average shedding rate for each type of tag. Type-I shedding, which occurs immediately after release, was estimated to be 0.040 for plastic and metal dart tags combined. Type-II (instantaneous) shedding was estimated to be 0.205 for plastic and metal tags combined on an annual basis.

The shedding rates for each type of tag were found to vary over the time period studied, and deviations from the assumption of constant shedding throughout the life of the tagged fish were noted. Due to these differences, one should not be satisfied with the results of one double-tagging experiment. We recommend that double tagging be employed whenever possible, as long as shedding occurs and the rate of shedding is found to vary. Also, tagged fish, especially the ones which have been at liberty for a long time, are more likely to continue to carry at least one tag if they were originally double tagged. The ones that do not continue to carry at least one tag are of no value. Furthermore, relative to the errors inherent in a study of this type we do not feel that there is really any important difference in shedding rates between the plastic and metal dart tags.

Since shedding may increase with time from release, extrapolations based on the assumption of constant L should be made with caution. Also because the tag shedding rates that we found are considerable, efforts should be made to develop a more efficient type of tag with a lower rate of shedding.

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INFLUENCE OF LITTLE GOOSE DAM ON UPSTREAM MOVEMENTS OF ADULT CHINOOK SALMON, *ONCORHYNCHUS TSHAWYTSCHA*

A major environmental and economic concern in the Pacific Northwest is the continuing decline in the numbers of Columbia and Snake River salmonids. Several investigators (Johnson 1960 and others) have used biotelemetry to study effects of hydroelectric dams (Figure 1) on the upstream movements of adult salmonids. Results indicated upstream movements were delayed at Bonneville (Schoning and Johnson[1]; Monan and Liscom[2,3,4,5]),

[1]Schoning, R. W., and D. R. Johnson. 1956. A measured delay in the migration of adult chinook salmon at Bonneville Dam on the Columbia River. Fish. Comm. Oreg., Contrib. No. 23, 16 p.

[2]Monan, G. E., and K. L. Liscom. 1971. Final report, radio tracking of adult spring chinook salmon below Bonneville Dam,

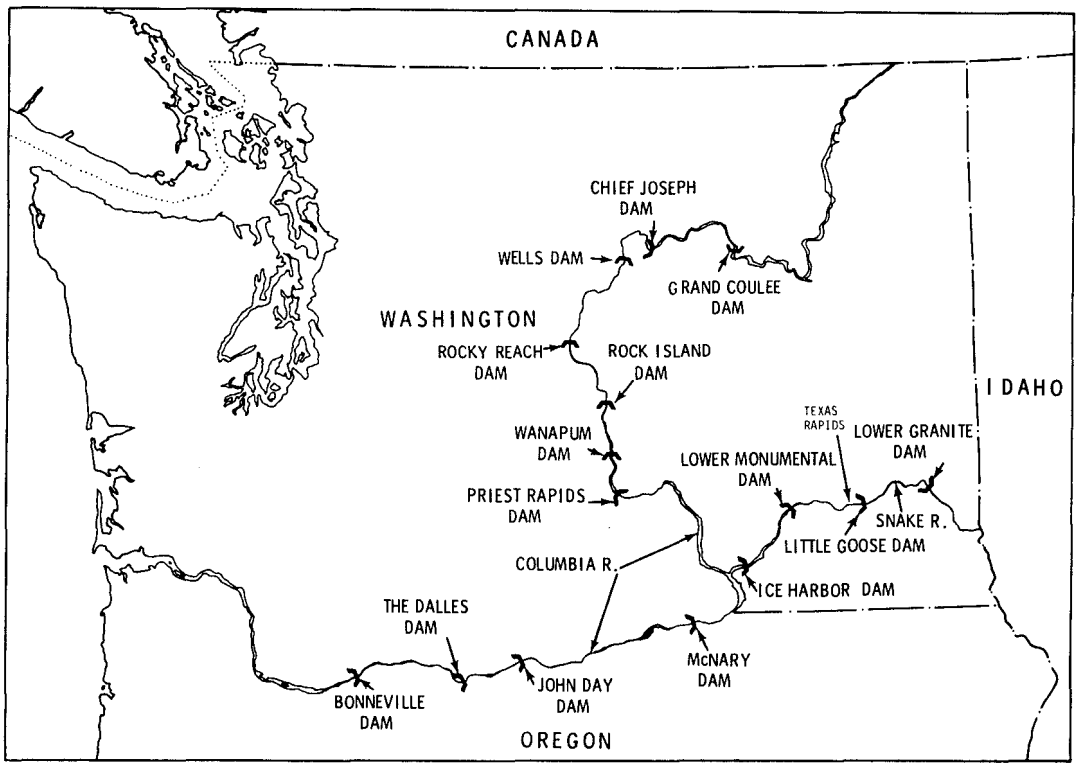

FIGURE 1.—Location of Columbia and Snake River hydroelectric dams.

