water of high mineral content. A small natural lagoon containing squawfish and salmonids was treated with Chemical B.

Keywords: chemical B, squawfish, selectivity index, salmonids

72.
MacPhee, C. and R. Ruelle. 1968. Fish culture by squawfish population eradication. United States Patent Number 3,389,685, 851(4), p. 989, June 25, 1968.

Abstract: Background is given on squawfish, how they became a threat to desirable species of fish and the ineffective previous efforts at control. An object of this invention is to protect native populations of food and game fish by rapid and substantial reduction of squawfish. Results of laboratory testing are given showing the effectiveness of 1,1'-methylenedi-2-naphthol in killing squawfish without harming nontarget species of fish. It is unlikely that mammals or fowl would be harmed. Methods supporting the claims are given.

Keywrds: patent, invention, squawfish, 1,1'-methylenedi-2-naphthol

73.
MacPhee, C. and R. Ruelle. 1969a. Lethal effects of 1,888 chemicals upon four species of fish from western North America. Bulletin Number 3, College of Forestry, Wildlife and Range Sciences, University of Idaho, Moscow, Idaho, USA.

Abstract: A piscicide screening program was conducted with 188 different chemicals mostly at concentrations of 10 ppm. The times at which fish lost their equilibrium and died are given for 2,552 separate 24-hour assays. The species tested were the northern squawfish (Ptychocheilus oregonensis), chinook salmon (Oncorhynchus tshawytscha), coho salmon (Oncorhynchus kisutch), and steelhead (Salmo gairdneri).

Keywords: piscicide screening, northern squawfish, chinook salmon, coho, steelhead

74.
MacPhee, C. and R. Ruelle. 1969b. A chemical selectively lethal to squawfish (Ptychocheilus oregonensis) and (P. umpquae. Transactions of the American Fisheries Society 98(4):676-684.

Abstract: A piscicide. 1,1'-methylenedi-2-naphthol, is lethal to Ptychocheilus oregonensis and P. umpquae at concentrations 3 to 100 times more toxic to squawfish than to salmonids. Selectivity of the chemical varies with the tolerances of the species and its potentcy varies positively with concentration and temperature. For a thermal range of 18.3 to 10.0°C, the minimum LC_{100} is 0.006 to 0.015 ppm for P. oregonensis and 0.01 to 0.03 ppm for P. umpquae. Within these ranges the mean survival times vary from 6 to 31 hours for P. oregonensis and 6 to 20 hours for P. umpquae. In 96-hour assays at similar temperatures, the maximum LCO is about 11.3 ppm for Salvelinus fontinalis, 0.1 ppm for Oncorhynchus tshawytscha, and from 0.6 to 1.3 ppm for O. kisutch and Salmo gairdneri depending on the water temperature. One domestic sheep and two ducks showed no ill effects when forced to drink water containing 10 ppm of the chemical for one week. A field application in a small lagoon containing several species of fish killed only P. oregonensis.

Keywords: piscicide, 1,1'-methylenedi-2-naphthol, Ptychocheilus oregonensis, P. umpquae, Salvelinus fontinalis, Oncorhynchus tshawytscha, O. kisutch, Salmo gairdneri

75.
MacPhee, C. and R. Ruelle. 1971. Fish culture by squawfish population eradication. Canadian Patent Number 864518, issued February 23, 1971.

Abstract: Background is given on squawfish, how they became a threat to desirable species of fish and the ineffective previous efforts at control. An object of this invention is to protect native populations of food and game fish by rapid and substantial reduction of squawfish. Results of laboratory testing are given showing the effectiveness of 1,1' methylene-di-2-naphthol in killing squawfish without harming nontarget species of fish. It is unlikely that mammals or fowl would be harmed. Methods supporting the claims are given.

Keywords: patent, invention, squawfish, 1,1'-methylenedi-2-naphthol

76.
Marking, L.L. 1975. Toxicological protocol for the development of piscicides, Pages 26-31 in P.H. Eschmayer, (ed.). Rehabilitation of fish populations with toxicants: A symposium. North Central Division, American Fisheries Society, Special Publication Number 4.

Abstract: Potential fish toxicants must be investigated intensively in the laboratory before they are used in fish culture or in the reclamation of waters to improve sport fishing. Laboratory studies are designed to provide data needed to meet safety and efficacy requirements for registration. A protocol is presented here to serve as a guide for evaluating the toxicity of a chemical to aquatic organisms. Acute and chronic toxicities are determined in static and flow-through tests in which the susceptibility of target and non-target organisms to the lethal action of the chemical is assessed. Properly designed tests generate data on classical and use-pattern toxicity. Classical toxicity information includes LC_{50} values that are determined under standard conditions and make possible the comparison of toxicity of a candidate compound with that of other substances or the comparison of toxicity to different species. The duration of a classical toxicity test usually is 24 to 96 hours. Usepattern toxicity relates to the determination of the effects of concentrations proposed for field use; LC_{99}'s or observed 100% effects are more meaningful than LC_{50}'s for these determinations. The duration of usepattern tests is governed by the exposure time required to kill target fishes and generally varies with different toxicants.

Keywords: toxicological protocol, toxicants, LC_{50}

77.
Maxfield, G.H., K.L. Liscom and R.H. Lander, 1959. Leading adult squawfish (Ptychocheilus oregonensis) within an electric field. United States Fish and Wildlife Service, Special Scientific Report - Fisheries No. 298.

Abstract: The nature of squawfish predation on hatchery-reared salmon fingerlings requires an economical and practical method for continuously removing the squawfish from the areas of releases. Research has been directed toward the development of an electrical trapping device employing

the principal of electrotaxis. The objectives of the study were to determine the systematic testing, (A) the optimum values of the electrical variables of (1) potential (60, 75, and 90 volts), (2) pulse frequency (2, 5, and 8 pulses per second), and (3) pulse duration (10, 20, and 30 milliseconds) for leading adult squawfish within an electrical array; and (B) the possible significance of the direction of movement of the electrical fields. Pulse frequency was found to be the most critical variable (optimum, 2 pulses per second). Potential was also significant (optimum, 60 volts), but pulse duration was not significant, at least in the range tested. The direction of the electrical fields in the laboratory tank was a highly significant variable. The fish showed a greater response when the electrical fields moved toward the north end of the laboratory tank than toward the south. The reason for this reaction was not determined.

