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BEHAVIOR OF SONIC TAGGED CHINOOK SALMON AND STEELHEAD

TROUT MIGRATING PAST HANFORD THERMAL DISCHARGES (1967)¹.

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ABSTRACT

Sonic tagged, adult chinook and steelhead were tracked in 1967 during upstream migration past cooling water discharges from nuclear reactors. All fish migrated near shorelines, showing preference for the river bank opposite reactors. Clear responses to local temperature differences were exhibited by few fish, these responses being to small shoreline seepages rather than to main center-channel outfalls.

Problems associated with the siting of steam electric generating plants - both nuclear and fossil fueled - are becoming of increasing concern not only to the electric power industry but to the scientific community and general public as well (1). To assess effects of thermal discharges from such plants on river fishes, it is important to understand the behavioral responses of fish to temperature changes and their behavior patterns in the geographical setting of added heat both before and after thermal modification (2).

Toward these objectives a cooperative field study was undertaken in 1967 by Battelle-Northwest (BNW) and the Bureau of Commercial Fisheries, Seattle Biological Laboratory (BCF). This study sought to determine the pathways of spawning migrations of summer chinook salmon, Oncorhynchus tshawytscha (Walbaum), and summer steelhead trout, Salmo gairdneri Richardson, in the vicinity of existing thermal discharges to the Columbia River from nuclear reactors at the Hanford Works, U.S. Atomic Energy Commission (AEC). Both chinook salmon and steelhead trout are important commercial and sport fishes in the Columbia River (3). This report describes the principal migration routes near existing discharges and relates observed changes in behavior believed due to temperature rise; no data are obtainable on migration patterns prior to plant operation.

The AEC, through its contractor Douglas-United Nuclear, Inc., operated five nuclear reactors in 1967 for plutonium production between river miles 376 and 385, about 60 km upstream from Richland, Washington (Fig. 1). One of these reactors (N) is dual-purpose, providing steam to generate approximately 800 megawatts of electrical power. Dates of initial operation of each reactor were as follows: B, 1944; C, 1952; KE, 1956; KW, 1956; N, 1964. Present migration paths thus result from the cumulative effects upon several generations of fish. The area of this study extended from the last upstream reactor area (BC) to a

sharp band in the river where nearly thorough mixing of all discharges and river water occurs. Cooling water outlets from all reactors are located near the main river channel at nearly maximum depths of approximately 6 meters. In addition, there are zones of shoreline seepage where small amounts of warmed groundwater enter the river. Surface temperature patterns for three rates of river flow (41,000, 80,000, and 110,000 cfs) are illustrated (Figure 2 a,b,c) based upon aerial infrared imagery (4). Flow of the Columbia fluctuated in this range daily due to power demands at Priest Rapids Dam, 23 km upstream. Representative temperature-depth profiles of one discharge are shown (Figure 3a).

Sonic tags and tracking equipment developed by the Seattle Biological Laboratory of BCF were used to follow fish movements. Chinook tags consisted of a battery-powered, ultra sound transmitter housed within a polystyrene capsule 10.8 cm long and 1.7 cm in diameter and a transducer crystal in a small hemispherical housing (Figure 4,a). The capsule was inserted into the fish's stomach through its mouth and esophagus while the transducer was fastened with a wire staple to the fish's snout forward of the nares. Transducer and transmitter were connected by insulated wires. Weight of the tag in water was 11 grams. Its transmitting life was approximately 12 weeks.

Because steelhead frequently regurgitated the stomach transmitter, an external attachment was necessary for this species. Figure 4b shows the double capsule tag used. It contained electronics in one capsule and battery and transducer in the other. Two aluminum pins, 0.32 cm in diameter, passed laterally through the muscle tissue immediately beneath the base of the dorsal fin, securing the twin capsules to the fish's back on either side of the fin.

Carrier frequency of both chinook and steelhead tags was 134 KHz (kilocycles per second), over 100 KHz above the highest frequency reported audible to fish (5). Recent work by Van Derwalker (b) with chinook salmon showed the upper limit of response to sound by this species is below 300 Hz.

