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AQUATIC BIOENVIRONMENTAL STUDIES IN THE COLUMBIA RIVER AT HANFORD 1945-1971

A BIBLIOGRAPHY WITH ABSTRACTS

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ABSTRACT

Publications prepared by Hanford staff scientists that deal with bio-environmental studies in the central Columbia River during the period 1945 to 1971 are listed and abstracted. Four general topics are covered: 1) biology and ecology of river organisms, 2) thermal and chemical effects of reactor effluent discharges, 3) radioactivity releases from reactor operations, and 4) hydrology of the Columbia River. Over 400 publications are included. The abstracts provide an insight into the scope and depth of diverse studies supported by the United States Atomic Energy Commission in order to evaluate any impact on the aquatic ecosystem (and to provide related data) throughout the "plutonium production phase" of the Hanford operations.

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INTRODUCTION

The purpose of this bibliography is to assemble, in one document, abstracts of various publications dealing with bioenvironmental studies in the central Columbia River over the period 1945 to 1971. All publications abstracted herein have resulted from the research effort of the supporting staff at Hanford, and cover four general topics: 1) biology and ecology of river organisms, 2) thermal and chemical effects of reactor effluent discharges, 3) radioactivity releases from reactor operations, and 4) hydrology of the Columbia River.

The publications abstracted provide valuable, albeit sometimes little-known, sources of information on the accomplishments of diverse research programs as well as the scope and depth of past research effort. In general, the programs were designed to evaluate the impact of the Hanford plutonium-production reactors on the Columbia River ecosystem. These programs were supported by the United States Atomic Energy Commission (AEC). The wealth of information available is difficult to integrate into proper perspective, if left unassembled, because of the number of research programs and reports, the shifts in program emphasis over the years, the different routes of publication, the classified status of many reports, and the passage of time with concomittant changes in research personnel.

The period over which these publications issued may be considered as the "plutonium production" phase of the Hanford operations.

The Hanford Project, a "reservation" of about 640 square miles in south central Washington, was conceived as a site for the construction of a plutonium production plant in 1943 by the Manhatten District of the U.S. Army Corps of Engineers. One of the important factors for selecting the

site was that the Columbia River, with a flow volume second only to the Mississippi River in the conterminous United States, was available to supply the required amounts of cooling water and to safely dilute the kinds and amounts of radionuclides expected in the effluent. The du Pont Company built and operated the original Hanford units. Arrangements were made for the General Electric Company to assume responsiblity for operation of the Hanford Project in 1946, under direction of the newly created Atomic Energy Commission. The scattered research and development activities of General Electric at Hanford were united into a single entity in 1956, the Hanford Laboratories.

In 1964, the AEC selected Battelle Memorial Institute to take over the Laboratory and Battelle-Pacific Northwest Laboratories (Battelle-Northwest) was created in 1965 to perform research and development for the AEC and other sponsors. Other firms also settled at Hanford thus establishing diversification of activities.

The first of the three original reactors built at Hanford for the production of plutonium began operation in September 1944, the second later in 1944, and third early in 1945. Eight reactors were on the line from 1955 through 1963 and a ninth was added early in 1964. Deactivation of the reactors began in early 1965. This process continued until early 1970 when only one, the N-reactor (now WPPS #1), remained in operation.

The Hanford plutonium reactors, with the exception of the N-reactor, used direct, once-through cooling with Columbia River water. Because of the relatively high concentrations of radionuclides and high temperatures of the discharge effluents, the plutonium reactors had unknown potential for causing undesirable effects in the aquatic ecosystem. Soon after the first reactors were built, laboratory and field bioenvironmental studies were implemented at the Hanford site. These programs have continued ever since with various aims including determining potential hazard to man, evaluating actual impact on the river ecology, studying ecological processes with radionuclides as tracers, and identifying means of operating plant facilities so as to minimize any possible damage.

Quantities of heat, radionuclides, and chemicals entering the Columbia River from the Hanford operations have varied considerably since 1944. The variations were a consequence of the construction and startup of additional reactors, the operation of individual reactors at different power levels, changes in physical and chemical characteristics of the river from hydroelectric development, modifications in the water treatment process, and the recent deactivation of successive reactors. The surveying N-reactor, activated in early 1964, is a dual-purpose reactor that produces both plutonium and steam-generated electricity. Unlike the plutonium reactors, N is cooled by demineralized water in a closed primary recirculation system, in which temperatures are regulated by a secondary circulation system utilizing direct intake and discharge of river water.

The papers abstracted herein were published in four ways: 1) the open literature, usually professional journals and symposium proceedings; 2) annual reports issued to the AEC Division of Biology and Medicine; 3) research and development reports of unrestricted but limited distribution, and 4) classified research and development reports of restricted distribution.

Security restrictions have been applied only to "classified" bioenvironmental studies, which contained data that might disclose information on plant capacity or certain technical details of the plutonium production process. Many of these reports have been "declassified" following the shutdown of the reactors and some of these are included herein. Various phases of bioenvironmental studies presented at public informative and semi-professional meetings are omitted, but these presentations usually contain information presented in detail in the abstracted material.

Informative review papers concerning the over-all aspects of the Hanford operations are provided by Foster, Junkins, and Linderoth 1961 (F-15), Wildman 1966 (W-44) and Foster 1972 (F-23). Much research emphasis during early years was placed on radionuclides, including the use of Columbia River water as a dispersal agent, accumulation by river organisms and through the aquatic food-chain, and mechanisms for potential transfer to man. Some review papers concerning radiological aspects of the Hanford operations are provided by Robeck, Henderson, and Palange 1954 (R-1), Foster and Rosterback

1954 (F-5), Foster and Davis 1956 (F-7), Foster 1959 (F-9 and F-10), Foster 1960 (F-13), Foster and McConnon 1965 (F-18), Foster and Soldat 1966 (F-20), Perkins, Nelson, and Haushild 1966 (P-18), and Watson et al. 1970 (W-33). More emphasis in recent years has been placed on the effect of thermal increments on aquatic organisms in the Columbia River. Some review papers concerning thermal effects of the Hanford operations are provided by Coutant 1969 (C-32), Nakatani 1969 (N-13), Jaske and Goebel 1967 (J-5), Jaske and Synoground 1970 (J-12), Templeton and Coutant 1971 (T-1), and Becker 1972 (B-29). Some hydrological information relevant to bioenvironmental studies in the Columbia River has been summarized by Wood 1954 (W-51), Robeck, Henderson, and Palange 1954 (R-1), Corley, Kramer, and Soldat 1961 (C-13), and Jaske and Synoground 1970 (J-12).

BIBLIOGRAPHY AND ABSTRACTS

A

1. Allen, R. L., T. K. Meekin, G. B. Pauley, and M. P. Fujihara. 1968. Mortality among chinook salmon associated with the fungus Dermocystidium. J. Fish. Res. Bd. Canada 25(11):2467-2475.

Abstract: Serious outbreaks of a pernicious disease caused by the fungus Dermocystidium are reported in both adult and juvenile salmon from the Columbia River and its tributaries. The disease evokes a characteristic histopathology and appears to cause death in a large percentage of the infected fish. The disease appears to be most virulent at water temperatures below 60 F (15.6 C). Some prophylactic relief is given by treatment with the organic herbicide Diquat, at a dilution of 1:500,000 for 1 hr. (Authors).

B

1. Backman, G. E. 1963. Determination of river dispersion factors. HW-SA-3056, Hanford Atomic Products Operation, Richland, Wash., 19 pp.

Abstract: Three tests with fluorescein dye were used to trace the liquid dispersion pattern from the outfall of the Recycle Test Reactor at the 300 Area. It was found that significant dispersion occurs before the dye reaches the surface of the river, that complete dispersion does not occur by the time the effluent reaches the water intake of the proposed Richland Pumping Station, and that near complete dispersion occurs by the time the effluent reaches the Pasco Pumping Station. (CDB)

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2. Bainard, W. D. 1966. Chemical disposal to the Columbia River by 100-N area. RL-NRD-828, Hanford Atomic Products Operation, Richland, Wash. 18 pp.

Abstract: A review was conducted to identify the disposal procedures for chemicals from the 100-N reactor to the Columbia River. It was concluded that no chemicals are released continuously to the river that would result in a hazardous condition. Seven cases were identified where intermittent releases might cause undesirable conditions. Recommendations for corrective action are given. (CDB)

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3. Ballou, J. E., and R. C. Thompson. 1959. Metabolism of cesium-137 in the rat: Comparison of acute and chronic administration experiments. Health Physics 1(1):85-89.

Abstract: Data were obtained for the retention of Cs^{137} in the rat over a period of 200 days following a single administration; and data showing the buildup of Cs^{137} during a period of 300 days of chronic feeding. Predictions of the chronic buildup results, based on the single administration data, were in close agreement with the results of the chronic feeding experiment. The highest equilibrium Cs^{137} concentration (10 per cent of the average daily intake per gram) was observed in muscle. Retention of cesium in muscle was closely approximated by a single exponential function with a biological half-life of 13 days. There was no evidence, in any tissue, for retention of Cs^{137} with a half-life longer than 17 days. (Authors)

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4. Ballou, J. E. 1959. Metabolism of Zinc-65, pp. 81-86. In: Biology Research Annual Report for 1958, HW-59500. Hanford Atomic Products Operator, Richland, Wash.

Abstract: This report describes the results of an experiment in which Zn^{65} was administered chronically to rats via their drinking water. Approximately 50 per cent of ingested Zn^{65} is absorbed from the gastro-intestinal tract of mature rats as judged from ratios of urinary to fecal excretion of the radioisotope during and following a period of chronic feeding. Tissues attaining the highest concentrations of Zn^{65}, during 200 days of chronic administration, were bone and dorsolateral prostate. The MPC calculated for bone as critical organ was 1.4×10^{-2} μc/ml. Based on prostate as critical organ, the calculated MPC is 3×10^{-3} μc/ml. The 24-hour retention of Zn^{65} absorbed from the gastro-intestinal tract of very young rats was as much as 5.5 times the adult level. (Author)

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5. Becker, C. D. 1969. The food and feeding of juvenile chinook salmon in the Columbia River at Hanford, pp. 2.45-2.49. In: Annual Report for 1968, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1050. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Young chinook salmon in a free-flowing section of the Columbia River in the Hanford environs feed primarily upon semiaquatic and aquatic insects and secondarily on terrestrial insects. There is no evidence that heated effluents discharged in midstream plumes, which rapidly mix with the colder river water, adversely effect either insect production or the feeding activity of the fish. Food intake was restricted, however, in a few areas receiving heated water via intra-gravel seepage from shoreline retention basins in April and early May; these areas were inundated by subsequent rise in river discharge during the annual spring runoff. Increments to the thermal regime of the Columbia in early spring, when water temperatures are below the preferred level of juvenile salmonids (12 to 14 °C), are not harmful and may actually benefit the fish. (Author)

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6. Becker, C. D., and C. C. Coutant. 1969. Experimental drifts of juvenile chinook salmon through effluent discharges at Hanford. Part I. 1968 Drifts. USAEC R&D Report, BNWL-1499. Battelle, Pacific Northwest Labs., Richland, Wash. 35 pp.

Abstract: Mortalities of young salmonids under simulated emigration condition, as in live box drifts, is primarily a function of thermal experience - temperature increase and exposure duration. Drifts conducted in 1968 indicate that exposure to the midriver plumes is insufficient to cause excessive mortalities under most conditions of river

flow. Shoreline drifts through areas heated by intragravel seepage effluent from retention basins causes some mortality due to prolonged exposures that result from inefficient effluent mixing. River discharge volumes and current velocities, prevailing water temperatures, and the extent of effluent mixing clearly influence thermal experience in the field. (See B-16 and B-21) (CDB)

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7. Becker, C. D. 1969. Preliminary report: relationship of thermal discharge to food and feeding of juvenile chinook salmon in the Columbia River at Hanford. USAEC R&D Rept., BNWL-1032. Battelle, Pacific Northwest Labs., Richland, Wash. 27 pp.

Abstract: Stomach contents of young chinook were examined during the spring of 1968. Food organisms consisted primarily of aquatic insects. There was little evidence that heated effluents discharged in midriver exerted any effect on food production or feeding activity. Fish collected from one shoreline area in April and early May, which was warmed by intragravel seepage of effluent from a retention basin, contained fewer food organisms than fish collected elsewhere. A discussion is given on mechanisms by which temperature may influence feeding habits. (See B-15) (CDB)

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8. Becker, C. D. 1970. Emergence and migration of juvenile chinook salmon, pp. 3.12-3.13 In: Annual Report for 1969. Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1306. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: In 1969, fish were found as early as mid-March, but they did not become abundant until the second week of April. Population levels remained relatively high until mid-June and declined rapidly during July. (See B-12) (CDB)

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9. Becker, C. D. 1970. Feeding bionomics of juvenile chinook salmon, pp. 3.16-3.18. In: Annual Report for 1969, Vol. I, Life Sciences Part 2, Ecological Sciences, BNWL-1306. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Review of food organisms consumed by juvenile chinook collected in the spring of 1969. The prey was dominated by aquatic midges (Diptera: Chironomidae). (See B-10) (CDB)

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10. Becker, C. D. 1970. Feeding bionomics of juvenile chinook salmon in the central Columbia River. Northwest Science 44(2):75-81.

Abstract: Juvenile chinook salmon (Oncorhynchus tshawytscha) feed primarily upon aquatic insects (96% of their diet) during their temporary spring sojourn in the free-flowing central Columbia River, Washington. Adult and larvae Tendipedidae (Diptera) dominated the food organisms consumed (81% of numerical total) whereas the orders Trichoptera (5%) and Hemiptera (4%) were of secondary importance. Hydroelectric development has inundated most of the mainstem Columbia; therefore the data relate to food habits of young chinook in a surviving natural environment. (CDB)

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11. Becker, C. D. 1970. Marine trematode Tubulovesicula lindbergi (Digenea: Hemiuridae) from resident white sturgeon in the Columbia River. J. Fish. Res. Bd. Canada 27(7):1313-1316.

Abstract: An infection with a marine trematode, Tubulovesicula lindbergi (Layman, 1930) (Digenea: Hemiuridae), was discovered in a resident white sturgeon, Acipenser transmontanus Richardson, taken in the central Columbia River, Washington, USA. Tubulovesicula lindbergi is normally restricted to marine environs by virtue of essential (but still unknown) invertebrate intermediate hosts, but may occur in migratory fish that enter fresh water. Since hydroelectric dams on the Columbia are now effective barriers to the passage of sturgeon, it is postulated that T. lindbergi was transported into the river system by a maturing, anadromous teleost. After the postspawning death of the "transport" teleost host, the sturgeon presumably acquired the infection when scavenging. Consideration of basic synecological relationships supports the hypothesis. The white sturgeon is a new host record for T. lindbergi. (Author)

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12. Becker, C. D. 1970. Temperature, timing and seaward migration of juvenile chinook salmon from the central Columbia River. USAEC R&D Report, BNWL-1472. Battelle, Pacific Northwest Labs., Richland, Wash. 21 pp.

Abstract: A sizeable population of adult chinook salmon now spawns each fall in the free-flowing Hanford environs of the central Columbia River. This population has acquired significance because other vital spawning areas in the mainstrem Columbia have been inundated by hydroelectric development. Studies conducted in 1969 show that the progeny of the Hanford population migrates seaward from April to July in the ancient pattern that correlates with favorable water temperatures and high discharge volumes. In contrast, the passage of juvenile chinooks that now issue from upriver reaches is known to be delayed until July and August when temperatures and discharge volumes are less favorable. Temperatures in the central Columbia are modified by discharges of heated effluent from plutonium production reactors at Hanford, in addition to largely seasonal changes in river flow, cooling or warming by

the upriver reservoir complex, and summer heat input from the atmosphere. In 1968 and 1969, mean weekly water temperatures peaked in late July, August, and early September with maximum daily temperatures briefly reaching 19.1 and 19.7 C, respectively at Priest Rapids and 19.7 and 20.6 C at Richland. The relationship of ambient temperatures and river discharges to the natural and delayed migration of juvenile chinooks through the Hanford area is evaluated. Maximum temperatures in the central Columbia seldom exceed 22 C and have not been recorded as approaching 25.1 C, the apparent upper incipient lethal limit for juvenile chinooks. Although peak summer temperatures (above 20 C) may be suboptimum for the survival of young salmon, such conditions probably existed long before the advent of modern man. Present peak temperatures do not appear to be directly lethal even with increments of heat from reactor effluent. Potentially adverse thermal effects from reactor operation would most likely appear at subacute levels and resist casual detection. This assumes that a slight increase in excess of the annual temperature cycle does not greatly intensify other existing environmental hazards. (Author)

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13. Becker, C. D. 1970. Parasites of Columbia River fishes, p. 3.6. In: Annual Report for 1969, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1306. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: A brief discussion is given of parasites and their environmental relations, as pertains to the central Columbia River. Mentioned are *Cestrahelmins rivularis* sp. n. from sturgeon and *Tubulovesicula lindbergi* (Laymen, 1930) from sturgeon. (See B-11 and B-19) (CDB)

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14. Becker, C. D., C. C. Coutant, and E. F. Prentice. 1970. Plume drifts with juvenile salmon, pp. 3.18-3.19. In: Annual Report for 1969, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1306. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: This paper reviews objectives and methodology of live-box drift studies and discusses 1969 field experiments. The summer drifts indicated that passage through mid-river plumes generally resulted in insufficient thermal shock to cause mortalities, but passage through inshore areas of limited mixing efficiency could cause fish death. (See B-16) (CDB)

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15. Becker, C. D. 1971. Food and feeding of juvenile chinook salmon in the central Columbia River in relation to thermal discharges and

other environmental features. USAEC R&D Report, BNWL-1528. Battelle, Pacific Northwest Labs., Richland, Wash. 68 pp.

Abstract: The relationship of thermal discharges from Hanford reactors to food and feeding of juvenile chinook salmon (Oncorhynchus tshawytscha) in the central Columbia River, Washington was studied in 1968 and 1969. The primary objectives were to (1) evaluate the food composition and feeding activities of the fish and (2) determine if heated effluents influenced their welfare. Environmental conditions, i.e., seasonal changes in river temperatures and flow volumes, relative to thermal requirements of young chinook, are detailed. Data on food organisms utilized by the fish are presented for 1968 and 1969, whereas analyses for possible thermal effects are based on the more extensive 1969 data. No consistent differences attributable to thermal increments were evident. The lack of detectable effects is apparently due to the fact that the main discharge plumes occur in midriver and the effluents are well mixed before reaching inshore feeding areas. (from Author's Abstract)

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16. Becker, C. D., C. C. Coutant, and E. F. Prentice. 1971. Experimental drifts of juvenile chinook salmon through effluent discharges at Hanford. Part II. 1969 drifts and conclusions. USAEC R&D Report, BNWL-1527. Battelle, Pacific Northwest Labs., Richland, Wash. 61 pp.

Abstract: Field investigations were conducted from March to September, 1968 and 1969 to determine the effect of heated reactor effluents on juvenile salmonids passing through the central Columbia River. The fundamental approach was to drift groups of fish held in liveboxes through areas representing maximum thermal increments while monitoring exposure temperatures and subsequently comparing survival or mortality amoung test and control groups. Drifts were conducted either through shoreline retention basins (peculiar to the Hanford site), or through midriver effluent plumes that issued from subsurface point discharges. Mortalities attributed to thermal dose (i.e. intensity and duration of exposure) were generally low. Shoreline drifts resulted in significant mortalities amoung only a few test groups whereas midriver drifts (primarily through the K reactor plume) resulted in losses only under unfavorable late summer conditions. The relative intensity of thermal dose for any set of river conditions depended largely upon onsite mixing patterns. Shoreline areas were characterized by reduced river flows, relatively low effluent mixing rates and persistence of heated water close inshore. In contrast, plume discharges were characterized by fast river flow, relatively high effluent mixing rates and rapid dispersal of heated water. The most important environmental features regulating thermal dose were river temperatures and river discharges, which ranged from about 2.0 to 20°C and 40,000 to 280,000 cf/sec. (from Author's Abstract)

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17. Becker, C. D. 1971. Some haematozoa of Columbia River fishes, p. 2.7. In: Annual Report for 1970, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1550. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Haemogregarina catostomi was found in 7 of 34 suckers (Catostomus macrocheilus and C. columbianus) and Cryptobia salmositica occurred in 1 of 19 squawfish (Ptychocheilus oregonensis). Both are new host and locality records. No pathological effects were indicated. (CDB)

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18. Becker, C. D. 1971. Growth of juvenile chinook above and below reactor discharges, pp. 2.11-2.12. In: Annual Report for 1970, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1550. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Length-weight data were compiled from over 700 juvenile chinooks in the 35 to 80 mm size range. The relationships of length to weight were approximately equal for all fish collected above and below the reactor discharges. (CDB)

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19. Becker, C. D. 1971. Cestrahelmins rivularis sp. n. (Digenea: Deropristidae) from white sturgeon, Acipenser transmontanus, in the Columbia River, Washington. Proc. Helminth. Soc. Wash. 38(1):23-26.

Abstract: Cestrahelmins rivularis sp. n. is described from the intestine of white sturgeon, Acipenser transmontanus Richardson, in the central Columbia River, State of Washington, USA. C. rivularis and C. laruei Fischthal, 1957 are the two existing representatives of the subfamily Cestraheminthinae Peters, 1961 (emended from Cestrahelminae). C. rivularis is differentiated from C. laruei by the following features: 1) distinct prepharynx, 2) genital pore with prominent sphincter, 3) unswollen forebody, 4) vitellaria extending anterior to the ventral sucker, 5) metraterm tubular, not saccular, 6) body spines uniform in size and distribution, and 7) seminal receptacle overlapping only the anterior testis. This initial record of Cestrahelmins from sturgeon, family Acipenseridae, supports morphological studies which demonstrate close affinities between the Cestrahelminthinae and Deropristiinae, within the family Deropristiidae Skrjabin, 1958. (Author)

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20. Becker, C. D., C. C. Coutant, and E. F. Prentice. 1971. Effects of effluent discharges on juvenile salmonids, pp. 2.13-2.16. In: Annual Report for 1970, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1550. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: This report summerizes the 1968 and 1969 field data on live-box drifts. Midriver drifts through the main discharge plumes resulted in insignificant mortalities except under unfavorable late summer conditions of high river temperature and low river discharges. But shoreline drifts through a few areas receiving heated water via intragravel seepage from retention basins resulted in some mortality. The contrasting effects were due to differences in effluent mixing patterns. Most juvenile chinook have departed seaward from April to July under protective conditions of favorable temperature and high discharge. (See B-21) (CDB)

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21. Becker, C. D., C. C. Coutant, and E. F. Prentice. ___. Ecological evaluation: migration of juvenile salmonids in relation to thermal discharges in the central Columbia River, pp. _____. In: D. E. Nelson (ed.). Radionuclides in Ecosystems, Proc. 3rd Nat'l. Symposium on Radioecology, Oak Ridge, Tenn., May, 1971. (In Press).

Abstract: Field investigations to evaluate the effects of heated reactor discharges on juvenile salmonids passing seaward through the central Columbia River at Hanford were conducted from March to September, 1968 and 1969. Test fish held in liveboxes were drifted through the discharge areas while the encountered thermal dose (i.e. temperature increase and exposure duration) was monitored. Some mortalities resulted in shoreline drifts through areas receiving heated water via intragravel seepage from effluent retention basins. Mortalities during drifts through the main discharge plumes in midriver were insignificant except under late summer conditions. The contrasting effects between the two sites were due primarily to differences in effluent mixing patterns. Environmental features regulating thermal effects, which varied over the migration season, were prevailing river temperatures (4-20°C) and discharges (40,000-280,000 ft^3/sec). Four seasonal combinations occurred in sequence with increasing potential for thermal damage: low temperature and low discharge (early spring), low temperature-high discharge (late spring), high temperature-high discharge (early summer), and high temperature - low discharge (late summer). Juvenile salmonids produced in the Hanford area migrate seaward from April to July when low river temperatures and/or high discharges are favorable, but delayed migrants originating above Hanford encounter less favorable conditions in July and August. (Authors)

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22. Becker, C. D. 1971. Response of Columbia River invertebrates to thermal stress, pp. 2.17-2.19. In: Annual Report for 1970, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1550. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Brief data are presented on the thermal tolerance of the caddisfly, Hydropsche cockrelli, and the crayfish, Pacifasticus leniusculus (P. trowbridgi). (CDB)

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23. Becker, C. D. 1971. Feeding habits of juvenile chinook in the central Columbia, pp. 2.24-2.25. In: Annual Report for 1970, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1550. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Monthly changes in feeding habits of juvenile chinook at Hanford in 1969 are tabulated. Food organisms were dominated by adult and larval midges (Chironomidae) from March through July. (See B-32) (CDB)

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24. Becker, C. D., and C. C. Coutant. 1971. Bionomics of Columbia River limpets in normal and reactor-warmed water, pp. 2.27-2.28. In: Annual Report for 1970, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1550. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Limpets collected below the production reactors showed no significant difference in growth rates and sizes even though the temperatures below were 0.5 to 2.5 C higher than those above. Limpets in laboratory troughs successfully deposited eggs during April to June, the period of high water flow, when field observations were not possible. (See C-41) (CDB)

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25. Becker, C. D. 1972. Temperature and development of aquatic invertebrates, pp. 1.1-1.3. In: Annual Report for 1971, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1650. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Thermal effect data are given on the development of blackfly (Simulium vittatum) larvae. (See B-30) (CDB)

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26. Becker, C. D. 1972. Thermal resistance of aquatic invertebrates, pp. 1.3-1.4. In: Annual Report for 1971, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNW-1650. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Preliminary data are given on the thermal resistance of Pacifasticus trowbridgi (crayfish) acclimated to 15, 20, 25 and 35°C.

This crustacean can survive exposure to 29 or 31°C for 48 hrs or more when acclimated to 15 and 25°C, respectively, but death occurs within 48 hrs even when acclimated to 30°C. (CDB)

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27. Becker, C. D. 1972. Thermal resistance of Columbia River fishes, pp. 1.4-1.5. In: Annual Report for 1971, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNW-1650. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Preliminary data are given on the thermal resistance of juvenile brown bullheads (*Ictalurus nebulosus*) from the central Columbia River. This fish can survive exposures to 25, 31 and 26°C when acclimated to 25, 15-16, and 4-5°C, respectively, for 48 hrs or more. (CDB)

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28. Becker, C. D. 1972. Monogenea of juvenile bass, pp. 1.23-1.24. In: Annual Report for 1971, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNW-1650. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: New records of branchial Monogenea on juvenile bass from the Hanford area of the central Columbia River are discussed. (See B-31) (CDB)

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29. Becker, C. D. 1972. Battelle-Northwest's contribution to the Columbia River Thermal Effects Study Program. BNWL-SA-4170. Battelle, Pacific Northwest Labs., Richland, Wash. (In Press).

Abstract: Thermal studies to enlighten the environmental impact of heated discharges from thermo-electric power plants, nuclear and fossile-fueled, are passing through a decisive phase. The Columbia River Thermal Effects Study utilized the expertise, programs and facilities of three agencies to focus on thermal problems peculiar to the sovereign river of the Pacific Northwest during 1968-1970. Studies in the central Columbia above Richland, Washington were conducted by Battelle-Northwest with support of the U.S. Atomic Energy Commission. The studies dealt with: 1) spawning populations of adult and migration timing of juvenile chinook salmon, 2) sonic tracking of adult salmonids past heated reactor discharges, 3) thermal resistance of adult salmonids, 4) passage of juvenile salmonids through reactor discharge plumes, 5) equilibrium loss and ecological death of juvenile salmonids from thermal shock, 6) thermal shock and predation on juvenile salmonids, 7) food and feeding of juvenile chinook salmon, 8) rearing temperatures and artificial propagation, 9) gas-bubble disease of salmonids, 10) columnaris disease in Columbia River fish, and 11) effects on Columbia River invertebrates. (Author)

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30. Becker, C. D. 1972. Development of Simulium (Psilozia) vittatum Zett. (Diptera: Simuliidae) from larvae to adults at thermal increments from 17 to 27 C. BNWL-SA-4265. Battelle, Pacific Northwest Labs., Richland, Wash.; Amer. Midland Naturalist 89(1):246-251 (1973).

Abstract: Exposure of 5-day old larval S. vittatum to 2.5 C thermal increments ranging from 17.0 to 27.0 C proportionally increases the rate of development through the pupal to adult stage. A 10 C rise in temperature reduces the subsequent mean development span by about half, from 8 days at 17 C to 4 days at 27 C. Temperatures of 27 C are below the upper thermal tolerance level of S. vittatum. (Author)

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31. Becker, C. D. 1972. Initial records of Monogenea from juvenile bass in the central Columbia River, Washington. Trans. Amer. Fish. Soc. 101(4):723-726.

Abstract: The initial records are given for five branchial Monogenea from juvenile largemouth bass (Micropterus salmoides) and smallmouth bass (M. dolomieui) in the Columbia River, Washington: Actinocleidus fusiformis, Clavunculus unguis, Urocleidus furcatus, U. principalis and U. helicis. Infection intensities were much lower on smallmouth bass than on largemouth bass, and consisted only of A. fusiformis, C. unguis and U. furcatus. Since centrarchids are not indigenous to the Pacific Northwest, these ubiquitous bass parasites must have been introduced transcontinentally with their hosts seven decades ago. Transmission is facilitated by the relatively simple life cycles of monogenetic trematodes, which require no intermediate hosts, and by conditions used in transporting living fish that permit survival of the parasites. (CDB)

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32. Becker, C. D. 1972. Food and growth parameters of juvenile chinook salmon in the central Columbia River. BNWL-SA-4381. Battelle, Pacific Northwest Labs., Richland, Wash. (In Press).

Abstract: Juvenile chinook salmon (Oncorhynchus tshawytscha) in the Hanford area of the free-flowing central Columbia River, Washington consume almost entirely adult and larval stages of aquatic insects. The diet is dominated by midges (Diptera: Chironomidae). By numbers, adult midges provided 64 and 58% of the diet and larval midges 17 and 18% of the diet, in 1968 and 1969, respectively. The families Hydropsychidae (Trichoptera), Notonectidae (Hemiptera) and Hypogastruridae (Collembola) are of minor numerical importance with a combined utilization of 7% in 1968 and 15% in 1969. Distinctive features of food and feeding activity of juvenile chinook at Hanford are fourfold: 1) the fish utilize relatively few insect groups, predominantly Chironomidae; 2) they depend largely upon autochthonous river organisms; 3) they

select prey drifting, floating or swimming in the water; and 4) they are apparently habitat opportunists to a large extent. Analyses were made of variations in diet and numbers of insects consumed between six sampling stations distributed along a 38 km section of the river. Data are provided on feeding intensity, fish lengths, length-weight relationships, and coefficients of condition. Seasonal changes in river temperature and discharge, as well as variations in regulated flow levels, are environmental features influencing feeding, growth, and emigration of fish in the Hanford environs. (Author)

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33. Berlin, J. D., and J. M. Dean. 1966. Ultrastructural changes in fish livers associated with temperature acclimation, pp. 115-117. In: Annual Report for 1965, Biological Sciences, BNWL-280. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Morphological expression of proteinaceous materials, one of which may be plasma albumin, is increased in hepatocytes from cold acclimated fish livers as compared to similar cells from warm acclimated fish. This observation may have critical significance to an understanding of temperature acclimation in poikilotherms. (Authors)

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34. Berlin, J. D. 1967. Temperature-induced differences in acid phosphatase levels of rainbow trout, pp. 157-159. In: Annual Report for 1966, Vol. I, Biological Sciences, BNWL-480. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Livers from cold acclimated rainbow trout were found to contain twice as much acid phosphatase activity as livers from warm fish. Cytochemical examination at the electron microscope level showed acid phosphatase to be localized in lysosomes in trout heptocytes, but not in the Golgi complex. (Author)

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35. Berlin, J. D., and J. M. Dean. 1967. Temperature-induced alterations in hepatocyte structure of rainbow trout (*Salmo gairdneri*). J. Expt'l Zool. 164(1):117-132.

Abstract: Electron microscopic examination showed that hepatocytes from rainbow trout (*Salmo gairdneri*) possess abundant amounts of rough endoplasmic reticulum. Particulate materials, presumably synthesized in the endoplasmic reticulum and transported to the Golgi apparatus, were more numerous in hepatocyte Golgi apparatus of trout acclimated at 5°C compared to fish acclimated at 18°C. This temperature induced structural modification is thought to reflect an increased secretion on the part of the hepatic cell as a result of the organism's adaptation to the temperature. (Authors)

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36. Buhler, D. R. 1967. Localization of Zn-65 in highly pigmented tissues of fishes. Federation Proc., 26:524 (Abstract).

Abstract: No copy available.

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37. Buhler, D. R. 1967. Tissue binding of zinc-65 in fish and other vertebrates, pp. 172-174. In: Annual Report for 1966, Vol. I, Biological Sciences, BNWL-480. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Preliminary studies compared the ^{65}Zn concentration and stable zinc content of Columbia River fishes and terrestrial species from the Hanford Reservation. (CDB)

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38. Buhler, D. R. 1968. Some sites for radionuclide binding in fish, pp. 9.26-9.29. In: Annual Report for 1967, Vol. I, Biological Sciences, BNWL-714. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: The highest concentrations of ^{65}Zn and stable zinc in the eyes of Hanford Reservation animals were found in fish from the Columbia River. Zinc-65 and other radionuclides were identified in the melanin-rich tissues of the choroid, iris, and peritoneal membrane. The distribution in subcellular fractions was investigated. (Author)

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39. Buhler, D. R., R. S. Caldwell, and R. M. Stokes. 1969. Tissue accumulation and metabolic effects of hexavalent chromium in rainbow trout, pp. 2.7-2.13. In: Annual Report for 1968, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1050. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Trout maintained in water containing 2.5 ppm Cr (VI) showed a rapid uptake which reached equilibrium in 2 to 4 days. Significant accumulation occurred in brain, caeca, small intestine and spleen. Differences were found in the activation of representative mitochondrial, microsomal and soluble enzymes, brain posterior kidney, gill and liver from trout maintained at the Naches and Hanford hatcheries. (Authors)

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40. Burnett, R. A., and D. G. Daniels. 1969. Evaluation of the SIMPL-1 computer concept on a water quality benchmark problem. BNWL-1228, Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: As part of a study to evaluate the Battelle-Northwest SIMPL-1 hybrid computer concept in comparison to large digital techniques, a hybrid version of an all-digital Columbia River water quality simulation was developed. The discrete-time, discrete-space digital water transport model was transformed into a continuous-time, discrete-space analog model for use in the hybrid program. Identical river and weather parameters were input to both models for a performance comparison. The hybrid results matched the all-digital output almost exactly. A minimum speed advantage of 3.6 to 1 and a machine economic advantage of 55 to 1 were achieved by the SIMPL-1 hybrid program over the all-digital program. Although requiring longer initial setup time, the hybrid program eliminated turnaround time between successive runs and provided the operational conveniences of man-machine interaction and graphical output displays. (CDB)

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1. Caldwell, R. S. 1968. Effect of acclimation temperature on mitochondrial enzymes in fish, pp. 7.23-7.26. In: Annual Report for 1967, Vol. I, Biological Sciences, BNWL-714. Battelle, Pacific Northwest Labs., Richland, Wash.