Keywrds: squawfish, electrical array, electrotaxis

78.
Maxfield, G.H., G.E. Monan and H.L. Garrett. 1969. Electrical installation for control of the northern squawfish. United States Fish and Wildlife Service, Special Scientific Report - Fisheries No. 583.

Abstract: Electricity was used experimentally to divert and trap squawfish during their spawning migration in 1958 at Cascade Reservoir, Idaho. Electrical fields, created by sequentially energizing a V-shaped array of vertically suspended round electrodes with square-wave, d.c. pulses, were evaluated as a means of diverting squawfish into traps. Three test conditions of varied pulse frequency, pulse duration and voltage were tested. Two sets had a pulse frequency of 10 pulses per second (2 per field per second when 5 fields were pulsed in sequence), a pulse duration of 50 milliseconds, and voltages of 140 and 180 v.; 1 set had a pulse frequency of 15 pulses per second (3 per field), a pulse duration of 25 milliseconds, and a voltage of 180 v. One set (pulse frequency, 10 pulses per second; pulse duration, 50 milliseconds, and voltage, 180 v.) was repeated. The electrical fields of the electrode array were effective in diverting squawfish into traps. The test condition with pulse frequency of 15 pulses per second, pulse duration of 25 millisecond, and voltage of 180 v. was less effective than the other test conditions.

Keywords: squawfish, electrode array, Cascade Reservoir

79.
Maxfield, G.H., R.H. Lander and C.D. Volz. 1970. Laboratory tests of an electrical barrier for controlling predation by northern squawfish. United States Fish and Wildlife Service, Special Scientific Report - Fisheries No. 611.

Abstract: The effectiveness of electrical fields in blocking squawfish passage was explored. On the basis of test results four electrode arrays, with capacitor discharge pulses at 8 pulses per second and a pulse duration equivalent to that of 40 millisecond "rectangular pulse," were tested at three voltage gradients. A staggered array of electrodes in which the electrodes were spaced 61-cm intervals in rows 200 cm. apart was most effective. At the voltage gradients of 0.75, 1.00 and 1.25 volts per centimeter, 85, 93, and 96% respectively, of the squawfish were blocked.

Keywords: squawfish, electrode arrays , capacitor discharge pulses, pulse duration, voltage gradient

80.
Meekin, T.K. and B.K. Turner. 1974. Tolerance of salmonid eggs, juveniles and squawfish to supersaturated nitrogen. Technical Report 12, Washington Department of Fisheries, Olympia, Washington, USA.

Abstract: Bioassays with juvenile salmonids show they can withstand prolonged exposure to concentrations of 112% dissolved nitrogen. Emboli are the most common external symptom of nitrogen gas. Squawfish can tolerate levels of 120% saturation but will not actively feed at this level.

Keywords: supersaturated nitrogen, squawfish, salmonids

81.
Metcalf, R.L., J.R. Sanborn, Po-Yung Lu and D. Nye. 1975. Archives of Environmental Contamination and Toxicology, 3:(2): 151-165.

Abstract: Radiolabeled tri-, tetra-, and pentachlorobiphenyl (PCB) and DDE were studies in a laboratory model ecosystem for degradation pathways, and biomagnification in alga, snail, mosquito, and fish. Trichlorobiphenyl was degraded in all the organisms of the model ecosystem much more rapidly than tetrachloro- and pentachlorobiphenyl. Pentachlorobiphenyl was approximately as persistent as DDE. There was a linear relationship between lipid/water partition and ecological magnification and between water solubility and ecological magnification. No evidence of conversion of DDE to PCB was detected.

Keywords: model ecosystem, degradation, partition

82.
Meyer, F.A. 1966. Chemical control of undesirable fishes. Pages 498-510 in Inland Fisheries Management, A. Calhoun, (ed.), California Fish and Game Department, Sacramento, California, USA.

Abstract: Planning for chemical treatment is outlined. A review is given for rotenone usage including a test for rotenone in water. Other chemicals are discussed along with application methods.

Keywords: rotenone, chemical treatment, application methods

83.
Meyer, F.P., R.A. Schnick, K.B. Cumming and B.L. Burger. 1976. Registration status of fishery chemicals, February 1976. Progressive Fish Culturist 38(1):3-7.

Abstract: The existing regulatory situation and registration status of selected chemicals is outlined. The Federal Environmental Pesticide Control Act (FEPCA) did not represent an arbitrary imposition of regulations on the fishery field but did cast a cloud over the use of chemicals in fish culture and fishery management. The FEPCA required a review of existing registrations by October 1976. Additional research directed toward meeting the requirements for registration was needed on all fishery chemicals except Terramycin and Sulfamerazine. A list was developed by the Fish and Wildlife Service to be used as a basis for establishing priorities for research toward registration. The Fish Control Laboratory, Lacrosse, Wisconsin, was designated as the lead facility to coordinate the registration effort. Status reports on existing registration were developed and a liaison officer with EPA and FDA was appointed in 1974. The status of chemicals used in fisheries is summarized.

Keywords: chemicals, registration, Federal Environmental Pesticide Control Act, Fish and Wildlife Service

84.
Mount, D.I. and T.J. Norberg. A seven-day life-cycle toxicity test. U.S. Environmental Protection Agency, Duluth, Minnesota.

Abstract: A three-brood life cycle test for Ceriodaphnia reticulata using renewal techniques and that can be completed in 7 days is described. The test is convenient where samples to be tested are limited in volume or where time is especially important such as in on-site effluent testing. The cladocerans, C. reticulata, are easily cultured, are not bothered by handling, and control survival in tests has not been a problem.

