BEHAVIOR OF ULTRASONIC TAGGED CHINOOK SALMON AND STEELHEAD
TROUT MIGRATING PAST HANFORD THERMAL DISCHARGES (1967)¹

by

Charles C. Coutant²

July 1973

Battelle Pacific Northwest Laboratories
Richland, Washington 99352

¹Work performed largely under U.S. Atomic Energy Commission Contract AT(45-1)-1830 with Battelle Memorial Institute.

²Present address: Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830

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.

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) for the combined KE and KW reactor discharges 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 this discharge are also shown (Figure 3). Other reactor discharges were smaller, and surface temperatures were cooler than the discharge illustrated.

Sonic tags and tracking equipment developed by the Seattle Biological Laboratory of BCF were used to follow fish movements (Figure 4). Chinook tags consisted of a battery-powered, ultrasound 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. 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. The double capsule tag 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). Work by Van Derwalker with chinook salmon showed the upper limit of response to sound by this species is below 300 Hz.

*DETECTION LIMIT OF AERIAL INFRARED IMAGING SYSTEM $\sim 0.5^{\circ}C$

FIGURE 2. Columbia River Surface Temperature Patterns at the Combined Discharge of the KE and KW Reactor 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 m³/min) and Ambient Temperature <3C. F designates the line of Maximum Temperature for the Plume.

FIGURE 4. Sonic Tags and Tracking equipment developed by the Seattle Biological Laboratory of BCF.

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). Tagging was conducted by BCF personnel.

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 22.8 °C.

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.

FIGURE 5. Observed Location of Sonic Tagged Chinook Salmon and Steelhead trout, August and September 1967. RM=River Mile

TABLE 1. Number of Water Depth Records
(Depth Data Not Taken For All Fish)
WATER DEPTH (meters)

<u>Water Depth</u>	<u>Chinook</u>	<u>Steelhead</u>
0-1.06	3	3
1.06-1.68	5	7
1.68-2.29	3	12
2.29-2.90	1	7
2.90-3.50	1	4
3.50-4.11	1	2
4.11-4.42	0	1

TABLE 2. Migration Rates of Chinook and Steelhead

<u>Fish</u>	<u>Short Run</u>		<u>Total Tracked</u>	
<u>Number</u>	<u>Rate</u> <u>(km/hr)</u>	<u>Distance</u> <u>(m)</u>	<u>Rate</u> <u>(km/hr)</u>	<u>Distance</u> <u>(m)</u>
Chinook				
8/11-2	0.90	300	1.29 ⁽¹⁾	600
	2.25	300		
8/15-4	1.62	3000	1.59	4900
	1.47	1100		
	1.60	800		
8/17-5	1.69	2800	1.64	3000
	1.25	200		
Steelhead				
8/12-2	0.93	400	0.76	3300
	0	1 hr. stop		
	0.78	1200		
	1.20	600		
	0.30	300		
	1.19	500		
	1.76	300		
8/14-10	0.80	600	0.60	1400
	0.80	600		
	0.40	200		
8/16-3	3.00	600	1.84	700
	1.00	100		
	0	5 min. stop		

1. Not an average of the short run rates, but the rate for the distance tracked, including periods of inactivity.

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 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.

REFERENCES

1. Office of Science and Technology. Considerations Affecting Steam Power Plant Site Selection. (U.S. Government Printing Office, Washington, D.C.) 133 p. (1968).
2. H. Harty, et al. Final Report on Nuclear Power Plant Siting in the Pacific Northwest for the Bonneville Power Admin., Contract No. 14-03-67868. (Battelle-Northwest, Richland, Washington) 547 p. plus appendices. (1967).
3. Fish Commission of Oregon and Washington Department of Fisheries. The 1966 Status Report of the Columbia River Commercial Fisheries. 97 p. (1967); F. Haw, H.O. Wendler and G. Deschamps. Wash. Dept. Fish., Res. Bull. No. 7, 1962 pp. (1967); Washington Department of Game. Summary of 1966 Steelhead catch. Staff Report, 4 p. (1967).
4. J. R. Eliason, H.P. Foote and G.R. Taylor. Techniques for Qualitative and Quantitative Evaluation of Infrared Imagry. (Battelle-Northwest, Richland, Washington) 26 p. (1968).
5. H. Kleerekoper and E.C. Chagnon. J. Fish. Res. Bd. Can., 11(2), 130. (1954).
6. J. VanDerwalker. In: Marine Bio-Acoustics, vol. 2, (Pergamon Press, Oxford, New York, 1967), p. 45.
7. J. Johnson. U.S. Fish and Wildlife Service, Fishery Bulletin 176, (60) p. 471. (1960).
8. R. Strickland. Sonic Tracking Study of Steelhead in the Rocky Reservoir. (Washington State Dept. of Game, Olympia, undated), 19 p.
9. J.R. Brett. J. Fish. Res. Bd. Can., 9(6), p. 265. (1952).
10. U.S. Army Corps of Engineers. Annual Fish Passage Report, North Pacific Division, for 1966 (Portland, Oregon, 1967) 15 p. plus figures.
11. This research was supported by the Environmental Sciences Branch, Division of Biology and Medicine, U.S. Atomic Energy Commission, under contract AT(45-1)-1830 with Battelle Memorial Institute, Pacific Northwest Laboratory. The author thanks Mr. Thomas Clement, Jr. for field assistance and Mr. Jay Eliason for infrared imagery. The work could not have been conducted without the assistance and support of Mr. James H. Johnson and his staff with the U.S. Bureau of Commercial Fisheries, Seattle Biological Laboratory.

DISTRIBUTION

No. of
Copies

No. of
Copies

OFFSITE

Battelle-Northwest (contd)

1 AEC Chicago Patent Group
A. A. Churm

171 AEC Technical Information Center

25 Oak Ridge National Laboratory
C. C. Coutant

T. O. Thatcher
R. Y. Ting
B. E. Vaughan (2)
Life Science Library (2)
Technical Information (5)
Technical Publications

ONSITE

1 AEC/RL Patent Attorney
R. M. Poteat

1 AEC Richland Operations Office
B. J. Melton

1 AEC/RL RRD Sr. Site
Representative, PNP
F. R. Standerfer

87 Battelle Northwest
W. J. Bair
C. D. Becker (10)
M. J. Duever
R. M. Emery
S. J. Farmer
R. F. Foster
J. J. Fuquay
R. T. Jaske
J. M. Nielsen
T. P. O'Farrell
D. E. Olesen
T. L. Page
M. J. Schneider
A. J. Scott
C. L. Simpson
J. A. Strand
W. L. Templeton (50)