   Abstract: Activity of cytochrome oxidase in homogenates from several tissues was higher in cold than in warm acclimated goldfish. The activities of cytochrome oxidase and succinate- and NADH- cytochrome c reductase were greatest in gill mitochondria from the cold adapted goldfish, but cytochrome levels were unchanged. Cold acclimated carp had higher gill homogenate cytochrome oxidase activity than warm carp. However, NADH-cytochrome c reductase activity in gill mitochondria decreased with cold acclimation. (Author)

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2. Clukey, H. V. 1956. Radiation aspects for river navigation through Hanford Project. HW-47152. Hanford Atomic Products Operation, Richland, Wash. 8 pp.

   Abstract: Three recommendations are given for river navigation: 1) avoid reactor shoreline and mark effluent bubbles; 2) post 100 D island and reactor shore against transpass, possibly some islands below; 3) need to establish emergency procedures in case of gross contamination of the river with radionuclides. Exposures are estimated for various phenomena (i.e. people on passing boats), less than 0.2 mrad/hr near the reactor and less than 0.1 mrad/hr from Ringold, etc. (CDB)

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3. Clukey, H. V. 1957. The Hanford Atomic Project and Columbia River pollution. HW-54243 (Rev.), Hanford Atomic Products Operation, Richland, Wash. 21 pp. (Official Use Only)

   Abstract: Since the initial operation of the Hanford reactors in 1944, the radioactive material released to the Columbia River in the reactor cooling water effluent has shown a general increase. Radioactive materials released to the Columbia River in 1957 averaged in the range of a few percent of the maximum permissible concentrations, and probably contributed less than 10% of the maximum permissible exposure to individuals living in the environs of the plant. Heat released to the Columbia River by the Hanford reactors is considered to be minor with respect to deleterious effects on fish. Of the chemicals released by the Hanford plants, only hexavalent chromium is of significant concentration in the Columbia River, and this was below the recommended limit of 0.02 ppm for Columbia River fish. Results of biological field studies indicated

no detrimental effects on biota from the Hanford effluents. Biological pollution from the Hanford project was found to be adequately controlled by proper disposal or treatment. (CDB)

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4. Conley, W. R. 1954. Hanford Atomic Energy plant - water supply. J. Amer. Water Works Assoc. 46(7):629-633.

Abstract: The Hanford Atomic Energy plant uses water from the Columbia River, but some comes from wells. The high qualities of river water makes high-rate filtration more practical at Hanford than at most other locations. The turbidity of the water rarely exceeds 500 ppm even during flood stage, while the average annual value is 10 ppm or less. Temperatures vary from zero to 20°C during the year. The water is of relatively uniform composition. Hardness rarely departs more than 5 ppm from the annual average, and the pH, methyl orange alkalinites, sulfates and chlorides exhibit small seasonal changes. The water contains little nitrogen or phosphorus.

After rapid sand filtration, river water is now coagulated with alum and activated silica (ferric sulfate formerly), and disinfected with chlorine. Water used as boiler feed is softened, deaerated and treated with sodium sulfite and sodium phosphate. Sodium dichromate is added as a corrosion inhibitor to water used for reactor cooling. Water for sanitary use has chlorine levels maintained between 0.1 and 0.5 ppm. The city of Richland uses chlorinated well water. (CDB)

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5. Coopey, R. W. 1948. The accumulation of radioactivity as shown by a limnological study of the Columbia River in the vicinity of Hanford Works. Preliminary Report. HW-11662, Hanford Works, Richland, Wash. 14 pp.

Abstract: The radioactivity present in bottom-living organisms of the Columbia River was investigated at nine stations in the vicinity of the Hanford Works from Nov. 1947 to April 1948. The activity accumulated by a variety of organisms was about similar for both dilution of pile effluent water as found in the river and higher concentrations under laboratory conditions. Data are tabulated. Considerable variation in concentrating ability was evident, with some insect larvae and crustacea showing high levels. A list is included of common plankton genera present in the river. (CDB)

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6. Coopey, R. W. 1951. Radioactive plankton from the Columbia River. HW-20668. Hanford Works, Richland, Wash. 21 pp.

Abstract: Plankton collections using a silk net were made from the Columbia River above and below the Hanford Works from February 1919 (sic) to Feb. 1960. The usual limnological chemical tests indicate a relatively stable river environment throughout the year with only small variations in Ph and percent of oxygen saturation. The overall view shows no considerations greatly different from those of other natural waters of this region. No significant influence on characteristics of the river due to plant operation can be found from the measurements taken. (CDB)

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7. Coopey, R. W. 1953. A preliminary comparison of the nannoplankton and net plankton of the Columbia River. HW-29298, Hanford Atomic Products Operation, Richland, Wash. 11 pp.

Abstract: Plankton collected from the Columbia River by the net method and by the centrifuge method were compared. The centrifuged plankton (nannoplankton) exceeded the net plankton in weight, in abundance of organisms, and in radioactivity. Similar seasonal trends were present in both types of plankton. (CDB)

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8. Coopey, R. W. 1953. The abundance of the principal crustacea of the Columbia River and the radioactivity they contain. HW-25191, Hanford Atomic Products Operation, Richland, Wash. 15 pp.

Abstract: The species and abundance of crustacea together with the radioactivity they contained were traced for a 14 month period. Seasonal changes were found to influence the amounts of radioactivity in the organisms. Rapid growth favored high activity density. Unequal seasonal changes in radioactivity levels of body organs indicated functional differences in the utilization of isotopes. A pronounced spring pulse and a smaller fall pulse were evident in the abundance of bottom cladocera. Radioactivity was highest during the fall pulse. Crayfish averaged 134 + - 22 g live weight and 39 + - 16 individuals per 36 square foot sampling area. Cladocera showed 2.6 g per square food live weight and 260,000 individuals per square foot at maximum. No decrease could be found downstream from the Hanford operation. P^{32} was the principal isotope present in crustacea, notwithstanding a variety of isotopes present in crustacean food and in the river water. (Author)

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9. Coopey, R. W. 1953. Radioactive plankton from the Columbia River. Trans. Amer. Microscop. Soc. 72(4):315-327.

Abstract: Net plankton collections were made weekly from the Columbia River above and below the Hanford Atomic Products Operation from February 1949 to February 1950. Hydrogen ion, alkalinity and oxygen

saturation showed little variation. Plankton and water activity densities were influenced by river volume and averaged 3.7 x 10^{-3}μc/g wet weight and 1.6 x 10^{-6}μc/ml respectively. Plankton was abundant during the summer freshet and declined to a winter minimum. Organisms per ml averaged 59 of which 98 percent were diatoms. Plankton dry weights averaged 200 mg/cu.m. It was estimated that 5.2 x 10^5 kg (570 tons) of wet weight plankton were carried past the Hanford station each day during May while the plankton radioactivity amounted to 0.6 curies per day in July. Radiochemical analyses indicated that 5 to 30 percent of the plankton radioactivity came from isotopes with half-lives near or longer than P^{32} while the remainder was of shorter half-life. Some radioactivity persisted beyond 600 days decay. No harmful influence due to the Hanford operation could be found from the measurements taken. (Author)

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10. Coopey, R. W. 1954. The abundance of the principal crustacea of the Columbia River and the radioactivity they contain, pp. 14-15. In: Biology Research Annual Report for 1953, HW-30437. Hanford Atomic Products Operation, Richland, Wash.

Abstract: The radioactivity and the abundance of crayfish and important small crustaceans of the Columbia River were determined for a 14-month period. In swift water habitats, exclusive of riffles, there was approximately one crayfish per square foot of bottom area; in eddies or riffles they were much less abundant. No significant reduction in numbers was apparent down-river from the reactors. Activity density of crayfish was highest from September through November and lowest from December through March. The activity density of the individual body organs, although showing similar seasonal trends varied according to the metabolic rate of the particular organ concerned. The radioactivity in young, rapidly growing individuals was significantly higher than that of older specimens. (Author)

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11. Copp, H. D. 1967. Thermal-hydraulic pilot models of the Columbia River Research Report No. 67/9-67. DUN-WSU-3, Hanford Atomic Products Operation, Richland, Wash.

Abstract: A physical model of the Columbia River in the vicinity of the Hanford Project has been built and tested. The purpose of the model is to determine the effects of a dam creating slack water at the reactors' intake and outfall structures. Model results did not match the stream data in all cases, but the changes in temperatures at the intake structure are felt to be accurate. (CDB)

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12. Corley, J. P. 1958. Generalized river model tests with heated effluent at Bonneville hydraulics laboratory. HW-57671, Hanford Atomic Products Operation, Richland, Wash.

Abstract: Hydraulic tests were conducted on a physical model of Ice Harbor Dam. The purpose of the tests was to evaluate the effects of a dam at Columbia River mile 348 on the production capability of the Hanford reactors. Modifications were made to duplicate the portion of the Columbia near Hanford. Test results showed that thermal stratification could occur at low velocities. (CDB)

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13. Corley, J. P., H. A. Kramer, and J. K. Soldat. 1961. A compilation of basic data relating to the Columbia River. Section I-VII. HW-69368. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Basic physical and chemical data are presented in seven sections:

Section I and II - Temperature
Section III - Temperature
Section IV - Chemical Characteristics
Section V - Hydrography
Section VI - Radioactivity (river water, river biota, animals)
Section VII - Effects of Effluents on River Biota
a. Toxicity of reactor effluents
b. Columnaris fish disease (CDB)

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14. Corley, J. P. 1970. Effects of Hanford operations on Columbia River temperatures, Appendix D, Section I. In: R. T. Jaske and M. O. Synoground, Effect of Hanford Plant Operations on the Temperature of the Columbia River 1964 to Present. BNWL-1345. Battelle, Pacific Northwest Labs., Richland, Wash. 47 pp.

Abstract: Direct temperature measurements were made below the ends of the reactor outfall lines (Table D.II-1). Depth readings are fairly similar at 400 yard distances. (CDB)

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15. Corley, J. P. 1970. Inter-reactor river temperature data, Appendix D, Section II. In: R. T. Jaske and M. O. Synoground, Effect of Hanford Plant Operations on the Temperature of the Columbia River 1964 to Present. BNWL-1345. Battelle, Pacific Northwest Labs., Richland, Wash. 66 pp.

Abstract: Temperature measurements below various reactor outfalls are tabulated. (CDB)

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16. Coutant, C. C. 1966. Positive phototaxis in first instar caddis larvae, pp. 122-123. In: Annual Report for 1965, Biological Sciences, BNWL-280. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Positive phototaxis was observed in newly hatched *Hydropsyche cockerelli* larvae despite a recognized negative phototaxis in later larval instars. (Author)

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17. Coutant, C. C., D. G. Watson, C. E. Cushing, and W. L. Templeton. 1967. Observations of the life history of the limpet snail *Fisherola nuttalli* Haldeman, pp. 190-191. In: Annual Report for 1966, Vol. I, Biological Sciences, BNWL-480. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: A one-year life span is indicated for this limpet snail, with reproduction occurring during high river flows in June and July and death following shortly thereafter. Dispersal of newly hatched snails to bottom areas free of reproducing adults was observed. (Authors)

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18. Coutant, C. C. 1967. Fairy shrimp in gravel pit ponds, pp. 188-189. In: Annual Report for 1966, Vol. I, Biological Sciences, BNWL-480. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: The fairy shrimp, *Streptocephalus seali* Ryder, was observed in temporary ponds created by an elevated water table associated with high Columbia River flows. Appearance of these ponds during warm weather in late spring causes hatching of embryos at high temperature and survival of individuals into late summer. (Author)

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19. Coutant, C. C. 1967. Retention of radionuclides in Columbia River bottom organisms, pp. 170-171. In: Annual Report for 1966, Vol. I, Biological Sciences, BNWL-480. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Effective retention half-lives were estimated for several radionuclides in Columbia River bottom organisms. Two-component systems were most frequently observed. There was evidence of seasonal variation and community senescence. (Author)

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20. Coutant, C. C., and J. M. Dean. 1967. Temperature tolerances of young chinook salmon with differing developmental temperatures. BNWL-SA-1487. Battelle, Pacific Northwest Labs., Richland, Wash. 9 pp.

Abstract: Raising chinook salmon from eggs to fingerlings at temperatures 2-10F above the normal seasonal cycle did not significantly affect the resistance of young fish to high temperatures as measured by times to death and lethal temperatures. Results differ with species and local races. Further study is recommended. (CDB)

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21. Coutant, C. C. 1967. Upstream dispersion of adult caddis flies, pp. 186-187. In: Annual Report for 1966, Vol. I, Biological Sciences, BNWL-480. Battelle, Pacific Nortwest Labs., Richland, Wash.

Abstract: Adult river caddis flies (Trichoptera: Hydropsychidae) are dispersed upstream from river reaches occupied by the larvae. The maximum extent of this dispersal would appear to be about 16 km. (Author)

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22. Coutant, C. C. 1968. Effect of temperature on the development rate of bottom organisms, pp. 9.13-9.14. In: Annual Report for 1967, Vol. I, Biological Sciences, BNWL-714. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Caddis flies emerged about 2 weeks earlier downstream from Hanford reactors than upstream. Temperature of emergence may be between 11-12°C. (Author)

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23. Coutant, C. C. 1968. Effects of thermal loading - The Columbia River story. BNWL-SA-2070. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: A general review of thermal effect studies conducted by BNW on the Columbia River is presented. (CDB)

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24. Coutant, C. C. 1968. Retention of radionuclides in Columbia River bottom organisms, pp. 9.21-9.22. In: Annual Report for 1967, Vol. I, Biological Sciences, BNWL-714. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: The limpet snail and rock-surface periphyton in their natural environment show seasonal changes in ^{65}Zn retention times, progressing from shorter to longer retention between October and April. (Author)

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25. Coutant, C. C. 1968. Thermal pollution-biological effects. In: A Review of the Literature of 1967 on Wastewater and Water Pollution Control. J. Water Pollut. Cont. Fed. 40(6):1047-1052.

Abstract: The literature published in 1967 on the biological effects of thermal pollution is reviewed. (CDB)

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26. Coutant, C. C. 1968. Behavior of adult salmon and steelhead trout migrating past Hanford thermal discharges, pp. 9.10-9.13. In: Annual Report for 1967, Vol. I, Biological Sciences, BNWL-714. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Migration paths of adult summer chinook salmon and steelhead trout were determined in the section of the Columbia River near Hanford reactor outfalls. Most fish migrated close to shorelines thereby avoiding heated plumes. (Author)

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27. Coutant, C. C., and C. R. Cole. 1968. Modelling of aquatic systems, pp. 9.30-9.32. In: Annual Report for 1967, Vol. I, Biological Sciences, BNWL-714. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Preliminary models have been developed for two aquatic systems: fish death in fluctuating lethal temperatures and maintenance of ^{65}Zn concentration in the limpet snail. (Authors)

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28. Coutant, C. C. 1969. Responses of salmonid fishes to acute thermal shock, pp. 2.19-2.26. In: Annual Report for 1968, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1050. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Several responses to acute thermal shock have been determined. There is a variation with test temperature in the relationship between times to loss of equilibrium and death in juvenile chinook salmon and rainbow trout. Equilibrium loss and death are statistically distinct at high lethal temperatures. Sublethal exposures to a lethal temperature increase the rate at which juvenile chinook salmon and

rainbow trout are captured by predators. This increase is observed in rainbows at exposures as low as 25% of the median equilibrium loss dose. Equilibrium loss in rainbow trout is reversible on return to cool water but delayed mortalities occur in significant numbers at shock temperatures below about 30°C. Coho salmon adults are significantly more sensitive than jack chinook to lethal temperatures below 30°F, while the reverse is true for juveniles. There are definite thermal tolerance differences between juveniles and large fish of both species. (Author)

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29. Coutant, C. C. 1969. Behavior of sonic-tagged salmon and steelhead trout migrating past Hanford thermal discharges, pp. 2.39-2.44. In: Annual Report for 1968, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1050. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Chinook and steelhead migrated mainly along shorelines, principally utilizing the left bank opposite reactors during peak river temperatures. This pattern was evident from Richland to Priest Rapids. No statistical difference was found between migration rates of the two species or between rates along shorelines inside and outside reactor thermal influence. Average migration rates and daily frequencies of point fish locations per river kilometer were not uniform throughout the area of operating reactors although the causes are still not clearly defined. (Author)

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30. Coutant, C. C., C. D. Becker, and E. F. Prentice. 1969. Passage of downstream migrants, pp. 2.27-2.30. In: Annual Report for 1968, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1050. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Drifting juvenile chinook salmon in a livebox through reactor discharge plumes induced no direct or 24 hr latent mortalities during spring and summer. Shoreline areas affected by intragravel seepage of heated water caused losses of half of the test fish in three drifts in mid-summer. Most temperature rises did not exceed the ultimate incipient lethal level for the species. Emigrating juvenile chinook trapped in May following passage through the K-reactor plume showed no signs of mortality, equilibrium loss or "gas bubble" disease. (Authors)

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31. Coutant, C. C. 1969. Thermal pollution-biological effects. A review of the literature of 1968. J. Water Pollut. Cont. Fed. 41(6):1036-1053.

Abstract: The literature published in 1968 on the biological effects of thermal pollution is reviewed. (CDB)

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32. Coutant, C. C. 1969. Temperature, reproduction and behavior. Chesapeak Sci. 10(3&4):261-274.

Abstract: Some current research being conducted on salmonid fishes at the Hanford nuclear complex on the Columbia River is discussed. Studies of thermal effects on reproduction and behavior include a 20-year, annual census of spawning chinook salmon near reactor discharges, laboratory experiments on incubation and rearing success at elevated temperatures, studies of equilibrium loss prior to thermal death at lethal temperatures, tests of relative predation rates upon thermally shocked and normal young salmonids, and tracking sonic tagged adults to determine migration behavior near thermal outfalls. (Author)

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33. Coutant, C. C. 1969. Effects of thermal shock on vulnerability to predation in juvenile salmonids. I. Single shock temperature. USAEC R&D Rept., BNWL-1521. Battelle, Pacific Northwest Labs., Richland, Wash. 31 pp.

Abstract: Thermally shocked juvenile rainbow trout and chinook salmon were selectively preyed upon by larger fishes under controlled laboratory conditions when both shocked and control fish were offered simultaneously. Relative vulnerability to predation increased with duration of sublethal exposure to lethal temperatures. Significant increases in predation rates were found at thermal doses above 10% (chinook) and 20% (rainbow) of the doses causing complete body inversion. The effects were partly reversible. Quantitative measures of harmful effects from sublethal thermal shock allows their use in designing safe thermal releases into aquatic environments. (Author)

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34. Coutant, C. C., and J. M. Dean. 1969. Relationships between equilibrium loss and death as responses of juvenile chinook salmon and rainbow trout to acute thermal shock. USAEC R&D Rept., BNWL-1520. Battelle, Pacific Northwest Labs., Richland, Wash. 21 pp.

Abstract: Loss of equilibrium by fishes is discussed as a manifestation of heat shock that is critical to survival of fishes. While similar to another endpoint of thermal resistance, the critical thermal maximum (CTM) the Equilibrium Loss Dose (ELD) defines the two pertinent variables, temperature and duration of exposure. In juvenile rainbow trout and chinook salmon, geometric mean ELD and death dose were statistically distinct at high lethal temperatures, where ELD was 30 to 60 percent of

the death dose. At low lethal temperatures, ELD was approximately 90 percent of the death dose, and the two end points were not statistically distinct. A cubic model for the ratio of ELD to death dose is presented. (Authors)(Reprinted in 1972) (See C-44)

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35. Coutant, C. C. 1970. Thermal resistance of adult coho (Oncorhynchus kisutch) and jack chinook (O. tshawytscha) salmon, and adult steelhead trout (Salmo gairdneri) from the Columbia River. USAEC R&D Rept., BNWL-1508. Battelle, Pacific Northwest Labs., Richland, Wash. 24 pp.

Abstract: Resistance times to upper lethal temperatures were determined for adult coho (Oncorhynchus kisutch) and "jack" chinook (O. tshawytscha) salmon, and adult steelhead trout from the Columbia River near Richland, Washington. Incipient lethal temperatures for steelhead and chinook appeared to be near 21 to 22 C. Resistance times were longer for chinook than for coho or steelhead. Relative resistances of juvenile and large fish varied with test temperature--juveniles were more resistant at low lethal temperatures up to about 28.5 C and adults were more resistant above that level. (Author)

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36. Coutant, C. C. 1970. Effect of thermal shock on vulnerability to predation in juvenile salmonids. II. A dose response by rainbow trout to three shock temperatures. USAEC R&D Rept., BNWL-1519. Battelle, Pacific Northwest Labs., Richland, Wash. 12 pp.

Abstract: Increased vulnerability to predation of juvenile rainbow trout thermally shocked at three temperatures was shown to depend upon the thermal dose (temperature and duration) received. At 30 C, a 0.55 min duration of exposure produced an identifiable effect, while 2 min was required at 28 C. The predation response paralleled dose responses of visible equilibrium loss and death. (Author)

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37. Coutant, C. C. 1970. Behavior of sonic tagged chinook salmon and steelhead trout migrating past Hanford thermal discharges (1967). USAEC R&D Rept., BNWL-1531. Battelle, Pacific Northwest Labs., Richland, Wash. 20 pp.

Abstract: Chinook and steelhead migrated mainly along shorelines, principally utilizing the left bank opposite reactors during peak river temperatures. This pattern was evident from Richland to Priest Rapids. No statistical difference was found between migration rates of the two species or between rates along shorelines inside and outside reactor thermal influence. Average migration rates and daily

frequencies of point fish locations per river kilometer were not uniform throughout the area of operating reactors although the causes are still not clearly defined. (Author)

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38. Coutant, C. C. 1970. Exploratory studies of the interactions of gas supersaturation and temperature on the mortality of juvenile salmonids. USAEC R&D Rept., BNWL-1529. Battelle, Pacific Northwest Labs., Richland, Wash. 10 pp.

Abstract: Results of this preliminary study show that fish prestressed with high nitrogen levels (115% saturation) suffer higher losses from thermal shock than those held at normal saturation values. Since passage through Hanford effluent plumes is relatively rapid (0.5 - 1.0 meter/sec), young migrants exposed to temperatures above ΔT 3°C for a few minutes or less would receive only a sublethal experience. (CDB)

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39. Coutant, C. C. 1970. Relative vulnerability of thermally shocked salmonids to predation, pp. 3.11-3.12. In: Annual Report for 1969, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1306. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Above certain minimum thermal doses, thermally shocked rainbow and chinook were selectively preyed upon. Relative vulnerability to predation increased with duration of sublethal exposure to lethal temperatures. Significant increases in predation rate were found at thermal doses above 10% for chinook and 20% for rainbow of the doses causing complete body inversion, or equilibrium loss. (CDB)

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40. Coutant, C. C., and C. D. Becker. 1970. Effects of thermal increments on invertebrate populations of the central Columbia River, pp. 3.8-3.9. In: Annual Report for 1969, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1306. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Limpet snail growth studies above and below the reactors and invertebrate drift samples above and below the reactors are reviewed. (See C-41) (CDB)

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41. Coutant, C. C., and C. D. Becker. 1970. Growth of the Columbia River limpet, *Fisherola nuttalli* (Haldeman), in normal and reactor-warmed water. USAEC R&D Rept., BNWL-1537. Battelle, Pacific Northwest Labs., Richland, Wash. 12 pp.

Abstract: Limpet snails (Fisherola nuttalli) were collected through 1969-70 at locations above and below thermal additions from reactor discharges in the central Columbia River above Richland, Washington. Temperatures of the mixed river water below the reactor operations were increased about 0.5 to 2.5 C. Limpet sizes and growth rates at any collecting period did not differ significantly between the two areas. Growth of young limpets was most rapid from July to October when Columbia River temperatures were high. Growth rates stabilized during the fall and winter when temperatures dropped and became minimum, then increased with warming temperatures of early spring. Adult limpets collected from downstream areas and held in the warmed water in the laboratory reproduced successfully. Deposition of egg cases by mature limpets occurred on rising temperatures in April, May and June during the period of maximum river flows. High mortality occurred among mature limpets during and following the reproductive period. The Columbia River limpet, like many other gastropod molluscs, has a predominantly one year life cycle. (Authors)

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42. Coutant, C. C. 1970. Thermal pollution - biological effects. A review of the literature of 1969. J. Water Pollut. Cont. Fed. 42(6):1025-1057.

Abstract: The literature published in 1969 on the biological effects of thermal pollution is reviewed. (CDB)

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43. Coutant, C. C., J. M. Dean and C. R. Cole. 1970. Modelling thermal death of fishes in fluctuating lethal temperatures, pp. 3.9-3.11. In: Annual Report for 1969. Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1306. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Reviewed is the development of a dynamic hybrid computer model to predict the mortality of juvenile salmonid fish under conditions of fluctuating temperatures that occur in the mixing zone of thermal dishcarges. (CDB)

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44. Coutant, C. C., and J. M. Dean. 1972. Relationships between equilibrium loss and death as responses of juvenile salmonids to thermal shock. USAEC R&D Rept., BNWL-1520. Battelle, Pacific Northwest Labs., Richland, Wash. 19 pp.

Abstract: Loss of equilibrium by fishes is discussed as a manifestation of heat shock that is critical to survival of fishes. While similar to another endpoint of thermal resistance, the critical thermal maximum (CTM), the Equilibrium Loss Dose (ELD) defines the two pertinent

variables, temperature and duration of exposure. In juvenile rainbow trout and chinook salmon, geometric mean ELD and death dose were statistically distinct at high lethal temperatures, where ELD was 30 tc 60 percent of the death dose. At low lethal temperatures, ELD was approximately 90 percent of the death dose, and the two endpoints were not statistically distinct. A cubic model for the ratio of ELD to death dose is presented. (Authors) (See C-34)

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45. Coutant, C. C. 1970. Thermal resistance studies on salmonid fish, pp. 3.19-3.20. In: Annual Report for 1969, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1506. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Tests were conducted with summer-run adult steelhead trout and jack chinook salmon obtained from Priest Rapids Dam in September. Fish were tested in 6 ft. diameter fiberglass tanks held outdoors. Deaths were recorded for groups of about 10 fish at test temperatures of 21, 22, 23, 24, 26, 27, 28, and 29 C. Steelhead were more sensitive than chinook jacks when tested simultaneously. The incipient lethal temperature for both species was between 21 and 22 C. This contrasts with 25 C for juveniles with a similar history of acclimation. (CDB)

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46. Coutant, C. C., and B. B. Owen. 1970. Productivity of periphyton communities under thermal stress, pp. 3.1-3.2. In: Annual Report for 1969, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1306. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: The system and method employed are described. Estimates of turnover, on the basis of standing crop (net collections), may be used to give estimates of the relative productivity of streams under various conditions of thermal stress. (CDB)

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47. Coutant, C. C., and C. D. Becker. _____. Growth of the Columbia River limpet, Fisherola nuttalli (Haldeman), in normal and reactor-warm water, pp. _____. In: D. E. Nelson (ed.). Radionuclides in Ecosystems, Proc. 3rd Natl. Symposium on Radioecology, Oak Ridge, Tenn., May, 1971. (In Press).

Abstract: (See C-41)

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48. Cushing, C. E. 1963. Plankton-water chemistry cycles in the Columbia River, pp. 227-231. In: Biology Research Annual Report for 1962, HW-76000. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Asterionella is the dominant diatom in the Columbia River; peak populations occurred in May. This increase appears related to increasing water temperatures and light penetration. Nitrate and phosphate concentrations decreased coincidently with the diatom peak, suggesting nutrient assimilation by the algae. (Author)

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49. Cushing, C. E. 1964. Plankton-water chemistry cycles in the Columbia River, pp. 212-218. In: Biology Research Annual Report for 1963, HW-80500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Asterionella, the dominant diatom enumerated, exhibited two seasonal increases, whereas the other genera each had single pulses. The spring pulse of diatoms coincided with an increased volume of water, a decrease of nitrate and phosphate, an increase in dissolved silica, and an increase in water temperature and effective light penetration. The data indicate that nutrients were not limiting and that the probable causal factors for population increases were the increasing water temperatures and effective light. The summer decrease of several nutrients suggests nutrient assimilation by the algae rather than dilution by runoff. (Author)

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50. Cushing, C. E. 1965. Radionuclide accumulation and transport by plankton in the Columbia River, pp. 187-189. In: Biology Research Annual Report for 1964, BNWL-122. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Cursory analysis of monthly averages of net plankton samples revealed that P^{32} and Zn^{65} concentration (nCi/g dry weight) was lowest during the summer months, probably related to dilution by runoff. Transport of these radionuclides by the plankton was highest in spring and late summer, coincident with seasonal increase of the plankton. The ability of the plankton to concentrate radioisotopes from the water varied seasonally with lowest values during the summer months. (Author)

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51. Cushing, C. E. 1965. Radionuclide accumulation and productivity of periphyton in the Columbia River, pp. 190-193. In: Biology Research Annual Report for 1964, BNWL-122. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Best correlations among four biomass measurements of periphyton were between dry weight, ash weight, and chlorophyll a. Net Production Rate varied from 0.005 to 0.070 mg dry weight/cm^2/day and was closely related to chlorophyll a content and solar energy. The accumulation of P^{32} and Zn^{65} was best related to dry and ash weight, and

chlorophyll a. Low correlations were found between radionuclide accumulation and the radionuclide content of the river. The data suggested that adsorption was the dominant mode of uptake. (Author)

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52. Cushing, C. E., and N. S. Porter. 1966. A system for measuring radionuclide uptake and turnover in periphyton, pp. 121-122. In: Annual Report for 1965, Biological Sciences, BNWL-280. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: An apparatus is described which will continuously measure uptake and cycling of radionuclides between periphyton and a controlled aqueous environment. (Authors)

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53. Cushing, C. E., and D. G. Watson. 1966. Accumulation and transport of radionuclides by Columbia River biota, pp. 551-570. In: Disposal of Radioactive Wastes into Seas, Oceans and Surface Waters. Proc. 1966 Symposium, Int'l. Atomic Energy Comm., Vienna.

Abstract: Periphyton studies relating productivity, radionuclide uptake and environmental influences showed that best biomass correlations were between dry weight, ash weight, and chlorophyll a content. Net production rate on glass slides varied from 0.005 to 0.070 mg dry weight $cm^{-2}d^{-1}$ and was closely related to chlorophyll a and solar energy. The accumulation of ^{32}P and ^{65}Zn was highly correlated with dry and ash weight and chloropll a. Unexplainably, low correlations were found between radionuclide accumulation and the index used to represent radioisotopic burden of the river. The data suggest that adsorption was the dominant mode of uptake. Analyses of net plankton samples collected below the reactors revealed that ^{32}P and ^{65}Zn concentrations were lowest during the summer months, coincident with and related to dilution of the isotopes in the water by the spring runoff. Concentration factors, (nCi/mg wet weight)/(nCi/ml water), varied seasonally and were also lowest in summer. Transport of these radionuclides by the plankton was highest in spring and late summer, coincident, generally, with seasonal increases of plankton biomass rather than with higher specific activities. Estimates of the total transport of ^{32}P and ^{65}Zn associated with the plankton are presented. Measurements of selected reactor-produced radionuclides in a variety of river organisms are compared to evaluate the effects of shutting down three production reactors. A significant decrease of biologically important radiounclides is evident with some indication of a trophic level response. The accumulation of radionuclides and movements of fish are being studied using the reactor effluent radioisotopes as tracers. Preliminary analyses indicate both a seasonal and species difference in ^{65}Zn accumulation. Seasonal differences in migration are also evident. (Authors)

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54. Cushing, C. E. 1967. Radionuclide cycling by periphyton, pp. 178-179. In: Biology Research Annual Report for 1966, Vol. I, Biological Sciences, BNWL-480. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Investigations of ^{65}Zn uptake rates by periphyton in a closed system reveal a general pattern-characterized by a brief but rapid initial uptake rate, followed by a prolonged slow uptake and eventual equilibrium. (Author)

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55. Cushing, C. E. 1967. Periphyton productivity and radionuclide accumulation in the Columbia River, Washington, U.S.A. Hydrobiologia 29 (1-2):125-139.

Abstract: An investigation of the periphyton of the Columbia River below the Hanford Atomic Works, Washington, was conducted to study the relationships between productivity, radionuclide uptake, and environmental influences. Best correlations between the four biomass measurements were between dry weight, ash weight, and chlorophyll a. Net Production Rate varied from 0.005 to 0.070 mg dry weight/cm^2/day and was closely related to chlorophyll a and also to solar energy. The accumulation of ^{32}P and ^{65}Zn was highly related to dry and ash weight and chlorophyll a. Low correlations were found between radionuclide accumulation and the radioisotope burden of the river. The data suggest that adsorption was the dominant mode of uptake. (Author's Summary)

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56. Cushing, C. E. 1967. Concentration and transport of ^{32}P and ^{65}Zn by Columbia River plankton. Limnol. and Oceanog. 12(2):330-332.

Abstract: The seasonal patterns of ^{32}P and ^{65}Zn concentrations of net plankton are discussed. Lowest seasonal values coincided with the spring-summer high water period when the greatest dilution of effluent in the river occurs. The combination of environmental factors results in lower concentrations of radionuclides per unit weight of plankton. Concentration factors for ^{32}P ranged from 5,000 to 118,000 and for ^{65}Zn from 300 to 19,000; highest values for both isotopes occurred in fall and winter. (CDB)

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57. Cushing, C. E. 1968. Uptake and retention of ^{65}Zn by periphyton, pp. 9.23-9.25. In: Annual Report for 1967, Vol. I, Biological Sciences, BNWL-714. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Investigations of ^{65}Zn uptake and retention rates by periphyton communities of different age and composition show similar times to reach equilibrium (16-24 hr) and similar accumulations of ^{65}Zn per unit weight. The total ^{65}Zn accumulated is related to the age and type of community. (Author)

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58. Cushing, C. E., and D. G. Watson. 1968. Accumulation of ^{32}P and ^{65}Zn by living and killed plankton. Oikos 19:143-145.