Keywords: toxicity test, chronic daphnid test, cladoceran test, aquatic toxicity, life cycle test method, Ceriodaphnia reticulata, culture of cladocerans

85.
Mullan, J.W. 1980. Fish predation on salmonids smolts in the Columbia River system in relation to the endangered species act. Unpublished paper United States Fish and Wildlife Service, Leavenworth, Washington, USA.

Abstract: A species may be listed under the Endangered Species Act if it is determined to be endangered or threatened by a variety of natural or

man made factors affecting its continued existence. Predation is one such factor possibly depressing salmonid stocks in the Columbia and Snake Rivers, particularly if such loss exceeds "natural" levels due to modifications in habitat. A reasonably logical case can be made, largely based on theoretical and circumstantial considerations, that predation is contributing to instability of upriver salmonid runs and could contribute to eventual extinction. The vulnerability of salmon smolts to predation can be exacerbated for any or all of the following: a) increased predator species densities resulting from physical changes in habitat, b) increased predator species densities resulting from the destabilization effects of harvest exploitation whereby large predators such as sturgeon, which may have tended to reduce competitive interaction at lower trophic levels by holding competitor populations in check, were replaced by medium-sized generalists such as squawfish, c) increased predator species densities resulting from the introduction of American shad which served to increase the base food supply for predators, but particularly medium-sized trophic generalists such as squawfish, d) control of flood runoff which historically allowed smolts to quickly exit the river with a minimum of energy expenditure and with the protection afforded by high turbidity and high volume of flow, e) concentation of prey and predators in dam forebays and tailraces due to migration impediment and chumming effects of prey killed in turbine passage coupled with the predilection of predators to prey crippled in turbine passage. Predator control is generally untenable economically and ecologically. Selective chemical control could only be justified experimentally. We have an obligation of holistic evaluation as we know very little about the fish community as a whole and whether predator-prey relationships have reached a new equilibrium.

Keywords: endangered species, predation, squawfish, dams, American shad

86.
Nakaue, H.S., R.S. Caldwell, and D.R Buhler. 1972. Bisphenols - uncouplers of phosphorylating respiration. Biochemical Pharmacology, 21:2273-2277.

Abstract: Hexachlorophene and other chlorinated bisphenolic compounds are used extensively in consumer products and in agriculture as antibacterial and antifungal agents. The mechanism of toxicity of these compounds is not well known. Hexachlorophene has been shown to inhibit the cytochrome oxidase, lactate dehydrogenase, and succinoxidase systems in rats. Hexachlorophene is a potent uncoupler of oxidative phosphorylation.

The effects of numerous bisphenols was determined on ATPase activity at different concentrations with various bisphenols. Also the concentration causing 50% inhibition of phosphorus uptake was measured. Generally the uncoupling activity of the bisphenols appears to be closely associated with the acidity of the compound (pKa). However, squoxin (bis [2-droxynaphthyl] methane) was much less active against mitochondrial systems

than the chlorinated bisphenols. It is apparent that factors other than the pKa influence the uncoupling potentcy. Lipid solubility is one factor that has been considered in determining the efficiency of the uncoupling. The poor correlation observed between uncoupling efficacy and partition coefficients for meythlene bridged bisphenols adds further support to the fact that other factors are also involved.

Indirect evidence was discussed of the mechanism of interaction of phenolic uncouplers with mitochondrial proteins. Their hypothesis considered the lipid solubility and pKa of uncouplers and uncoupling potentcy since they suggested that the uncoupler must first cross the lipoid boundary in the unionized state and then ionize in order to interact with the charged mitrochondrial protein. It was considered likely that the interaction of the bisphenol uncouplers with mitochondrial proteins is an essential part of the uncoupling process.

Keywords: bisphenol, toxicity mechanism, his (2-hydroxynaphthyl) methane, oxidative phosphorylation

87.
Neely, W.B., D.R. Branson and G.E. Blau. 1974. Partition coefficient to measure bioconcentration potential or organic chemicals in fish. Environmental Science and Technology 8(13):113-115.

Abstract: The bioconcentration of several chemicals in trout muscle was found to follow a straight line relationship with partition coefficient. Bioconcentration in this paper is defined as the ratio of the concentration of the chemical between trout muscle and the exposure water measured at equilibrium. Partition coefficient has the usual meaning that it is the ratio of the equilibrium concentration of the chemical between a nonpolar and polar solvent (in this case, n-octnaol and water were the two solvents used). The relationship was established by measuring the bioconcentration in trout of a variety of chemicals over a wide range of partition coefficients. An equation of the straight line of best fit was determined and used to predict the bioconcentration of other chemicals from their partition coefficients. The predicted values agreed with the experimental values in the literature.

Keywords: bioconcentration, partition coefficient, organic chemicals

88.
Not-berg, T.J. and D.I. Mount. A new subchronic fathead minnow (Pimephales promelas) toxicity test. U.S. Environmental Protection Agency, Duluth, Minnesota.

Abstract: The most commonly used tests for evaluating the concentration of effluents toxic to fish and invertebrates has been the acute lethality

test. However, effluents are frequently not acutely toxic, so assessing the sublethal effects on fish and invertebrates is important. The method described in this paper is a rapid method to estimate the chronic toxicity of effluents using growth and survival of the fathead minnow (Pimephales promelas). Tests are initiated using newly hatched minnow larvae and are run for 7 days. It is a cost-effective, simple, short-term renewal toxicity test with dry weights of the minnows measured at test termination. Approximately 40 tests using this technique have been done with various types of effluents at this time. Included in this paper are results from some of those tests and also tests run with Dursban, zinc, and copper.

Keyword: effluents, Pimephales promelas, sublethal effects, growth, toxicity test, zinc, copper, and Dursban

89.
Ogata, Y., A. Kawasaki, and T. Goto. 1969. Mechanism of sulphomethylation of B-naphthol; kinetics of the formation of sodium 2- hydroxy-1-naphthylmethanesulphonate from bis-(2-hydroxy-1-naphthlyl) methane. Tetrahedron 25:2589-2602.