the Dalles (Monan and Liscom see footnote 3), and Rock Island (French and Wahle 1956) Dams on the Columbia River and at Lower Monumental (Monan and Liscom[6]; Gray and Haynes[7]) and Lower Granite (Liscom and Monan[8]) Dams on the Snake River. However, delays of upstream migrants were generally not considered excessive. We used radiotelemetry to evaluate effects of Little Goose Dam on upstream movements of chinook salmon, *Oncorhynchus tshawytscha*, in the lower Snake River, and compared our results with those of previous studies at other dams.

Materials and Methods

Our telemetry equipment was developed at the Bioelectronics Laboratory, University of Minnesota (Tester and Siniff[9]; Winter et al.[10]). Transmitters were pressure-sensitive and permitted determination of salmon location and swim-

1971. Northwest Fisheries Center, Natl. Mar. Fish. Serv., NOAA, Seattle, Wash., 24 p.

[3]Monan, G. E., and K. L. Liscom. 1973. Final report, radio tracking of adult spring chinook salmon below Bonneville and the Dalles Dams, 1972. Northwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Seattle, 37 p.

[4]Monan, G. E., and K. L. Liscom. 1974. Radio tracking studies of fall chinook salmon to determine effect of peaking on passage at Bonneville Dam, 1973. Northwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Seattle, 28 p.

[5]Monan, G. E., and K. L. Liscom. 1975. Final report, radio tracking studies to determine the effect of spillway deflectors and fallback on adult chinook salmon and steelhead trout at Bonneville Dam, 1974. Northwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Seattle, 38 p.

[6]Monan, G. E., and K. L. Liscom. 1974. Final report, radio tracking of spring chinook salmon to determine effect of spillway deflectors on passage at Lower Monumental Dam, 1973. Northwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Seattle, 20 p.

[7]Gray, R. H., and J. M. Haynes. 1976. Upstream movement of adult salmonids in relation to gas supersaturated water. *In* Pacific Northwest Laboratory Annual Report for 1975, p. 73-76. Vol. I, Life Sciences, Part 2, Ecological Sciences. Battelle, Pacific Northwest Laboratories, Richland, Wash.

[8]Liscom, K. L., and G. E. Monan. 1976. Final report, radio tracking studies to evaluate the effects of the spillway deflectors at Lower Granite Dam on adult fish passage, 1975. Northwest Fish. Cent., Natl. Mar. Fish Serv., NOAA, Seattle, 18 p.

[9]Tester, J. R., and D. B. Siniff. 1976. Vertebrate behavior and ecology progress report for period July 1, 1975-June 30, 1976. COO-1332-123. Prepared for U.S. Energy Research and Development Administration. Contract No. E(11-1)-1332. University of Minnesota, Minneapolis, 63 p.

[10]Winter, J. D., V. B. Kuechle, D. B. Siniff, and J. R. Tester. 1978. Equipment and methods for radio tracking freshwater fish. Univ. Minn. Agric. Exp. Stn. Misc. Rep. 152-1978, 18 p.

ming depth (Gray and Haynes 1977). Transmitters were individually identifiable and operated on a carrier frequency of 53 MHz. Transmitter range varied with depth and transmitter orientation to a receiving antenna. Transmitter life was 2-3 wk. Receivers were capable of distinguishing 100 discrete crystal-tuned transmitters.

Transmitters used in spring 1976 weighed about 68 g in water and were 11.5 cm long and 2.7 cm in diameter. Transmitters used in 1977 were about one-half the weight and two-thirds the volume of those used initially, weighed about 34 g in water, and were 7.9 cm long and 1.9 cm in diameter. In spring 1976 and 1977, chinook salmon were trapped, anesthetized (tricaine methanesulfonate-quinaldine), and tagged externally with radio and metal-core anchor tags (experimental) or metal-core anchor tags only (controls). Tagging was accomplished in cooperation with the National Marine Fisheries Service (NMFS) at Little Goose Dam. Methods of external tag attachment were reported by Gray and Haynes (1977). After tagging, salmon were transported 6.4 km downstream and released at Texas Rapids (Figure 1).