Abstract: An experiment using living and killed plankton showed that killed plankton accumulated significantly more ^{65}Zn than living plankton; the opposite was true for ^{32}P. The ecological significance of these findings is discussed. (CDB)

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59. Cushing, C. E., and N. S. Porter. 1969. Radionuclide cycling by periphyton: An apparatus for continuous *in situ* measurements and initial data on Zinc-65 cycling, pp. 269-290. *In*: D. J. Nelson and F. C. Evans (eds.), Symposium on Radioecology, 1967. CFSTI, Nat'l. Bur. Stds., Springfield, Virginia (CONF-670503).

Abstract: A system is decribed which permits the continuous measurement of uptake and cycling of radionuclides between stream periphyton and a controlled aqueous environment. The system was designed to avoid inherent difficulties in aquaria studies, i.e., the necessity of destroying or sub-sampling the community for sequential analyses, the lack of a continuous flow of water over the algae to simulate stream conditions, and the inability to maintain a fixed ambient radionuclide concentration because of immediate uptake and recycling by the organisms. The apparatus permits evaluation of the effects of individual physical and chemical environmental factors in either an open one-pass system or in a closed recirculating system. Preliminary results of six uptake and two retention experiments using ^{65}Zn in the closed system are presented. (Authors)

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60. Cushing, C. E., L. A. Rancitelli, R. E. Wildung, and W. L. Templeton. 1969. Stable elements in the Columbia River ecosystem, pp. 2.1-2.2. *In*: Annual Report for 1968, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1050. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: A study to investigate the basic chemical and physical parameters of the Columbia River water, plankton, and suspended sediments was initiated in September 1968. (Authors)

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61. Cushing, C. E., and F. L. Rose. 1969. Zinc-65 cycling in periphyton pp. 2.16-2.19. In: Annual Report for 1968, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1050. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Cycling of ^{65}Zn by periphyton has been followed in the field and under controlled conditions in the laboratory. Accumulation appears to result from adsorption to cellular surfaces because uptake is similar in living and killed communities and rates of uptake are directly related to ambient concentration. However, regulation of the photoperiod produced a marked effect on uptake. Field data support the laboratory results and indicate that the isotope is rapidly lost when the ambient concentration is suddenly reduced. (Authors)

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62. Cushing, C. E., R. E. Wildung, and L. A. Rancitelli. 1970. Chemical characterization of Columbia River water, plankton and sediments, pp. 3.2-3.3. In: Annual Report for 1969, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1306. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Neutron activation analyses provided useful data for elements present at extremely low concentrations. Most important was discrepancies between the two methods for the fairly abundant elements such as sodium and potassium. (CDB)

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63. Cushing, C. E., and F. L. Rose. 1970. Cycling of zinc-65 by periphyton, p. 3.4. In: Annual Report for 1969, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1306. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Doubling the number of stable zinc atoms decreased the uptake of Zinc-65 to about 25%. Doubling the number of stable magnesium atoms produced a approximate 50% decrease in ^{65}Zn uptake, illustrating the competitive for adsorption binding sites by these divalent cations. Autoradiographs of an intact periphyton community revealed that the major site of adsorption was at the surface and that there was a diffusion gradient within the periphyton. (CDB)

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64. Cushing, C. E., and F. L. Rose. 1970. Zinc-65 cycling by Columbia River periphyton in a closed lotic microcosm. Limnol. Oceanog. 15(5):762-767.

Abstract: Studies of ^{65}Zn cycling by periphyton were performed in a closed, lotic microcosm under varying light regimes, community state,

initial ambient concentrations and stable divalent cation concentrations. Uptake of ^{65}Zn was considerable in continuous light, continuous darkness, a 12-hr photo-period, or by killed communities, indicating a dominant adsorptive uptake mechanism. Uptake of ^{65}Zn was shown to be proportional to the initial ambient concentration of ^{65}Zn, which decreased during the course of an experiment. Increasing the concentration of stable zinc or magnesium proportionately decreased the uptake of ^{65}Zn, illustrating a competition for binding sites and supporting the adsorptive uptake theory. A discussion of the significance of this work to the reporting of concentration factors is presented. The similarity in function between the heterogeneous periphyton community and unialgal cultures or single species of plants is pointed out. (Authors)

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65. Cushing, C. E. 1970. Radiation ecology in freshwater communities, pp. 45-56. In: Man and Aquatic Communities. Inst. of Water Resources Res., Oregon State Univ., Corvallis.

Abstract: The presence of radioactive isotopes in the freshwater environment, disregarding their source, can provide a wealth of ecological data. Information ranging from the movement of a single element from one organism to another, or from one tissue to another, to data unraveling the complexities of entire aquatic foodwebs can be gained with properly designed experiments and data treatment. The dynamics of radionuclide cycling are basically no different from their stable counterparts, but their value lies in the increased precision of measurement, particularly at concentrations too low to measure by standard analytical procedures. (Author's Conclusion)

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66. Cushing, C. E. 1970. Mineral cycling in semi-natural systems, pp. 28-30. In: The Stream Ecosystem. Tech. Rept. No. 7, Inst. Water Res., Michigan State Univ., East Lansing.

Abstract: Studies in a closed microcosm have shown that: 1) closed system "equilibria" are related to physicochemical changes as the ambient zinc-65 concentration decreases, and perhaps metabolic by-products interfere; 2) zinc-65 uptake is predominantly adsorptive in nature with direct composition for binding sites with other divalent cations; and 3) caution is advised in using and interpreting concentration factors, a widely used and mis-used term in the literature. (CDB)

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67. Cushing, C. E., and L. A. Rancitelli. 1971. Chemical characterization of Columbia River water and phytoplankton, pp. 2.6-2.7. In: Annual Report for 1970, Vol. I, Life Sciences, Part 2, Ecological Sciences. BNWL-1550. Battelle, Pacific Northwest Labs., Richland Wash.

Abstract: Tabulated data are given on elemental composition of Columbia River water and phytoplankton analyzed by neutron activation. Discrepancies were noted with this method and with "standard methods" employed. Apparently the latter method did not dissolve the entire sample during pretreatment, thus giving incorrect results. (CDB)

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68. Cushing, C. E., and L. L. Eberhardt. 1971. Radionuclide cycling by periphyton, pp. 2.7-2.8. In: Annual Report for 1970, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1550. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Field sampling programs for radionuclide cycling are usually deficient in that insufficient samples can be obtained to provide adequate data for fitting the nonlinear mathematical models usually involved. Laboratory periphyton cycling apparatus circumvents this problem. Computer routines for rapid analysis of the data are available. (CDB)

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69. Cushing, C. E., and L. A. Rancitelli. 1972. Trace element analyses of Columbia River water and phytoplankton. Northwest Sci. 46(2): 115-121.

Abstract: This paper: 1) describes the elemental composition of the Columbia River water and phytoplankton during the period of November 1968 to August 1969, as analyzed by neutron activation, and 2) compares these data with those obtained from samples submitted to a routine analytical laboratory where the analysts were unfamiliar with the sample consitituents or particular problems involved with sampling and processing. The paper also presents data on concentration factors of the elements in the phytoplankton. (CDB)

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70. Cushing, C. E., and D. G. Watson. 1972. Activation analysis of caddis larvae and whitefish, pp. 1.18-1.20. In: Annual Report for 1971, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1650. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: As the second link in the aquatic food chain, activation analyses of the elemental composition of caddis fly larvae and whitefish flesh were initiated in 1970. Data analyzed to date are tabulated, in terms of eighteen basic elements, ppm of dry weight. (CDB)

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71. Cushing, C. E., and L. L. Eberhardt. 1972. Modeling of mineral cycling by periphyton, pp. 2.31-2.32. In: Annual Report for 1971, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1650. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Modeling was undertaken to provide information on 1) rate values, 2) the fit for known models, and 3) the functioning of the community ecosystem. An analysis was made of data from four experimental runs in a closed, simulated stream microcosm. (CDB)

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72. Cushing, C. E., and D. W. Watson. ____. Cycling of ^{65}Zn in a simple food web, pp. _____. In: D. E. Nelson (ed.), Radionuclides in Ecosystems, Proc. 3rd Nat'l. Symposium on Radioecology, Oak Ridge, Tenn., May, 1971. (In Press)

Abstract: The experiment was designed to investigate the cycling of ^{65}Zn in a simple water-periphyton-fish food-web under constant flow, light, and ambient radionuclide concentration. Water temperatures followed the seasonal pattern of the Columbia River. Concentrations of ^{65}Zn in periphyton approached equilibrium in about 28 days at levels of 17 and 90 nCi/g wet weight in low and high level streams, respectively. These concentrations are about 23 times and 150 times that of the controls and are very close to the differential spike levels in the water. Under conditions of this experiment, periphyton concentrate ^{65}Zn in nearly direct proportion to ambient concentrations. The specific activity of periphyton at equilibrium was 35 and 210 pCi/mg in the low and high level streams, respectively. The estimated effective half-life was about 15 days. Data on the fish were more variable due to the influence of temperature on metabolic rates. Approximate equilibrium was reached in about 43 days at concentrations of 0.25 and 1.3 nCi/g wet weight in low and high level streams, respectively. These concentrations are 6 and 29 times that of the control fish. Specific activities were 3 and 20 pCi/mg. These data suggest that true equilibrium had not been reached. Water temperatures varied from 6C to 18C during the experiment. (CDB)

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1. Davis, J. J., R. W. Coopey, D. G. Watson, C. C. Palmiter and C. L. Cooper. 1952. The radioactivity and ecology of aquatic organisms of the Columbia River, pp. 19-29. In: Biology Research Annual Report for 1951, HW-25-21, Hanford Works, Richland, Wash.

Abstract: Field studies on fish began in 1946 and this study was initiated in 1948. As many forms as possible were assayed for radioactive density in the initial phase. In the second phase, only representative forms were obtained. Activity densities of various nuclides in selected organisms are given. Maximum activity occurs during the fall and winter when river flow is low, minimum activity occurs during the spring freshet. Assessment of abundance of benthic forms indicate no significant change in population density above and below the Hanford pile effluent discharges. (CDB)

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2. Davis, J. J., R. W. Coopey, D. G. Watson, and C. C. Palmiter. 1953. Radiobiological survey of the Columbia River, pp. 8-13. In: Biology Research Annual Report for 1952, HW-28636. Hanford Atomic Products Operation, Richland, Wash.

Abstract: The distribution of radioactivity in river organisms during 1952 was similar to that of previous years. Radioactivity in plankton and algae followed seasonal fluctuations in the activity of the water while in animals it was more closely related to temperature. Some whitefish caught in a popular angling area upstream from the reactors contained significant amounts of radioisotopes with 2.2×10^{-3} μc/g observed in the flesh of one specimen. For non-migratory organisms, maximum activity densities were found in the vicinity of Hanford. Salmon spawning, with a total of 545 nests, and the juvenile population appeared normal for this section of the Columbia. (Authors)

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3. Davis, J. J., D. G. Watson, C. C. Palmiter, and R. W. Coopey. 1954. 1953 radiological survey of the Columbia River, pp. 8-13. In: Biology Research Annual Report for 1953, HW-30437. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Radiobiological conditions in the Columbia River during 1953 were comparable to those of previous years but with slight differences in radioactivity densities. Plankton had the highest activity density among organisms sampled between manufacturing areas and Richland, but small fish and caddis fly larvae were higher downstream from McNary Dam. This condition was attributed in part to the proportionally higher initial content of short-lived isotopes in plankton. Comparisons were made of abundance and radioactivity density of net and

nonnoplankton. During the winter and spring months relatively high radioactivity densities were found in some whitefish which had migrated upstream from the vicinity of reactor areas. A lower than average number of salmon nests within the environs of the Hanford project was consistent with small fall runs to other sections of the Columbia. (Authors)

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4. Davis, J. J., D. G. Watson and C. C. Palmiter. 1955. Radiobiological survey of the Columbia River - 1954, pp. 6-10. In: Biology Research Annual Report for 1954, HW-35917. Hanford Atomic Products Operation, Richland, Wash.

Abstract: The distribution of radioactivity among river organisms was comparable to that found in 1953. In the newly formed McNary Dam impoundment, activity densities of plankton and bottom organisms were lower along the Oregon side owing to dilution from the Snake River. The number of salmon nests between Richland and Priest Rapids was comparable to those observed during 1953, but was appreciably lower than the number for the parent year of 1953; the reduction was commensurate with small runs of salmon to other sections of the Columbia. (Authors)

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5. Davis, J. J. 1956. Radioactivity density studies of Columbia River organisms. HW-40712, Hanford Atomic Products Operation, Richland, Wash.

Abstract: Data or radioactivity in Columbia River organisms are presented. (See D-7)

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6. Davis, J. J., D. G. Watson and C. C. Palmiter. 1956. Radiobiological studies of the Columbia River through December, 1955. HW-36074, Hanford Atomic Products Operation, Richland, Wash. 188 pp.

Abstract: This paper presents and interprets data from studies completed between Sept. 1948 and Dec. 1955. All forms of life were many times more radioactive than the water they inhabited. Some radioisotopes were much more readily accumulated than others in living organisms. Differences are described in concentration levels by geographical, seasonal and annual fluctuations in the river. Faunistic lists are given. (CDB)

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7. Davis. J. J., R. W. Perkins, R. F. Palmer, W. C. Hanson, and J. F. Cline. 1958. Radioactive materials in aquatic and terrestrial organisms

exposed to reactor effluent water, pp. 423-428. In: Proc. 2nd Int'l. Conference on Peaceful Uses of Atomic Energy, Vol. 18, United Nations, N. Y.

Abstract: Of the many radioisotopes that have been measured in Columbia River water, none were present in quantities near the recommended maximum limits for drinking water by the International Commission on Radiological Protection. Studies in which rats were maintained on reactor effluent that contained concentrations of radioisotopes several thousand times the concentrations in the river water indicated that the danger of assimilating harmful levels of radioisotopes by drinking Columbia River water was negligible. Significant quantities of various isotopes were concentrated, however, in the bodies of most organisms which had access to the contaminants via the natural food web. It is apparent that food organisms of man could accumulate hazardous levels of certain radioisotopes from water which contained concentrations of the contaminants that were well within the permissible limits for drinking water. Representative organisms are routinely sampled from natural environments which are exposed to dilution of effluent from the Hanford reactors to ascertain that the amounts of radioactive contamination are well below hazardous levels. (Author's Conclusions)

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8. Davis, J. J., and R. F. Foster. 1958. Bioaccumulation of radioisotopes through aquatic food chains. Ecology 39(3):530-535.

Abstract: Some radioactive materials introduced into aquatic environments may be accumulated by the organisms. The amount of accumulation will vary over many orders of magnitude depending upon the kinds of isotopes involved and many physical, chemical, and biological factors. Such concentration is of considerable importance in the control of radiological hazards and the aquatic biologist has definite responsibilities in this area.

The processes of adsorption and absorption are of major importance in the uptake of radioisotopes by plants but appear to be of less importance than the food chain in the uptake by aquatic animals. The concentration of radioactive substances will vary between species and tissues and will fluctuate according to food habits, life cycles, and seasonal changes.

Within the biotic mass, a major fraction of most radioactive contaminants will be held by the organisms which make up the primary trophic levels. In a flowing stream, the specific activity of a radioisotope will diminish along the food chain. Where the turnover rates of certain isotopes can be measured, inferences can be drawn on feeding habits. (Author's Summary)

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9. Davis, J. J. 1958. Dispersion of radioactive materials by stream. J. Amer. Water Works Assoc. 50(1):1505-1515.

Abstract: Summary points are fivefold:

1. Fresh-water streams provide an important means by which to dispose of radioactive contamination.
2. The main potential sources of radioactive contamination in streams are the mining and smelting of radioactive ores; effluents from atomic-products manufacturing; wastes from industrial, research, and medical users of radioisotopes; accidents involving radioactive materials or nuclear-powered apparatus; and fallout from atomic detonations.
3. The chemical and physical properties of radioactive materials that can influence their dispersion in streams include their state, mass, density, radioactive lifetime, chemical state, and the temperature of the effluent that bears them.
4. Nonbiotic, limnological factors that can influence dispersion of radioactive contamination include stream morphology, flow volume, velocity, temperature, and water chemistry.
5. The biota of a stream can significantly affect the dispersion of radioactive contamination by accumulating and retaining certain radioisotopes, and by spreading the contamination through migration.

(Author's Summary)

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10. Davis, J. J. 1959. The effects of environmental factors upon the accumulation of radioisotopes by ecological system, pp. 37-41. In: Proc. 2nd Annual Texas Conf., Utilization of Atomic Energy, College Station, Texas, Nov. 12-13.

Abstract: Radioisotopes produced by man may be concentrated in specific components of ecological systems. The dominant sources are airborne and liquid wastes. Environmental factors influencing accumulation of radioactive materials include the food web, metabolic and physiological processes of different organisms, life cycles and seasons, stage of development, type of habitat, and the geographical distribution of the organism. Data on radioactive contaminants from Columbia River animals and plants are given, and a basic food web from the Columbia River is figured. (CDB)

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11. Davis, J. J. 1963. Cesium and its relation to potassium in ecology, pp. 539-556. In: Radioecology, Proc. 1st Int'l Symposium on Radioecology (1961), Reinbold Publ. Co., N. Y.

Abstract: Data on cesium and potassium studies at Hanford are reviewed, including data from the available literature. (CDB)

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12. Davis, J. J. 1965. Accumulation of radionuclides by aquatic insects, pp. 211-215. In: Biological Problems in Water Pollution, Trans. 3rd Seminar (1962), Publ. No. 999-WP-25, R. A. Taft Sanit. Engr. Center, Cincinnatti, Ohio.

Abstract: Data is provided on the accumulation of various radionuclides by aquatic insects in the Columbia River at Hanford, Wash. Includes data from plankton, chironomid larvae (Hyrobaeninae and Tendipedinae), Caddis fly larvae (Hydropsyche and Glossosoma), Caddis fly larvae (Leptocella), black fly larvae (Simuliidae), and aquatic moth larvae (Argyractis). Some data on the life cycle of the organisms are given. (CDB)

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13. Dean, J. M. 1965. Cycling of Sr^{90} in moulting crayfish, pp. 46-48. In: Biology Research Annual Report for 1964, BNWL-122. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Crayfish injected with SR^{90}-Y^{90} while in the premolt stage concentrated the isotope in the gastrolith and fixed it in the exoskeleton. At molt the Sr^{90}-Y^{90} in the gastrolith was mobilized and deposited in the postmolt exoskeleton. (See D-20) (Author)

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14. Dean, J. M., J. Eapen, and R. E. Nakatani. 1965. Metabolism of Cs^{137} in trout, pp. 73-74. In: Biology Research Annual Report for 1964, BNWL-122. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Cesium-137 injected intravenously into yearling rainbow trout was distributed uniformly through the soft tissues with the exception of the white muscle. The effective half-life of Cs^{137} in red muscle was 5 1/2 days and in white muscle was 13 days. (Authors)

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15. Dean, J. M., and J. D. Berlin. 1965. The effect of temperature acclimation on the tissues of Salmo gairdneri (rainbow trout). Amer. Zool. 5(4):696. (Abstract).

Abstract: Not available.

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16. Dean, J. M., and R. E. Nakatani. 1966. Temperature effects on cesium metabolism in trout, pp. 112-113. In: Annual Report for 1965, Biological Sciences, BNWL-280. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Cesium-137, injected intravenously into trout acclimated to 5°C, is retained with a half-life of about 20 days, a much longer half-life than previously measured in 18°C, acclimated fish. Fish in colder waters will tend to develop higher tissue concentrations. (Authors)

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17. Dean, J. M. 1966. Temperature effects on energy reserves in trout, pp. 113-115. In: Annual Report for 1965. Biological Sciences, BNWL-280. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Higher levels of lipid reserves were observed in cardiac muscle of trout acclimated at 5°C than at 18°C, but red muscle, white muscle and liver showed no significant effect of temperature. The 5°C fish had significantly higher glycogen levels in liver and cardiac muscle but showed no difference in red and white muscle. (Author)

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18. Dean, J. M. 1967. Metabolism of acetate and palmitate by tissues of warm and cold adapted trout, pp. 155-157. In: Annual Report for 1966, Vol. I, Biological Sciences, BNWL-480. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Oxidation of acetate and palmitate to CO_2 was more rapid in tissues from cold adapted fish. Incorporation of acetate into lipids was higher in liver from cold adapted fish. These results are interpreted as signifying a reduced oxidative capacity in tissues from warm adapted fishes. (Author)

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19. Dean, J. M. 1967. Temperature of tissues of freshwater fishes, pp. 162-163. In: Annual Report for 1966, Vol. I, Biological Sciences, BNWL-140. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: The temperature of the gastrointestinal tract of five Columbia River fishes were not different from the ambient water temperature, but the deep muscles were 0.1 to 1.2°C higher than the water. Swimming exercise reduced the deep muscle temperature of trout to ambient water temperatures. (Author)

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20. Dean, J. M. 1968. Cycling of ^{90}Sr in molting crayfish. Comp. Biochem. Physiol. 25(3):1113-1116.

Abstract: Crayfish injected with Sr^{90}-Y^{90} while in the premolt stage concentrated the isotope in the gastrolith and fixed it in the

exoskeleton. During molt the Sr^{90}-Y^{90} in the gastrolith was mobilized and deposited in the postmolt exoskeleton. This cycle was repeated for two complete molting periods. (Author)

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21. Dean, J. M. 1968. Metabolism of acetate by trout tissues at high temperatures, pp. 7.2.-7.22. In: Annual Report for 1967, Vol. I, Biological Sciences, BNWL-714. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Acetate-1-^{14}C was incubated with trout tissues at temperatures from 18-38°C. There was a general increase in rate of oxidation of acetate with increased temperature. The production of energy is apparently not the limiting factor in thermal death of fish. (Author)

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22. Dean, J. M., and C. C. Coutant. 1968. Lethal temperature relations of juvenile Columbia River chinook salmon, p. 9.5. In: Annual Report for 1967, Vol. I, Biological Sciences, BNWL-714. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: The median resistance time of juvenile salmon to acute temperature stress was not affected by the developmental temperature regime, and size did not influence the time to death. There was a correlation between the time to loss of equilibrium and time to death. Eighty-five percent of the juveniles that lost equilibrium with thermal shock died, even if returned to nonlethal temperatures, and the duration of exposure to lethal temperature was a critical factor for survival. (Authors)

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23. Dean, J. M. 1969. The response of juvenile salmonids to acute thermal shock, pp. 6.37-6.42. In: Annual Report for 1968, Vol. I, Life Sciences, Part 1, Biological Sciences, BNWL-1050. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Juvenile salmonids were acclimated at different temperatures and were tested for their response to high-temperature exposures. The temperature of acclimation and the rate of exposure had marked effects on the response of the fish to acute thermal exposure. (CDB)

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24. Dean, J. M. 1969. The metabolism of tissues of thermal acclimated trout (*Salmo gairdneri*). Comp. Biochem. Physiol. 29(1):185-196.

Abstract:

1. Tissues from cold-acclimated fish oxidized acetate and palmitate more rapidly than tissues from warm-acclimated fish.
2. Red muscle converted acetate and palmitate to CO_2 at a faster rate than did white muscle.
3. The rate of conversion of acetate to $^{14}CO_2$ increased with incubation temperature, up to temperatures as high as 38°C. (Author)

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25. Dean J. M., and J. D. Berlin. 1969. Alterations in hepatocyte function of thermally acclimated rainbow trout (Salmo gairdneri). Comp. Biochem. Physiol. 29(1):307-312.

Abstract:

1. There was a higher level of total protein (mg/g wet wt.) in the liver of cold-acclimated as compared with warm-acclimated trout.
2. Cold-acclimated trout had a higher level of incorporation of ^{14}C-leucine into total liver protein than did warm-acclimated fish.
3. There was a decreased secretory rate in the cold-acclimated fish.

(Authors)

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26. Dean, J. M., and J. D. Berlin. 1969. Alterations in hepatocyte function of thermally acclimated rainbow trout (Salmo gairdneri), pp. 6.43-6.45. In: Annual Report for 1968, Vol. I, Life Sciences, Part 1, Biological Sciences, BNWL-1050. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: There was an increased level of leucine incorporation into protein in hepatocytes from cold-acclimated fish as compared to warm-acclimated fish. The results suggest that there is a decreased rate of secretion of plasma protein from the hepatocytes of cold-acclimated fish. (CDB)

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27. Dean, J. M. 1970. The response of juvenile salmonids to acute thermal shock, pp. 6.37-6.42. In: Annual Report for 1968, Vol. I, Life Sciences, Part 1, Biological Sciences, BNWL-1050. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Juvenile salmonids were acclimated at different temperatures and were tested for their response to high-temperature exposures. The temperature of acclimation and the rate of exposure had marked effects on the response of the fishes to acute thermal exposure. (Author)

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28. Dean, J. M., and J. D. Berlin. 1970. Alterations in hepatocyte function of thermally acclimated rainbow trout (Salmo gairdneri), pp. 6.43-6.45. In: Annual Report for 1968, Vol. I, Life Sciences, Part 1, Biological Sciences, BNWL-1050. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: There was an increased level of leucine incorporation into protein in hepatocytes from cold-acclimated fish as compared to warm-acclimated fish. The results suggest that there is a decreased rate of secretion of plasma protein from the hepatocytes of cold-acclimated fish. (Authors)

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29. Donaldson, L. R., and R. F. Foster. 1957. Effects of radiation on aquatic organisms, pp. 96-102. In: The Effects of Atomic Radiation on Oceanography and Fisheries, Chapter 10. National Acad. Sci., National Res. Council, Wash., D.C., Publ. No. 551.

Abstract: The somatic effects of ionizing radiation are discussed under 1) relative sensitivity of different organisms, 2) relative sensitivity of different stages of development, and 3) pathology of radiation damage. Somatogenic effects of ionizing radiation are also discussed and other considerations in atomic energy use are mentioned. (CDB)

E

1. Eliason, J. R. 1967. Thermal mapping of the Columbia River at Hanford using an infrared imaging system. BNWL-CC-1074, Battelle, Pacific Northwest Labs., Richland, Wash.

   Abstract: The experimental technique of thermal imaging is presented, and data taken on the Columbia River using this technique is shown. (CDB)

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2. Erickson, R. C., A. H. Seymour, and R. E. Nakatani. 1967. Apparatus for measuring voluntary swimming activity: Effect of zinc-65 in trout, pp. 176-178. In: Annual Report for 1966, Vol. I, Biological Sciences, BNWL-480. Battelle, Pacific Northwest Labs., Richland, Wash.

   Abstract: An automatic recording apparatus was developed to measure voluntary swimming activity of fish. Limited tests with ^{65}Zn-burdened trout showed no significant differences among treatment groups and controls, but demonstrated the utility of the apparatus. (Authors)

F

1. Foster, R. F. 1946. Some effects of pile effluent water on young chinook salmon and steelhead trout. HW-7-4759. Hanford Works, Richland, Wash.

   Abstract: Publication not available.

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2. Foster, R. F. 1951. The 1951 transplantation of bass from the Hanford Reservation. HW-72804. Hanford Works, Richland, Wash. 11 pp.

   Abstract: Publication not available. (See H-21)

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3. Foster, R. F. 1952. Biological problems associated with the discharge of pile effluent into the Columbia River, pp. 11-13. In: Biology Research Annual Report for 1951, HW-25-21. Hanford Atomic Products Operation, Richland, Wash.

   Abstract: A general review of bioenvironmental studies at Hanford is provided. Covers studies designed to determine the dilution level that reactor discharges first exert an adverse effect, using juvenile salmon and trout, and field studies of communities and radionuclide concentrations. (CDB)

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4. Foster, R. F., and P. A. Olson, Jr. 1953. Effect of reactor effluent water on young silver salmon, pp. 31-38. In: Biology Research Annual Report for 1952, HW-28636. Hanford Atomic Products Operation, Richland, Wash.

   Abstract: The eggs and young of silver salmon were subjected to a series of dilutions of reactor effluent for eleven months. No adverse effects were observed at concentrations of 3.5 per cent or less but slight effects occurred at the 5 per cent level. At 10 per cent appreciable mortality occurred throughout the test and growth was poor during the last four months. Radiation received by the fish is estimated at not over 6 rep for the entire period and adverse effects are attributed to unfavorable temperatures and chemical toxicity. Fish from the control and 5 per cent lots were marked before liberation to the ocean and will be studied for possible latent effects when they return as adults. (Authors)

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5. Foster, R. F., and R. E. Rostenbach. 1954. Distribution of radioisotopes in Columbia River. J. Amer. Water Works Assoc. 46(7): 633-640.

Abstract: A review of bioenvironmental studies pertaining to radioisotopes at Hanford is given. Five facets are discussed:

1. The Columbia River,
2. Radioactivity in reactor coolant,
3. Sampling and processing methods,
4. Radioactivity in river water, and
5. Radioactivity in aquatic life.

The paper concludes that: "Although detectable amounts of radioactivity occur in the water of the Columbia River below the Hanford reactors, no health hazard to users currently exists." . . . "The amount of radioactive material deposited in the fish of the river is likewise low in comparison to accepted standards." (CDB)

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6. Foster, R. F. 1955. Tritium oxide absorption and retention in the body water of some aquatic organisms, pp. 98-100. In: Biology Research Annual Report, HW-35917. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Salmon fry, mayfly nymphs, and snails immersed in water containing tritium oxide incorporated the tritium into their body water at a rate corresponding to a half-time of about 15 minutes. In an uncontaminated environment the half-time for elimination varied from about 10 minutes for the snails to about 24 minutes for the small fish. (Author)

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7. Foster, R. F., and J. J. Davis. 1956. The accumulation of radioactive substances in aquatic forms, pp. 364-367. In: Proc. Ist International conference on Peaceful Uses of Atomic Energy, Vol. 13(P/280), Geneva, Switzerland (Aug. 8-25).

Abstract: This paper explains how aquatic forms in the Columbia River below the Hanford reactors become radioactive and describes prevailing river conditions. The reactor effluents contain a complex mixture of radioisotopes but radioactive levels are well below permissible levels before discharge. These isotopes are emitters of beta and gamma radiation only. The radioactivity density in different Columbia River organisms are compared, and mechanisms of accumulation are discussed. Seasonal variations in radioactivity result from changes in temperature, water volume (dilution), feeding activity, and metabolism. Since most radioactivity is due to short-lived isotopes, activity drops rapidly

with river transport time; some eventually reach the sea while others accumulate in sediments. The radiation hazards of short-lived isotopes is of limited consequence. Although P^{32} is highly concentrated, existing amounts in the Columbia River are well below dangerous levels. (CDB)

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8. Foster, R. F., and P. A. Olson. 1959. Water temperatures for the Columbia River above the Hanford reactors, September, 1946, through December, 1958. HW-60028. Hanford Atomic Products Operation, Richland, Wash. 53 pp.

Abstract: Data for the period before Oct. 28, 1952, were tabulated from records obtained in the water treatment facilities. Data since then were obtained from a temperature recording instrument placed in the pump house of the most upriver reactor. One measurement is reported for each day through Dec. 1953; thereafter, a maximum, minimum and average is reported. (CDB)

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9. Foster, R. F. 1959. Behavior of radionuclides in food chains, freshwater studies. HW-SA-1725, Presentation, Radiological Health Training Course, Cincinnati, Ohio (Sept. 17, 1959). 11 pp.

Abstract: This presentation reviews mechanisms through which aquatic forms may accumulate radioactive materials from their environment, and how certain nuclides may become distributed in freshwater lakes and streams. It is based on Hanford studies and data from the existing literature. Topics covered in detail are: 1) Sources of radioactive materials, 2) Uptake by living organisms, 3) Concentration factors, 4) Concentration by different species, 5) Exchange between different organisms, and 6) Seasonal variations in concentration of radioactivity between species. Radioactive concentration levels are affected by a large number of physical, chemical, and biological factors. Although the limits of maximum concentration can be estimated, continued release of radionuclides must be conducted prudently and with adequate monitoring. (CDB)

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10. Foster, R. F. 1959. The need for biological monitoring of radioactive waste streams. Sew. Indust. Wastes 31(12):1409-1415.

Abstract: The paper discusses: 1) Estimation of radionuclide exposure, 2) Loss of radioactive materials from the water, 3) Reconcentration of diluted isotopes, 4) Need for field measurements, and 5) Limiting factors. It also presents a table of Maximum Permissible Concentrations (MPC) for P^{32}.

For water conditions similar to the Columbia River, the limiting situation for P^{32} is not the MPC in the drinking water but the accumulation levels in fish which are caught and eaten. If the concentration of P^{32} is sufficiently low in fish to permit their use as food, then it is unlikely that the fish will be significantly affected by radiation. (CDB)

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11. Foster, R. F. 1960. The significance of the uptake of radioisotopes by fresh-water fishes, pp. 15-20. In: Biological Problems in Water Pollution, Trans. 1959 Seminar, R. A. Taft Sanit. Engr. Center, Cincinnati, Ohio, Tech. Rept. W60-3.

Abstract: This paper reviews: 1. Measurements of radionuclides in fish, with consideration of background radiation and the necessity of identifying individual isotopes; 2. Permissible limits for human consumption (no limits adopted for fish); 3. Permissible limits for fish (nothing is known on limits causing death in exposed fish); and 4. The available data for comparing nuclide concentrations between humans and fish. (CDB)

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12. Foster, R. F. and R. L. Junkins. 1960. Off-project exposure from effluent. HW-63654 REV. Hanford Atomic Products Operation, Richland, Wash. 47 pp.

Abstract: This paper concerns the discharge of reactor effluent water to the Columbia River, and includes calculated and measured radioactivity downstream in relation to limits. It contains data on: 1. Quantities of radionuclides in the river, 2. Calculated exposures from drinking river water, 3. Measured exposures directly from the consumption of foods, 5. Distribution of Columbia River water in the ocean, and 6. The radionuclide content of marine organisms. Recommendations for additional studies are provided. (CDB)

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13. Foster, R. F. 1960. The influence of radiological wastes on water quality, pp. 171-176. In: Conference on Water Quality in the Columbia River Basin, Nov. 28-30, 1960 (HW-SA-2053).

Abstract: With the exception of world-wide fallout, the Hanford plant is the only significant source of artificial radionuclides to the Columbia River at this time. No new sources of consequence are visualized for at least a decade. Although effluent from the Hanford reactors contributes to the radiation dose of those who use the river downstream, the concentration of the nuclides is well within the maximum permissible limits recommended by the NCRP for persons in the neighborhood of controlled areas. (Author's Summary)

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14. Foster, R. F. 1961. Existing and proposed studies at HAPO relating to the Columbia River. HW-69723. Hanford Atomic Products Operation, Richland, Wash. 16 pp.