Abstract: Suphomethylation of B-naphthol, i.e. the reaction of bis-(2-hydroxy-1-naphthyl) methane (BHNM;I) with sodium sulphite to form 2-hydroxy-1-naphthylmethanesulphonate (SNMS;II), has been studied kinetically by iodometry of sodium sulphite. The rate law, v=k(BHNM), together with the relation k vs.(OH-) suggests a S_N1 mechanism via the dianion of BHNM(V) and quinone-methide (VIII). This shows that quinonemethide (VIII) and not BHNM is an intermediate in the sulphomethylation of B-naphthol. The behavior of BHNM in aqueous alkali is discussed in terms of the alkalimetric titration and UV spectra.

Keywords: 1,1'-methylenedi-2-naphthol, bis-(2-hydroxy-1-naphthyl) methane (BHNM) (squoxin)

90.
Oliver, J.E. 1979. Degradation of the piscicide squoxin in water. Final Report Interagency Reimbursable Agreement 1001-0022, United States Departments of Agriculture and Commerce.

Abstract: The initial intention of this project was to study the degradation reaction of squoxin (1,1'-methylenebis (B-naphthol) under conditions recommended by the Environmental Protection Agency for hydrolysis of pesticides. The reported rap'id decomposition of squoxin in natural waters is evidently an oxidative, and not a simple hydrolytic process. Squoxin is relatively stable in pure water in the absence of oxygen. Furthermore, aqueous solutions of squoxin were also found to be stable in the presence of oxygen if no metal ions were present. Different metals may catalyze different reaction rates and formation of different products.

Keywords: squoxin, decomposition, oxidation

91.
Oliver, J.E., C.N Lamb and R.H. Smith, Jr. 1983. Oxidation degradation of the pesticide squoxin in aerated river water. Journal Agricultural Food Chemistry 31: 1178-1183.

Abstract: The title piscicide squoxin (1) 1,1'-methylenebis-2-naphthol rapidly decomposes in aerobic river water, unlike its oxidation by most chemical reagents, evidently produces an unstable hydroperoxide that fragments to 1,2-napthoquinone (5) and 1,2-naphthoquinone l-methide (7). 1,2-naphthoquinone (5) further decomposes to a number of products whereas 7 instantly hydrates to form the relatively stable 1-(hydroxymethyl)-2-naphthol (4). Further decomposition of 4 produces formaldehyde and probably additional 5.

Keywords: squoxin, 1,1'-methylenebis (2-naphthol), 1,2-naphthoquinone, 1,2-naphthoquinone 1-methide, 1-(hydroxmethyl)-2-naphthol, formaldehyde

92.
Olney, F.E. 1975. Life history and ecology of the northern squawfish, Ptychocheilus oregonensis, in Lake Washington. Master's thesis, University of Washington, Seattle, Washington, USA.

Abstract: Squawfish are concentrated near the bottom of Lake Washington in winter and move inshore in spring and summer. Feeding on longfin smelt and sockeye salmon decreased or ceased altogether in the summer months when the squawfish were concentrated inshore and thus were spatially segregated from the two prey species. The largest components of the total yearly ration (103.31%) were cottids (33.95%), sockeye salmon (17.66%) and crayfish (15.02%). Female squawfish were aged up to 21years and males to 16 years of age. Male squawfish first reached sexual maturity at age IV (251-275 mm), and females matured between age IV and VI (301-350). Spawning took place between early June and early August.

Keywords: squawfish, Lake Washington, life history

93.
Ortman, D.W. 1972. Evaluation of squawfish control program, catch restrictions and hatchery releases. Annual Progress Report, Federal Aid Project F-60-R-4, Job 3, Idaho Fish and Game Department, Boise, Idaho, USA.

Abstract: A spot-check type of creel census on the lower St. Joe River indicated a considerable improvement in catch rate of trout since 1968. Comparisons of live fish counts in trend areas since 1967 show a substantial decrease in the numbers of squawfish in the lower St. Joe River while trout, whitefish and suckers have increased.

Keywords: squawfish, creel census, St. Joe River

94.
Patten, B.G. and D.T. Rodman. 1969. Reproductive behavior of northern squawfish, *Ptychocheilus oregonensis*. Transactions of the American Fisheries Society 98(1):108-111.

Abstract: Squawfish were observed spawning in Merwin Reservoir, Washington, over coarse rubble in depths below 3 m during June and July. Coloration during spawning was different than at other times. Squawfish on the spawning grounds have a dark lateral band from the snout to the base of the caudal fin highlighted dorsally by a light yellow strip and subdivided on the anterior half of the body by a light yellow lateral line. Pectoral fins are bright orange. Males exhihit sexual dimorphism in the form of small tubercles on the dorsal surface of the head. Congregated spawning behavior of the males consisted of "swarming" and "chasing" which culminated in the spawning act. Females did not swarm and were pursued by the males which outnumbered females from 50 to 200:1. Single spawning acts lasted 1 second or less about 3 cm off the bottom in a rocky crevice. Eggs were demersal, adhesive, pale orange and about 1 mm in diameter. They were driven into the rock interstices or settled on the bottom.

Keywords: squawfish, spawning, sexual dimorphism

95.
Pintler, H.E. and W.C. Johnson. 1958. Chemical control of rough fish in the Russian River drainage, California. California Fish and Game 44(2):91-124.

Abstract: A total of 286 miles of the Russian River was treated chemically to control rough fish and improve the steelhead fishery. Treatment took place over three years and cost approximately $6,000, or $20 per mile. Slightly more than 9,720 pounds of cube powder were used. Twenty-nine species of fish were observed after treatment. The main species consisted of Western sucker, roach, carp and squawfish in that order with less than 1% gamefish, mostly steelhead. Following treatment, steelhead had increased 13 times while the rough fish population was drastically reduced. The economic feasibility of the project should be revealed by the permanency of the increase of gamefish and the rate of recovery of the rough fish population.