Total lengths and weights of tagged salmon ranged from 66 to 100 cm and 3.4 to 11.4 kg and were consistent with the sizes of fish used in other Columbia River studies (Monan and Liscom see footnotes 2-6). Fish movements between Lower Monumental and Lower Granite Dams (Figure 1) were monitored day and night for the duration of transmitter life. Tagged fish passing through fish ladders at Little Goose and Lower Granite Dams were automatically diverted into fish traps by a magnetometer-triggered device (Durkin et al. 1969), or observed and recorded at fish-counting windows. This allowed comparison of travel time data for control and experimental fish. Total distance traveled was calculated for each fish by summing movements between successive locations.

Results and Discussion

Extensive timing variability among individual salmon was common throughout the study. However, travel times of salmon carrying external radio transmitters and control fish were not significantly different (Gray and Haynes 1979). Average passage delays at Little Goose Dam for radio-tagged and control salmon (combined) were 216±210 h (n=45) in 1976 and 90±57 h (n= 48) in 1977 (Table 1). Passage delays for the same fish at Lower Granite Dam were <50 ±19 h (n = 3) in 1976 and 58 ±45 h (n = 18) in 1977.

While our observations of delay at Lower Granite Dam were consistent with previous research at other Columbia and Snake River Dams (Table 1), it appears that excessive delays occurred at Little Goose Dam, especially in 1976. Differences in passage times at Little Goose Dam compared with other dams (Table 1) were significant ($P<0.05$, Mann-Whitney test).

Several observations indicate extensive salmon

TABLE 1.—Delay of tagged adult chinook salmon below Columbia and Snake River Dams.

Dam	Study year(s)	Citation	Tag type[1]	No. of fish	Time[2] (h) Mean	Time[2] (h) Range
Bonneville	1948	Schoning and Johnson (text footnote 1)	NT	35	67	62-72
Bonneville	1971	Monan and Liscom (text footnote 2)	R	20	[3]>63	4-86
Bonneville	1972	Monan and Liscom (text footnote 3)	R	20	141	11-408
Bonneville	1973	Monan and Liscom (text footnote 4)	R	52	[4]<96	24-384
Bonneville	1974	Monan and Liscom (text footnote 5)	R	42	54	3-540
The Dalles	1972	Monan and Liscom (text footnote 3)	R	30	33	4-69
Rock Island	1954-56	French and Wahle (1956)	NT	2,217	72	48-96
Lower Monumental	1973	Monan and Liscom (text footnote 6)	R	20	62	—
Lower Monumental	1975	Gray and Haynes (text footnote 7)	R	20	18	2-42
Little Goose	1975	Gray and Haynes (text footnote 7)	R	10	139	20-288
Little Goose	1976	This study	R, NT	45	216	44-858
Little Goose	1977	This Study	R, NT	48	90	23-212
Lower Granite	1975	Liscom and Monan (text footnote 8)	R	30	78	—
Lower Granite	1976	This study	R	3	<50	35-72
Lower Granite	1977	This study	R	18	58	2-145
Average passage delays, h:						
Little Goose Dam					148.3±63.5	
Other dams					66.0±31.0	
All dams					82.5±49.9	

[1]R = radio transmitter; NT = nontelemetering fish tag.
[2]Values averaged over all fish used in a study.
[3]Time spent in fish ladders only.
[4]Time from release 6.4 km downstream to dam passage.

delays occurred below Little Goose Dam. Radio-tagged salmon travelled mean distances of 26.5 km in 1976 and 42.0 km in 1977 before crossing Little Goose Dam, despite its location only 6.4 km above the Texas Rapids release site. Dropbacks after arrival of fish in the Little Goose Dam spill were common, averaging 1 or 2/fish. Delay times and distances ranged up to 100 h and 40 km/dropback episode. Radio-tagged (1976-77) salmon exhibited three movement patterns after release at Texas Rapids until arrival at Little Goose Dam: 31% (12/39) moved to the dam within 4 to 12 h; 31% (12/39) remained within ±5 km of the release point overnight and moved to the dam the next day; and 38% (15/39) moved downstream as far as 32 km, and then upstream to the dam 1-6 days later.

Once an individual salmon began moving upstream, it traveled 2-5 km/h and, generally, did not stop until reaching Little Goose Dam. After entry into the dam spill, three behavior patterns were observed: 34% (12/35) crossed the dam 2-5 days after release without dropping back; 40% (14/35) crossed the dam after averaging 1.6 dropbacks/fish; and 26% (9/35) were not observed or recorded crossing Little Goose Dam. However, at least four salmon in the latter group were observed passing Lower Granite Dam or were recovered upstream by anglers or at hatcheries, and properly belong in the second group.