Abstract: This paper reviews: 1) Chemical characteristics and water quality; 2) Temperature characteristics and heat budget; 3) Effluent dispersion and hydrologic characteristics; 4) Fate of radioactive contaminants; 5) Ecological, toxicity and fish disease studies; and 6) the effluent control program. (CDB)

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15. Foster, R. F., R. L. Junkins and C. E. Linderoth. 1961. Waste control at the Hanford plutonium production plant. J. Water Pollution Control Fed. 33(5):511-529.

Abstract: This paper reviews: 1) Nature and distribution of radioactive wastes, 2) The basis of the waste management program, 3) Limiting the release of wastes to the environment, 4) Tracking the released material, 5) Measuring radiation from environmental sources, and 6) Determining permissible concentrations of nuclides.

Waste disposal practices at Hanford have used the topographical and climatological features of the area to advantage. Through careful studies of the hydrology, geology, meteorology, and biology of the site, and the movement of radioactive materials through the between various media, it has been possible to release wastes into the Columbia River, to the atmosphere, and to the ground with safety. The propriety of such releases have been confimed by extensive radiation monitoring. (CDB)

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16. Foster, R. F. 1963. Environmental behavior of chromium and neptunium, pp. 569-576. In: Radioecology. Proc. 1st Int'l. Symposium on Radioecology (1961), Reinhold Publ. Co., N. Y.

Abstract: Data on chromium and neptunium in the Columbia River at Hanford are provided. (CDB)

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17. Foster, R. F. (ed.). 1964. Report to the working committee for Columbia River studies on progress since September, 1962, for projects carried out by the General Electric Company at Hanford. HW-80649. Hanford Atomic Products Operation, Richland, Wash. 36 pp.

Abstract: This paper contains the following contributions:

1. Jaske, R. T. - Temperature studies on the Columbia River above Hanford;

2. Corley, J. T. - Effect of reator effluent on chemical quality of river water;
3. Nakatani, R. E. - Reactor effluent monitoring and bioassay of industrial chemicals with fish;
4. Watson, D. G. - Chinook salmon spawning near Hanford - 1963;
5. Cushing, C. E. - Plankton-water chemistry cycles in the Columbia River;
6. Foster, R. F. - Radiological characteristics of the Columbia River, 1963;
7. Conley, J. P. - Rate of transport of effluent downstream;
8. Fujihara, M. P. and P. A. Olson - Incidence and virulence of Columnaris, and
9. Nielsen, J. M. - Transport and deposition of radionuclides in the Columbia River.

(CDB)

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18. Foster, R. F., and D. McConnon. 1965. Relationships between the concentration of radionuclides in Columbia River water and fish, pp. 216-223. In: Biological Problems in Water Pollution, Trans. 3rd Seminar (1962), Publ. No. 999-WP-25, R. A. Taft Sanit. Engr. Center, Cincinnati, Ohio.

Abstract: Radionuclides entering the Columbia River at Hanford are not comparable to those in world-wide fallout because they are not fission products. About 60 different radionuclides can be identified in reactor effluent but, only about a dozen can be detected some 40 miles downstream.

Differences in radioactive levels in fish are due to food habits, migratory cycles, and other factors. Data on radionuclide concentration in C. R. fish are provided. Factors affecting the phosphorous 32 content of fish are discussed. Concentrations peak in warm temperature seasons, due to increased metabolism, and also to the spring spate which dilutes the effluent. (CDB)

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19. Foster, R. F. 1966. Evaluation of radiological conditions in the vicinity of Hanford for 1966, Appendices. BNWL-316APP. Battelle, Pacific Northwest Labs., Richland, Wash. 138 pp.

Abstract: Data on radiological conditions in the Columbia River at Hanford in 1966 are provided. (CDB)

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20. Foster, R. F., and J. K. Soldat. 1966. Evaluation of the exposure resulting from the disposal of radioactive wastes into the Columbia River, pp. 683-695. In: Disposal of Radioactive Wastes into Seas, Oceans and Surface Waters. 1966 Symposium, Int'l. Atomic Energy Comm., Vienna.

Abstract: People who use the Columbia River downstream from the Hanford atomic energy complex may receive small increments of the permissible amounts of radiation exposure from radionuclides released to the river. Comprehensive studies have been made of the ways in which this exposure can occur, the nuclides and exposure pathways of greatest significance, the characteristics of the exposed population, and the probable magnitude of the exposure.

The food chains of greatest significance involve local fish and the produce from a few irrigated farms. In each of these food chains, the neutron activation products ^{32}P and ^{65}Zn are of greatest importance. The short-lived nuclides ^{24}Na, ^{76}As, ^{239}Np, and ^{131}I have greater significance in drinking water than in food chains that start with river water. The ^{24}Na also contributes some external exposure to persons who swim in the river. Chromium-51 is the most abundant nuclide in the river, but it is not concentrated in food chains and makes a relatively insignificant contribution to human exposure.

Evaluation of the total exposure received by people in the neighborhood of the Plant requires consolidation of the contributions from the river with the exposure from pathways that involve the atmosphere. The individuals that receive the greatest dose are persons who eat unusually large quantities of fish caught in the river immediately downstream from the reactors. The dose estimated for the bone of these individuals exceeds that estimated for other organs because of the ^{32}P content of the fish and the ^{90}Sr (from world-wide fallout) content of other foods. For the vast majority of people who live in the vicinity, drinking water provides the only source of waterborne radionuclides and the gastro-intestinal tract is the organ that receives the greatest exposure. Atmospheric pathways are responsible for virtually all of the intake of long-lived nuclides. Whole-body counting of large numbers of local people has shown that the intake of radioactive materials from the Hanford Plant is less than that estimated by common dietary assumptions.

These exposure evaluations confirm that the total dose to members of the public has always been well within appropriate limits and that the radioactive wastes generated by the plants have been under sound and continuous control. (Authors)

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21. Foster, R. F. 1970. Effects of Hanford reactors on Columbia River and adjacent land areas. BNWL-SA-3679. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: A summary of the environmental effects of the Hanford operations is presented. Radiation entry into the food chain is presented as well as the temperature trends and thermal patterns in the Columbia River. (CDB)

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22. Foster, R. F., R. T. Jaske, and W. L. Templeton. 1972. The biological cost of discharging heat to rivers, pp. 631-640. In: Peaceful Uses of Atomic Energy, (A/COF. 491P/086), International Atomic Energy Agency, Vienna.

Abstract: In view of the widespread conjecture that the addition of cooling water to rivers entails a substantial biological cost, comprehensive studies are being made both under controlled laboratory conditions and on major rivers of the USA to determine whether adverse effects actually occur. These studies include: (1) those carried out over a period of 25 years by the USAEC on the Columbia River in the Pacific Northwest, which is noted for salmon and is used to cool plutonium-production reactors; (2) the Connecticut River in New England, noted for shad and used to cool a series of thermal power plants; and (3) the Tennessee River and its tributaries in the southeastern USA, noted for warm-water game fish and heavily developed for both hydroelectric and thermal power. The potential for a significant biological cost at these operating sites has been uncommonly great because of the high temperatures of the effluents, the quantities of heat discharged and the kinds of fish at risk. The studies embrace all the obvious ways that heat might directly affect anadromous fish, including upstream migration, spawning, egg development, growth and survival, downstream migration, entrainment of plankton, food organisms and disease. Some laboratory and field experiments suggest that a very small percentage of the river fish may at times encounter unmixed effluent that could prove lethal and that entrainment can briefly depress the abundance of zooplankton. Of much greater significance is that none of the field studies has thus far detected any heat-caused degradation of the stocks of desired fish nor significant alteration of the quality of the ecosystems except in the immediate vicinity of the discharges. Effects, if any, are of a much lower order than those produced by other factors that influence the abundance of fish and other aquatic life. (Authors)

23. Foster, R. F. 1972. The history of Hanford and its contribution of radionuclides to the Columbia River, pp. 3-18. In: A. T. Pruter and D. Alverson (eds.). The Columbia River Estuary and Adjacent Ocean Waters, Bioenvironmental Studies. Univ. Washington Press, Seattle, Wash.

Abstract: The history of the Hanford operations, with emphasis on radionuclide dispersal in the Columbia River, is reviewed. The scientific benefits derived from radiological studies are mentioned. (CDB)

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24. Fowler, S., L. F. Small, and J. M. Dean. 1967. Metabolism of zinc-65 in euphausids, pp. 399-411. In: D. J. Nelson and F. C. Evans (eds.), Symposium on Radioecology, CFSTI, Nat'l. Bur. Standards, Springfield, Va. (CONF-670503).

Abstract: In order to understand the biological role of zinc in marine food-chain organisms, uptake and retention of ^{65}Zn by the pelagic crustaceans Euphausia pacifica and Thysanoessa spinifera was studied. Experiments were performed at three temperatures (5, 10, and 15 C) and two concentrations of radiozinc (10 and 25 μCi/l). Weight-specific uptake and eliminations of ^{65}Zn by dead (formalin-preserved) animals and by live animals (before molting) were statistically similar over all temperatures and ^{65}Zn concentrations tested. Molted exoskeletons averaged 41% of total live body activity. Dissection of euphausiids into exoskeleton, eyes, and muscle and gut combined showed that the largest fraction of radiozinc was always associated with the exoskeleton. The second largest fraction was associated with muscle and gut, with a smaller fraction in the eyes and body fluid. Autoradiographs showed that ^{65}Zn mainly was located on the exoskeleton and between the muscle fibers, not intra-myofibrillar. Weight-specific activity varied inversely with weight, suggesting a surface area phenomenon for uptake and loss. An inverse linear relationship between animal weight and percentage of total activity in exoskeletons, with a concomitant positive linear relationship between animal weight and percentage of total activity in muscle and gut, also suggested that uptake and elimination of ^{65}Zn were largely a function of surface area. The Q_{10} for ^{65}Zn uptake (5-15 C) was almost twice that for oxygen consumption. The relationships between ^{65}Zn uptake and dry weight, and between oxygen consumption and dry weight, varied by an order of magnitude. We conclude from the above evidence that ^{65}Zn uptake from water is neither directly nor indirectly related to euphausiid metabolism. Some of the factors that make radiozinc uptake a poor index of metabolism (particularly molting) are responsible for making euphausiids potentially important in the cycling of radioactivity from "hot" pools in the sea. (Authors)

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25. Fujihara, M. P., P. A. Olson, and R. F. Foster. 1960. Mutation and temperature effects in C. columnaris, pp. 188-193. In: Biology Research Annual Report for 1959, HW-65500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Mutation rate in C. columnaris was found to be comparable with that in many other haploid bacteria. Survival of young salmon following exposure to water containing the organism was inversely related to the concentration of organisms, the length of exposure, and temperature. C. columnaris suspended in river water survived several days. (Authors)

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26. Fujihara, M. P., and P. A. Olson. 1961. Studies on the fish disease Chondrococcus columnaris, pp. 160-165. In: Biology Research Annual Report for 1960, HW-69500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Young salmon and rainbow trout showed increased resistance to columnaris as size and age progressed. Increased size also was related to a longer lag period between exposure and death. Temperature effects on survival differed between organisms suspended in sterile river water and in sterile river mud. (Authors)

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27. Fujihara, M. P., and P. A. Olson. 1962. Incidence and virulence of columnaris, pp. 151-155. In: Biology Research Annual Report for 1961, HW-72500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Fish samples from the Columbia River system showed a low incidence of columnaris disease compared to fish from an artificial spawning channel. Strains collected varied from avirulent to highly virulent. Ploidy of C. columnaris was found to have questionable significance to virulence differences although high virulent strains tested were diploid and avirulent haploid. Prolonged sublethal irradiation had no effect on virulence. (Authors)

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28. Fujihara, M. P., P. A. Olson, and R. E. Nakatani. 1964. Incidence and virulence of columnaris-III, pp. 195-202. In: Biology Research Annual Report for 1963, HW-80500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Incidence of C. columnaris on fish taken from the Yakima River was much earlier and greater than from fish taken from slough areas within the Hanford Reservation. The presence of general skin lesions or necrotic gill areas is not a reliable indication of columnaris infection. Trough studies showed high temperatures and crowding increased mortalities from both columnaris and other causes. The pattern of death and recovery from infection suggests an immunity response. To date there does not appear to be a correlation between the presence of high virulence forms and high death rate. (Authors)

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29. Fujihara, M. P., P. A. Olson, and R. E. Nakatani. 1965. Antibody production and immune response to fish to C. columnaris, pp. 194-196. In: Annual Report for 1964, BNWL-122. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Incidence of Chondrococcus columnaris in yearling rainbow trout, which were exposed to natural infection as fingerlings, suggests yearlings are immune and frequently active carriers of the organism. The maximum saline agglutinin titers induced in trout were 1:640 for vaccine and 1:5120 for Freund's adjuvant, plus vaccine. Preliminary surveys of Columbia River fish for antibody titers suggested that a majority of the fish had previous exposure to columnaris. (Authors)

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30. Fujihara, M. P. 1966. Columnaris disease in Columbia River fishes, pp. 127-130. In: Annual Report for 1965, Biological Sciences, BNWL-280. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Studies of the incidence of Columbia River fishes with antibodies against C. columnaris disclosed a single annual cycle apparently related to water temperature and re-exposure of fish to the columnaris organism. Four sampling sites, Bonneville, McNary, Hanford, and Wenatchee, showed a similar pattern of decline during cold water periods and a sharp rise with warmer temperatures and with the presence of columnaris organisms in the water. (Author)

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31. Fujihara, M. P. 1967. Immune response of salmonids and exposure of river fishes to Chondrococcus columnaris, pp. 183-185. In: Annual Report for 1966, Vol. I, Biological Sciences, BNWL-480. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Immunity to subcutaneous challenge, but not to intraperitoneal challenge, was developed in yearling rainbow trout by repeated injections of attenuated columnaris organisms. Ladder facilities at Columbia River dams were shown to be important sites for repetitive columnaris exposure and infection of salmonids. (Author)

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32. Fujihara, M. P. 1968. Columnaris exposure and antibody production in seaward and upstream migrant sockeye salmon, pp. 9.16-9.21. In: Annual Report for 1967, Vol. I, Biological Sciences, BNWL-714. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Columnaris exposure during seaward migration was slight until the juvenile salmonids reached the Columbia River estuary. Duration of exposure at the estuary was probably insufficient to cause mortality. Although most of the adults lost residual antibodies developed as juveniles, all were exposed upon reentering fresh water and developed antibodies. Many developed high agglutinating titers by the end of upstream migration and were probably immune to the disease. Nonimmune trout exposed to columnaris in Bonneville ladder water and under laboratory conditions did not die from exposure but developed antibodies against columnaris. Scrapfish residing in warm water areas of the Columbia River were not carriers of columnaris disease during winter months. (Author)

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33. Fujihara, M. P. 1970. Oral immunization of juvenile coho salmon against *Chondrococcus columnaris*, pp. 6.33-6.36. In: Annual Report for 1968, Vol. I, Life Sciences, Part 1, Biological Sciences, BNWL-1050. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Juvenile coho salmon were protected against *C. columnaris* disease by daily oral administration of heat-killed columnaris organisms incorporated into fish food. Ten weeks after occurrence of the pathogen in the troughs, 48% columnaris induced mortality was observed among 600 controls (average titer, 1:17) as compared to 8% mortality among 600 orally immunized fish (average titer 1:168). (Author)

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34. Fujihara, M. P. 1970. Columnaris exposure and antibody development among upstream migrant salmonids, pp. 6.29-6.33. In: Annual Report for 1968, Vol. I, Life Sciences, Part 1, Biological Sciences, BNWL-1050. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Columnaris exposure and infection during upstream migration was not a problem for the spring run of chinook salmon. Sockeye, coho, and summer-run chinook salmon showed an initial heavy exposure at downstream fish ladders and a successive increase in exposure and infection during passage through upstream ladder sites. Columnaris exposure and infection decreased for salmon which entered the cooler Columbia River tributaries. (Author)

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35. Fujihara, M. P. 1970. Temperature and fish disease, pp. 3.22-3.24. In: Annual Report for 1969, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1036. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Data are presented on three diseases of salmonids and coarse fish:

1. Columnaris: Incidence was determined by agglutinating antibodies over the year in the Columbia and Snake Rivers.
2. Furunculosis: Also observed at White Bluffs and the Snake River; prevalance of the disease at all sampling sites suggests that it is not as temperature dependent as Columnaris.
3. Dermocystidium: Was not observed among course fish or summer run chinook at Wells Dam, but in December of 1969, 42% of the mortalities at Wells Dam were heavily infected. Disease not evident until temperatures drop to 10 C or below. (CDB)

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36. Fujihara, M. P., and F. P. Hungate. 1971. Chondrococcus columnaris disease of fishes: Influence of Columbia River fish ladders. J. Fish. Res. Bd. Canada 28(4): 533-536.

Abstract: Columbia River fish ladders were surveyed as a possible ecological niche for Chondrococcus columnaris, the causative agent for columnaris disease of fishes. Water samples from Bonneville, McNary, Priest Rapids, and Rocky Reach fish ladders during periods of warm water temperature and high population density of fishes showed C. columnaris levels of from 0.06 to 4.1 organisms/ml. Samples taken upstream or downstream from the ladders were consistently negative. Average agglutinating titers and incidence of C. columnaris infection in largescale suckers were higher at the Bonneville ladder than at a site several miles downstream. Coho salmon from an upper-river fish ladder (Rocky Reach) showed a higher incidence of infection and greater antibody production than at the downriver Bonneville ladder. It is concluded that fish-ladder facilities on the Columbia River are important sites for repetitive exposure of anadromous salmonids to C. columnaris. (Authors)

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37. Fujihara, M. P., and R. E. Nakatani. 1971. Antibody production and immune responses of rainbow trout and coho salmon to Chondrococcus columnaris. J. Fish. Res. Bd. Canada 28(9): 1253-1258.

Abstract: Active immunity to Choncrococcus columnaris disease was established in coho salmon (Oncorhynchus kisutch) approximately three months old by oral vaccination with heat-killed cells. Average agglutinating titers were 1:17 for control survivors and 1:168 for the orally vaccinated salmon. When rainbow trout (Salmo gairdneri) approximately three months old were exposed in a trough to C. columnaris present as a natural contaminant in Columbia River water, 52% of the fish died during the first six weeks of the test. Fish that survived the exposure were generally resistant to subsequent challenge. Many age 1+ rainbow trout that survived the C. columnaris infection as juveniles, when sampled after several months of reexposure to the disease, were immune carriers of the pathogen and developed agglutinating antibody titers ranging from 1:80 to 1:640. Titers up to 1:5120 were developed in disease-free yearling rainbow trout by parenteral vaccination. (Authors)

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38. Fujihara, M. P., P. A. Olson, and R. E. Nakatani. 1971. Some factors in susceptibility of juvenile rainbow trout and chinook salmon to Choncrococcus columnaris. J. Fish. Res. Bd. Canada 28(11):1739-1743.

Abstract: Susceptibility of juveniles of chinook salmon (Oncorhynchus tshawytscha) and rainbow trout (Salmo gairdneri) to Chondrococcus columnaris disease appeared to be influenced by age of fish, crowding, and water temperature. Rainbow trout of about 1 g and chinook salmon of about 3 g were less susceptible than smaller fish, and tests with chinook salmon suggested that age were more important than weight. When chinook salmon averaging 4.3 g were exposed from July to October to the pathogen in river water, mortality ranged from 1.0% in a trough with 50 fish to 12% in one with 900. Mortality of rainbow trout averaging 2.4 g that were exposed to the pathogen in trough river water averaged 4.7-22% after four weeks, at temperatures from 17.2 to 17.8 C; the survivors, however, were generally resistant to subsequent infection, suggesting development of an immune response. Times to 100% mortality of sibling chinook salmon averaging 3.9 g that were exposed for 25 min to about 2.5×10^5 organisms per liter of sterile river water were about 19 hr at 10 C and 8 hr at 22 C. Survival of rainbow trout was higher when they were held at 2.2 degrees C below than when held at 2.2 degrees C above seasonal river temperatures. (Authors)

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39. Fujihara, M. P. 1971. Studies of Furunculosis and Columnaris disease in fishes, pp. 2.30-2.34. In: Annual Report for 1970, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1550. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Data are given on:

1. Furunculosis - Incidence of the disease in coarsefishes determined at various sites; these fish lack typical septicemic conditions and were probably immune carriers.
2. Columnaris - Fish ladders determined as a focus of infections. Infections were recorded at 2.8 to 3.3 C river temperatures, suggesting that a psychophilic strain of columnaris was being sampled. Large numbers of sockeye salmon found infected.

Concluded that: "Although many factors undoubtedly contribute to columnaris disease in Columbia River in 1970, the combined stresses of lower than normal river flow and higher river temperatures (1 to 2C) were probably the most important contributors." (CDB)

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40. Fujihara, M. P., and F. P. Hungate. 1972. Seasonal distribution of Chondrococcus columnaris infection in river fishes as determined by specific agglutinins. J. Fish. Res. Bd. Canada 29(2):173-178.

Abstract: River fish populations infected with Chondrococcus columnaris disease were surveyed by measurements of C. columnaris agglutinating antibodies in blood sera of fishes and by isolation of the pathogen using microbiological plating methods. Agglutinins were demonstrated in all 13 fish species collected except whitefish (Prosopium williamsoni). Blood serum from samples of fishes at four Columbia River sites during 1965 and three Columbia River sites and one Snake River site during 1969-70 demonstrated single annual cycles of C. columnaris antibody production. During the two annual sampling periods, the magnitude of antibody titers and frequency of fish with agglutinins increased in warm water and declined in cool water. The rise in titers occurred after a winter low, and usually followed the period when the first C. columnaris organisms were isolated from native fish. Agglutinating titers up to 1:5000 were found but most peak titers were between 1:320 and 1:640. (Authors)

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41. Fujihara, M. P. 1972. C. columnaris disease, pp. 1.24-1.26. In: Annual Report for 1971, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1650. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Sampling at three stations on the central Columbia River in April, May and July, 1971 revealed a higher percentage of coarsefish with agglutins and average titers than observed in 1970. This was probably a result of a larger carry-over of fish with residual antibodies from 1970 and an earlier re-challenge of these fish by the pathogen. (CDB)

G

1. Glover, R. E. 1964. Dispersion of dissolved or suspended materials in flowing streams. U. S. Geological Survey, Profess. Paper 433-B.

   Abstract: Dispersion correlations are presented based on data collected on limited radioactivity measurements made from reactor effluents at Hanford. Lateral dispersion coefficients of 2.1 ft^2/sec were determined. (CDB)

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2. Grande, L. A. 1966. Gamma spectrum, count rate, and dose rate measurements on the Columbia riverbank from Vernita to Sacajawea. BNWL-CC-468. Battelle, Pacific Northwest Labs., Richland, Wash. 15 pp.

   Abstract: The instruments used included a NaI (Tl) scintillation counter normally used for aerial monitoring, a bioplastic scintillation counter normally used as a road monitor, and a portable 40 L. ionizing chamber normally used to measure very low gamma dose rates. Only limited data are provided. (CDB)

H

1. Hall, R. B., W. N. Koop, and J. D. McCormack. 1958. Effects of direct disposal of reactor effluent water to the river. HW-55249. Hanford Atomic Products Operation, Richalnd, Wash. 5 pp.

   Abstract: This report discusses the effect of coolant detention on off-site pollution of drinking water and on aquatic life in the Columbia River, on shoreline release of normal effluent coolant, and on rupture debris monitoring. It concludes that the discontinuance of retention basins along the shore for effluent water would not increase the hazards of direct discharge to the river significantly--to either humans or aquatic life. (CDB)

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2. Hall, R. B., J. P. Corley, J. K. Soldat, and R. T. Jaske. 1970. Environmental effects of an extended Hanford Plant shutdown, Appendix E. In: R. T. Jaske and M. O. Synoground, Effect of Hanford Plant Operations on the Temperature of the Columbia River 1964 to Present. BNWL-1345. Battelle, Pacific Northwest Labs., Richland, Wash. 14 pp.

   Abstract: Data is provided on the reduction of radioactivity, heat, and chemical concentrations in the river and river biota following plant shutdown. (CDB)

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3. Hampton, J. C., J. M. Dean and R. R. Adee. 1970. Fine structural effects of temperature in fish, pp. 19-21. In: Annual Report for 1969, Vol. I, Life Sciences, Part 1, Biological Sciences, BNWL-1306. Battelle, Pacific Northwest Labs., Richland, Wash.

   Abstract: A comparative study of red and white muscle ultrastructure is being completed on trout acclimates to 7.5°C. This work is a background for future studies on histopathological and histochemical effects of elevated temperatures up to 30°C. Autoradiographic studies on cell turnover and protein synthesis will be used. (CDB)

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4. Hampton, J. C. and R. R. Adee. 1971. Fine structural effects of temperature in fish, pp. 103-106. In: Annual Report for 1970, Vol. I, Life Sciences, Part 1, Biological Sciences, BNWL-1550. Battelle, Pacific Northwest Labs., Richland, Wash.

   Abstract: This study began as an attempt to understand why trout die when exposed to temperatures above 25°C. Extreme capillary dilation

was characteristic of fish exposed to a lethal temperature of 30°C. The vascular system clearly responds to abrupt changes in water temperature and this phenomenon will be studied further. (CDB)

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5. Hampton, J. C. and R. R. Adee. 1972. Preliminary observations of fine structural effects of temperature in fish, pp. 288-289. In: Annual Report for 1971, Vol. I, Life Sciences, Part 1, Biological Sciences, BNWL-1650. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Vascular dilatation, mainly in capilliary beds, was consistently found in gills and swim bladders of rainbow trout transferred from water at ambient river temperature to water held at 30°C. Lateral line organs and the lateral line nerve trunk were also studied in detail in an attempt to resolve some of the uncertainties concerning vacuolization of sensory cells comprising the lateral line organ and separation of myelin layers in the lateral line nerve in fish subjected to temperatures above 25 °C. The results are thus far inconclusive. (Authors)

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6. Hanson, W. C., and R. L. Browning. 1957. Role of food habits in wildlife contaminations at Hanford, pp. 201-208. In: Biology Research Annual Report for 1956, HW-47500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Food items in stomachs of 522 wildfowl collected along the Columbia River and at waste ponds on the Hanford Project were identified to correlate tissue concentrations of radioisotopes with wildfowl food habits. (Authors)

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7. Hanson, W. C. 1958. Chinook salmon spawning in the vicinity of Hanford - 1957, pp. 219-221. In: Biology Research Annual Report for 1957, HW-535000. Hanford Atomic Products Operation, Richland, Wash.

Abstract: A record number of salmon nests were observed during the fall of 1957. This was consistent with increased spawning density elsewhere in the Columbia River system (4). The number of salmon nests recorded during the past five years are tabulated. The 1953 nests produced the parents of the fish which nested in the fall of 1957. Because there was not an appreciable increase in the number of 1957 fall run chinook salmon that ascended Bonneville Dam, it is assumed the larger number of upstream spawners was due to flooding of the Celilo Falls Indian fishing grounds by the impoundment behind The Dalles Dam. It is concluded that Hanford operations have had no apparent effect upon this population. (CDB)

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8. Hanson, W. C. 1958. Arctic tern and black brant in eastern Washington. The Murrelet 39(1):12.

Abstract: First records of the Arctic tern, Sterna paradisaea, and black brant, Branta nigricans, at Hanford are given. (CDB)

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9. Hanson, W. C. 1959. Chinook salmon spawning in the vicinity of Hanford - 1958, pp. 134-134. In: Biology Research Annual Report for 1958, HW-59500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: A 12-year record number of chinook salmon spawned near Hanford during the fall of 1958. The largest upstream passage of salmon in recent years, elimination of an Indian fishery, and a deterrent from dam construction upstream from Hanford are considered the major influencing factors. (Author)

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10. Hanson, W. C., and J. J. Davis. 1959. Radioactive contamination in wildlife, pp. 138-143. In: Biology Research Annual Report for 1958, HW-59500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Radioactive contamination in terrestrial and aquatic wildlife in the environs of Hanford Atomic Products Operation is routinely measured by sampling indicator organisms. In addition, game species of birds and fish are sampled during periods when they contain maximum contamination and when they are available to sportsmen. During the past three years radioactive contamination levels in terrestrial organisms have remained comparable and levels in river organisms have increased slightly. (Author)

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11. Hanson, W. C., and R. L. Browning. 1959. Nesting studies of Canada geese on the Hanford Reservation, 1953-56. J. Wildl. Mgmt. 23(2):124-127.

Abstract: Nesting studies of Canada geese were conducted on the Hanford Reservation of southeastern Washington during 1953 to 1956. Complete histories were obtained from 1,032 nests. Nesting density on the islands varied from 0.003 to 4.0 nests per acre. Seventy-one percent of the nests were hatched, 13% were destroyed by predators, 11% were deserted, and 3% were flooded. Hatchability of eggs in successful nests averaged 92%. Average clutch sizes were 5.3 in 1953 and 1955, and 5.5 in 1954 and 1956. Hatching peaks occurred from the third week of April to the first week of May, and the total nesting season ranged from 10 to 12 weeks. No adverse effect on the adult geese, their eggs, or young by Hanford reactor operations was noted. (from Author's Summary)

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12. Hanson, W. C., and D. G. Watson. 1960. Radioactive contamination in wildlife - 1959. pp. 171-179. In: Biology Research Annual Report for 1959, HW-65500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Concentrations of radioisotopes in the tissues of jack rabbits and shiners, the indicator organisms, and in ducks, whitefish and deer, the important game species, collected from the Hanford Reservation in 1959 are presented. Values are generally lower than those observed in 1958. Factors responsible for this decrease are discussed. (Authors)

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13. Hanson, W. C., and D. G. Watson. 1961. Radionuclides in Hanford wildlife - 1960, pp. 173-179. In: Biology Research Annual Report for 1960, HW-69500. Hanford Products Operation, Richland, Wash.

Abstract: Concentrations of radioisotopes in tissues of biological indicator organisms and game species of the Hanford Reservation were generally greater than during 1959. Important increases occurred in fish and waterfowl from the Columbia River. Total beta emitters in Richarsonius balteatus and Prosopium williamsoni (the indicator organisms). Total beta emitters are highest in herbivorous forms, such as suckers and chiselmouths. (CDB)

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14. Hanson, W. C. 1963. Census of ring-billed and California gull colonies in eastern Washington. The Condor 65(2):163-164.

Abstract: Two nesting colonies of ring-billed (Larus delawarensis) and California (L. californicus) gulls located on the Columbia River within the Hanford Reservation, Washington were censused in 1961. On both islands, the California gulls nested on higher ground near the center which the ring-billed gulls nested on the periphery. Ring-billed gull nests comprised 90-95% of all nests at one colony, and 75-90% at the other colony. Many nests were inundated during the survey by rising water levels due to annual spring freshets. A greater percentage of ring-bill gull nests were flooded. Numbers of eggs and young per nest are tabulated. (CDB)

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15. Hanson, W. C., and A. C. Case. 1963. A method of measuring waterfowl dispersion utilizing phosphorus-32 and zinc-65, pp. 451-455. In: Radioecology. Proc. 1st Int'l. Symposium on Radioecology (1961), Reinhold Publ. Co., N.Y.

Abstract: Waterfowl which inhabit the Columbia River within and downstream from the Hanford Reservation accumulate small amounts of radionuclides from reactor effluents. A method is described for identifying these birds in the hunter harvest. Waterfowl heads were rapidly scanned for total gamma radiation, due principally to zinc-65, and those with above-background counting rates were subsequently associated with the Hanford section of the Columbia River by analyses for phosphorus-32. The phosphorus-32 tag was detected in 41 percent of 601 waterfowl harvested within a 50 mile radius of the Hanford Reservation during the 1960-1961 hunting season. Initial results showed seasonal fluctuations in the tagged portion of the population with three major arrival periods of unmarked immigrants. (CDB)

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16. Hanson, W. C. 1968. Recent history of double-crested cormorant colonies in southeastern Washington. The Murrelet 39(2):25-26.

Abstract: Two breeding colonies of double-crested cormorants (*Phalacrocorax auritus albociliatus* Ridgway) were lost as a result of hydroelectric dam impoundment and interspecies strife. (CDB)

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17. Hanson, W. C. 1969. First sight records of blue geese in Washington. The Murrelet 50(2):24.

Abstract: First records of blue geese, *Chen caerulescens*, in Washington (at Hanford) are given. (CDB)

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18. Hanson, W. C. and L. L. Eberhardt. 1971. A Columbia River Canada goose population, 1950-1970. Wildlife Monographs, No. 28. 61 pp.

Abstract: Nesting and banding studies of a western Canada goose population resident within the Hanford AEC Reservation in southeastern Washington were conducted during 1950-1970. The objectives were to determine population dynamics, and to assess possible effects upon geese resident near the largest nuclear reactor complex within the United States. The nesting Canada goose population increased from about 200 pairs in 1950 to a maximum of 300 pairs during 1953-1956 and then declined to about 200 pairs in 1964-1970. Unemployed geese, presumably less than 3 years of age, numbered 50-150 each year. The number of pairs associated with each island used by nesting geese was fairly constant until serious coyote predation forced a population shift during the later years of the study. Goose nesting began when average daily temperatures of 5C (40F) were reached, with most of the nests begun during the third week of March. The 18-year average nesting season lasted 12 weeks. Information was obtained

from 3,824 nests, of which 70% were successful (hatched), 14% were deserted, 12% were destroyed by predators, 2% were flooded, and 1% were incomplete. Coyotes were the most important predators of geese, while magpies and other predators were occasionally important.

Human disturbance and destruction of nests was of major consequence on islands open to public access. A total of 490 bands were recovered from 2,197 geese banded from 1950 through 1967. Audlts comprised 29% of the recoveries locally. Distant band recoveries showed that Hanford geese did not undertake a late season northward migration. Most young geese remained in southeastern Washington throughout their first winter, but migrated into Canada the following spring. Several management recommendations based on the results of the study are made. (CDB)

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19. Haushild, W. L., H. H. Stevens, Jr., J. L. Nelson and G. R. Dempster, Jr., 1971. Radionuclides in transport in the Columbia River from Pasco to Vancouver, Washington. U.S. Geological Survey, Water Resources Division, Portland, Ore. (open-file report). 77 pp.