Keywords: Russian River, chemical treatment

96.
Pollard, H.A., II. 1972. Squawfish control in Anderson Ranch Reservoir. Federal Aid Project F-53-R-7, Job IIIa, summary report. Idaho Fish and Game Department, Boise, Idaho, USA

Abstract: Shoreline spawning areas in Anderson Ranch Reservoir were treated with rotenone from 1965 to 1970 to kill newly hatched squawfish fry. Sampling indicates little change in abundance of squawfish. Differential habitat preference probably minimizes interaction between kokanee and squawfish during much of the year. A reduction in squawfish may not benefit kokanee.

Keywords: Anderson Ranch Reservoir, kokanee, squawfish

97.
Ravert, J. and G. St. E. Parke. 1976. Thirteen-week oral toxicity study of squoxin in rats. In Petition Proposing an Exemption from the Requirement of a Tolerance for the Use of Squoxin to Reduce the Numbers of Squawfish in Trout Streams in Washington, Oregon and Idaho. (Petition to U.S. Environmental Protection Agency No. 7E1928 by Interregional Research Project No. 4, Rutgers University, New Brunswick, New Jersey) Contract Study by Cannon Laboratories, Reading, Pennsylvania, USA.

Abstract: Squoxin was administered to rats orally in amounts equivalent to 100 mg/kg and 1,000 mg/kg for 13 weeks. Mortality was limited to two male and one female rats from the control group. Administration of squoxin was associated with a significant decrease in hody weight of the high dose (1,000 mg/kg) group when compared to the other levels. Hematological results were normal. Alkaline phosphatase values were slightly higher in the 1,000 mg/kg group. Organ weights of six test animals were significantly lower than controls. The 1,000 mg/kg males had a significantly higher organ weight to body weight than other groups.

Keywords: toxicity study, squoxin, rats

98.
Raymond, H.L. 1974. Snake River runs of salmon and steelhead trout and trends in abundance of adults and downstream survival of juveniles. Processed Report National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Center, Seattle, Washington, USA.

Abstract: There was no serious decline of adult Pacific salmon and steelhead trout runs to the Snake River until 1974. Increased hatchery releases and above average survival of juveniles masked the effect of new dams and impoundments. Adult return percentages of both chinook and steelhead decreased at an alarming rate since 1970. Analysis shows that the decline is in the significant losses of juveniles reaching the ocean. A 95% loss of both chinook and steelhead migrants was measured from the Salmon River to The Dalles Dam in 1973. Flip lip devices to reduce concentrations of dissolved gases in water, transportation'of fish past dams, screening of turbine intakes in the improvement of systems to bypass fish around dams could significantly reduce losses.

Keywords: Snake River, chinook salmon, steelhead, dams, nitrogen supersaturation

99.
Raymond, H.L., W.W. Bentley and C.S. Thompson. 1973. Progress report, effects of power peaking operations on juvenile salmon and steelhead trout migrations 1973. United States Corps of Engineers Contract DACW57-74-F-0621, National Marine Fisheries Service, Seattle, Washington, USA.

Abstract: Thousands of squawfish were collected and tagged in the Palouse arm of the Lower Monumental Pool in December, 1973, for subsequent recovery and estimate of abundance in the tailraces and other locations in reservoirs.

Keywords: Lower Monumental, squawfish, tagging

100.
Raymond, H.L., C.W. Sims, R.C. Johnson and W.W. Bentley. 1975. Progress report - effects of power peaking operations on juvenile salmon and steelhead trout migrations 1974. United States Corps of Engineers Contract DACW57-74-F-0621, National Marine Fisheries Service, Seattle, Washington, USA.

Abstract: Squawfish were captured for tagging or marking in the Palouse Arm of the Lower Monumental Reservoir. Tolerance tests for total dissolved gas and its effects on feeding behavior were conducted. Squawfish apparently travel at a depth sufficient to compensate for dissolved gas supersaturation. Data suggests that squawfish are vulnerable to high dissolved gas levels. There are considerable numbers of squawfish in lower John Day Reservoir in spring and summer.

Keywords: total dissolved gas, squawfish, Lower Monumental, John Day Reservoir

101.
Reid, G.E. 1971. St. Joe River cutthroat trout and northern squawfish studies. Federal Aid Project F-60-R-02, Job 2, Idaho Cooperative Fishery Research Unit, University of Idaho, Moscow, Idaho, USA.

Abstract: Squawfish life-history data was collected over a two-year period. Depth is the most important parameter correlated with distribution of mature squawfish. Mature squawfish migrate from Lake Coeur de Alene into St. Joe River with most returning to the lake after spawning. Both sexes have the capacity for multiple spawning. Juvenile squawfish 3 years and younger rear in slough areas off the main river. Growth is about 30 mm per year for the first 5 years. The oldest squawfish found was 17 years.

Keywords: Lake Coeur de Alene, St. Joe River, squawfish, life history

102.
Reinert, H.K. and G. St. E. Parke. 1976. Eight-day dietary LC_{50} study of squoxin in coturnix quail and mallard ducks. In Petition Proposing an Exemption from the Requirement of a Tolerance for the Use of Squoxin to Reduce the Numbers of Squawfish in Trout Streams in Washington, Oregon and Idaho. (Petition to U.S. Environmental Protection Agency No. 7E1928 by Interregional Research Project No. 4, Rutgers University, New Brunswick, New Jersey) Contract Study by Cannon Laboratories, Reading, Pennsylvania, USA.

Abstract: No mortalities occurred in test groups of mallard ducks and corturnix quail exposed to concentrations between 5,000 and 20,000 ppm of squoxin. The 8-day dietary LC_{50} for squoxin is greater than 20,000 ppm for both mallard ducks and coturnix quail.

Keywords: squoxi n, LC_{50}, mallard duck, corturnix quail

103.
Schnick, R.A. and F.P. Meyer. 1978. Registration of thirty-three fishery chemicals: status report of research and estimated costs of required contract studies. Investigations in Fish Control No. 86, United States Fish and Wildlife Service, Lacrosse, Wisconsin, USA.

Abstract: An estimated $8.8 million for contract studies is needed to meet registration requirements for 33 chemicals now used or being considered for use in fish culture and management. Information given for each chemical includes its sponsor, current registration status, research situation in 6 categories (toxicity to target and non-target organisms, field testing, physiological studies, analytical methods development, counteraction, and mammalian safety determination), costs of required contract studies, and the prognosis for registration of the use of each compound.