At Little Goose Dam, especially with continuous spring 1976 spilling, salmon appeared "confused." Movements to and from the spill area were common. Substantial milling, previously reported at Lower Granite Dam (Liscom and Monan see footnote 8), occurred in a large back eddy on the north side of Little Goose Dam in 1976 and in front of turbine outflows in 1977. Salmon may use rheotactic, olfactory and/or acoustical cues to navigate upstream (Harden Jones 1968). These cues may be distorted by continuous and heavy spilling near dams. Milling may be an attempt to relocate orientation cues (Hasler et al. 1978). In both study years movements into the fish ladder were frequent, but salmon frequently fell back and returned to the spilling basin, especially upon nearing the trapping facility in midladder.

Periodically, fish trapping operations were halted to allow large groups of salmon, which were suspected of accumulating in the spill to pass Little Goose Dam (Slatick[11]). From 26 April to 30 May 1977, the trap was inoperative 17% of the time (6 of 35 days). However, 30% of all salmon counted (7,382 of 24,238) at the fish viewing window by NMFS personnel and 59% (16/27) of our tagged salmon crossed Little Goose Dam during nontrapping periods. Daily viewing window counts of salmon passage averaged 562±497 fish during trapping and 1,230±1,040 fish during nontrapping periods. A t-test showed these differences were significant ($P<0.05$) and indicated trapping operations at Little Goose Dam impeded chinook salmon passage.

Other aspects of dam operations affected salmon passage at Little Goose Dam. One morning in May 1976, spillways were closed for several hours. The five radio-tagged salmon present left the spill and moved downstream as far as 16 km. During the 24 h after spilling was restored, fish returned to the dam. In the absence of spilling in spring 1977, radio-tagged salmon moved into turbulent areas created by water leaving power generating turbines at Little Goose and Lower Granite Dams. When turbine operations were altered, in response to power generation demands, salmon generally exited the area and returned after water-flow conditions stabilized. Salmon passage through the fish ladder was also impeded by turbine operations (Slatick see footnote 11). Finally, the fish ladder at Little Goose Dam uses pumped river water rather than a gravity flow. Of all salmonid species studied, chinook salmon may be most sensitive to and least likely to swim through pumped water (Slatick see footnote 11).

Gray and Haynes (1977) showed that mean swimming depths of adult chinook salmon in the Snake River were significantly greater ($P<0.05$) in spring 1976 than in spring 1977. However, in both years, mean swimming depths in the Little Goose Dam spill were significantly greater ($P<0.05$) than in all other sections of the study area (Haynes 1978). In contrast, swimming depths in the Lower Granite Dam spill were similar to those in the open river between dams. As delays increased in the Little Goose Dam spill, salmon swimming depths increased. Since fish ladder entrances are near the surface, this decreased opportunities for passage.

Although some delays may have resulted from tagging, we believe other factors caused the extensive delays observed at Little Goose Dam. First, our radio-tagged and control salmon had similar passage times at Little Goose and Lower Granite

[11]E. Slatick, National Marine Fisheries Service, Little Goose Dam, Starbuck, Wash., pers. commun. 1977.

Dams in 1976 and 1977 (Gray and Haynes 1979). Second, the 63% passage of internally radio-tagged salmon in 113 h observed by Liscom and Monan (see footnote 8) at Lower Granite Dam was similar to the 69% passage of radio-tagged salmon in 106 h that we observed in spring 1977 for fish that crossed Little Goose Dam or were initially released above it (Haynes 1978).

Our studies provide the first information on salmon movements near Little Goose Dam. Although they affected salmon movements, spilling and turbine operations are regular events at all dams and would not appear to be solely responsible for excessive delays occurring at Little Goose Dam. Fish passage delays may have resulted from tagged salmon being forced to retravel a portion of their migratory route after release. However, tagging and transport stresses, per se, are common to all tagging studies. Our salmon (1976-77) moved to Little Goose Dam in an average of 38 h, a figure consistent with similar studies at Bonneville Dam (Monan and Liscom see footnotes 2-5). Thus, our tagging and handling methods would not appear to be responsible for extensive delays of salmon movements upstream.

Dropback and milling of radio-tagged salmon in the Snake River at Little Goose Dam may be related to salmon trapping operations. Two factors that may contribute to trapping effects are the mechanical aspects of the trap itself and the possible olfactory sensing of trapped salmon by other salmon moving up the fish ladder. Trap entrances are narrow and steep, the trap emits sharp noises when operating, and hydraulic fluid may reach the fish ladder. It is well known that a human hand in the water of a fish ladder can interrupt salmon movement. Many authors (Hasler et al. 1978) have demonstrated great olfactory sensitivity among salmon. The presence of trapped salmon upstream and other disturbances may inhibit salmon passage through fish ladders.