Abstract: The radionuclide discharges in the cooling-water effluent of the reactors on the U.S. Atomic Energy Reservation at Hanford, Wash., were formed by neutron activation of: 1) impurities in the Columbia River water used to cool the reactors, 2) corrosion products from the reactor components, and 3) chemicals used in the water-treatment process. Until all the eight reactors that were cooled by once-through flow were shut, their cooling-water effluents were the main source of dissolved and particulate radionuclides in the Columbia River. Concentrations and discharges of 13 dissolved and particulate radionuclides were observed at Pasco and Vancouver, Wash., for all or parts of the period from January 1964 to September 1966, and at Umatilla, Ore., from May 1965 to September 1966. A time-series analysis of concentrations and discharges of eight of the 13 particulate and dissolved radionuclides at Pasco and Vancouver showed a progressive decrease in the concentrations and discharges of many radionuclides during the study period. The decrease was mainly attributable to a decrease in the number of operating reactors. The hydrodynamic and sedimentation characteristics of the Columbia River and the chemical characteristics of the radionuclides were found to be important factors affecting the disposition in the Pasco-Vancouver reach of the radionuclides discharged at Pasco. (Authors)

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20. Henderson, C., R. C. Palange, and G. C. Robeck. 1954. Columbia River water studies (preliminary draft). U.S. Public Health Service, No. GEH 21, 328, R.A. Taft Sanit. Engr. Center, Cincinnati, Ohio. 136 pp.

Abstract: This paper reports a 2-year (1951-1953) study of the Columbia River and its tributaries, to determine the water quality characteristics of the stream prior to impoundment by McNary Dam and the effects of radioactivity on the physical, chemical, and biological characteristics of surface waters. Most of the work was done between Priest Rapids and Paterson, with some studies on Roosevelt Lake, Bonneville Reservoir, and the areas around Portland and Astoria, Oregon. Considerable data on water quality are tabulated and figured. (See R-1) (CDB)

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21. Henderson, C., and R. F. Foster. 1956. Studies of smallmouth black bass (*Micropterus dolomieu*) in the Columbia River near Richland, Wash. Trans. Amer. Fish. Soc. 86:112-127.

Abstract: Observations on smallmouth black bass were made during a transplantation program and monitoring program of reactor radioactivity. The average bass caught with sport fishing gear was 15 1/2 inches long and weighed 40 ounces. Females were larger and more abundant than males. About half of the catch consisted of 7 and 8 year old fish, but the range was from 3 to 11 years. Growth was rapid, in spite of a short season and temperatures considered to be below optimum. Fry hatched from eggs spawned in July and August when temperatures of the water were from 60 to 75 F. Many translocated fish returned to the site of capture. Radioactive materials were acquired by bass through their food chain. The principal isotope concentrated was radiophosphorus. The level of activity was greatest in September and least in April. Radioactive contamination of bass was too low to be of harm to man. (CDB)

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22. Henderson, C., G. G. Robeck, and R. C. Palange. 1956. Effects of low-level radioactivity in the Columbia River. Public Health Reports 71(1):6-14.

Abstract: The following major conclusions regarding radioactivity in the Columbia River are drawn from the Public Health Service studies of 1951-53: 1. Low-level beta activity has had no adverse effect upon the numbers and species of aquatic organisms in the Columbia River. 2. The radioacticity levels in plankton and attached algae are directly dependent upon levels in the river water. 3. The radioactivity levels in aquatic animals vary with their metabolic rates (which in turn vary with water temperatures) and with the radioactivity levels of the materials upon which they feed. 4. Migratory species in the Columbia River such as salmon, the adults of which do not feed in fresh waters, have low radioactivity levels at the same time that levels in resident species are high. 5. Radioactive materials are concentrated in all parts of the body of the fish. The activity levels, however,

are about 10 times higher in scales, bones, and internal organs than in the edible parts, such as muscle and skin. 6. Since aquatic organisms concentrate specific radioisotopes such as phosphorus-32 many thousand times above the levels in water, the use of these organisms for human or animal consumption presents a potential public health problem. However, to date the levels of radioactivity in the flesh of Columbia River fish are not dangerously high.

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23. Herde, K. E. 1947. Radioactivity in various species of fish from the Columbia and Yakima Rivers. HW-3-5501. Hanford Works, Richland, Wash. 16 pp.

Abstract: Radioactivity accumulated by fish was highest in the liver (maximum) and kidney, followed by the skin, gills, bone and muscle. (CDB)

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24. Herde, K. E. 1948. One year study of radioactivity in Columbia River fish. HW-11344. Hanford Works, Richland, Wash. 11 pp.

Abstract: Results are presented from a survey of the radioactivity in Columbia River fish collected between April 1947 and April 1948. Algae samples were also collected and analyzed for radioactivity. Results on the beta activity in 194 fish are presented. Procedures and results are discussed. (CDB)

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25. Herde, K. E. 1951. Deposition of radioactivity in rats drinking pile effluent water. HW-20102, Hanford Atomic Products Operation, Richland, Wash. 13 pp.

Abstract: Two groups of rats drank *ad libitum* only effluent nuclear reactor cooling water adjusted to activity density levels of approximately 3×10^{-4} μc/ml and 3×10^{-6} μc/ml for periods of 200 to 500 days. A control group drank sanitary water. Growth rate of the experimental rats was not affected by the radioactivity and no histological changes were observed. Both effluent-drinking groups showed beta radiation levels significantly higher than the controls. In the group receiving the greater concentration, blood and kidneys usually had the highest activity density with an accumulation of Na^{24} and P^{32} approximating 2×10^{-5} μ/g. This study suggests that the hazard to mammals drinking Columbia River water containing greatly diluted effluent is negligible if the diet provides all the essential elements. (Author)

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26. Honstead, J. F. and R. G. Clark. 1953. Temperature and activity density gradients in a Columbia River gravel bed. HW-29217. Hanford Works, Richland, Wash. 21 pp.

Abstract: 30 inches below the river bottom, temperatures tended to be isothermal, while variations up to 4.5C were found in the upper layers of the gravel. Significant day to day changes were attributed to climatic temperature changes. No difference in radio-isotope composition was found below the bottom of the river from that found in the river itself. But the actual concentration was reduced by a factor of 50 in the first 30 inches of gravel. It was concluded that fresh ground water was diluting the water in the gravel bed. (CDB)

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27. Honstead, J. F. 1957. Dispersion of dissolved material in the Columbia River. HW-49008. Hanford Atomic Products Operation, Richland Wash. 16 pp.

Abstract: Data were obtained downstream from a reactor cooling water discharge structure to permit application to semi-empirical diffusion equations. Ten traverses cf the river were made at different distances from the discharge point to collect samples of water and obtain velocity readings. Data were obtained during field surveys in 1951-1953. (CDB)

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28. Hubbell, D. W., and J. L. Glenn. 1971. Distribution of radionuclides in bottom sediments of the Columbia River. Open File Report, USGS.

Abstract: A summary analysis is made of the radioactivity distribution in the bottom of the Columbia River and McNary Reservoir. (CDB)

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29. Humphreys, L. L., and R. W. Perkins. 1963. Preliminary measurements of the adsorption of reactor effluent water radionuclides by Columbia River particulate material. HW-79279. Hanford Atomic Products Operation, Richland, Wash. 9 pp.

Abstract: This study was made to measure the approximate adsorption rates of soluble effluent water radionuclides by river water particulate material. Laboratory experiments have shown that the dilution of reactor effluents tenfold in the river results in rapid adsorption; about 25 and 40% of those adsorbed in 24 hrs are removed in one minute of contact. In this study, the fraction associated with particulates in the effluent water ranged from 0.25% (Na^{24}) to 42% (Sc^{46}). The fraction adsorbed by river water particles in one minute ranged from 0.2% (Na^{24}) to 14% (La^{140}). (CDB)

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30. Humphreys, L. L. 1964. Sediment studies: Isolation of organic material from suspended Columbia River particles, pp. 3.84-3.86. In: Annual Report for 1963. HW-81746. Hanford Atomic Products Operation, Richland, Wash.

Abstract: A density-gradient method has been applied to the separation of organic material from suspended Columbia River particles. Extent of separation is determined by "chlorophyll A" extractions. Differences in the adsorption of Co^{60}, Zn^{65}, Sc^{46}, and Cr^{51} onto inorganic and organic material were determined by gamma ray spectroscopy. (Author)

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31. Humphreys, L. L. 1964. Preliminary measurements of the adsorption of reactor effluent water radionuclides by Columbia River water particles, pp. 3.81. In: Annual Report for 1963. HW-81746. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Initial adsorption of soluble reactor effluent water radionuclides onto Columbia River water particles is rapid. In the first minute of contact, adsorption ranged from 0.2% for Na^{24} to 14% for La^{140}. This absorption is 25 to 40% of that occurring in 150 minutes. (CDB)

J

1. Jaske, R. T. 1963. Some observations of Columbia River and reservoir behavior from Hanford experience, pp. 98-100. In: Water Temperatures--Influences, Effects and Control. Proc. 12th Pacific N. W. Symposium on Water Pollution Res., Corvallis, Ore.

Abstract: A continued study of thermal aspects of the Columbia River system should form an essential part of planning to determine ultimate optimum use of the river. The General Electric Company, under contract to the Atomic Energy Commission, expects to continue a program related primarily to operational aspects of the Hanford plant. (CDB)

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2. Jaske, R. T. 1966. The use of a digital simulation model for the evaluation of the Columbia River cooling program. BNWL-SA-905, Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: This report presents a summary of previous work on heat budget analysis as applied to large lakes and rivers and discusses the development of the temperature prediction model COLHEAT. With the use of COLHEAT the Columbia River cooling program, where cooler water is released from the bottom of Lake Roosevelt, is evaluated. (CDB)

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3. Jaske, R. T. 1966. An evaluation of the use of selective discharges from Lake Roosevelt to cool the Columbia River. USAEC R&D Rept., BNWL-208. Battelle, Pacific Northwest Labs., Richland, Wash. 67 pp. plus appendices.

Abstract: This document reviews the results of the general operation of the annual Columbia River cooling program for 1963, 64, and 65. The following conclusions were reached: 1) Variations of Columbia River temperatures introduced by manipulation or alteration of the natural water course upstream persists as far downstream as Hanford. 2) Reported efforts to cool the river have been overstated, due to incorrect assumption that the spill flow is drawn primarily from the upper 5 to 10 ft of Lake Roosevelt and the accumulation of temperature data inaccuracies. 3) The existence of density currents and subsurface jet formation cannot be ignored in the development of heat budgets, such as from intermediate size projects like Wanapum, and high level discharges from Chief Joseph Project appear to minimize the transitional nature of thermal cycles. 4) A high degree of integration among flood control, power, and cooling water interests is required to minimize effects on fisheries. 5) Additional research is required to develop an optimal plan to minimize river temperatures. (from Author's Summary and Conclusions)

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4. Jaske, R. T. 1967. Columbia River hydrograph. BNWL-CC-1236. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: A standard hydrograph for the Columbia River is proposed. The hydrograph presents river water surface elevations for flows from 36,000 cfs to 800,000 cfs for the stretch from Priest Rapids to the confluence with the Yakima River. (CDB)

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5. Jaske, R. T., and J. B. Goebel. 1967. Effects of dam construction on temperatures of Columbia River. J. Amer. Water Wks. Assoc. 59(8):935-942.

Abstract:

1. The use of the Benson-Lehner data plotter with suitable least-squares fitted model functions, provides a basis for the processing of significant amounts of stream temperature and other water quality data into promptly available reports.
2. The erection of low-head reservoirs on the main stem of the Columbia River has not produced significant change in the average temperature of the river.
3. The erection of Grand Coulee Dam on Lake Roosevelt has resulted in a 30-day delay in the transport of water through the reservoir system. This delay and additional delays associated with the expected construction of the Canadian Treaty Dams, when combined, may be significant ecologically.
4. The erection of dams and reservoirs decreases expected variance in the water temperatures. The ecologic effects of changes resulting from Columbia River impoundments, including the expected reduction in effective effluent dispersion is not, however, expected to be directly comparable to projects with large storage and relatively small stream flow, such as Lake Mead or some of the TVA impoundments. In the latter cases, significantly large reductions in stream mean temperature have been reported with accompanying reductions in variance. (Author's Conclusions)

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6. Jaske, R. T. 1968. The use of digital systems modeling in the evaluation of regional water quality involving single or multiple releases. Chem. Engr. Prog., 64(90):1-9.

Abstract: This report summarizes the extensive work done to set up and calibrate the COLHEAT thermal and water quality river model. The theoretical development, data used, and program output are discussed.

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7. Jaske, R. T., and J. L. Spurgeon. 1968. A special case, thermal digital simulation of waste heat discharges. Water Resources Res., 2(11):777-802.

Abstract: This report presents an analysis of waste heat discharges on water bodies using digital models developed at Hanford. (CDB)

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8. Jaske, R. T. 1968. Thermal modification of river water quality. BNWL-719. Battelle, Pacific Northwest Labs., Richland, Wash. 21 pp.

Abstract: Analyses of water temperature data from the Columbia River indicates that: 1) The erection of hydraulic power dams and reservoirs on the Columbia River has had only nominal effect on the mean annual temperature of the entire system, less than 1°C over a 30 year period, and this might be due to long-term weather changes. 2) These projects have significantly altered the timing of the annual temperature and, to a limited extent, the seasonal extremes. The net effect is the time displacement of a relatively identical thermodynamic history. 3) The conclusion is supported that 65 to 85% of a one degree change imparted at Grand Coulee Dam persists at Hanford, and perhaps through the entire main stem. 4) The erection of Canadian dams may be expected to have considerable effect on the annual temperature cycle of the Columbia River throughout its length, possibly delays of 20 to 40 days and some reduction of critical summer and fall temperatures. (from Author's Conclusions)

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9. Jaske, R. T., W. L. Templeton, and C. C. Coutant. 1969. Thermal death models. Indust. Water Engr., Oct. 1969.

Abstract: Death models have been developed which predict the mortality and equilibrium loss of young salmon under conditions of fluctuating but lethal temperatures, such as those occurring in many industrial waste outlets. (CDB)

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10. Jaske, R. T. 1969. Columbia River temperature trends -- facts and fallacy. USAEC Rept., BNWL-SA-2536. Battelle, Pacific Northwest Labs., Richland, Wash. 22 pp.

Abstract: Careful analysis of water temperature records for the period 1937 to present leads to the conclusion that the erection of dams on the Columbia River has had little effect on the annual average temperature. Further, it appears that increases in travel time caused beneficial reductions in peak summer temperatures and increases in winter temperatures in a majority of years. The Columbia Treaty Dams, now

being completed, will have major temperature effects on the upper Columbia. Temperature reductions of 2C (3.6F) can be expected at Priest Rapids Dam during August and September of an average year. In only one year out of twenty can temperatures be expected to reach above 17C (62.6F). These effects have not been considered in the development of water quality standards, or the implementation of the planning for future power development in the Northwest. (CDB)

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11. Jaske, R. T., and D. G. Daniels. 1970. Simulation of the effects of Hanford at the Oregon-Washington border. USAEC R&D Rept., BNWL-1344. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: A series of transects taken in the summer and fall of 1969 at the Oregon and Washington border are used as the basis for checking the accuracy of the COLHEAT simulation model and the extent of stratification and mixing which occurs in the reservoir under conditions where solar thermal input is at a maximum. The model is then used to estimate the extent to which heat additions at the Hanford Plant (Columbia River Mile 382) persist to the Washington-Oregon border (River mile 308) under a range of statistically determined extreme and normal conditions expected after completion of the Columbia Treaty dams in 1975. The results show that 65% or more of the incremental addition to the temperature of the Columbia River between Priest Rapids dam and Richland is dissipated in the reach under study. The remaining 35% is only weakly related to the weather in terms of yearly variations. The study suggests the practicability of using computer simulation as the basis for management of stream standards using *in situ* stream conditions as the basis of the judgment. (Authors)

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12. Jaske, R. T., and M. O. Synoground. 1970. Effect of Hanford plant operations on the temperature of the Columbia River 1964 to present. USAEC R&D Rept., BNWL-1345. Battelle, Pacific Northwest Labs., Richland, Wash. 104 pp. plus Appendices.

Abstract: Since the initiation of operations of the Hanford plant in 1944, a continuing program of monitoring the effects of plant operation has been conducted under Atomic Energy Commission sponsorship. This report reviews salient observations from the evaluation programs in relation to other thermal modifications of the Columbia River, and is concerned primarily with temperature and other physical changes rather than radionuclides. The report attempts to compile in a single document the basic information needed to obtain a sound perspective of thermal modifications induced by the Hanford reactors. (CDB)

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13. Jaske, R. T., W. L. Templeton, and C. C. Coutant. 1970. Methods for evaluating effects of transient conditions in heavily loaded and extensively regulated streams. Chem. Eng. Progress 67(107):31-39.

Abstract: New methods for prediction of dispersion are illustrated. They include high-speed photography of intermittent dye releases by using special light filtering to enhance imagery, use of infrared imagery, computer processing of imagery, and the development of evaluation methods which are superior to Fickian diffusion models. A thermal death model that predicts the probability of damage to involuntary transient migrants through a spreading plume is described. Actual river temperature data from the Hanford nuclear production plants are used as a basis for the modelling. (CDB)

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14. Jaske, R. T., W. L. Templeton, and J. C. Sonnichsen. 1971. Improved methods for placing of thermal discharges before site acquisition with a specific case example on the Columbia River, pp. 731-755. In: Symposium on Environmental Aspects of Nuclear Power Stations, 10-14 August 1970. N. Y., IAEA, Vienna, (SM-146/46).

Abstract: The waste heat from the operation of Rankine cycle generating plants must in some way be dissipated to the environment. Freshwater streams and estuaries remain as a feasible location for such plants. However, because of the size of the thermal releases it is necessary to determine the capacity of these areas to receive heat within water quality standards without adverse effect on aquatic organisms outside control zones. In the United States of America, temperature differences as low as 0.82°C are seriously proposed as limits in estuarine circumstances. An order of magnitude improvement in our understanding of the technology of mixing and heat dispersion phenomenon appears necessary. Commencing in 1963 and continuing to the present, a highly flexible computation system COL HEAT has been developed and extended for use in estimating interrelated physical effects in estuaries and rivers with transient flow conditions. This simulation model permits detailed planning of discharges in advance for single and multiple plant locations of overlapping complexity limited only by the accuracy of the input data. To gain fuller understanding of the situation close to the point of discharge, extensive research has been conducted using a variety of physical measurement techniques. The most promising has been the use of airborne remote imagery. The system has produced state-of-the-art capabilities which permit detailed, real time measurements of two-dimensional concentration gradients in mixing areas. The application of these methods to a practical case problem was accomplished in work supporting a license application for a direct cooled reactor plant at Columbia River Mile 78 (Kalama, Wash.). The predictive needs at this site are very complex because of flow reversals.

Based on extensive field data for determining modelling coefficients applicable to the river reach, and prediction of appropriate concentration gradients for the mixed effluent, siting feasibility was recommended. In conclusion, the improved technological insight required under newly expected siting criteria in all countries demands new and improved methods for doing work. Usefulness of these new methods is not confined to the nuclear industry. (Authors)

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15. Jaske, R. T. 1972. Potential thermal effects of an expanding power industry: Columbia River Basin. USAEC R&D Rept., BNWL-1646. Battelle, Pacific Northwest Labs., Richland, Wash. 84 pp. plus Appendices.

Abstract: The once-through cooling capacity of the Columbia River basin between the International Border and Bonneville Dam (RM 146.4) was predicted for a number of weather conditions, flow management options, and upstream developments resulting from Columbia Treaty Dams. The study used the MAXPWR version of the COLHEAT simulation system to locate plants and compute thermal assimilative and dissipative capacity entirely within the Water Quality Criteria developed by the States of Washington and Oregon. Under these published criteria, some 20 GW_e of thermal plants of 31% thermal efficiency could be sited on the Columbia River above Pasco, Washington. An additional 10 GW_e could be accommodated on the middle Columbia above Bonneville Dam, but operational continuity would be interrupted without full integration of water management in that reach. The Snake River was determined to have little or no potential capacity for once-through cooling. (CDB)

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16. Johnson, T. S., F. P. Conte, and R. E. Nakatani. 1967. The effects of temperature and X-irradiation on the intestinal epithelial cells of juvenile silver salmon, pp. 159-161. In: Annual Report for 1966, Vol. 1, Biological Sciences, BNWL-480. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Cell kinetics of the intestinal epithelium of the juvenile silver salmon were shown to be temperature dependent. DNA-synthesis was temperature and X-irradiation dependent. Cell damage from irradiation was minimal at levels below 1000 R, but severe at 8000 R and higher levels. (Authors)

K

1. Knauss, H. J., and J. W. Porter. 1953. The absorption of inorganic ions by Chlorella pyrenoidosa, pp. 128-131. In: Biology Research Annual Report for 1952, HW-28636. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Using radioactive isotopes as tracers, the absorption by algae of P, Ca, S, Fe, Mn, Zn, Cu and Sr, was studied as a function of the nutrient concentration of the element in question. (Authors)

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2. Knauss, H. J., and J. W. Porter. 1954. The absorption of inorganic ions by Chlorella pyrenoidosa. Plant Physiol. 29: 229-234.

Abstract: The isotope method was used to determine the quantities of an element present in Chlorella when the nutrient concentration of that element was varied. Elements used in these studies were P, Ca, S, Fe, Mn, Zn, Cu, and Sr.

The absorption, by the algae, of all elements except P and S was directly proportional to the concentration of that element in the nutrient solution. The quantities of P and S in the algal cells were constant when the cells were grown in the higher nutrient concentrations of these elements.

A brief discussion is presented of: 1) the sources of error existent in the isotope method of determining the elemental content of algae; 2) the effect of the nutrient concentration of an element on its absorption by algae. (Author's Summary)

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3. Kramer, H. A. 1959. Artificial cooling of the Columbia River by dam regulation, Part I. HW-60285, Pt. I. Hanford Atomic Products Operation, Richland, Wash. 54 pp.

Abstract: The temperature of the Columbia River could be significantly reduced by increasing the amount of water flowing from the lower depths of Lake Roosevelt if the spill of the warmer top water could be stored. Increased generation and flow through by-pass tubes reduced temperatures by amounts up to 2.9°C (5°F). Basin climatology caused temperature rises ranging upward to 4.4°C (8°F). The cooling effect after passing through Chief Joseph reservoirs and the river reaches was calculated to be 80 percent of the initial cooling. A heat balance in BTU per square foot was derived from the sum of the insolation, and sensible heat transfer, less reflected heat, minus back radiation, less evaporation, all modified by heat storage. (Author)

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4. Kramer, H. A. 1960. Artificial cooling of the Columbia River by dam regulation - 1959. HW-65767. Hanford Atomic Products Operation, Richland, Wash. 26 pp.

Abstract: The Grand Coulee reservoir was used to reduce river temperatures at HAPO during the 1959 warm water period. Generation increases at Grand Coulee Dam provided the basic influx of colder water. Temperatures at HAPO were reduced an average of 1.014°C. Increased production was valued at $172,875, for an estimated cost of $10,000. Details of dam operation and tables of flow and temperature are given. (CDB)

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5. Kramer, H. A., and J. P. Corley. 1961. Use of Lake Roosevelt storage to lower river temperatures. HW-SA-2301. Hanford Atomic Products Operation, Richland, Wash. 20 pp.

Abstract: The reduction of Columbia River temperatures below Grand Coulee Dam by releasing cooler bottom water was envisioned in 1948. Temperature readings showed a large amount of cooling water available in Lake Roosevelt, with differentials of 8 to 20°F between top and bottom. In 1958, when Columbia River temperatures reached an all-time high, arrangements were made to use the controlled Grand Coulee spill. Dam operations and temperatures in Lake Roosevelt are described. River temperatures have been substantially reduced since the start of the program. (CDB)

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6. Kramer, H. A. 1961. Artificial cooling of the Columbia River by dam regulation - 1960. HW-68337. Hanford Atomic Products Operation, Richland, Wash. 23 pp.

Abstract: Generation levels at Grand Coulee Dam were increased 1 Aug. One to five by-pass tubes were used from 1 Aug. to 16 Aug. Temperatures were reduced during the cooling period an average of 1.22°C. Useful increases in production were achieved relative to current invoice costs of the cooperating agencies. (Author)

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7. Kramer, H. A. 1962. Artificial cooling of the Columbia River by dam regulation - 1961. HW-73707. Hanford Atomic Products Operation, Richland, Wash. 48 pp.

Abstract: Grand Coulee Reservoir was again used to reduce river temperatures at HAPO during the warm water period in 1961. Generation levels were increased 20 July. One to twelve by-pass tubes were used from 26 July to 14 Sept. Temperature reduction over the 78 day cooling

period averaged 7.7°C. Useful increases in production resulted relative to current invoice costs. Recommendations were made for continued operation. (CDB)

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8. Kramer, H. A. 1963. Artificial cooling of the Columbia River by dam regulation - 1962. HW-76887. Hanford Atomic Products Operation, Richland, Wash. 27 pp.

Abstract: Cooling occurred mostly by increased generation levels at upriver dam. Temperature reductions averaged 1.5C for the active cooling period of 69 days. (CDB)

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9. Krumholz, L. A., and R. F. Foster. 1957. Accumulation and retention of radioactivity from fission products and other radio-materials by freshwater organisms, pp. 88-95. In: The Effects of Atomic Radiation on Oceanography and Fisheries, Chapter 9. Nat'l. Acad. Sci. - Nat'l. Res. Council, Publication No. 551.

Abstract: The complex relationships of freshwater biota, together with their diverse individual anatomies, physiological processes, and life histories indicate the enormous scope of the problem in determining the role of radionuclides in metabolic processes. At this time, the available information arises primarily from studies conducted at the General Electric Company at Richland, Washington, The Oak Ridge National Laboratory at Oak Ridge, Tennessee, and studies of lesser magnitude at other AEC installations, colleges and universities. These studies are reviewed under the following topics: 1) Concentration of radioactive materials in aquatic organisms, 2) Methods of accumulation of radiomaterials by organisms, 3) Concentration of radioactive materials in different organisms, 4) Variations with season, age, and growth, and 5) Retention and elimination. (CDB)

L

1. Lappenbush, W. L., D. G. Watson, and W. L. Templeton. 1971. In situ measurement of radiation dose in the Columbia River. Health Physics 21: 247-251.

   Abstract: Through the use of lithium fluoride thermoluminescent dosimeters comparative environmental dose measurements were made in the Columbia River upstream from an atomic reactor effluent discharge site, near the point of discharge and at a location downstream from the effluent outfall. These dose estimates were related to water depth, periphyton biomass, and concentration of radionuclides in the periphyton. (Authors)

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2. Liu, D. H. W., and R. E. Nakatani. 1964. Toxicity of industrial chemicals to fish, pp. 209-211. In: Biology Research Annual Report for 1963, HW-80500. Hanford Atomic Products Operation, Richland, Wash.

   Abstract: The toxicity of nine chemical agents was evaluated to obtain estimates of critical concentrations for young chinook salmon, a cichlid, and rainbow trout. Estimates of the median lethal concentration (TLm) and "threshold indices" were calculated graphically, and a 0.1 safety factor was applied to the latter to obtain a safe river concentration. The chemicals evaluated were Sulfam-3, Bisulf-16, INHIB-7, sodium dichromate, ALK-15, ALK-14, trisodium phosphate, INHIB-30, and hydrazine-ammonia. (CDB)

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3. Lodge, J. D. 1966. Radiation survey of the Columbia River shoreline near the Hanford reactor areas. BNWL-CC-835. Battelle, Pacific Northwest Labs., Richland, Wash. 26 pp.

   Abstract: The shoreline covered extended from 100 B area to the White Bluff ferry landing. Highest radiation dose levels were found on islands opposite and below D area. Plant shore readings peaked below K and N area. A G.M. survey, aerial survey, dose rate measurements at selected sites, and gamma ray spectra measurements at selected sites were made. (CDB)

M

1. McConnon, D. 1962. Dose-rate measurements of beaches and islands on the Columbia River between Ringold and Richland. HW-72229 REV. Hanford Atomic Products Operation, Richland, Wash. 22 pp.

Abstract: Radioactive contamination levels were not much different from those in the Richland area. (CDB)

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2. Moore, D., and T. H. Essig, (eds.). 1966. Evaluation of radiological conditions in the vicinity of Hanford for 1965. BNWL-316 APP. Battelle, Pacific Northwest Laboratory, Richland, Wash. 138 pp.

Abstract: This supplemental report (to BNWL-316) is a compilation of results obtained from radiochemical analyses of environmental samples and from radiological measurements made in the Hanford environs during 1965. The radiological significance is discussed in the parent report. The topics are covered in 8 Appendices; A. Radionuclides in Columbia River water, B. Radionuclides in sanitary waste, C. Radionuclides in fish and waterfowl, D. Radionuclides in marine organisms, E. Radionuclides in the atmosphere, F. Radionuclides in farm produce and commercial foodstuffs, G. I^{131} in cattle thyroids, and H. Measurements of external radiation dose. (CDB)

N

1. Nakatani, R. E., and R. F. Foster. 1961. Damage to rainbow trout from repetitive feeding of Sr^{90}-Y^{90}, pp. 1-7. In: Biology Research Annual Report for 1960, HW-69500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Growth depression and significant mortalities were observed for rainbow trout when they were fed 0.5 μc of Sr^{90}-Y^{90}/g of fish daily for 21 weeks, but two other groups of lower treatment levels of 0.05 μc and 0.005 μc Sr^{90}-Y^{90}/g of fish did not differ from the control group. A pronounced leukopenia was observed for the high-level treatment group at the end of the test, but leukopenia was not observed for the medium group until six-months post treatment. The body burden of a 300-g trout of the medium-level group was about 310 μc at the end of the test, but no obvious damage was observed. (Authors)

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2. Nakatani, R. E. 1962. Distribution and retention of Sr^{90}-Y^{90} in trout, pp. 26-29. In: Biology Research Annual Report for 1961, HW-72500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: After trout were fed a single dose of 15 μc Sr^{90}-Y^{90}, the concentration of the isotope in various tissues was followed as a function of post-administration times. All tissues showed a sharp increase in Sr^{90}-Y^{90} concentration within the initial 24-hour period, and with the exception of bone, declined rapidly thereafter. After 16 days bone had a concentration of 0.2 μc/g which decreased to 0.05 μc/g at 100 days. The per cent of administered dose retained by trout averaged 25 per cent at 24 hours and then gradually decreased to about 4.4 per cent at 100 days. (Author)

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3. Nakatani, R. E., and W. P. Miller. 1963. Distribution of ^{65}Zn after ingestion by trout, pp. 111-114. In: Biology Research Annual Report for 1962, HW-76000. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Yearling trout fed a dose of 8.8 μc Zn^{65} at seven days post-administration showed the tissues in descending order of concentration as follows: gill filaments, spleen, kidney, bone, liver, eye, blood and muscle. Pilot tests on 30-month-old trout fed 880 mc Zn^{65} excreted less than 0.2% dose in the urine over a period of 3-4 days. The amount absorbed through the gastro-intestinal tract is estimated at 40-50%. (Authors)

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4. Nakatani, R. E., and R. F. Foster. 1963. Effect of chronic feeding of Sr^{90}-Y^{90} on rainbow trout, pp. 359-362. In: Radioecology, Proc. 1st. Nat'l Symposium on Radioecology (1961), Reinhold Publ. Comp., N. Y.

Abstract: The appropriate quantity of orally administered Sr^{90}-Y^{90} required to produce radiation damage and the syndrome involved in yearling rainbow trout was determined. Growth depressions and significant mortalities were observed when trout were fed 0.5 microcuries Sr^{90}-Y^{90} per gram of fish daily for 21 weeks, but two other groups of lower treatment levels of 0.05 microcuries and 0.005 microcuries Sr^{90}-Y^{90} per gram of fish did not differ from the control. A pronounced leukopenia was observed for the high level treatment group at the end of the test. The growth in weight of all groups with the exception of the high group was described as exponential growth during the 21 weeks.

About 25 per cent of the administered dose was retained in all treatment groups. The total body burden of a 309 gram trout in the high group was in the order of 2,200 microcuries. At the end of the test no obvious damage was observed in low and medium groups; however, six months post-treatment leukopenia was indicated in the medium group. Clinically observed effects for the high group were anorexia, weight loss, listlessness, and a diminished response to external stimuli. (Author's Summary)

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5. Nakatani, R. E. 1963. Swimming performance of chinook salmon reared in reactor effluent, pp. 219-222. In: Biology Research Annual Report for 1962, HW-76000. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Comparisons between the average swimming performance of 24 groups of young chinook salmon after the fish were reared in 0, 3, and 5% reactor effluent showed no difference when tested at a water velocity of 1.6 fps. The exponential curve, $y = (9400)(0.16)^x$ where y equals the performance time in seconds and x equals the water velocity in fps, estimates the performance of control chinooks tested at various water velocities. (Author)

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6. Nakatani, R. E., and D. H. W. Liu. 1964. Distribution and retention of Zn^{65} in trout, pp. 109-112. In: Biology Research Annual Report for 1963, HW-80500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Trout fed a single oral dose of 200 μc Zn^{65} were killed serially from 8 to 182 days post-administration to study distribution and retention. The decrease in body burden of 25 μc Zn^{65} at day 8 to about 10 μc Zn^{65} at day 182 is described by Y = 1.41 - 0.0021 X, where Y is the log μc Zn^{65} and X is the time in the days post-administration. The relatively high activity found in the gastrointestinal tract comprised over 50% of the body burden from day 85 to day 182. Further observations will continue to cover about a year. (Authors)

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7. Nakatani, R. E., and D. H. W. Liu. 1964. Swimming performance of chinook salmon reared in reactor effluent-II, pp. 205-208. In: Biology Research Annual Report for 1963, HW-80500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Swimming performance of chinook salmon at three different water velocities after being reared for 17 weeks in 3 and 6% reactor effluent with a corrosion inhibitor additive of either sodium dichromate or INHIB-7 showed no difference due to effluent concentration or type of additive. The size of fish (51-55 mm and 56-60 mm) tested emphasized the importance of size by the obviously better performance of the longer fish. The question is raised of whether within a particular size stratum the runts are poorer swimmers than fish representing the average size of a lot. (Authors)

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8. Nakatani, R. E., D. H. W. Liu, and W. J. Clarke. 1965. Effects of chronic ingestion of Zn^{65} in trout, pp. 101-106. In: Biology Research Annual Report for 1964, BNWL-122. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Three groups of rainbow trout fed Zn^{65} at a daily rate of 0.01, 0.1, and 1.0 μCi/g fish for 17 weeks differed insignificantly from control fish in mortality, clinical hematology, and histology. However, damage was indicated when fish were fed at a rate of μCi/g fish. The effective half-life for long term retention was 135 days. Trout with a body burden of 1600 μCi suffered no swimming performance decrement. Fish with more than 10,000 times the burden observed in river fish showed no effect. (Authors)

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9. Nakatani, R. E., and R. F. Foster. 1966. Hanford temperature effects on Columbia River fishes. BNWL-CC-591. Battelle, Pacific Northwest Labs., Richland, Wash. 15 pp.