Keywords: fishery chemicals, registration, research, cost, contract studies

104.
Shearing, E.A. and S. Smiles. 1937. Journal of the Chemical Society, Part II. London: The Chemical Society. pp. 1348-1351.

Abstract: For further study of the alkali derivatives of di-2hydroxy-naphthyl-l-methane we required the unsymmetrical derivatives of the latter, and the experiments now described were undertaken with the object of synthesising these. A suitable process has been found in the reaction between 2-naphthol and its 1-methanesulphonate which is shown to be reversible. Sodium 2-hydroxybenzysulphonate and its nuclear homologues may be

obtained (1) from the relevant phenol with formaldehyde and sodium sulphite, (2) from the 2-hydroxbenzyl alcohol and sodium bisulphite, but the reactivities of these products with 2-naphthol are in general less than that of 2-hydroxynaphthyl-1-methanesulphonate. An interpretation of the notably high activity of R in $C_{10}H_6OHCH_2R$ is offered and this has led to the observation that 2hydroxynaphthyl-1-thiolsulphonate is readily formed from sodium sulphite and di-2-hydroxynaphthyl-1-sulphide.

Keywords: 1,1'-methylenedi-2-naphthol, squoxin

105.
Sims, C.W., R.C. Johnson and W.W. Bentley. 1976. Effects of power peaking operations on juvenile salmon and steelhead trout migrations, 1975. Processed Report National Marine Fisheries Service, Seattle, Washington, USA.

Abstract: Higher numbers of squawfish were counted migrating up the fishways of Columbia River dams than at Snake River dams. Data from traps and seines indicate greater numbers of squawfish in the Snake River. Most squawfish below Little Goose Dam during the salmonid outmigration were found at depths greater than 10 feet and would not have been susceptible to gas bubble disease.

Keywords: Columbia River, Snake River, squawfish, gas bubble disease

106.
Sims, C.W., W.W. Bentley, R.C. Johnson. 1977. Effects of power peaking operations on juvenile salmon and steelhead trout migrations - progress 1976. Processed Report National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Center, Seattle, Washington, USA.

Abstract: Studies were conducted on downstream migrant salmon in steelhead populations of the Columbia and Snake Rivers. Information was obtained relative to migrational timing, travel time, magnitude, survival, and diel movement. Residualism in reservoirs and predator fish populations were also examined. The squawfish populations in the upper half of Lower Monumental Reservoir were estimated at 133,000 fish. The percentage of squawfish examined that had salmonid remains in their stomachs ranged from 2.2 to 32.2%.

Keywords: Columbia River, Snake River, squawfish, Lower Monumental

107.
Staley, G.S. 1977. The impact of squoxin on aquatic invertebrates and the assessment of its fate in the aquatic environment. Master's thesis, University of British Columbia, Vancouver, B.C., Canada.

Abstract: Squoxin was found to be much less toxic to aquatic invertebrates than it was to squawfish. The most sensitive invertebrate species tested was the blackfly larva, Simulium canadense, which is distributed in streams having high current velocity and abundant dissolved oxygen. These larvae exhibit an LC_{50} value of 60 ug/l in 48 hours. Chaohorus trivittatus larvae, known to tolerate anoxic conditions, were resistant to treatments up to 10 mg/l, exhibiting a maximum response of 30% in 96 hours. Degradation was most severe in water having a high pH and high alkalinity. Degradation was also found to occur due to the presence of dissolved organic compounds of high molecular weight. Freshwater bacteria did not exhibit any ability to utilize squoxin as a carbon source in short term tests. A 100 ug/l squoxin treatment depressed the natural heterotrophic activity of bacteria by nearly 25% based on studies of uptake of ^{14}C-glucose over a P-hour period. ^{14}C-squoxin residues initially adsorbed to phytoplankton and organic sediment in simple laboratory microcosms. However, the residues steadily desorbed from these components and became increasingly soluble throughout the test period. Daphnia pulex and Hyalella azetca in the microcosms took up squoxin rapidly in the first 24 hours after treatment. Uptake then leveled off and tissue concentration of squoxin increased only at a very slow rate during the remainder of the test. Only small amounts of squoxin were transferred to organisms feeding on contaminated food items when compared to the dose obtained from a contact exposure. C. trivittatus fed contaminated D. pulex retained only 6% of the ingested squoxin residues. These residues, however, appeared to be retained for a longer period than tissue residues gained through a contact exposure. Invertebrates exhibited an ability to excrete squoxin residues given time and an uncontaminated environment. D. pulex excreted over 90% of the toxicant in 96 hours; H. azteca required-275-s. It was postulated that because of squoxin's water solubility, low partition coefficient, rapid degradation and the ability of a wide variety of organisms to excrete it, the toxicant would not be biologically magnified to a significant degree in aquatic ecosystems.

Keywords: Squoxin, squawfish, invertebrates, blackfly, daphnia, microcosms, partition coefficient

108.
Staley, G.S., and K.J. Hall, 1974. Squoxin: A review of research and applications. British Columbia Fish and Wildlife Branch, Fisheries Technical Circular No. 3.

Abstract: The report reviews the laboratory and field investigations that have been conducted on squoxin and outlines the areas of research considered necessary to certify this material for utilization by fishery managers in British Columhia.

Keywords: squoxin, British Columbia

109.
Swan, R.L. 1972a. Clearance of squoxin for general use, statewide fishery rehabilitation - North Fork John Day segment. Federal Aid Project F-20-R-54, Job 5, Oregon Game Commission, Portland, Oregon, USA.

Abstract: A 35-mile section of the North Fork John Day River was treated with squoxin. A total kill of squawfish was obtained in 11 hours at the 3-mile station and in 12.5 hours at 5 miles. A 1/2-acre pond was treated to measure the persistence of squoxin. The concentration dropped from 142.0 ppb to 17.6 ppb in 6 hours and gradually diminished to 3.6 ppb in 14 days.