Tags emitted a sequence of sound pulses which could be heard through the receiving system at distances up to 3 km under certain river conditions. Separate groups of fish carried tags of differing pulse patterns, which made it possible to tell whether the fish being tracked was a salmon or steelhead, and approximately when it had been tagged. Portable tracking equipment designed for use in a small boat consisted of a directional hydrophone, transistorized receiver and earphones.

Migrating adult fish 54 to 110 cm in length (chinook), and 52 to 96 cm (steelhead), were trapped in fishways at McNary Dam, about 113 km downstream from the study area. Tags were affixed after fish were lightly anesthetized with MS-222 (Tricaine Methanesulphonate).

Tracking effort was concentrated on the late portion of the summer chinook run and the early peak of summer steelhead, both of which migrated past McNary Dam in August when river temperatures there were 18.9 to 22.8C.

Migrating fish were located in the study area from a drifting boat. Multiple fixes from the moving boat to the fish allowed rough triangulation which located fish positions within about 1.5 meters. These locations were recorded by reference to shoreline markers 200 meters apart. Water depth and time were estimated and recorded whenever possible. For fish followed continuously, triangulations were made every 10-15 min. Previous studies by BCF (7) indicated that careful boat operation does not alter the migrating behavior of salmon. Observations were restricted to daylight hours.

Approximately 70 fish were either located once or tracked for some distance. Figure 5 illustrates the apparent migration routes derived from a composite of all data. No difference was detected between species.

Both chinook salmon and steelhead trout migrated largely along the shorelines at depths less than 3 meters. Modal depths for data obtained

(Table 1) were near 2 m for steelhead and 1.3 m for chinook, assuming that fish moved close to the river bottom at all times. Preference of Columbia River salmonids for migration paths near shorelines has been demonstrated at other locations (7,8) and may be the normal condition here.

The northwest shore, opposite the reactors, was preferred by both species. This tendency was established before the fish reached the most downstream region of the study area. This principal route for migration corresponds with a band of cooler water which remains to the north of the thermal plume throughout most of the study area (Fig. 2b). Preference for the northwest shoreline was sufficiently marked that a small, shallow channel at Coyote Rapids was utilized by most fish tracked in preference to the main river. This channel was less than 1 meter deep during much of the day, and up to 2 degrees centigrade warmer than the main river in mid-afternoon of bright summer days. All records for the southeast (reactor) shore were in two areas, one between Coyote Rapids and the K area jetty, and the other near the B-C reactor area. Fish did not migrate through effluent plumes except during infrequent crossings of the river channel.

Whether these observations are indicative of pre-reactor migration routes or were the result of fish avoiding traces of effluents downstream from the study area could not be determined. Velocity differences among the several channels near the White Bluffs may normally orient fish to the far side. Since these bluffs extend for about 45 km downstream from the study area, such a pattern may be well developed long before reactor discharges are detected. This aspect was studied in 1968; a detailed report of that year's work is in preparation.

Most fish experiences insufficient temperature change in passing through

approximately 70 fish located, only two appeared to enter and respond to areas of reactor-warmed water. These warm areas were not principal reactor discharges, but relatively small shoreline seepages. These fish approached heated water along the southeast river bank, one travelling in it for about 200 meters. Both fell back and crossed the river apparently to avoid a thermal obstruction. At no times did the water temperatures in their paths reach lethal levels (9), nor were elevations beyond 2°C above river temperature recorded. Upstream migrations were resumed after periods of inactivity lasting about 1 1/2 hours.

Rates of migration (relative to the shoreline) varied from periods of apparent rest to spurts of activity reaching 3 km/hr. Both extremes were exhibited by steelhead (Table 2). Chinook migrated at a more uniform pace of about 1.6 km/hr, pausing only to find their way past obstructions. The long-term rate of individual chinook exceeded that of steelhead.

There were two physical features of the river bed in the study area which provided temporary obstacles to migration. These were Coyote Rapids on the southeast shore and a rocky point opposite the jetty at the K reactor area (Fig. 5). No fish were tracked rounding the point at Coyote Rapids, where there are flow velocities ranging from 0.8 m/sec at the bottom to 1.9 m/sec at the surface at a water depth of 1 meter. Tagged fish were absent from the reactor shoreline immediately upstream of Coyote Rapids. One chinook was swept into the center channel in an attempt to round the point, and continued its migration on the other shore. The rock point opposite K area delayed many fish (for over 3 hours in one instance) during which time they swam back and forth within the deep back-eddy between the point and the shore.