Abstract: Available data indicate that the present level of heat burden introduced by Hanford operations into the Columbia River do

not create any serious damage to vulnerable salmon resources. However, the general warmer temperature regime of the Columbia River of recent years tends to favor warm water fishes and should the temperature of the lower Columbia repeatedly reach or exceed about 24C during the peak season (August and September), those runs of salmon that migrate through the river at this season may be expected to decline. Portions of the summer and fall runs of chinook salmon are enroute to their spawning grounds during the critical period and are now encountering water temperatures of about 21C. These runs are vulnerable to further increases in river temperatures. The salmon runs that enter during the spring and late fall are far less vulnerable. (CDB)

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10. Nakatani, R. E. 1966. Biological response of rainbow trout (Salmo gairdneri) ingesting zinc-65, pp. 809-823. In: Symposium on Disposal of Radioactive Wastes in Seas, Oceans and Surface Waters. Proc. 1966 Symposium, Int'l Atomic Energy Comm., Vienna.

Abstract: Zinc-65 is one of the dominant radionuclides identified in fishes sampled from the Columbia River and off the coasts of Washington and Oregon. Radiation damage has not been observed in these fish, nor is it expected, because of the extremely low levels of ^{65}Zn present. This paper reports laboratory work on the biological response of rainbow trout force-fed relatively high levels of ^{65}Zn.

After a single dose, fish rapidly excrete ^{65}Zn for several days, primarily through the gastrointestinal tract and gills. Data on the distribution and retention of ^{65}Zn in various tissues showed high concentrations in the gills, gastrointestinal tract and bone. The high concentration observed in the gills is associated with excretion. The gastrointestinal tract contained about 30 - 50% of the body burden after both chronic and single feeding. Little ^{65}Zn is excreted in the urine.

Growth, mortality, haematology, histopathology and swimming performance were studied as related to chronic ingestion levels. Groups of trout fed ^{65}Zn at a daily rate of 0.01, 0.1 and 1.0 μCi/g fish for 17 weeks differed insignificantly from controls. No deaths occurred, and growth of the ^{65}Zn-fed fish exceeded that of the controls. However, damage was indicated when fish were fed at a rate of 10 μCi/g fish for 10 weeks. Blood samples showed no anomalies in haematocrit, haemoglobin or erythrocytes, but leukopenia was indicated. Histopathologic examinations of the liver, kidney, spleen, bone, gastrointestinal tract and gills showed no evidence of tissue damage with the exception of the gill filaments. Because trout with a 10,000 times greater burden of ^{65}Zn than river fish showed no detrimental effect, there is considerable assurance that Columbia River fish populations are not adversely affected by the present levels of ^{65}Zn in the Columbia River. (Author)

11. Nakatani, R. E. 1968. Status of chinook salmon spawning in the Hanford reach of the Columbia River. BNWL-SA-1724. Battelle, Pacific Northwest Labs., Richland, Wash. 12 pp.

Abstract: This is a general article on the effects of river temperature on salmon, steelhead, etc. over the past 20 years. The threat to fish life over this period has appeared to be negligible or non-existent. (CDB)

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12. Nakatani, R. E. 1968. Biological effects of Hanford heat on Columbia River fishes - a review. BNWL-SA-1682. Battelle, Pacific Northwest Labs., Richland, Wash. 14 pp.

Abstract: See N-13.

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13. Nakatani, R. E. 1969. Effects of heated discharges on anadromous fishes, pp. 294-317. In: Krenkel, P. A. and F. L. Parker (eds.), Biological Aspects of Thermal Pollution, Vanderbilt Universtiy Press, Nashville, Tenn.

Abstract: This paper covers the following topics: 1) Hanford reactors and biological problems, 2) River temperatures, 3) Temperature effects on adults - transients and residents, 4) Temperature effects on eggs and young salmon resident in the Hanford reach, 5) Temperature effects on seaward migrants, and 6) Columnaris - a warm-water fish disease. It concludes that "A review of the laboratory and field studies concerning the biological effects of Hanford heat on salmonids shows no demonstrable evidence that the present level of heat burden introduced by Hanford reactors creates damage to our valuable salmon resources." (CDB)

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14. Nelson, I. C., and R. F. Foster. 1964. Ringold - a Hanford environmental study. HW-78262. REV. Hanford Atomic Products Operation, Richland, Wash. 16 pp.

Abstract: Radioactivity was measured in the Ringold area of the central Columbia River immediately below the Hanford plutonium reactors. Humans at Ringold were first to be tested with the whole body counter. This paper describes the Ringold area, the people who live there, and the radiological results of their examination. Only a few nuclides were detected in Ringold residents and these were present in small, acceptable amounts. (CDB)

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15. Nelson, J. L., R. W. Perkins, and J. M. Nielsen. 1964. Progress in studies of radionuclides in Columbia River sediments. A summary of Hanford achievements in this program under General Electric 1963-1964. HW-83614. Hanford Atomic Products Operation, Richland, Wash. 24 pp.

Abstract: Progress is reported on studies dealing with the behaviour of Hanford-produced radionuclides in the Columbia River, and their relation to both suspended and deposited sediments. (CDB)

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16. Nelson, J. L., and L. L. Humphreys. 1964. Sediment studies: particle size separation of bottom sediments from The McNary Reservoir of the Columbia River, pp. 381-383. In: Annual Report for 1963. HW-81746. Hanford Atomic Products Operation, Richland, Wash.

Abstract: A wet sieving particle sizing technique was used to size bottom sediments from The McNary Dam reservoir. The radionuclide contents of the size fractions are reported. (Authors)

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17. Nelson, J. L., R. W. Perkins, and W. L. Haushild. 1965. Determination of Columbia River flow times using radioactive tracers introduced by the Hanford reactors. BNWL-176. Battelle, Pacific Northwest Labs., Richland, Wash. 14 pp.

Abstract: Averaged travel time estimates are made based upon the decay of radioactive effluents introduced to the Columbia River by the Hanford reactors. These estimates are in agreement with earlier measurements made to flow times in the river between the reactor areas and the Pasco-Kennewick area. (See N-18 and N-19). (CDB)

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18. Nelson, J. L., R. W. Perkins, and W. L. Haushild. 1966. Determination of Columbia River flow times using radioactive tracers introduced by the Hanford reactors. Water Resources Res. 2(1): 31-39.

Abstract: A study of flow time of the Columbia River between Pasco, Washington and the ocean has been made using the radioactive tracers which are introduced into the river in cooling water from the Hanford Reactors. Two tracer methods were used. One used the decay of Na^{24} (15 hr.) as an index of travel time to various points downstream while the other measured the time required for a "peak" of I^{131} activity to reach these locations. The methods were also used simultaneously and showed good agreement. The data from travel time measurements at four river discharges have been plotted and extrapolated to provide estimates of travel time to any downriver point at any flow volume. (Authors)

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19. Nelson, J. L., R. W. Perkins, J. M. Nielsen, and W. L. Haushild. 1966. Reactions of radionuclides from the Hanford reactors with Columbia River sediments, pp. 139-161. In: Disposal of Radioactive Wastes into Seas, Oceans and Surface Waters. Proc. 1966 Symposium, Int'l Atomic Energy Comm., Vienna.

Abstract: On disposal to the Columbia River, effluent water from the nuclear reactors at Hanford contains many different radionuclides. These radionuclides provide numerous tracers for studying river phenomena. Among the radionuclides are activation products produced by n,γ reactions on water salts and smaller amounts of fission products resulting from fission of the trace quantities of uranium in the water. Although most of these radionuclides have such short half-lives or low abundances that they are not useful in studying river processes, ^{51}Cr, ^{65}Zn, ^{46}Sc, ^{54}Mn, ^{58}Co, ^{59}Fe, ^{60}Co, ^{95}Zr-^{95}Nb, ^{106}Ru, ^{124}Sb and ^{140}Ba are present in sufficient amounts to serve as useful tracers.

As these radionuclides are diluted and move downstream with the Columbia River water, various processes operate to remove some of each of them from solution. Some become associated with inorganic and organic suspended sediments, which either settle to the river bottom or are carried to the Pacific Ocean. The depletion, sedimentation scouring and inventory of eleven radionuclides have been studied for a 350-km reach of the Columbia River over a three-year period to show depletions of radionuclides of as much as 90% and total radionuclide inventories in the deposited sediments of about 30,000 Ci. Much of this inventory is in the McNary Dam reservoir, the first major depositional area below Hanford. A study of sediment scouring from this reservoir by the spring freshet using the ^{65}Zn/^{51}Cr ratio in suspended sediments as a measure of sediment age indicates that about 30% of the annual deposit may be moved downstream. Studies of the mechanisms of retention and release of radionuclides from the sediments indicate that the attached radionuclides are held tightly. They are not readily replaced by contact with salt solutions; sizeable fractions can, however, be removed with oxidizing agents, reducing agents and acidic solutions. Although no change in oxidation state occurs on sorption of most of the radionuclides by the sediments, ^{51}Cr is reduced from the hexavalent to the trivalent state. These findings have provided an understanding of many important processes in the Columbia River and can be extrapolated to provide predictions of radionuclide behaviour in other river systems. (Authors)

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20. Nelson, J. L., and W. L. Haushild. 1968. Accumulation of radionuclides in bed sediments of McNary Reservoir of the Columbia River. BNWL-SA-1730. Battelle, Pacific Northwest Labs., Richland, Wash. 22 pp.

Abstract: See N-21.

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21. Nelson, J. L., and W. L. Haushild. 1970. Accumulation of radionuclides in bed sediments of the Columbia River between the Hanford reactors and McNary Dam. Water Resources Res. 6: 130-137.

Abstract: Amounts of radionuclides from the Hanford reactors contained in bed sediments of the Columbia River were estimated by two methods: (1) from data on radionuclide concentration for the bed sediments between the reactors and McNary Dam, and (2) from data on radionuclide discharge for river stations at Pasco, Washington, and Umatilla, Oregon. Umatilla is 3.2 kilometers below McNary Dam. Accumulations of radionuclides in the Pasco to Umatilla reach estimated by the two methods agree within about 8%. In October 1965 approximately 16,000 curies of gamma emitting radionuclides were resident in bed sediments of the river between the Hanford reactors and McNary Dam. Concentrations and accumulations of chromium-51, zinc-65, cobalt-60, manganese-54, and scandium-46 generally are much higher near McNary Dam than they are in the vicinity of the reactors. These changes are caused by an increase downstream from the reactors in the proportion of the bed sediment that is fine grained and the proportions of the transported zinc, cobalt, manganese, and scandium radionuclides associated with sediment particles. (Authors)

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22. Nielsen, J. M. 1962. The removal of radioisotopes from the Columbia River by natural processes. NW-SA-2411. Presentation, American Geophysical Union Meeting, Washington, D.C., April 24-27. 13 pp.

Abstract: By measuring radioisotope input to the river with amounts traveling downstream, the self-purification rate can be determined. Removal in the first 40 miles downstream was about 35% for 15 of the most prominent radioisotopes. The removal rate seemed to decrease with subsequent distance for the 3 radioisotopes measured. Analyses of water, filterable solids, and sediment samples indicate that incorporation in sediments accounts for most of the removal. Sediments are deposited in significant amounts only in slack water areas. Radiochemical analyses of core samples from McNary Reservoir (Lake Wallula) for some long-lived radionuclides, including Mn^{54}, Co^{60}, Zn^{65m} and Cs^{137}, indicate a widely varying rate of deposition. Dating cores was accomplished by isotope ratio measurements. (CDB)

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23. Norton, H. T. 1957. The turbulent diffusion of river contaminants. HW-49195. Hanford Atomic Products Operation, Richland, Wash. 13 pp.

Abstract: Both theoretical and empirical approaches were pursued to define the turbulent diffusion process in the Columbia River. Merits and limitations of each approach are discussed. No solution was obtained for the diffusion equation obtained in theoretical development, but the equation's derivation is given. The empirical approach is completely outlined and gives adequate fit to available data, but cannot be extended to other conditions without additional experimental work. (CDB)

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1. Olson, P. A., Jr. 1948. Some effects of pile area effluent water on young silver salmon. HW-8944. Hanford Works, Richland, Wash. 21 pp.

   Abstract: No copy available.

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2. Olson, P. A., Jr. 1952. Observations on the transfer of pile effluent radioactivity to trout, pp. 30-40. In: Biology Research Annual Report for 1951, HW-25021. Hanford Works, Richland, Wash.

   Abstract: Snails, crayfish, and carp selectively concentrate isotopes from pile effluent water. P-32 is the bulk of the longer-lived material and is the most important isotope for radiation hazard. In fish, the greatest concentration of radioactive material is in the calcareous tissues and the least in the fat and muscle. Trout reared effluent water and fed uncontaminated food did not concentrate the longer-lived materials. The food chain is thus important in accumulation. During March when the water was 5C, the concentration factor for P-32 in liver of trout fed contaminated food was about 0.3 that in the food organisms. Livers of trout fed radioactive trout were about 25 times more active during the summer than during the cold winter months. (CDB)

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3. Olson, P. A., Jr., and R. F. Foster. 1952. Effect of pile effluent on fish, pp. 41-52. In: Biology Research Annual Report for 1951, HW-25021. Hanford Works, Richland, Wash.

   Abstract: Young chinook and young rainbow were reared in various dilutions and temperatures of pile effluent water. Eggs and fry were not affected by radioactivity or chemical toxicity of the pile cooling water in concentrations up to 10%. Concentrations of 5% effluent caused increased mortality of eggs and fry due to temperature. Dichromate caused significantly higher mortality of fingerlings in concentrations 5% or over, and a slower growth rate. Growth of salmon during the coldest parts of the year were stimulated by the warmed temperatures. (CDB)

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4. Olson, P. A., Jr. and R. F. Foster. 1952. Accumulation of radioactivity in Columbia River fish in the vicinity of the Hanford works. HW-23093. Hanford Works, Richland, Wash. 59 pp.

Abstract: The data obtained from the radioassay of fish collected in the vicinity of the Hanford Works between April 1948 and June 1950 are presented. Most of the radioactivity in the fish resulted from the concentration of P-32 in the scales, bone and certain visceral organs. The level of activity density in the fish was influenced by size, feeding habits, and metabolic rate in addition to the activity density in the water. (CDB)

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5. Olson, P. A., Jr., and R. F. Foster. 1953. Extended retention of rainbow trout in dilute reactor effluent, pp. 20-30. In: Biology Research Annual Report for 1952, HW-29636. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Rainbow trout were held in five per cent reactor effluent over a complete generation -- three years. Algae, contaminated with radioisotopes from the effluent, was fed to one group which increased their activity density. The mortality of the trout in the effluent was slightly higher among controls during the first year. Growth appeared to be slightly retarded in the effluent during the first few months, but ultimately the size of the fish was not affected. The spawning success of the trout held in the effluent was poorer than for controls. Adverse effects probably resulted from unfavorable temperature and chemical toxicity rather than radiation damage since the inclusion of the radioactive algae in one diet appeared to have no harmful result. (Authors)

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6. Olson, P. A., Jr., and R. F. Foster. 1954. Reactor effluent monitoring with young chinook salmon, pp. 24-35. In: Biology Research Annual Report for 1953, HW-30437. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Chinook salmon eggs and young were subjected to a series of dilutions of reactor influent, dechlorinated reactor influent and reactor area effluent for a period of seven months. Survival of the eggs were slightly impaired in 2 1/2 per cent effluent, probably due to unfavorable temperatures. Significant mortalities resulted with reactor influent if residual chlorine was detectable, but dechlorinated influent was not toxic until chromate addition was resumed. No effect from radioactivity was observed since only low doses were received. Extrapolation to conditions existing in the river indicates no adverse effect on young salmon of the Columbia. Juvenile rainbow trout showed similar response, slight retardation of growth, but no increase in mortality occurred in 2 1/2 per cent area effluent and in 5 per cent reactor influent. (Authors)

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7. Olson, P. A., and R. F. Foster. Reactor effluent monitoring with young chinook salmon, 1954, pp. 11-18. In: Biology Annual Research Report for 1954, HW-35917. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Chinook salmon eggs and young were subjected to a series of dilutions of dechlorinated reactor influent and reactor area effluent for a period of seven months. A slight increase in mortality occurred among the fry held in 5 per cent influent and growth was slightly retarded in the 3 per cent influent. Although a detectable mortality resulted among eggs incubated in one per cent effluent this probably resulted from a typically high temperature. More severe loss of eggs and young fish in higher effluent concentrations is attributed to unfavorably high temperature and dichromate content. The amount of radiation received was low and presumably did not contribute to the effect. Extrapolation to conditions existing in the river indicates no adverse effect on the young salmon. (Authors)

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8. Olson, P. A., and R. F. Foster. 1955. Effect of reactor area effluent water on chinook salmon fingerlings, pp. 19-23. In: Biology Research Annual Report for 1954, HW-35917. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Fingerling-size chinook salmon from Columbia River stock tolerated 10 per cent strength reactor area effluent for three and a half months before mortality rate was affected. No adverse effect was observed at the 5 per cent level even after five months -- conditions far more severe than such fingerlings would encounter in the Columbia River. Chinook fingerlings from Puget Sound stock were somewhat more sensitive to the effluent and to elevated temperature than those of Columbia River origin. Growth of the Puget Sound fish was slightly retarded in 1 per cent effluent. (Authors)

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9. Olson, P. A., and R. F. Foster. 1955. Effect of reactor area effluent water on migrant juvenile blueback salmon, pp. 24-27. In: Biology Research Annual Report for 1954, HW-35917. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Young blueback salmon, typical of those which migrate past the Hanford reactors enroute to the ocean, were exposed to dilutions of reactor area effluent water for over three months. No adverse effects were observed even at the 10 per cent level, the most concentrated mixture tested. Since young blueback salmon in the Columbia River would experience much weaker concentrations for much shorter periods of time, no hazard from the effluent is visualized for this species. (Authors)

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10. Olson, P. A., and R. F. Foster. 1956. Effect of chronic exposure to sodium dichromate on young chinook salmon and rainbow trout, pp. 35-47. In: Biology Research Annual Report for 1955, HW-41500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Young chinook salmon and rainbow trout were exposed to series of concentrations of sodium dichromate. Salmon eggs hatched successfully in the highest concentration - 0.18 ppm Cr(VI). Survival of the young salmon and trout was affected at 0.08 ppm chromium, however, and growth was possibly retarded in the low concentration of 0.013 ppm chromium. (Authors)

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11. Olson, P. A. 1956. Effect of sodium dichromate in reactor cooling water on young chinook salmon. HW-44357. Hanford Atomic Products Operation, Richland, Wash. 13 pp.

Abstract: This report compares mortality and growth of young coho salmon reared in control (declorinated) and contaminated (sodium dichromate) river water. Amounts of dichromate tested are deleted. The addition of XXX dichromate retarded growth and caused mortality. (See 0-10, 0-12 and 0-16) (CDB)

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12. Olson, P. A., and R. F. Foster. 1957. Further studies on the effect of sodium dichromate on juvenile chinook salmon, pp. 214-224. In: Biology Research Annual Report for 1956, HW-47500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Chinook salmon eggs were not affected by concentrations of sodium dichromate which are lethal to the young fish after they have hatched from the eggs. When young chinook salmon were exposed to toxic quantities of dichromate, the effect was somewhat more severe when addition of the chemical was continuous than when an equivalent amount was added intermittently. Young salmon held in water at 41 F showed less tolerance for dichromate than salmon held in the more optimum temperature of 50 F. (Authors)

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13. Olson, P. A., and R. F. Foster. 1957. Temperature tolerance of eggs and young of Columbia River chinook salmon. Trans. Amer. Fish. Soc. 85(1955): 203-207.

Abstract: A study was made on the temperature tolerance of eggs and young of chinook salmon which spawn in the main stem of the Columbia River. The control temperature followed a seasonal trend typical for the locality. It started at 57°F., reached a minimum of 36°F.,

and increased to 47°F. at the end of the test. Other experimental lots averaged about 4°F. colder and 2°F., 4°F., and 8°F. warmer than the control throughout the greater part of the test.

Significant mortality above that of the control occurred only in the warmest lot. Although about 90 percent of the eggs in this group hatched successfully, the fry and early fingerlings suffered heavy mortalities even though the mean temperature of this lot was well below 50°F. during the fingerling stage.

The results of this single experiment indicated that the eggs could begin incubation at temperatures as high as 61°F. without significant loss. (Authors)

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14. Olson, P. A. 1958. Temperature tolerance of eggs and young of Columbia River fish, pp. 211-214. In: Biology Research Annual Report for 1957, HW-53500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: A study was made on the temperature tolerance of eggs and young of Rocky Mountain whitefish which spawn in the main stem of the Columbia River. The control temperature followed a typical seasonal trend starting at 8.4 C, reaching a minimum of 2.7 C and a maximum of 18.4 C. Two other temperature conditions tested were 2 C and 3 C higher. Mortality was lowest in the control and increased at each temperature increment. (Authors)

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15. Olson, P. A., and R. F. Foster. 1958. Effect of Separan on rainbow trout. HW-55292. Hanford Atomic Products Operation, Richland, Wash. 5 pp.

Abstract: Rainbow trout were exposed to 0.035 and 0.070 ppm of "Separan" for four months. No mortality was experienced. No growth retardation was evident at the lesser concentration and only slight retardation occurred at the higher concentration. Actual concentrations of "Separan" in the Columbia River is only 1/30 of the lesser concentration. Thus no harm should be caused to fish life in the river because of the use of this material in the water plants. (CDB)

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16. Olson, P. A. 1958. Comparative toxicity of Cr(VI) and Cr(III) in salmon, pp. 215-218. In: Biology Research Annual Report for 1957, HW-53500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Young chinook salmon were exposed for 12 weeks to either 0.2 ppm Cr(VI) or 0.2 ppm Cr(III) for the purpose of comparing the relative toxicity of the two valence states. Cr(VI) was definitely toxic at this level (reduced growth and increased mortality), whereas the Cr(III) had no observable effect. (Author)

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17. Olson, P. A. 1959. Effects of variable river flow on the toxicity of reactor effluent, pp. 135-137. In: Biology Research Annual Report for 1958, HW-59500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Toxicity of reactor effluent to young salmon and whitefish was no greater when the concentration was varied throughout the day than when the concentration was held constant. Diurnal fluctuations in river flow over a 2.5 fold range should not create an effluent toxicity problem for Columbia River fish. (Author)

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18. Olson, P. A., and R. F. Foster. 1960. Effect of mode of administering P^{32} to fish, pp. 94-98. In: Biology Research Annual Report for 1959, HW-65500. Handford Atomic Products Operation, Richland, Wash.

Abstract: Continuous addition of P^{32} to the water of aquaria containing cichlids resulted in very inconsistent concentrations of P^{32} in the fish. On the other hand, reasonably consistent concentrations in the fish were achieved from ad libitum feeding of food which contained the isotope. (Authors)

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19. Olson, P. A. 1961. Effect of treatment of reactor effluent on radionuclides in fish, pp. 147-150. In: Biology Research Annual Report for 1960, HW-69500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Treatment of reactor effluent water by passage through beds of aluminum turnings was effective in reducing the P-32 content of fish by more than 50%. (CDB)

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20. Olson, P. A., and R. E. Nakatani. 1962. Reactor effluent monitoring with salmon, 1960-1961., pp. 144-147. In: Biology Research Annual Report for 1961, HW-72500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Comparisons of the mortality and growth between groups of young chinook salmon reared in concentrations of 0, 4, and 8 per cent reactor effluent water showed significantly greater mortality in the 8 per cent group, but not between the 4 and 0 per cent groups. The accelerated growth rate of the 4 and 8 per cent groups is attributed to the elevated water temperatures. (Authors)

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21. Olson, P. A., and M. P. Fujihara. 1963. Incidence and virulence of Columnaris-II, pp. 223-226, In: Biology Research Annual Report for 1962, HW-7600. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Sampling of salmon in the Columbia River indicated that C. columnaris was widely distributed. Juvenile rainbow trout grown in the laboratory in river water showed peak mortalities within four weeks of the first identification of the disease. Peak mortality was not correlated with maximum water temperature. Ten-month-old salmon tested for susceptibility to columnaris showed no relationship between size of individual fish and resistance to the disease. (Authors)

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22. Olson, P. A., and R. E. Nakatani. 1963. Reactor effluent monitoring - 1962, pp. 211-214. In: Biology Research Annual Report for 1962, HW-76000. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Chinooks reared for 11 weeks in 0, 3, 5, and 7% effluent showed growth inhibition due to effluent. This inhibition is attributed to the presence of dichromate. Significantly higher mortalities were observed for the 5 and 7% effluent groups but not for the 3%. (Authors)

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23. Olson, P. A., and R. E. Nakatani. 1965. Reactor effluent monitoring - 1964, pp. 198-201. In: Biology Research Annual Report for 1964, BNWL-122. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Comparisons between groups of chinook fingerlings reared in regular and cooled reactor effluent showed the importance of the accumulative effect of small temperature increments. Higher mortalities were observed in the present studies with local stock chinooks than in past studies with Puget Sound chinooks, due, perhaps, to physiological differences in racial stocks. (Authors)

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24. Olson, P. A. 1966. Reactor effluent monitoring - 1965, pp. 132-133. In: Annual Report for 1965, Biological Sciences, BNWL-280. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Young chinook salmon were reared in 0, 2 and 4% reactor effluent at three different temperatures to determine effect on mortality, growth and uptake of radionuclides. There was no significant effect of temperature or effluent concentration on mortality, but warmer waters accelerated growth regardless of effluent concentration. The radionuclides detected in whole fish were related to effluent concentration, but not to temperature. (Author)

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25. Olson, P. A. 1967. Reactor effluent monitoring: Comparison of Puget Sound and Priest Rapids chinook salmon, pp. 180-181. In: Annual Report for 1966, Vol. I, Biological Sciences, BNWL-480. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Chinook salmon of Puget Sound and Priest Rapids stock were reared in 0, 2, 4, and 6% reactor effluent. Local chinook tolerated effluent levels up to 6% without adverse effects from the egg to the migration stage. No marked racial differences were evident between Puget Sound and local chinook stocks in terms of mortality, growth and accumulation of radionuclides. (Author)

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26. Olson, P. A., and R. E. Nakatani. 1968. Effect of elevated temperatures on mortality and growth of young chinook salmon, pp. 9.3-9.5. In: Annual Report for 1967, Vol. I, Biological Sciences, BNWL-714. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Chinook salmon spawned between October and December were reared under seven temperature regimes, each following the Columbia River's seasonal pattern, but differing by 2 °F increments. Temperatures more than 4 °F above normal river temperature resulted in excessive mortality in the October spawn, but only nominal mortality resulted from a 12 °F increase in the December spawn. All lots showed faster growth in warmer waters. (See 0-20) (Authors)

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27. Olson, P. A., and R. E. Nakatani. 1969. Effects of variable water temperatures on survival and growth of young chinook salmon, pp. 2.35-2.38. In: Annual Report for 1968, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1050. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Chinook salmon spawned November 2 were reared under six temperature regimes following the Columbia River's seasonal pattern and expressing different rates of heating on a cumulative weekly basis during the early part of the developmental period. Constant temperature increment of 2.5 °C above base river temperatures tended

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to cause slightly increased mortalities. However, when this increment was added by five cumulative weekly increments of 0.5 °C after spawning, it was not damaging. An eventual 5 °C increment above base river temperatures tended to produce no increased mortality in the majority of spawns when added by 20 cumulative weekly increments of 0.25 °C. However, some increased mortality resulted when this 5 °C addition was added by weekly increments of 0.5 °C for 10 weeks. All lots showed faster growth in warmer waters. (See 0-20) (Authors)

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28. Olson, P. A. 1970. Effects of fluctuating temperatures on fall chinook eggs and young, pp. 3.15-3.16. In: Annual Report for 1969, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1306. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: The effect of periodic fluctuating temperatures above and below a mean reference temperature using two lots of chinook salmon was investigated. Similar mean temperatures and incremental variations of 0, 1.1, 2.2, and 3.3 C were used. The entire range of fluctuating temperatures tested resulted in no adverse mortalities or growth over non-fluctuating conditions. Lot. No. 2 had a higher mortality than Lot. No. 1 because of egg infertility. In all cases, increased temperatures resulted in larger fish. (CDB)

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29. Olson, P. A., R. E. Nakatani, and T. Meekin. 1970. Effects of thermal increments on eggs and young of Columbia River fall chinook. USAEC R&D Report, BNWL-1538. Battelle, Pacific Northwest Labs., Richland, Wash. 56 pp.

Abstract: Four series of spawn from adult chinook salmon taken from Oct.-Dec. were reared for 177 days. Lots within series were held at elevated temperatures differing at intervals of 2F, for a test range of 12F. The coldest (central) temperature paralleled the Columbia River's normal seasonal pattern of decrease during the fall. Successively later series tolerated greater thermal increments. Temperatures 7F above river temperatures resulted in excessive mortality in Series I (spawned Oct. 30) and 12F resulted in total mortality. However, a 12.5F increment in Series IV (spawned Dec. 8) produced a mortality of only 12.4, well within the range of normal hatchery production. Mortality pattern and time of mortality were related to lethal temperature levels.

Exposure to sublethal temperatures resulted in accelerated growth rates, with a 2F increment increasing growth by a factor of 1.4 X. It was concluded that developmental stages of fall chinook can safely withstand higher thermal levels during winter when river temperatures are low, and that elevated temperatures favor eggs and fry survival of the late spawners. (CDB)

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30. Olson, P. A. 1970. Effects of temperature increments on juvenile steelhead, p. 3.16. In: Annual Report for 1969, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1306. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Juvenile steelhead were reared at an average of 0.8 gms per fish of weight. Test groups were held at ambient Columbia River temperatures and thermal increments of 1.7, 2.2 and 2.6C. Maximum river temperatures occurred from mid-August to mid-September, with an average of 21.1C daily temperatures in the warmest groups and maximum temperatures slightly over 22.7C. Maximum summer temperatures slowed fish growth in the warmest lots, but the growth of these fish was favored during the colder months of the year. (See 0-22) (CDB)

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31. Olson, P. A., and W. L. Templeton. 1970. Effects of temperature increments on juvenile steelhead. BNWL-SA-3719. Battelle, Pacific Northwest Labs., Richland, Wash. 9 pp.

Abstract: Young steelhead were reared in water with temperatures elevated 3, 4 and 5F above ambient Columbia River levels. High summer temperatures slowed the rate of growth of incremental groups, but growth of these groups were favored during the winter. At termination, fish reared at the three elevated temperatures were significantly larger than the controls, but there was no significant difference between them. (See 0-32) (CDB)

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32. Olson, P. A., E. G. Tangen, and W. L. Templeton. 1971. Effects of temperature increments on juvenile steelhead. In: D. E. Nelson (ed.), Radionuclides in Ecosystems, Proc. 3rd Nat'l Symposium on Radioecology, Oak Ridge, Tenn., May, 1971. (In Press).

Abstract: Young steelhead were reared in Columbia River water at ambient and elevated temperatures (ΔT 1.7, 2.2 and 2.6 °C) for 18 months. Fish reared at elevated temperatures were significantly heavier than those reared at ambient, but there was no significant differences between weights of the incremental groups. Temperatures did not appear to increase mortality during the first 12 months, but higher losses are suggestive in the two warmest groups during the final six months. (CDB)

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33. Olson, P. A., and E. G. Tangen. 1971. Effects of temperature increments on juvenile steelhead, pp. 2.22-2.33. In: Annual Report for 1970, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1550. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: This reports a continuation of studies began in July 1969. Maximum temperatures during the summer of 1970 again slowed growth rates in the warmest groups. With decreasing temperatures of fall, growth in the highest temperature group increased in comparison with the coldest. On Oct. 1, 1970 the average weight of surviving fish in four groups were 187.8 (control), 201.3 (plus 3F), 206.5 (plus 4F), and 185.5 (plus 5F) grams, respectively. Mortalities were not correlated with temperature but with columnaris disease. (CDB)

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34. Owen, B. B., Jr. 1971. Columbia River periphyton communities under thermal stress, pp. 2.19-2.20. In: Annual Report for 1970, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1550. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Studies were conducted of periphyton development in five experimental channels receiving normal river water (control) and elevated temperatures of 2.5, 5.0, 7.5 and 10.0 C, respectively. Standing crops and pigment content of mature communities did not differ significantly among streams on any collection date, regardless of temperature level. However, data on seasonal colonization indicate that the rate of growth or colonization was directly related to temperature. (CDB)

P

1. Palmer, R. F. 1957. Accumulation of radioisotopes in rats chronically exposed to reactor effluent water, pp. 209-211. In: Biology Research Annual Report 1956, HW-47500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: A study is described which was designed to give a biological measure of the potential hazard of radioisotopes contained in reactor effluent water, under chronic exposure conditions. The P^{32} concentration in bone was higher than that of any other of the radioisotopes measured. (Author)

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2. Palmer, R. F. 1958. Radioisotopes in rats exposed to reactor effluent water, pp. 189-190. In: Biology Research Annual Report for 1957, HW-53500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: This experiment, which involved the chronic feeding to rats of concentrated effluent water from Hanford reactors, was described, together with preliminary results, in the previous Annual Report (1957). The subsequent availability of a gamma ray spectrometer permitted measurement of the Zn^{65} content of bone and soft tissue from two of the experimental animals. The average concentration of this isotope in bone at the time of sacrifice was 0.1×10^{-4} μc/g, and in soft tissue, 1.1×10^{-4} μc/g. These concentrations were higher than those of any other radioelement measured. (Author)

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3. Pauley, G. B. 1967. Freshwater mussels with pedunculated adenomas, pp. 191-193. In: Annual Report for 1966, Vol. I, Biological Sciences, BNWL-480. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Of 40 freshwater mussels examined, four were found to possess a total of 14 tumors, all arising from the foot. The neoplasms closely resemble the pedunculated adenomas or polyps commonly observed in the human colon. (Author)

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4. Pauley, G. B. 1967. Four freshwater mussels (*Anodonta californiensis*) with pedunculated adenomas arising from the foot. J. Invet. Pathol. 9(4): 459-466.

Abstract: See P-3.

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5. Pauley, G. B., and R. E. Nakatani. 1967. Zinc-65 metabolism in freshwater mussels, pp. 174-176. In: Annual Report for 1966, Vol. I, Biological Sciences, BNWL-480. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Zinc-65 was accumulated in the following tissues of the freshwater mussel, listed in descending order of concentration: gills; mantle and palps; body mass, including the digestive gland, digestive tract, and gonad; adductor muscles; and foot. (Authors)

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6. Pauley, G. B., and R. E. Nakatani. 1967. Histopathology of "gas-bubble" disease in salmon fingerlings. J. Fish. Res. Bd. Canada 24(4): 867-871.