Extensive passage delays, due to dropback and milling and greater swimming depths in the spill below the dam indicate a unique effect of Little Goose Dam on the upstream migration of chinook salmon. We observed delays at Little Goose Dam averaging 148±64 h (Table 1). Delays reported at other dams were significantly less ($P<0.05$) and averaged only 66±31 h. Cause for great concern is the 83±50 h average delay salmon encounter at each dam while migrating through the Columbia and Snake Rivers. Many salmon must pass eight dams (Figure 1) to reach home spawning areas, and the additive effects of a 4 wk, multidam passage delay may significantly influence spawning success, especially in fall run chinook salmon which have shown the greatest decline in numbers. From 1962 to 1969, before Little Goose Dam was operational, annual passage of fall chinook salmon at Ice Harbor Dam averaged nearly 18,000 fish (U.S. Army Corps of Engineers[12]). However, in 1976 and 1977 fall chinook salmon passage at Ice Harbor Dam was only 1,474 and 1,956 fish (U.S. Army Corps of Engineers[13,14]). Little Goose Dam is 95 km upriver from Ice Harbor Dam (Figure 1). Since the position of fishways, navigation locks, and spillways is different at each dam, effects of each dam must be studied independently. Only then can methods be devised to increase passage success throughout the river system.

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MATURITY, SPAWNING, AND FECUNDITY OF ATLANTIC CROAKER, *MICROPOGONIAS UNDULATUS*, OCCURRING NORTH OF CAPE HATTERAS, NORTH CAROLINA

The Atlantic croaker, *Micropogonias undulatus*, is an important inshore, bottom fish ranging from the Gulf of Maine to Bay of Campeche, Mexico (Chao 1978). United States commercial landings have reached 50,000 metric tons (t) in recent years (Gutherz et al. 1975; McHugh 1977), though dramatic declines in landings have occurred; at least in the area from Cape Hatteras, N.C., to Cape Cod, Mass. (Joseph 1972). White and Chittenden (1977) have postulated the existence of an abrupt change in life histories and population dynamics of Atlantic croaker and other species whose ranges traverse Cape Hatteras. They showed differences in spawning times, size at maturity, maximum size and age, and total annual mortality rates of Atlantic croakers from north and south of Cape Hatteras and speculated the differences may result from different temperature regimes.

Few studies exist on reproduction of Atlantic croaker occurring north of Cape Hatteras. Wallace (1940) studied size at maturity and sexual development of fish from Chesapeake Bay and ocean waters off Virginia and North Carolina. Welsh and Breder (1923) reported size and age at maturity based on collections from Massachusetts to Florida. Occurrence of larval stages and gonad development indicated that spawning occurred from July through December and peaked during October and November (Welsh and Breder 1923; Hildebrand and Schroeder 1928; Wallace 1940). Haven (1957) and Chao and Musick (1977) found indications from juvenile length frequencies of late winter or early spring spawning. The only report of fecundity was that a 395 mm female contained approximately 180,000 eggs (Hildebrand and Schroeder 1928).

This paper presents size at maturity, spawning times as indicated by ovarian development, and fecundity observations of the Atlantic croaker population north of Cape Hatteras.

Methods

All fish were collected during seven National Marine Fisheries Service bottom-trawl surveys of the continental shelf from Cape Hatteras to Block Island, R.I., during 1973-76 (Table 1). The survey design and sampling methods were described by Grosslein (1969). Atlantic croakers were captured each year between lat. 39°00′ N (Cape May, N.J.) and 35°15′ N (Cape Hatteras) in depths from 7 to 131 m.

Subsamples of approximately 25 fish, representative of the length frequency of each catch, were frozen whole for laboratory examination. Each fish was weighed (grams), measured (millimeters total length, TL), sexed, and its maturity stage was determined using the sexual development classification and criteria of Wallace (1940).

TABLE 1.—Summary of Atlantic croaker data collected between Cape May, N.J., and Cape Hatteras, N.C., during 1973-76.

Collection no.	Dates	No. of observations	Number used in probit analysis	
			Males	Females
1	9-16 Oct. 1973	556	245	286
2	27-30 Sept. 1974	699	324	258
3	16-18 Sept. 1975	79	31	28
4	30 Oct.-6 Nov. 1975	607	204	145
5	14-17 Dec. 1975	122	—	—
6	6-17 Oct. 1976	438	84	103
7	18 Dec. 1976	16	—	—
Total		2,517	888	820