Keywords: John Day River, squawfish, squoxin

110.
Swan, R.L. 1972b. Sonar 300 application, Phillips Reservoir, Oregon, Mimeo Report, Oregon Game Commission, Portland, Oregon, USA.

Abstract: Sonar 300 was applied to Phillips Reservoir, Oregon, in a 10-foot wide section of the shoreline in July and again in September. The July treatment was effective while the September treatment was not; the chemical was thought to be weak. The effect on the squawfish population was not significant.

Keywords: Sonar 300, Phillips Reservoir

111.
Swan, R.L. 1973. Sonar 300 application, Smith River, Oregon. Mimeo Report, Oregon Game Commission, Portland, Oregon, USA.

Abstract: Sonar 300 was applied to a 15-mile section of Smith River, Oregon. An estimated 10,000 squawfish were killed.

Keywords: Sonar 300, Smith River, squawfish

112.
Taft, A.C. and G.I. Murphy. 1950. The life history of the Sacramento squawfish (Ptychocheilus grandis). California Fish and Game 36(2):147-164.

Abstract: The Sacramento squawfish is confined to the Sacramento-San Joaquin drainage basin and several small adjoining stream systems. It inhabits lowland and middle elevation streams and lakes. It frequently participates in spawning migrations, remaining in the spawning stream through the summer. The young compete with trout for food and "living room," and adults compete for space and probably prey on young trout. Spawning generally takes place during April and May. The adhesive eggs are deposited on stones in areas with running water. The age of the squawfish can

be determined by a study of the scales. An annulus is formed in March. The length of the fish at the time of the formation of the annulus for any year can be calculated from the scales.

Keywords: Sacramento squawfish, spawning migrations, scale study

113.
Terrell, Y. and G. St. E. Parke. 1976. Thirteen-week oral toxicity study of squoxin in beagle dogs. In Petition Proposing an Exemption from the Requirement of a Tolerance for the Use of Squoxin to Reduce the Numbers of Squawfish in Trout Streams in Washington, Oregon and Idaho. (Petition to U.S. environmental Protection Agency No. 7E1928 by Interregional Research Project No. 4, Rutgers University, New Brunswick, New Jersey) Contract Study by Cannon Laboratories, Reading, Pennsylvania, USA.

Abstract: The potential toxic effect of "squoxin" was evaluated in beagle dogs. The compound was administered orally by capsule, daily for 90 consecutive days in amounts equivalent to 100 mg/kg and 250 mg/kg. A third group was administered the capsule for the same time period as the treated levels. Potential toxic effects were evaluated in terms of the following: body weight, food consumption, behavioral changes, hematology, clinical chemistry, urinalysis, necropsy examinations, organ weights, organ to body weight ratio. The administration of "squoxin" did not reveal any significant abnormalities in any of the above mentioned parameters.

Keywords: squoxin, beagle dog, toxic effects

114.
Terriere, L.C. 1974. Chemical and biological studies of the selective piscicide squoxin (1,1'-methylenedi-2-naphthol). Summary of unpublished research papers of Department of Agricultural Chemistry, Oregon State University, Corvallis, Oregon, USA.

Abstract: A summary is presented of studies of persistence of squoxin in field applications in Oregon and Idaho. The method is described for using gas chromatography for detection of squoxin in water using a colorimetric method. Bioconcentration in squawfish and rainbow trout was studied in the laboratory and in the field. Metabolism and excretion studies on rats are described using ^{14}C and ^{3}H labeled squoxin. The stability of squoxin under various conditions of light, oxygen and the presence of metal ions is explored.

Keywords: squoxin, 1,1'-methylenedi-2-naphthol, gas chromatography, metabolism, stability

115.
Terriere, L.C. 1977. Biochemical studies on squoxin. Unpublished report of Departments of Agricultural Chemistry and Entomology, Oregon State University, Corvallis, Oregon, USA.

Abstract: A series of 14 pages of figures and tables showing rat and fish metabolism studies and structure of possible degradation products.

Keywords: squoxin, radioactive, degradation products

116.
Terriere, L.C. and R.J. Burnard. 1975. Uptake, tissue distribution and clearance of the selective piscicide, 1,1'-methylenedi-2-naphthol (squoxin), by the rainbow trout and the squawfish. Agricultural and Food Chemistry 23(4):714-717.

Abstract: Rainbow trout and squawfish were exposed to the selective piscicide squoxin, (1,1'-methylenedi-2-naphthol), in the laboratory using a commercial formulation. Laboratory exposures were at concentrations of 50 ppb, the exposures repeated as many as four times in the case of the trout. Radioassays of whole body and certain tissues and organs of the trout immediately after exposure and after freshwater purges up to 8 days showed that there was no tendency for the piscicide to be retained. Maximum residues, based on the radioassays, were equivalent to 9.45 ppm of squoxin in the trout. Squawfish killed by a single exposure, had maximum residues as squoxin of 3.50 ppm. The field-treated fish were exposed to squoxin at a concentration of 100 ppb. Analyses were by gas chromatogra-[illegible]. Surviving trout contained residues as high as 1.48 ppm (whole body), while dead squawfish contained residues ranging from 0.84 to 2.38 ppm. Residues in the edible tissues of the trout were less than 0.1 ppm.

Keywords: 1,1'-methylenedi-2-naphthol, squoxin, residues, radioassays, squawfish, rainbow trout

117.
Terriere, L.C., U. Kiigemagi, and E. Chan. 1970. The stability of 1,1'-methylenedi-2-naphthol (squoxin) in water. Unpublished report of Department of Agricultural Chemistry, Oregon State University, Corvallis, Oregon, USA.

Abstract: A number of factors affecting the stability of squoxin in water are explored including solubility, effect of metal ions, adsorption, light, oxygen, pH. A colorimetric method for detection is described with results of samples from field application.

Keywords: stability, squoxin, colorimetric, solubility, detection

118.
United States Comptroller General. 1978. Special pesticide registration by the EPA should be improved. Report to the United States Congress.