Abstract: Chinook salmon fingerlings were diagnosed as having "gas-bubble" disease. Gross symptoms were similar to those described by other investigators. The histopathology associated with this disease has not been previously reported. The following 10 tissues and organs were examined: gills, liver, spleen, heart, kidney, intestine, stomach, roof of the mouth, skin, and muscle. All exhibited histopathological changes with the exception of the hearts and stomachs, which did not differ from the control fish. The most striking pathological changes occurred in the roof of the mouth of all fish examined. (Authors)

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7. Pauley, G. B., and R. E. Nakatani. 1967. The uptake of the radioisotope ^{65}Zn by various tissues of the freshwater mussel, *Anodonta californiensis* Lea. Proc. Nat'l Shellfisheries Assoc. 57: 7-8.

Abstract: The total body burden of ^{65}Zn was approximately linear to the amount of radioisotopes in the test environment. After 36 days and with exposures of 100 μCi/ℓ of ^{65}Zn, the average total body burden was about 100 μCi. Tissues accumulated ^{65}Zn in the following order: 1) gills, 2) mantle and palps, 3) body mass, 4) aductor muscles, and 5) foot. (CDB)

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8. Pauley, G. B. 1968. Tumor incidence among freshwater mussel populations, pp. 9.33-9.34. In: Annual Report for 1967, Vol. I, Biological Sciences, BNWL-714. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Several populations of freshwater mussels were examined for the presence of neoplasms. The lowest incidence observed was 4.2% and the highest was 15.7%. The majority of the growths were found on the foot of the animals. (Author)

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9. Pauley, G. B., and C. D. Becker. 1968. Aspidogaster conchicola in molluscs of the Columbia River system with comments on the host's pathological response. J. Parasitol. 54(5): 917-920.

Abstract: Infections of Aspidogaster conchicola (Aspidogastridae) are reported in three species of freshwater mussels (all Unionidae) in the Columbia River and one of its tributaries, the Yakima River, near Richland, Washington. Infections in Anodonta californiensis Lea and A. oregonensis Lea were restricted to the renal and pericardial cavities, and renal metaplasia was a typical host response. In Gonidea angulata (Lea), the parasite also became encapsulated in various tissues of the body and foot where it induced a marked hemocyte infiltration into the surrounding tissues. This is the first record of A. conchicola from the Pacific Northwestern States and in the molluscan hosts listed. (Authors)

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10. Pendleton, R. C. 1958. Absorption of Cs^{137} by an aquatic community, pp. 35-43. In: Biology Research Annual Report for 1957, HW-53500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Concentration factors for bioaccumulation of Cs^{137} by aquatic organisms range from 50 to over 10,000 times that of water. This high bioaccumulation suggests that the principal route through which Cs^{137} in hazardous amounts could reach man is via aquatic food organisms, and disposal of Cs^{137} at MPC levels for drinking water will presumably produce hazardous levels of contamination in aquatic organisms which may be consumed by man. (Author)

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11. Pendleton, R. C., and W. C. Hanson. 1958. Adsorption of cessium-137 by components of an aquatic community, pp. 419-422. In: Proc. 2nd Int'l Conference on Peaceful Uses of Atomic Energy, Vol. 18, Geneva, Switzerland, Sept. 1-14.

Abstract: The study demonstrated that plants exposed to Cs^{137} in an aquatic environment accumulated the isotope at least 500 times as much as reported for plants grown in soils. Animals feeding on these plants have a richer source of the isotope and become proportionately more contaminated than those receiving their food through terrestrial food chains. (CDB)

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12. Pendleton, R. C. 1959. Effects of some environmental factors on bioaccumulation of cessium-137 in an aquatic community, pp. 42-46. In: Biology Research Annual Report for 1958, HW-59500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Algae, submerged seed plants, grass, fish and amphibians changed Cs^{137} contamination levels in response to temperature variations. Shading reduced uptake by submerged plants and emergent plants rooted in gravel accumulated more Cs^{137} than those rooted in mud. Contamination levels in all organisms decreased because of loss to bottom mud and dilution by increased biomass. Highest contamination generally occurred in the highest trophic levels. (Author)

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13. Pendleton, R. C., and R. L. Uhler. 1960. Accumulation of cessium-137 by plants grown in simulated pond, wet meadow, and irrigated field environments. Nature 185(4714): 707-708.

Abstract: The calculated uptake ratio for plants grown in a shallow pond was 450; in a wet meadow, 30; and in an irrigated field, 1.0. (CDB)

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14. Perkins, R. W. 1959. Zinc-65 in foods and people. Science 129(3341): 94-95.

Abstract: Disposal of trace amounts of Zn^{65} is made in the Columbia River via Hanford reactor effluent water. The subsequent utilization of river water for irrigation permits the concentration of this radioisotope in farm products and eventually in man. The Zn^{65} in irrigation water, in farm produce, and in individuals utilizing these materials has been measured. (Author)

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15. Perkins, R. W. 1960. Radiochemical analyses of reactor effluent waste materials at Hanford. Talanta 6: 117-132.

Abstract: Analytical procedures are described that were found suitable for the measurement of radioisotopes in effluent water and in erosion products. The procedures were applied following start-up of a reactor to study changes in concentration of isotopes in effluent water, and to identify and measure isotopes deposited on metal surfaces during operation. Quantitative and qualitative data are provided. (CDB)

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16. Perkins, R. W. 1964. Columbia River sediment and transport studies, pp. 3.86-3.94. In: Annual Report for 1963. HW-81746. Hanford Atomic Products Operation, Richland, Wash.

Abstract: A current project, in cooperation with the U.S. Geological Survey, is to study transport of radionuclides in the Columbia River as well as adsorption, sedimentation, translocation, and uptake by inorganic

and organic detritus. This report gives a brief description of the more general observations of the study, as regards the radionuclide concentration in suspended and bottom sediments. (CDB)

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17. Perkins, R. W., J. L. Nelson, and W. L. Haushild. 1965. Behavior and transport of radionuclides in the Columbia River and the ocean. BNW-SA-16. 25th Ann. Soc. Limnol. Oceanog., Washington, D.C., June 14-17.

Abstract: See P-18.

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18. Perkins, R. W., J. L. Nelson, and W. L. Haushild. 1966. Behavior and transport of radionuclides in the Columbia River between Hanford and Vancouver, Wash. Limnol. Oceanog. 11(2): 235-248.

Abstract: A study of the behavior and transport by the Columbia River of the eleven radionuclides ^{46}Sc, ^{51}Cr, ^{24}Mn, ^{68}Co, ^{59}Fe, ^{60}Co, ^{65}Zn, ^{95}Zr-^{95}Nb, ^{106}Ru, ^{124}Sb, and ^{140}Ba was carried out in the research between Pasco and Vancouver, Washington, during the period January 1964 through January 1965. This study was accomplished by direct counting of water salts and filter samples on a multidimensional gamma-ray spectrometer and represents the first measurements of the interactions of most of these radionuclides in the river. Through this sample tracer technique, the specific and relative behaviors of these radionuclides in regard to their sorption by and movement with suspended particulate matter in the Columbia River were determined. Depletion of these radionuclides from the river during transport and the radionuclide inventory in the stream bed for the river reach between Pasco and Vancouver were also estimated. (Authors)

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19. Porter, J. W., and H. J. Knauss. 1953. Inhibition of growth of Chlorella pyrenoidosa by beta-emitting radioisotopes, pp. 110-116. In: Biology Research Annual Report for 1952, HW-28636. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Algae were grown in the presence of H_2^3O, P^{32}, Sr^{90}-Y^{90} and S^{35}. Growth rates were decreased in proportion to the radiation dosage. The reduced rate of growth was maintained on subculture in non-radioactive media. (Authors)

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20. Porter, J. W., and H. J. Knauss. 1954. The effects of tritium oxide on some synthetic processes of Chlorella pyrenoidosa, pp, 73-76. In: Biology Research Annual Report for 1953, HW-30437. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Chlorella previously grown in inorganic media containing tritium oxide were subcultured in media containing C^{14}-labeled bicarbonate. Incorporation of C^{14} into fatty acids was markedly increased in the previously irradiated cells. Nucleic acid synthesis was also increased, and chlorophyll a synthesis decreased. Further experiments with C^{14}-labeled acetate indicate certain similarities in the metabolic behavior of previously irradiated algae and algae growing in organic media. (Authors)

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21. Porter, J. W., and M. S. Watson. 1954. Gross effects of growth-inhibiting levels of tritium oxide on Chlorella pyrenoidosa, pp. 71-72. In: Biology Research Annual Report for 1953, HW-30437. Hanford Atomic Products Operation, Richland, Wash.

Abstract: The mass of cells formed at the end of three days' growth in the presence of tritium oxide, and at the end of three days' subsequent growth in subculture in non-radioactive nutrient solution, was an inverse function of the amount of irradiation received by the cells. When irradiated cells were subcultured repeatedly in non-radioactive nutrient solution, it was found that the culture returned to the same growth rate as the control. Cells grown three days in the presence of 5 mc/ml of tritium oxide required one subculture of three days to return to normal growth rate, whereas those grown three days in the presence of 15 mc/ml of tritium oxide required two subculture periods. (Authors)

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22. Porter, J. W., and H. J. Knauss. 1954. Inhibition of growth of Chlorella pyrenoidosa by beta-emitting radioisotopes. Plant Physiol. 29: 60-63.

Abstract: 17 Chlorella pyrenoidosa cells were grown for 3 days in the presence of several levels of H_2O, P^{32}, Sr^{90}-Y^{90}, and S^{35} and then subcultured for 3 days in nonradioactive inorganic nutrient solution. Growth rates of cells were decreased in proportion to the dose of radiation received above levels of approximately 1000 rep/day. The reduced rate of growth continued in subculture with time (for the 3-day period) as a function of the dose received. An increase in the average cell size also occurred during the growth of the algae in the radioactive solutions. The results reported do not allow a deduction of the specific site of action of the ionizing radiations on the algae. However, several possible modes of action consistent with the reported results are discussed. (Authors)

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23. Porter, J. W., and M. S. Watson. 1954. Gross effects of growth-inhibiting levels of tritium oxide on Chlorella pyrenoidosa. Amer. J. Botany 41(7): 550-555.

Abstract: Studies were made of the effect of ionizing radiations from tritium oxide on the rates of growth and cell division, cell viability, genetic stability and the ability of Chlorella cells to synthesize the membrane-permeable substances present in yeast extract and bacto-peptone. The effect of the beta radiations on cell division and growth was slight during the first day of growth, but thereafter the extent of inhibition, in relation to controls, became progressively greater. The effect continued in subculture in nonradioactive solution, and the total effect was dose dependent. The effect on cell division was greater than the effect on growth, and this finding was substantiated by a small, but definite, increase in average diameter of irradiated cells. Many cells (70 percent of those grown 3 days in the presence of 20 mc/ml H_2^3O) failed to form colonies on inorganic nutrient agar. Growth assays showed that these cells were not dead when plated, but died after plating. Survival of irradiated cells could not be increased by supplying the cells with organic nutrients. Hence it is concluded that the processes of photosynthesis and biosynthesis of the substances present in yeast extract and bacto-peptone are not selectively damaged by ionizing radiations. An appreciable number (25 percent) of selections obtained from colonies derived from cells surviving irradiation with tritium oxide grew much more slowly than control cultures in inorganic nutrient solution. One selection, however, was a biochemical mutant for it grew as rapidly in organic solution as controls, but only 1/8 as rapidly in inorganic nutrient, when repeatedly subcultured. Others of the surviving cells formed rough or yellow colonies, or clumped when grown in nutrient solution, but the majority appeared no different from colonies of unirradiated cells. The results reported herein emphasize the time course of action of ionizing radiations and the subsequent major effect, death of many of the cells. (Author's Summary)

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24. Porter, J. W., and H. J. Knauss. 1954. The effect of tritium oxide on some synthetic processes of Chlorella pyrenoidosa. Radiation Res. 1(3): 253-261.

Abstract: Chlorella were grown for 3 days in the presence of 20 mc/ml of tritium oxide. Then the cells were grown for 30 hours in non-radioactive inorganic nutrient solution in the presence of tracer quantities of C^{14} bicarbonate.

The cells were fractionated into several gross fractions and aliquots were picked and counted for radioactivity. C^{14} contents in each fraction were compared with those in identical fractions of unirradiated control cells.

Irradiated cells synthesized 2-7 times as much triglycerides as did control cells. The irradiated cells also incorporated more C^{14} into the nucleic acid fraction and less into the chlorophyll a fraction, than did unirradiated control cells. (Author's Summary)

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25. Porter, N. S., N. C. Hoitink, and C. E. Cushing. 1966. Measurement of radionuclide uptake by algae, p. 159. In: Proc. 19th Ann. Conf., Engr. in Medicine and Biology, San Francisco.

Abstract: A system using in situ radiation detectors, with counting instrumentation, and providing for a flow of water over sessile algae, was used to provide data on mineral cycling in the Columbia River. This paper provides a brief description of the system with emphasis on detection and measurement techniques. Preliminary instrument specifications of a detection limit at least 10^4 times the natural river background levels for Zn^{65} and P^{32} were bettered by a factor of three. (CDB)

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26. Prentice, E. F. 1969. Gull predation in a reactor discharge plume, pp. 2.33-2.34. In: Annual Report for 1968, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1050. Battelle, Pacific North-West Labs., Richland, Wash.

Abstract: Gulls actively feed in the K-reactor outfall area of the Columbia River in the fall of the year. Observational and stomach analysis data have not yet positively identified the prey species. No differences have yet been shown between stomach contents obtained at the K-outfall and at the Vernita Bridge area of the Columbia. (Author)

R

1. Robeck, G. C., C. Henderson, and R. C. Palange. 1954. Water quality studies on the Columbia River. Special Report, U.S. Public Health Service, R. A. Taft Sanit. Engr. Center, Cincinnati, Ohio. 294 pp.

Abstract: Study of the Columbia River and its tributaries extended from the spring of 1951 to the spring of 1953. Most of the work was confined to the area between Priest Rapids and Paterson, a section which includes the Hanford Works of the Atomic Energy Commission and McNary Reservoir, an impoundment placed in operation in late 1953. Limited studies were also made in Roosevelt Lake, Bonneville Reservoir, and the areas around Portland and Astoria, Oregon.

The principal objectives were to determine: (a) the water quality characteristics of the stream prior to impoundment and (b) effects of radioactivity on the physical, chemical, and biological characteristics of surface waters. The studies have also provided data which can be used to establish stream sanitation objectives for developing comprehensive water pollution control programs and provided an opportunity for scientists to obtain experience in stream surveys where radioactive wastes are involved. The data obtained are presented in detail. (CDB)

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2. Robertson, D. E., W. B. Silker, and J. C. Langford. 1972. Radionuclide decline in Columbia River water. In: Annual Report for 1971, Vol. 1, Life Sciences, Part 2, Ecological Sciences, BNWL-1650. Battelle, Pacific Northwest Labs, Richland, Wash.

Abstract: The radionuclide depletion processes in the Columbia River are being characterized following the closure of the Hanford reactors. Residual radioactivity is associated mainly with sedimentary deposits behind McNary Dam. The most abundant radionuclides are ^{55}Fe, ^{65}Zn, ^{46}Sc, ^{155}Eu, ^{60}Co, ^{152}Eu and ^{154}Eu. These radionuclides are bound to the sediments and enter the river by sediment resuspension and dissolution into soluble forms. The main mechanism for depletion of radioactivity from the river, other than radioactive decay, is by scouring of surface sediments during high river flow, and their subsequent transport into the Pacific Ocean. It appears that eventually the radioactive sediment deposits behind McNary Dam will become covered by new, uncontaminated silt deposits. The high fraction of radionuclides in the particulate form in Columbia River water changes their availability for biological uptake. (Authors)

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3. Rose, F. L., and C. E. Cushing. 1970. Periphyton: autoradiography of zinc-65 adsorption. Science 168: 576-577.

Abstract: The major site of sorption of zinc-65 in natural matlike periphyton is on the upper surface of the community. There is a diffusion gradient within the community. Expression of results from short-term spiking experiments should thus be presented on an areal rather than gravimetric basis. (CDB)

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4. Rostenbach, R. E. 1955. Temperature of the Columbia River between Priest Rapids, Washington and Umatilla, Oregon. HW-39347. Hanford Atomic Products Operation, Richland, Wash. 49 pp.

Abstract: Columbia River temperature data for the period 1944-1955 have been summarized. The Snake River has a considerable influence on the temperature of the Columbia, especially during the critical summer months. The surface water of McNary Reservoir immediately above the dam did not become generally warmer than the bulk of the reservoir until May 1955, in the Nov. 1954 to Sept. 1955 period. Flow relation ships of the Columbia and Snake Rivers are described. Natural climatic and river conditions cause greater temperature variations in the Columbia River than do the Hanford Reactor effluents. (CDB)

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5. Routson, R. C., and R. E. Wildung. 1972. Methods for the characterization of suspended sediment and selected applications for the acquired data. BNWL-SA-4385. Presentation: Nat'l Highway Res. Bd., Nat'l. Acad. Sci., Madison, Wisc., Aug. 2.

Abstract: Analytical methods have been developed, from studies on the Central Columbia River, to acquire data necessary to develop predictive models of sediment and sorbed pollutant transport. Methods include: 1) isolation of suspended sediment from water, 2) determination of the quantity of suspended sediment, 3) determination of particle-size distribution and separation into particle-size fractions, 4) mineralogical analyses, and 5) characterization of surface chemistry. Use of acquired sediment data from the Columbia River transport model development is discussed. Selected applications for predictive models are given. (CDB)

S

1. Schiffman, R. H. 1959. The uptake of strontium from diet and water by rainbow trout, pp. 16-19. In: Biology Research Annual Report for 1958, HW-59500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: The concentration (μc/g) of Sr^{90}-Y^{90} in trout approached about 1.5 times the concentration (μc/ml) in the surrounding water in three weeks. Approximately 21 percent of the isotope administered in gelatin capsules was retained after one day but when incorporated into natural food, the retention was only about 7 percent. Fish which ingested 0.24 μc Sr^{90}-Y^{90} each day evidenced damage to the gut. (Author)

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2. Schiffman, R. H. 1960. Effects of intramuscular injections of Sr^{90}-Y^{90} on rainbow trout, pp. 56-58. In: Biology Research Annual Report for 1959, HW-65000. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Fish intramuscularly injected twice a week up to 1.5 x 10^{-2} μc Sr^{90}-Y^{90}/g of body weight gave no evidence of growth response or effect on mortality. Weight variability in the medium and high levels of injection did increase, however. There was no pathological evidence of damage to the gastrointestinal tract. (Author)

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3. Schiffman, R. H. 1960. A technique for measuring movement of isotopes across gill membrane, pp. 161-164. In: Biology Research Annual Report for 1959, HW-65000. Hanford Atomic Products Operation, Richland, Wash.

Abstract: A method of perfusing the gill of a teleost fish is described. Using this method to determine the influx and outflux of Sr^{85} showed the rates to be 1.3 x 10^{-5} cm/sec and 5.2 x 10^{-8} cm/sec, respectively. These rates indicate an outflux of Sr^{++} will occur against a concentration gradient. (Author)

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4. Schiffman, R. H. 1961. The uptake of strontium from diet and water by rainbow trout. HW-72107. Hanford Atomic Products Operation, Richland, Wash.

Abstract: The concentration (μc/g) of Sr^{90}-Y^{90} in trout approached about 1.5 times the concentration (μc/ml) in the surrounding water in three weeks. Approximately 21 percent of the isotope administered in gelatin capsules was retained after one day, but when the isotope was incorporated into natural food, the retention was only about

7 percent. It was inferred that under the conditions of the experiment, uptake from the environmental water was greater than uptake through the food chain. (Author)

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5. Schiffman, R. H. 1961. A perfusion study of the movement of strontium across the gills of rainbow trout (Salmo gairdnerii). Biol. Bull. 120(1) : 110-117.

Abstract: A perfusion technique for the study of transport across the intact gill of rainbow trout is described. It was found that the outflux rate of 1.6×10^{-6} cm/sec was greater than the influx rate of 5×10^{-8} cm/sec for strontium, and that strontium would go out of a fish gill against a concentration gradient under these experimental conditions. (Author's Summary)

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6. Schiffman, R. H. 1961. Preliminary studies on the elimination of strontium by trout, pp. 81-86. In: Biology Research Annual Report for 1960, HW-69500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: A method to evaluate the pathways of strontium excretion from rainbow trout was developed. Results of two experiments indicate that 6 to 7 percent of the injected dose is in the urine, 3 to 4 percent in the gut, and 50 to 75 percent remains in the fish after 22 hours. This would infer that 15 to 40 percent of the injected dose is transported out of fish via the gills and/or the skin. (Author)

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7. Schiffman, R. H. 1962. Movement of strontium across the gill of trout, pp. 23-25. In: Biology Research Annual Report for 1961, HW-72500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: A perfusion technique was used to determine the effect of calcium, phosphate, and pH on the influx rate os strontium across trout gills. The strontium influx was not affected by varying the calcium concentration in the external medium. Phosphate on either side of the gill caused an increased influx rate that was decreased by 2, 4-dinitrophenol thus suggesting strontium is actively transported. As pH increased the strontium influx rate decreased. (Author)

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8. Schneider, M. J. 1970. Physiology of gas bubble disease, pp. 3.24-3.25. In: Annual Report for 1969, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1306. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: The initial phase of the present project attempts to determine the composition of blister gas by gas chromatography. Probable cause of death in fish is blockage of circulation due to gas emboli. A Doppler Telemetering Flowmeter implanted on the heart is tested to detect the time of first bubble formation in fish exposed to supersaturated water. (CDB)

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9. Schneider, M. J. 1971. Vulnerability of juvenile salmonids to predation following thermal shock, pp. 2.16-2.17. In: Annual Report for 1970, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1550. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: This report reviews thermal shock-predation studies at Hanford (methods used) and presents some additional data. The effect or degree of vulnerability becomes more pronounced with increased duration of exposure to any one temperature. (CDB)

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10. Schneider, M. J. 1971. Gas bubble disease of salmonid fishes, pp. 2.29-2.30. In: Annual Report for 1970, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1550. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: This report reviews gas bubble disease studies at BNW. A Doppler Telemetering Flowmeter is implanted on the conus arteriosus to detect formation of emboli, and the gaseous components in bubbles or blisters forming on the head of rainbow trout exposed to gas supersaturation.

Supersaturation of air, not just nitrogen, appears to be the cause of gas bubble disease. Sites where the nitrogen-oxygen rations differ significantly from that of air are also sites of high metabolic activity wherein oxygen becomes depleted. (CDB)

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11. Schneider, M. J. 1971. Sonic tracking of adult salmonids, pp. 2.25-2.27. In: Annual Report for 1970, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1550. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: This report describes the results of 1970 tagging studies at Hanford. This year fish were collected upriver at Priest Rapids and returned below Hanford for tagging and release. Tracks were made when no reactors were operating. Seven adult chinook and one adult steelhead were used. Three of the 8 fish released on the north side of the river crossed to the south side before continuing upriver; two of the 5 released on the south side remained there throughout their passage; three released on the north shore stayed there. Tracks made in late August to early September. (CDB)

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12. Schneider, M. J. and W. L. Templeton. ____. Effect of thermal history on the resistance of steelhead trout (Salmo gairdneri) to thermal stress, pp.____. In: D. E. Nelson (ed.), Radionuclides in Ecosystems, Proc. 3rd Nat'l. Symposium on Radioecologes, Oak Ridge, Tenn., May, 1971. (in Press)

Abstract: Steelhead trout eggs were hatched and the fish raised for two years according to the temperature class: ambient Columbia River temperature, ambient plus 1.7, 2.2, and 2.6C. After four years, the fish were tested for resistance to three lethal temperatures--25.0, 27.0, and 29.0C. Significant differences were found in time to thermal death but not in time to loss of equilibrium. Acclimation of some fish in each temperature class to 12C removed the differences in thermal death times. (See S-13) (CDB)

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13. Schneider, M. J. 1972. Effect of thermal history on the resistance of Columbia River steelhead trout (Salmo gairdneri) to thermal stress, pp. 1.5-1.6. In: Annual Report for 1971, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1650. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: The purpose of this study was to evaluate the effect of long-term thermal history or the resistance of steelhead to thermal stress. Fish were reared from fry at ambient Columbia River temperatures, and at increments of 1.7C(3F), 2.2C(4F), and 2.7C(5F) above ambient. At the age of two years, the fish were tested for resistance to thermal shock at 25, 27 and 29 C. A difference of 2.2 C in thermal history altered the response of steelhead to thermal stress. Acclimation for three weeks to a common temperature (12 C) eliminated the differential sensitivity. (CDB)

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14. Schneider, M. J. 1972. Gas bubble disease of salmonid fishes, pp. 1.26. In: Annual Report for 1971, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1650. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: A gas chromatographic procedure was used for rapid analysis of dissolved gas levels in Columbia River water. Data on nitrogen levels at the Priest Rapids Dam forebay and spilling basin, and at Vernita in 1971 are figured. The Columbia River was supersaturated from late May to early September, and considerable variation in dissolved gas levels existed on a given day between stations. (CDB)

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15. Silker, W. B. 1964. Variations in elemental concentrations in the Columbia River. Limnol. Oceanog. 9(4): 540-545.

Abstract: The seasonal changes in concentration of several elements in the Columbia River at Hanford, Washington, were measured during 1962. An annual spring increase in the concentration of arsenic, manganese, copper, and lanthanum was related to the introduction of water from the Spokane River to the Columbia River system, while other elemental concentration changes were ascribed to the relative contribution of the Pend Oreille and Spokane rivers to the Columbia River. Data are presented on the concentration of several elements at various points on the Columbia River upstream from the Hanford project. (Author)

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16. Soldat, J. K. 1956. Columbia River travel time measurements by float methods. HW-41275. Hanford Atomic Products Operation, Richland, Wash. 18 p.

Abstract: Travel times between the most upstream reactor effluent discharge point and the Pasco and Kennewick city water plant intakes were measured by float methods. Minimum travel times varied from 22.4 hrs at a flow rate of 0.9×10^5 cfs to 11.2 hrs at 3.6×10^5 cfs. (CDB)

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17. Soldat, J. K. 1958. Columbia River flow-time calculations. HW-58312. Hanford Atomic Products Operation, Richland, Wash. 10 pp.

Abstract: Comparisons were made between data collected by the U.S. Army Corps of Engineers and Regional Monitoring with the equation for calculation of flow times developed by H. T. Norton. Re-appraisal was undertaken to permit extrapolation of the flow-time curves to lower river flow rates. (CDB)

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18. Soldat, J. K. 1962. Columbia River flow-time calculations. HW-58312 REV (Supersedes HW-58312). Hanford Atomic Products Operations, Richland, Wash. 10 pp.

Abstract: This report incorporates a change in units used for river flow rates from gallons per second to cubic feet per second, and minor revisions in mileage scales. Predictions of river flow times between the reactor area (100 Area) and Pasco are presented in 6 figures. (CDB)

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19. Soldat, J. K., and T. H. Essig (eds.). 1966. Evaluation of radiological conditions in the vicinity of Hanford for 1965. BNWL-316. Battelle, Pacific Northwest Labs., Richland, Wash. 32 pp.

Abstract: During 1965, the environmental surveillance program of the Hanford environs again showed that the amounts of radioactive materials present were well within nationally accepted limits at all times and that releases of radioactive wastes were well controlled.

P^{32} released to the Columbia River in reactor effluent continued to be the most significant source of radiation from the Hanford project. This P^{32} is concentrated by fish that inhabit the river downstream from the reactors. Individuals who regularly eat such fish as a major part of their diet throughout the year could conceivably have taken in as much as 11% of the annual permissible amount of this bone seeker.

There was one unusual release of radionuclides from the Hanford plant during 1965 that warranted special assessment of the radiation dose to persons in the environs. (Author's Conclusions)

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20. Soldat, J. K. 1968. A statistical study of the habits of fisherman utilizing the Columbia River below Hanford. BNWL-SA-1451. Battelle, Pacific Northwest Labs., Richland, Wash. 14 pp.

Abstract: For a period of one year, over 2,100 fishermen were contacted and 2/3 of these provided complete data for analysis. There was an estimated 41,000 pounds of sport fish harvested per year, an estimated edible weight of 20,000 pounds, and an estimated 45,000 meals (200 gm of meat per meal). The average fisherman made 4.7 trips per year to the area of the survey and averaged 1 sport fish per trip. Estimates of species caught were: spiny rays - 35,000 per year (mostly crappie, some perch and bluegills), catfish - 12,100 per year, bass - 11,900 per year, steelhead - 1,000 per year, whitefish - 1,340 per year, trout - 1,180 per year, sturgeon - 180 per year, and salmon - 110 per year. (CDB)

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21. Sonnichsen, J. C., Jr., D. A. Kottwitz, and R. T. Jaske. 1970. Dispersion characteristics of the Columbia River between river sites 383 and 355. USAEC R&D Report, BNWL-1477. Battelle, Pacific Northwest Labs., Richland, Wash. 30 pp.

Abstract: This report contains an analysis of the dispersion characteristics of the Columbia River between River Miles 383 and 355. The techniques employed included both remote sensing systems and physical contact sampling systems. Both techniques used dye as a tracer. The effect of effluent buoyancy on the lateral dispersion coefficient is empirically examined. Results indicate that the lateral diffusion coefficient depends upon density differentials. Values for the longitudinal diffusion coefficient generally range between 500 ft^2/sec and 3000 ft^2/sec for flow rates of 80,000 to 130,000 ft^3/sec. (Authors)

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22. Strand, J. A., W. L. Templeton, and E. G. Tangen. 1971. Effects of short-range particle irradiation and embryogenesis of marine teleost fish, pp. 2.36-2.39. In: Annual Report for 1970, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1550. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Eggs of rainbow trout were spawned and exposed to 0.01, 0.1 and 1.0 μCi/ml tritium throughout embryogenesis for 25.5 days at about 10.5C. Tritium uptake was rapid for the first 1-2 days, followed by a slight decline during equilibrium for 23-24 days. After transfer to uncontaminated water, both volatile and bound fractions of tritium were eluted rapidly. Exposure to tritiated water resulted in a near uniform distribution of the isotope in all tissues of the embryo and larvae. A statistically significant reduction in hatching percentage could not be demonstrated. The high concentrations produced larvae of greater length. (CDB)

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23. Strand, J. A., W. L. Templeton, E. G. Tangen, and P. A. Olson. 1971. Fixation and long-term accumulation of tritium in an experimental aquatic environment, pp. 2.39-2.40. In: Annual Report for 1970, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1550. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Tritiated water was introduced to an experimental aquatic ecosystem established in a 30 ft diameter concrete pond, which was stocked with sediment, emergent plants, invertebrates, and fish. Concentrations of tritium were 1.0 μCi/liter or 10 mCi/day, and this level has been maintained for 5 months. Samples of biological material are being analyzed for volatile and nonvolatile or "bound" tritium. (See S-25 and S-26) (CDB)

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24. Strand, J. A., M. P. Fujihara, W. L. Templeton, and R. G. Genoway. 1972. Effect of short-range particle irradiation on embryogenesis of teleost fish, pp. 1.8-1.13. In: Annual Report for 1971, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1650. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Eggs of rainbow trout (Salmo gairdneri) were reared through embryogenesis at 10.6 ± 0.5C in spring water spiked with 0.01, 0.1, 1.0 and 10.0 μCi/ml of tritium. In Experiment No. 1, no significant reduction in hatching percentage or delay in time of hatching was found, but there was an increase in the incidence of abnormal larvae. In Experiment No. 2, embryos exposed to 0.1 and 1.0 μCi/ml produced significantly more abnormal larvae than the controls. Application of selected tests to detect sublethal effects on juvenile and yearling rainbows reared in tritium-spiked water in earlier experiments revealed no impairment. However, the production of antibody titers from the pathogen Chondrococcus columnaris tended to be suppressed in tritium-irradiated fish, in some instances. (CDB)

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25. Strand, J. A., W. L. Templeton, and E. G. Tangen. ____. Accumulation and retention of tritium (tritiated water) in embryonic and larval fish, and radiation effect, pp. ____. In: D. E. Nelson (ed.), Radionuclides in Ecosystems, Proc. 3rd Nat'l. Symposium on Radioecology, Oak Ridge, Tenn., May, 1971. (in Press)

Abstract: Eggs of rainbow trout (Salmo gairdneri) were reared in 0.01, 0.1 and 10.0 uc/ml tritium H_3 contaminated spring water through embryogenesis at 10.5 ± .5C. Tritium uptake was rapid at all concentrations the first 1-2 days, followed by maintenance of equilibrium levels the ensuing 27-28 days of exposure. The "bound" tritium fraction accounted for about 20% of the total label in each egg. Both volatile and "bound" fractions, after transfer to free-flowing water, eluted rapidly with estimated half-times of ∿1.0 and ∿2.0 hours, respectively. A slow component of the volatile fraction persists for a longer period and a trace remains after 3 months in juvenile fish. Evaluation of hatching success, abnormal larvae, and selected behavioral and physiological tests indicated no significant effect from exposure. (From Author's Abstract)

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26. Strand, J. A., W. L. Templeton, and E. G. Tangen. 1972. Fixation and long-term accumulation of tritium in an experimental aquatic environment, pp. 1.13-1.14. In: Annual Report for 1971, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1650, Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Tritium water at doses of 1.0 μCi/liter or 10 μCi/day was introduced into an experimental ecosystem for nine months. Samples were analyzed for volatile and nonvolatile or "bound" tritium. A rapid uptake of the isotope was shown in all tissues analyzed. Equilibrium was reached in about five days, and was thereafter maintained at about the same level. Bound tritium accounted for about 20% of the total label. (See S-25) (CDB)

T

1. Templeton, W. L., and C. C. Coutant. 1971. Studies on the biological effects of thermal discharges from nuclear reactors to the Columbia River at Hanford, pp. 591-612. In: Environmental Aspects of Nuclear Power Stations, (IAEC-SM-146/33), Inter'l Atomic Energy Agency, Vienna.