Migration rates for chinook through the study area were comparable to the 1.67 km/hr rate between The Dalles and McNary Dams in 1966 as determined by peak daily passages through fish ladders (10). That stretch of river was only partially impounded in 1966 and, therefore, is the most appropriate reach for comparison with the unimpounded Hanford region. Steelhead in the study area travelled significantly faster, however, than the 0.48 km/hr indicated between dams. The reason for this different pace is not readily apparent, but may be related to reactor operations.

Three steelhead trout were tracked while moving rapidly downstream. This movement occurred during the latter part of the run. These were the only fish found in water greater than 4.6 m that were not in the process of crossing the channel. Their rate of movement was approximately equal to that of the boat drifting above them (about 3.3 km/hr). This occurrence may be related to an apparent blockage of entry of steelhead into the Snake River, 75 km downstream, that was observed during the previous few weeks or to normal assumption of river residence by this species which spawns the following spring.

Based on available data, the upstream migration of summer steelhead trout and summer chinook salmon between River Miles 376 and 385 can be described as follows. Both species enter this reach principally along the north shoreline, opposite the reactor areas, migrating in relatively shallow water. This pattern persists past the unheated discharge from D area, past the discharges of both N reactor and its associated electricity-generating steam plant, and past the plume from the K area outfall. the fish exhibit no direct responses to the discharges located about 150-200 m away from them in mid-river, but follow (perhaps coincidentally) a band of cooler water along the north shoreline. A rock outcrop and associated eddy currents opposite the K reactor area impede

Migration, perhaps causing some fish to cross the channel to the reactor shore.

Migration then proceeds up both shorelines, with some fish near the reactor shore encountering warmed seepage water which may stimulate them to recross the channel. At Coyote Rapids, fish remaining on the south (reactor) shore avoid the relatively swift currents there and recross the channel. Many fish proceed up the shallow side channel on the north side of a prominent island rather than remain in the main river. Once upstream of Coyote Rapids some fish again move to the south shore, where a few encounter and avoid warm seepage water from the B,C area. The B and C discharges, although closer to the south shoreline than are the others, nonetheless allow unobstructed passage between their plumes and the shoreline. Both river shorelines are utilized by fish passing upstream of the B,C area. The B and C discharges, although closer to the south shoreline than are the others, nonetheless allow unobstructed passage between their plumes and the shoreline. Both river shorelines are utilized by fish passing upstream of the B,C reactor area.

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FIGURE 1. Columbia River near the Hanford Works, U.S. Atomic Energy Commission. The study segment and reactor areas are indicated. Inset locates Hanford in the Pacific Northwest of the U.S.

(1871 PMT)

Make arrow point to bend in river, not Richland.

The basic photo is PNL 0691775

FIGURE 2. Columbia River surface temperature patterns at three flows:
a) 41,000 cfs, b) 80,000 cfs and c) 110,000 cfs.

Figure 4. Columbia River surface temperature patterns at three flows:
 a) 41,000 cfs, b) 80,000 cfs and c) 110,000 cfs.

FIGURE 3. Maximum water temperatures in vertical sections of the K reactor plume taken in winter at low flow. ($70,000 \text{ m}^3/\text{min}$) and ambient temperature $< 30^\circ\text{C}$. F designates the line of maximum temperature for the plume.

DEPTH (meters)

isotherms °C

Section C-C 20 yd from Q

DISTANCE FROM RELEASE (yd)

U.S. AIR FORCE
SERIAL 21

FIGURE 4. Sonic tags. (a) Stomach capsule and transducer crystal used for chinook salmon, and (b) double capsule steelhead tag.

FIGURE 5. Observed location of sonic tagged chinook salmon and steelhead trout, August and September 1967. RM=River Mile

Figure 5. Principal migration route of point-bellied shrews and speed, representation of point-bellied shrews migration speeds.

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hill & circles

WAHLUR SLOPE

CORDON
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