Abstract: Environmental Protection Agency administration of special pesticide registration activities has not always been effective. Agency processing of requests for emergency and experimental uses of pesticides often takes too long. The agency often approves requests for emergency use of canceled pesticides in non-emergency situations. Some participating Federal and State agencies have violated their authority by using unregistered, canceled or suspended pesticides. As a result, the public may not be protected from potentially harmful and dangerous pesticides used under this program.

Keywords: pesticides registration, emergency use, EPA

119.
United States Department of Agriculture. 1971. Temporary permit issued under the Federal Insecticide and Rodenticide Act for shipment or an economic poison for experimental purposes only. Permit number 241-EXP-55G, May 28, 1970, issued to American Cyanamid Company, Princeton, New Jersey, for the selective piscicide Sonar 300.

Abstract: An experimental-use permit was issued for 1 year to American Cyanamid Company for use of Sonar 300 selective piscicide (1,1'-methylenedi-2-naphthol) by the Idaho Fish and Game Department. A permit was also issued by the U.S. Environmental Protection Agency (Reg. No. 241) to American Cyanamid Company for use of Scavenger 300 by the Idaho Fish and Game Department, the Oregon Game Commission and the Washington Game Department.

Keywords: American Cyanamid Company, Sonar 300, Scavenger 300, selective piscicide, experimental-use permit

120.
United States Department of Interior, Bureau of Sport Fisheries and Wildlife. 1969. Progress in sport fishery research, 1968. Resource Publication 77, p. 114-121.

Abstract: The results of static bioassays with squoxin (1,1'-methylenedi-2-naphthol) are given. The LC_{50}'s are defined for coho salmon, rainbow trout, brook trout, goldfish, carp, white sucker, black bullhead, green sunfish, and bluegill.

Keywords: static bioassay, LC_{50}, squoxin

121.
Uremovich, B.L., S.B. Cramer, C.F. Willis, and C.O. Junge. 1980. Passage of juvenile salmonids through the ice and trash sluceway and squawfish predation at Bonneville Dam, 1980. Annual Progress Report to U.S. Army Corps of Engineers, Contract DACW57-78-C-0058, Oregon Department of Fish and Wildlife, Portland, Oregon, USA.

Abstract: A squawfish predation study was conducted at Bonneville Dam in 1980. Fish were found in 67.7% of the squawfish fore-guts containing food. Of the identifiable fish found in the fore-guts, 97.7% were juvenile salmonids. No relationship was found between the size of squawfish and the size of prey items contained in its fore-guts. The average numbers of salmonids per squawfish fore-gut did not change significantly throughout the day, but the catch rate of squawfish peaked distinctly at dawn (6 a.m.) and dusk (8 p.m.). Angling may selectively capture hungry squawfish. An estimated 1.7 million juvenile salmonids were consumed by squawfish in the first powerhouse forebay between April 13 and August 30, 1980. An estimated 3.8 million juvenile salmonids may have been consumed by squawfish in the entire Bonneville forebay (powerhouse and spillway) during the 20-week study period. This consumption estimate represented an 11% mortality to the 34 million juvenile salmonids estimated to have entered the Bonneville pool during 1980. The consumption rate of juvenile salmonids by squawfish was generally unaffected by the abundance of juvenile salmonids.

Keywords: squawfish, predation, Bonneville Dam

122.
Walker, C.R. 1969. Problems in clearance and registration of chemical tools used by fish culturists and fishery biologists. A symposium at 99th Annual Meeting of the American Fisheries Society, New Orleans, Louisiana, USA.

Abstract: The need for better information on pesticides was identified by the Federal Committee on Pest Control. The Interagency Ad Hoc Committee for the Use of Herbicides and Aquatic Sites outlined needed information to support clearance and registration. Information needs for a petition for clearance and registration of chemicals that may be water pollutants are listed. An appalling situation exists regarding the specific uses and status of registration of 95 chemicals used in fish culture and fish management. The chemical industry has little profit or other motive on the majority of chemicals, and the data must be generated by states and federal research. A cooperative effort will be required to pursue the registration process.

Keywords: pesticides, clearance, registration, research needs

123.
Watson, R.E. 1973. 1973 squoxin (l,l'-methylenedi-2-naphthol, sodium salt) application to the Chehalis River System. Mimeo Report, Washington Department of Game, Olympia, Washington, USA.

Abstract: The effectiveness of squoxin (SCAVENGER 300, Sonar 300), a piscicide selective to squawfish and related minnows was evaluated after application in a Washington river system that terminates in a saltwater estuary. Insect and fish mortality was monitored. Squoxin applied at 100 ppb effectively eradicated squawfish up to 11 miles below the point of application. There was no harm done to the salmonid stocks, and very few other minnows and sculpins were killed. No insects or other aquatic organisms suffered any observable mortalities. No salt or brackish water organism appeared to be affected by this application.

Keywords: squoxin, squawfish, Chehalis River

124.
Welsh, T.L. 1975. Squawfish control in Cascade Reservoir. Federal Aid Project F-53-R-10, Job IIa, Idaho Department of Fish and Game, Boise, Idaho, USA.

Abstract: The North Fork Payette River was treated with squxoin. A total of about 1,500 squawfish were killed. This compares with a kill of about 27,000 in 1973. No squawfish spawning runs of a size large enough to warrant treatment were observed in Gold Fork and Lake Fork Creeks.

Keywords: squoxin, squawfish, Payette River

125.
Whitworth, W.R. and M.D. Collins. 1973. Chemical eradication of non-salmonids in the Molalla River. Mimeo Report, Oregon Fish Commission, Clackamas, Oregon, USA.

Abstract: Two sections of the Molalla River were treated chemically for eradication of non-salmonid fish. The upper section (19.5 miles) was treated with squoxin for (2) hours; the lower 13.6-mile section was treated with Pro-Noxfish. Large numbers of non-salmonids were killed by Pro-Noxfish, but only a few squawfish and dace were killed by squoxin. There was a subsequent reduction of all fish from the squoxin treated area from unknown causes.

Keywords: squoxin, squawfish, Molalla River, Pro-Noxfish