Abstract: In 1945, within a few months after the start-up of the original Hanford reactors, studies were begun to determine whether the cooling water discharged to the Columbia River might affect the important fisheries resources. The comprehensive program embraced the effects of heat as well as radioactivity and toxic chemicals. The broad approach to the problem included a pragmatical identification and investigation of the physical and biological facets of the river, complemented with rigorously controlled laboratory experiments. This integration of the field and laboratory work has yielded a much better understanding of the possible biological effects of heated effluents and the mechanisms involved than could have been derived by separate studies not carried out in situ. This paper reviews highlights of some of the research carried out over the past twenty-five years on the biological effects of elevated water temperatures on fish and other aquatic life of the Columbia River. The work embraces all of the life stages of salmon, including the eggs, the fry, the juveniles, and the adults. New technology was developed to evaluate the risks to young salmon as they pass the reactor discharges en route to the sea. Field and laboratory data were combined to create a hybrid computer model that predicts the hazards to young fish in the mixing zones. The behavior of adult salmon and trout on their spawning migration upstream past the reactor discharges was studied with the use of sonic tags. Some fish diseases are known to be aggravated by increases in temperature and studies were made on the incidence of the bacterial disease columnaris. The information derived from these studies is essential to the derivation of appropriate temperature criteria applicable to cold-water fish and to the specification of boundary conditions that must be met by the engineering design of outfall structures. (Authors)

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2. Templeton, W. L. and R. J. Olson. ____. Predictive models of mortality of young fish in a thermal plume, pp. ____. In: D. E. Nelson (ed.), Radionuclides in Ecosystems, Proc. 3rd Nat'l. Symposium on Radioecology, Oak Ridge, Tenn., May, 1971, (in Press).

Abstract: Previous studies conducted at Hanford involving acute mortality, equilibrium loss and predation, and migration timing provide the basis for simulation models to predict thermal effects on young salmonids encountering heated discharge plumes. Simulation indicates that, under low river flows and high river temperatures, a potential exists for significant loss of fish only if they enter the center line of a plume. Earlier data indicate that less than 1% of the seaward migrants would do so. (CDB)

W

1. Watson, D. G. 1952. Observations on spawning and migration of chinook salmon Oncorhynchus tshawytscha (Walbaum), in the Columbia River in the vicinity of Hanford Works, pp. 14-18. In: Biology Research Annual Report for 1951, HW-25021. Hanford Works. Richland, Wash.

Abstract: This is the first report on salmon spawning at Hanford. Redd counts are valuable indications of discharge effects on salmon populations. Aerial surveys first began in 1947 (by Foster and Olson). Spawning begins about mid-October and is over by the end of November. Data on counts in 1947 through 1951 are tabulated. Less than 10^{-5} μc/g radioactivity was recorded in salmon carcasses. (CDB)

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2. Watson, D. G. 1956. Chinook salmon spawning in the vicinity of Hanford 1947-1955, pp. 29-34. In: Biology Research Annual Report for 1955, HW-41500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Results of observations on chinook salmon spawning near Hanford from 1947 to 1955 are summarized and compared with the fall run in the Columbia River. Although numbers of fish spawning locally and the total run in the river have declined, there is no indication that Hanford effluents have caused the reduction. (Author)

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3. Watson, D. G. 1957. Chinook salmon spawning in the vicinity of Hanford-1956, pp. 225-227. In: Biology Research Annual Report for 1956, HW-47500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: The tenth in a series of annual surveys of the extent of chinook salmon spawning in the Columbia River near Hanford was made during the fall of 1956. A comparison of the nest counts in local spawning areas with the fall runs of chinook salmon ascending Bonneville Dam is given. In 1956 the numbers of fish at both locations were below the average for the past ten years. In 1955 and 1956 the decrease in local spawning was greater than the decrease in the fall run passing Bonneville Dam. Because of the multitude of factors which affect the survival of salmon between the time the eggs are laid and their return as adults to the spawning grounds, no single factor can be assigned as the cause of the decrease. (CDB)

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4. Watson, D. G. 1957. Effect of massive doses of P^{32} on trout, pp. 238-235. In: Biology Research Annual Report for 1956, HW-47500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: The effects of feeding P^{32} to yearling trout at rates of 600, 3,000, and 3,800 microcuries each week for 12 weeks are described. All fish fed the two higher levels died of radiation damage within seven weeks, after receiving approximately 12 millicuries of P^{32}. Severe breakdown of the vascular system was evident at death. About 55 percent of the ingested P^{32} was retained by the trout. (Author)

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5. Watson, D. G., and J. J. Davis. 1957. Concentration of radioisotopes in Columbia River whitefish in the vicinity of the Hanford Atomic Products Operation. HW-48523. Hanford Atomic Products Operation, Richland, Wash. 136 pp.

Abstract: Results of a study on the uptake of radioisotopes by Columbia River whitefish for the period from June 1950 to December 1956 are presented. Differences in concentrations of radioactive materials as related to geographical location, season, age, specific tissue, and concentration of reactor effluent in the river are discussed. Changes in concentration with cooking were determined.

Maximum concentrations of P^{32} on the order of 2×10^{-4} μc/g of flesh were recorded for sportfishing areas immediately upstream and downstream from the Hanford Atomic Products Reservation. Human consumption of whitefish flesh at the rate of 2.7 pounds per week from public fishing areas during the fall months would produce maximum permissible concentrations of P^{32}. (Authors)

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6. Watson, D. G., L. A. George, and Patricia L. Hackett. 1959. Effects of chronic feeding of phosphorus-32 on rainbow trout, pp. 73-77. In: Biology Research Annual Report for 1958, HW-59500. Atomic Products Operation, Richland, Wash.

Abstract: Phosphorus-32 fed daily for six months at the rate of 0.006 μc per gram body weight produced no abnormalities in trout. At the 0.06 μc feeding level, rate of growth was reduced in 17 weeks and about 62 percent of the administered P^{32} was retained. Effective half-life ranged from 8.4 days in liver to 14 days in bone. The 0.6 μc level was lethal, with reduction in rate of growth at 11 weeks and damage to the GI tract, anterior kidney and reduction of leukocytes at three weeks. (Authors)

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7. Watson, D. G. 1960. Chinook salmon spawning in the vicinity of Hanford-1959, pp. 180-182. In: Biology Research Annual Report for 1959, HW-65500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Chinook salmon spawning for 1959 was approximately 19 percent of the 1958 value. High river levels reduced the effectiveness of nest enumeration. There were indications that delay of upstream migration by Priest Rapids Dam added to the numbers of fish spawning near Midway. (Author)

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8. Watson, D. G., J. J. Davis, and W. C. Hanson. 1960. Zinc-65 in marine mollusks near the mouth of the Columbia River, pp. 183-187. In: Biology Research Annual Report for 1959, HW-65500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Levels of radiozinc in mollusks in 1957 and 1959 are presented together with possible factors responsible for interspecies and seasonal changes in concentration. (Authors)

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9. Watson, D. G., J. J. Davis, and W. C. Hanson. 1961. Dispersion of gamma emitters in marine organisms near the mouth of the Columbia River, pp. 151-153. In: Biology Research Annual Report for 1960, HW-69500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Gamma-emitting radioelements have been detected and measured in marine plants and animals collected from the coasts of Washington, Oregon and Alaska during 1959 and 1960. Some of these radioelements occurred in nearly all samples from all collecting sites, others were found only in specimens from near the mouth of the Columbia River. (Authors)

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10. Watson, D. G. 1961. Salmon spawning in the vicinity of HAPO-1960, pp. 156-158. In: Biology Research Annual Report for 1960, HW-59600. Hanford Atomic Products Operation, Richland, Wash.

Abstract: The salmon nest counts for 1960 were approximately the same as those for 1959. Fluctuations in the local population are compared with the yearly salmon counts at Bonneville and McNary Dams. Rapid change in river level due to dams upstream from HAPO left some salmon nests completely out of water. (Author)

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11. Watson, D. G., J. J. Davis, and W. C. Hanson. 1961. Zinc-65 in marine organisms along the Oregon and Washington coasts. Science 133 (3467): 1826-1828.

Abstract: The concentration of zinc-65 in marine animals and plants near the mouth of the Columbia River is presented. Amounts of radiozinc found in the biota diminished rapidly with the distance from the river mouth. The highest levels were found in plankton, algae, and mollusks. Of the human foods, oysters exhibited the highest levels, followed by razor clams. The concentration of radiozinc in crabs, fish and marine birds was about 1/10th of that found in algae or mussels. (CDB).

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12. Watson, D. G. 1962. Chinook salmon spawning in the Columbia River, pp. 148-150. In: Biology Research Annual Report for 1961, HW-72500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: The number of chinook salmon spawning in the Columbia River near Hanford was the second highest since surveys were started in 1947. Priest Rapids Dam appears to affect the distribution and number of spawning fish in this area. (Author)

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13. Watson, D. G. 1963. Chinook salmon spawning near Hanford-1962, pp. 215-218. In: Biology Research Annual Report for 1962, HW-76000. Hanford Atomic Products Operation, Richland, Wash.

Abstract: The number of chinook salmon nests in the Columbia River near Hanford was the second highest since surveys were started in 1947. Spawning was again particularly dense in the Midway region apparently due to barrier effects of the Priest Rapids Dam. (Author)

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14. Watson, D. G., J. J. Davis, and W. C. Hanson. 1963. Interspecies differences in accumulation of gamma emitters by marine organisms near the Columbia River mouth. Limnol. Oceanog. 8(2): 305-309.

Abstract: More than 60 different radionuclides have been detected in the Hanford Atomic Products Operation reactor effluents that are discharged into the Columbia River: Davis, et al. (1958) measured about a third of these in organisms living in the river near Hanford outfalls. Most of the radionuclides are eliminated from the river or are reduced to trace amounts through radioactive decay and retention by river sediments and the biota before the river reaches the Pacific Ocean, 370 miles downstream from the Hanford reactors. The principal gamma emitters found in water near the river mouth are Cr^{51}, Np^{239}, and Zn^{65}. (CDB)

15. Watson, D. G. 1964. Chinook salmon spawning near Hanford-1963, pp. 203-205. In: Biology Research Annual Report for 1963, HW-80500. Hanford Atomic Products Operation, Richland, Wash.

Abstract: The approximate 1300 chinook salmon nests observed in the Columbia River near Hanford were the second highest in 17 years. Trends in numbers of local salmon spawners generally follow that of the salmon runs in the river prior to 1960; thereafter, the increase in numbers of Hanford salmon is greater than the runs in the river. (Author)

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16. Watson, D. G. 1965. Chinook salmon spawning near Hanford-1964, p. 195. In: Biology Research Annual Report for 1964, BNWL-122. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: The number of chinook salmon nests observed in the vicinity of Hanford was only slightly less than the 18 year maximum. Success of the local salmon population appears to be better than that of the overall fall run in the Columbia River. (Author)

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17. Watson, D. G. 1966. Migration of Columbia River fish, pp. 123-126 In: Annual Report for 1965, Biological Sciences, BNWL-280. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: The movement of resident Columbia River fish upstream from Hanford reactor outfalls or into a tributary stream was studied. The presence of ^{65}Zn, acquired by fish when downstream from reactor outfalls, served as a radioactive tag. (Author)

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18. Watson, D. G. 1966. Columbia River Chinook salmon spawning near Hanford, pp. 131-132. In: Annual Report for 1965, Biological Sciences, BNWL-280. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: A record number of 1768 salmon nests were observed in the section of the Columbia River near the Hanford Project. This is approximately 300 more than the previous high of the past 19 years. (Author)

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19. Watson, D. G., C. E. Cushing, and R. W. Perkins. 1966. Radionuclides in Columbia River biota, pp. 126-127. In: Annual Report for 1965, Biological Sciences, BNWL-280. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Measurements of the concentration of several reactor-produced radionuclides in Columbia River biota were made before and after closure of three Hanford reactors. A noticeable reduction of radionuclides in the biota was evident after reactor shutdown, but this may have been influenced by river temperature changes and channeling of effluent. (Author)

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20. Watson, D. G., C. E. Cushing, C. C. Coutant, and W. L. Templeton. 1967. Radionuclides in Columbia River organisms, pp. 164-169. In: Annual Report for 1966, Vol, I, Biological Sciences, BNWL-480 Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: The definition of seasonal variations in concentration of reactor-produced radionuclides in Columbia River biota was interrupted by closure of all reactors for a six-week period. Reactor shutdown reduced levels of ^{32}P and ^{51}Cr by two orders of magnitude in primary producers. Changes in radionuclide burden were much less in fish. Near equilibrium levels of radioisotopes in river organisms were reached within 2 weeks to 1 month after reactors resumed operation. (Author)

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21. Watson, D. G. 1967. Chinook salmon spawning near Hanford-1966, pp. 181-183. In: Annual Report for 1966, Vol. I, Biological Sciences, BNWL-480. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Number of fall chinook salmon nests was 3100, a 20-year high, which exceeded last year's record count by about 70 percent. This local increase did not correspond to any general increase in the overall salmon run in the Columbia River. (Author)

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22. Watson, D. G. 1968. Chinook salmon spawning near Hanford-1967. pp. 9.14-9.15. In: Annual Report for 1967. Vol. I, Biological Sciences, BNWL-714. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: A 21-year record number of 3270 fall chinook salmon nests were observed in 1967. The increase in numbers of fish spawning downstream from reactor outfalls was comparable to that in the spawning area immediately upstream. (Author)

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23. Watson, D. G. and G. B. Pauley. 1968. Acute gamma irradiation effects in juvenile chinook salmon, pp. 1.16-1.18. In: Annual Report for 1967, Vol. I, Biological Sciences, BNWL-714. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Exposure to ^{60}Co-gamma doses of 3000 R and above produced a transient erythema. No other gross changes were noted until just prior to death. Mortality and histopathological changes were dose dependent over a range from 550 to 5470 R. (Authors)

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24. Watson, D. G., and W. L. Templeton. 1969. Thermoluminescent dosimetry in Columbia River organisms, pp. 2.5-2.7. In: Annual Report for 1968, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1050. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: LiF thermoluminescent dosimetry appears to be a practical means of measuring radiation dose of aquatic organisms in their natural environment. Highest measurements were observed in the benthos; and external radiation was a significant contributor to the total in fish. Dose to fish from contained radionuclides may be inversely related to body weight. (Authors)

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25. Watson, D. G., and C. E. Cushing. 1969. Seasonal variation in radionuclides in Columbia River organisms, pp. 2.13-2.15. In: Annual Report for 1968, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1050. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: The spring-early summer high-water flow in the Columbia River results in two effects upon the seasonal concentrations of radionuclides in the biota; (1) first a dampening of increasing concentrations in early spring as light and temperature become metabolically favorable, and (2) low summer levels as a result of dilution of ambient radionuclide concentrations. (Authors)

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26. Watson, D. G. 1969. Chinook salmon spawning near Hanford-1968, pp. 2.31-2.32. In: Annual Report for 1968, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1050. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: A 22 year high of 3560 fall chinook salmon redds were observed in 1968, exceeding the previous high, recorded in 1967, by about 300. (Author)

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27. Watson, D. G., C. E. Cushing, C. C. Coutant, and W. L. Templeton. 1969. Effect of Hanford reactor shutdown on Columbia River biota, pp. 291-299. In: D. J. Nelson and F. C. Evans (eds.), Symposium on Radioecology, 1967. CFSTI, Nat'l Bur. Stds., Springfield, Va. (CONF-670503).

Abstract: Closure of Hanford reactors for an extended period caused a rapid and extensive decline in the concentration of radionuclides in Columbia River biota. Chromium-51 and ^{32}P decreased two to three orders of magnitude in the lower tropic levels; declines in concentrations of ^{65}Zn, ^{54}Mn, and ^{59}Fe were much less, suggesting a cycling of these nuclides from the sediments to the water during shutdown. In fish, ^{32}P was lost rapidly, ^{65}Zn slowly. New equilibrium concentrations of radionuclides in most river organisms were approached within two or three weeks after the resumption of reactor operation. (Authors)

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28. Watson, D. G., and C. E. Cushing. 1970. Zinc-65 cycling through an aquatic food web, pp. 3.4-3.5. In: Annual Report for 1969, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1306. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Lab studies on transfer of ^{65}Zn through a simple food web (water-periphyton-fish) is in progress. Radiozinc is introduced at about 103 and 104 pCi/liter. Results after 2 weeks indicate that the uptake is not directly proportional to ambient concentration at temperatures of 6-°C. There is a 3 to 5 fold difference in concentration at ^{65}Zn in periphyton growing in water whose Zn concentration differs by a factor of 10. Concentrations of ^{65}Zn in periphyton at the two experimental levels are about 7 and 30 times that of the river water controls. Intake by fish is more erratic than that by periphyton. After 2 weeks, concentrations in fish are about 3 times that of the low level concentration. (CDB)

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29. Watson, D. G., and W. L. Templeton. 1970. Nuclear radiation regimes in the Columbia River, p. 3.14. In: Annual Report for 1969, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1306. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Dose measurements of periphyton grown on artificial substrates placed on the river bottom at a location 23 km below the reactor outfalls ranged from about 30 mrad/day during March to September, to about 45 mrad/day from September to November. The summer rate was similar to that in 1968, but the fall rate was about 40% higher, even though 1 less reactor was discharging effluent. Dose rates beneath stones was about 25% less than on the upper side. (CDB)

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30. Watson, D. G. 1970. Salmon population studies, pp. 3.21-3.22. In: Annual Report for 1969. Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1306. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: A total of 4,500 chinook salmon redds was observed, establishing a new high for the 23 years (since 1949) of surveying. An estimated 32,000 salmon spawned in the Hanford reach, or 40% of the fall chinook that passed over McNary Dam. (CDB)

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31. Watson, D. G. 1970. Fall chinook salmon spawning in the Columbia River near Hanford 1947-1969. AEC R&D Report, BNWL-1515. Battelle, Pacific Northwest Labs., Richland, Wash. 40 pp.

Abstract: This report reviews the accumulated data on fall chinook spawning at Hanford since 1947. There has been no evident relationship between the operation of the Hanford reactors and the numbers of fish spawning in the Hanford reach of the river. Recent increases in numbers of fall chinook spawners seem more closely associated with the construction of dams downstream and immediately upstream from Hanford, and the probable displacement of fish from these areas. Water temperatures are less than 15°C during the peak of spawning, well within the upper tolerance limits for this species. (CDB)

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32. Watson, D. G., C. E. Cushing, C. C. Coutant, and W. L. Templeton. 1970. Cycling of radionuclides in Columbia River biota, pp. 144-157. In: D. D. Hemphill (ed.), Proc. 4th Ann. Conf. on Trace Substances in Environmental Health IV, Univ. of Missouri, Columbia.

Abstract: A study of the cycling of six radionuclides in Columbia River biota was initiated in February 1966 to define the interspecies and seasonal variations in concentrations. These data were related to major ecological factors such as light, temperature, flow, and stable element concentrations.

Concentrations of radionuclides in Columbia River water are generally inversely proportional to flow levels, with highest values in winter and lowest in summer. This is related to dilution by seasonal runoff.

^{32}P, ^{65}Zn, and ^{51}Cr were the elements present in highest concentrations in the biota. Levels followed a pattern of high levels in winter and low values in summer. This relationship was particularly apparent in those organisms with high surface to volume ratios whose dominant mode of uptake is adsorption. The influence of the seasonal run-off overwhelmed the beneficial effects of seasonal changes in light and temperature in spring. The magnitude of seasonal changes decreased in the higher trophic levels.

Concentration factors (CF) were highest for the biologically important radionuclides ^{32}P and ^{65}Zn and were highest in the primary producers. CFs decreased in higher trophic levels. (Authors)

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33. Watson, D. G., C. E. Cushing, C. C. Coutant, and W. L. Templeton. 1970. Radioecological studies on the Columbia River. Parts I and II, USAEC R&D Report, BNWL-1377. Battelle, Pacific Northwest Labs., Richland, Wash. 46 pp.

Abstract: Part I reviews the accumulated data on radionuclide concentration levels in Columbia River biota. It defines the interspecies and seasonal variations in the levels of several of the more biologically important radionuclides, and updates the findings of some earlier investigations. Conclusions: 1) Concentrations of radionuclides in the river water are generally inversely proportional to flow levels, 2) concentrations in the biota are high in the winter and low in the summer, 3) total beta concentrations were similar in the present data and that collected prior to 1956, 4) no consistent time-related trends were apparent in gamma activity, 5) shutdown in reactors produces marked changes in radionuclide concentrations in the biota, and 6) concentration factors are highest for phosphorus-32 and zinc-65. Part II contains tabular data of all analyses. (CDB)

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34. Watson, D. G., and C. E. Cushing. 1971. Cycling of zinc-65 in a simple food-web, pp. 2.8-2.9. In: Annual Report for 1970, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1550. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Periphyton concentrate ^{65}Zn at equilibrium levels in about 28 days, at levels of 17 and 90 nCi/g wet weight, in high and low level troughs, respectively. These concentrations are about 23 and 150 times that of the control periphyton. Under the experiment, periphyton concentrate ^{65}Zn in nearly direct proportion to ambient concentration. After shutoff, the estimated effective half life was about 15 days. Data on fish were more variable, due to influence of temperatures on metabolic rates. (CDB)

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35. Watson, D. G., G. J. Paulik, and R. O. Gilbert. 1971. Fall chinook salmon population studies, pp. 2.23-2.24. In: Annual Report for 1970, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1550. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: 3825 redds were counted in the fall of 1970, the second highest on record. River temperatures were about 16C at start of spawning, but dropped to about 12C at peak spawning. Statistical analysis showed no correlation between the size of the local spawning population and numbers of reactors in operation at Hanford. (CDB)

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36. Watson, D. G. and W. L. Templeton. Thermoluminescent dosimetry of aquatic organisms, pp.___. In: D. E. Nelson (ed.). Radionuclides in Ecosystems, Proc. 3rd Nat'l Symposium on Radioecology, Oak Ridge, Tenn., May, 1971 (In Press).

Abstract: Lithium fluoride thermoluminescent dosimeters were employed to estimate the radiation exposure to Columbia River organisms downstream from the effluent outfalls of the Hanford plutonium producing reactors. Highest dose measurements were made in the river benthos. Observed dose was inversely related to distance downstream from the effluent outfalls. Radionuclides in suspension or solution in the river water contributed significantly to the total radiation exposure to both fish and benthic organisms. The dose to fish homogenate and intact fish kept frozen during dosimeter exposure was generally inversely related to fish size. This relationship did not hold for the major gamma emitting nuclides contained in the fish carcass, but appeared to be associated with the body burden of radiophosphorus. (Authors)

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37. Watson, D. G. 1972. Fall chinook salmon population studies, pp. 1.15-1.16. In: Annual Report for 1971, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1650. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Only one reactor is now operating at Hanford. Spawning started near the middle of October, peaked about the middle of November (one week later than usual), and was nearly complete on November 18. 3600 salmon redds were observed, the third highest recorded, exceeded only by the 1969 and 1970 populations. (CDB)

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38. Watson, D. G. 1972. Uptake of mercury-203 by fish, pp. 1.16-1.17. In: Annual Report for 1971, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1650. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Juvenile carp (*Cyprinus carpio*) and catfish (*Ictalurus nebulosus*) were maintained in a system containing mercury-203 at a concentration of 50 pCi/l. The experimental temperatures were 7 and

14C. After 4 weeks exposure, both species held at high temperatures had body burdens more than twice that of fish held at low temperatures. Uptake by carp was more than twice that of catfish, or about equal to the average weight of the two species. (CDB)

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39. Watson, D. G., and C. E. Cushing. 1972. Decline of radioactivity in biota following shutdown of Hanford reactors, pp. 1.20-1.21. *In*: Annual Report for 1971, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1650. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Biological samples were collected in an attempt to monitor the retention and/or elimination of radioactivity following the shutdown of the last plutonium production reactor. Many of the samples have been counted but no complete analytical data are yet available. (CDB)

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40. Weinberger, D., and J. W. Porter. 1953. Incorporation of tritium oxide into growing Chlorella *pyrenoidosa* cells. Science 117(3049): 636-638.

Abstract: Chlorella pyrenoidosa cells were grown in the presence of hydrogen and tritium oxide. Tritium moved more slowly along anabolic pathways than hydrogen. Tritium incorporation was between a third and a half that of hydrogen. Data are provided on the relative uptake of tritium and protium by algae. (CDB)

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41. Weinberger, D., and J. W. Porter. 1954. Metabolism of hydrogen isotopes by rapidly growing Chlorella pyrenoidosa cells. Arch. Biochem. Biophy. 50(1): 160-168.

Abstract: Chlorella *pyrenoidosa* cells have been grown in the presence of deuterium and tritium oxide, and the quantity of each of these isotopes incorporated into the whole cells, methanol-insoluble, ether-soluble, and methanol-soluble, ether-insoluble fractions has been determined. The quantity present has been recorded in terms of the percent expected on the assumption of no isotope effect.

It has been found that the cells incorporate deuterium approximately 50% as rapidly as hydrogen, and that they incorporate tritium 90% as rapidly ad deuterium. Further, the extent of incorporation of tritium or deuterium by the enzymes involved in hydrogen transfer in the synthesis of lipides is significantly higher than the extent of incorporation by enzymes involved in the transfer of hydrogen in the synthesis of proteins, nucleic acids, and starch (methanol-insoluble fraction). (Authors)

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42. Whittaker, R. H. 1953. Removal of radiophosphorus contaminant from the water in an aquarium community, pp. 14-19. In: Biology Research Annual Report for 1952, HW-28636. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Tracer amounts of P^{32} were introduced into three large aquaria containing biological communities. Biological processes effectively removed the P^{32} from the water as algae concentrated the tracer to levels 300,000 times those in the water. During the first few hours after tracer introduction the P^{32} was rapidly absorbed by plankton algae, but after 15 hours plankton activity densities decreased while the P^{32} was more gradually taken up by bottom and sidewall algae. After maximum activity densities were reached by the algae (18 days), the slower processes of sedimentation and binding to surfaces continued to remove the tracer from the water. (Author)

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43. Whittaker, R. H. 1954. An experiment on the relation of phosphate level in the water to the removal and concentration of radiophosphorus, pp. 16-23. In: Biology Research Annual Report for 1953, HW-30437. Hanford Atomic Products Operation, Richland, Wash.

Abstract: Tracer P^{32} was introduced into aquarium communities with different levels of non-radioactive phosphate, ranging from 0.05 to 525 ppm. At higher phosphate levels (5 to 525 ppm) little of the P^{32} was removed from the water by organisms. At low phosphate levels (0.05 to 0.5 ppm) the P^{32} was rapidly and effectively removed and high concentration factors for P^{32} into the organisms resulted. The range between 0.5 and 5.0 ppm is thus the critical one separating effectiveness and ineffectiveness of biological removal of P^{32} contaminant. Limited prediction of removal and concentration effects for P^{32} on the basis of phosphate content of water is possible, but the relation is shown to be complex and non-linear. (Author)

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44. Wildman, R. D. 1966. The United States Atomic Energy Commission's Columbia River program, pp. 673-682. In: Disposal of Radioactive Wastes into Seas, Oceans and Surface Waters, Proc. 1966 Symposium, Int'l Atomic Energy Comm., Vienna.

Abstract: The Columbia River at Richland, Washington, contains radioactivity from three primary sources: naturally occurring, world-wide fall-out, and from the Atomic Energy Commission's Hanford operations. The small amount of radioactivity in the river at Hanford origin comes primarily from the five production reactors. Stable elements present in the cooling water are transformed into radionuclides during passage through the reactors. Also, radioactive materials formed on the

surfaces of fuel elements and channels are eventually carried by the cooling water to the river. As a result of the presence of radioisotopes in the cooling water returned to the river, a continuous evaluation program is maintained. The presence of these isotopes also provides an excellent opportunity to use them as radioactive tags or tracers in many studies in the river, estuary and ocean. In addition to the radioisotopes released from the reactors, ruthenium-106 and tritium are believed to be entering the river after being discharged to the ground from the chemical separations plants. Although detectable in the ground water within a few miles of the river, the amounts of these isotopes added to the river are so small that they are essentially indistinguishable from the radioruthenium and tritium already present in the river.

Investigation of the rate and effect of radioisotopes released to the Columbia from the Hanford reactors have been under way since the 1940's. While the early work was devoted to determining the potential effect of the reactor effluent on aquatic organisms, later effort was broadened to include studies on the distribution of various radioisotopes in the river and the ocean, uptake and concentration of several isotopes by aquatic organisms and effects of specific isotopes on certain animals. Of the over 60 radionuclides which have been identified in the reactor effluent water, ^{24}Na, ^{32}P, ^{46}Sc, ^{51}Cr, ^{65}Zn, ^{76}As, ^{131}I and ^{239}Np have received the greatest attention in the various studies.

In 1962, the AEC's many separate studies were drawn together for integration and coordination by the Working Committee for Columbia River Studies. This Committee assures that the comprehensive program will provide the desired information without duplication of effort. The present program is described and those studies not discussed by other speakers are reviewed. Also, the highlights of the studies to date are presented in summary form along with a bibliography of the significant publications which report the results of the AEC-sponsored studies. (Author)

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45. Wildung, R. E. 1970. Isolation and measurement of the physiochemical properties of particulate matter suspended in a river system, pp. 3.3-3.4. In: Annual Report for 1969, Vol. 1, Life Sciences, Part 2, Ecological Sciences, BNWL-1306. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: An ultracentrifugation-filtration technique was used to isolate and determine particle size fractionation of suspended particles. Seasonal differences in characteristics were measured. The concentration of particulate matter suspended in river water ranged from 2002 μg/l in winter to 34680 μg/l in spring. The bulk of the suspended material was in the 53.0 to 2.0 μ or silt-size range during the fall, winter and summer, with 12 to 30% in the less than 2.0 μ

or clay size range. However, during the spring, the major portion (63%) of the particulate matter was in the less than 2.0 μ size range. (CDB)

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46. Wildung, R. E., and R. L. Schmidt. 1971. Electron micrographic observations of particulate matter suspended in the Columbia River, pp. 2.1-2.2. In: Annual Report for 1970, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1550. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Suspended particles consisted of a complex mixture of organic, mineral, and organomineral detritus. To provide an absolute measure of particle size, and insight into the physical configuration of the separated particles, an electronmicrographic study was undertaken. The particle size distribution was dependent upon particle density, i.e., the relatively large organic detrital components of low density were found mixed with smaller mineral particles of high density. However, the range of particle sizes generally fell within the range defined by the centrifugation parameters employed. (CDB)

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47. Wildung, R. E., and R. L. Schmidt. 1971. Mineral composition of particulate matter suspended in the Columbia River as influenced by watershed characteristics and particle size, pp. 2.3-2.4. In: Annual Report for 1970, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1550. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Data are given on: 1) Seasonal changes in the relative abundance of minerals in particulate matter (less than 53 μ) isolated from the Columbia River, and 2) The relative abundance of minerals (quartz, feldspar, amphibole, micaillite, chlorite, montmorillonite) in size fractions, of suspended particulate matter isolated from the Columbia River water. Seasonal changes in primary minerals were not pronounced; proportions of layer silicate minerals differed significantly during the year, increasing from April to August. (CDB)

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48. Wildung, R. E., R. C. Routson, and R. L. Schmidt. 1971. Isolation and size fractionation of microparticulate matter suspended in the Columbia River. Northwest Science 45(3): 133-136.

Abstract: A modified centrifugation method was used to isolate and provide reproducible size fractionation of particulate matter in

sufficient concentration for further study of ion sorption and release. Mean recovery of total solids in several size fractions amounted to over 95%. During the spring freshet, particles less than 2μ in size accounted for 7.5% of the total fraction, particles 0.5 to 0.2μ for 15.3%, particles of 2.0 to 0.5μ for 37.5%, particles of 53 to 2.0μ for 35.8%. (CDB)

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49. Wildung, R. E., R. L. Schmidt, D. G. Watson, and W. L. Templeton. 1972. Mercury levels in lower Columbia River watershed. pp. 1.17-1.18. In: Annual Report for 1971, Vol. I, Life Sciences, Part 2, Ecological Sciences, BNWL-1650. Battelle, Pacific Northwest Labs., Richland, Wash.

Abstract: Total mercury levels were determined in water samples taken at various stations in the central Columbia River during September, 1971. Mercury levels in all river and waste water samples were less than methodological sensitivity (0.1 μg/liter or 0.1 ppb). Sediments behind Priest Rapids, NcNary and Bonneville Dams contained 0.115, 0.331 and 0.096 μg mercury per gram of sediment, respectively, on a dry weight basis. (CDB)

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50. Wildung, R. E., R. C. Routson, and R. L. Schmidt. 1972. Seasonal changes in particle size distribution, chemical composition and strontium exchange capacity of particulate matter suspended in the Columbia River. USAEC R&D Report, BNWL-1638. Battelle, Pacific Northwest Labs., Richland, Wash. 26 pp.

Abstract: A centrifugation method was employed to fractionate, particulate matter suspended in the Columbia River during November, February, April, June and August. The isolated size fractions were characterized as to particle size distribution, carbon content, predominant primary and secondary minerals and strontium exchange capacity.

Relative to other seasons, the concentration of suspended matter increased over 100 fold during the spring freshet. This increase was accompanied by a change in particle size distribution with the clay size fraction (<2.0 μ) accounting for about 63% of total solids compared to a range of 14 to 30% for other periods of the year. Of the total suspended sediment load in the spring, 24% and 8% occurred in the <0.5 and <0.2 μ fractions, respectively.

Primary minerals inherited from parent rocks and the layer silicate mineral species were generally present in particulate matter throughout the year. Whereas seasonal changes in the primary mineral composition were not pronounced, the relative concentrations of the layer

silicate minerals commonly present in soils increased during spring and summer, corresponding to the periods of spring runoff and the return of irrigation water to the river. Mineral composition also differed between size fractions. Montmorillonite, a layer silicate mineral of comparatively high ion exchange capacity, increased in relative abundance with decreased particle size.

The Sr exchange capacity of materials isolated in the spring increased with decreased particle size, ranging from 11.5 to 93.9 me./100g for the <2.0 μ and <0.2 μ fractions, respectively. This likely reflected relative differences in mineral type as well as increased reactive surface area. Increases in suspended particulate concentration due to spring runoff and the return of irrigation waters results in a large capacity for cation sorption and transport during the spring and summer months. In fact, the Sr exchange capacity of particulate matter in equivalent volumes of river water amounted to 6 to 26 times higher in the spring than during other periods of the year. (CDB)

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51. Wood, V. W. 1954. A summary of Columbia River hydrographic information pertinent to Hanford Works, 1894 to 1954. HW-30347. Hanford Atomic Products Operation, Richland, Wash. 81 pp.

Abstract: This report provides data on Columbia River hydrology that is pertinent to operation of the Hanford Works. Information is given on high and low water levels, flows at given elevations and locations, and the annual temperature cycles at different stations. Limitations on early data are discussed. Problems of icing and flooding in respect to existing and proposed new facilities are evaluated. Descriptions of river gauging stations used by different agencies are provided. (CDB)

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52. Wood, V. W. 1956. Hydrographic information on Columbia River, 1954-1955; supplemental report to HW-30347. Hanford Atomic Products Operation, Richland, Wash. 36 pp.

Abstract: Data on the hydrology of the Columbia River in 1954 and 1955 are provided as a supplement to previous work presented in HW-30347. (CDB)

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