Barge Transportation of Juvenile Salmonids on the Columbia and Snake Rivers, 1977

GEORGE T. McCABE, Jr., CLIFFORD W. LONG, and DONN L. PARK

Introduction

Transporting ocean-bound juvenile Pacific salmon, *Oncorhynchus* sp., and steelhead trout, *Salmo gairdneri*, from upriver collection points to safe release sites in the lower Columbia River is one of the major tools being developed by the National Marine Fisheries Service (NMFS) and the U.S. Army Corps of Engineers to reduce fish mortality caused directly or indirectly by dams on the Columbia and Snake Rivers.

Dams are responsible for three major causes of fingerling mortality: 1) Gas bubble disease caused by supersaturation of the river with atmospheric gas, 2) passage of fish through turbines, and 3) delays in migration through reservoirs (Ebel and Raymond, 1976; Collins et al., 1975[1]; Chaney and Perry 1976). Research to solve each problem individually has been only partially successful. The most promising research approach is the development of a fish transportation system that circumvents the known causes of mortality associated with both dams and impoundments.

In 1968, a system for collecting the downstream migrants at the uppermost dams and transporting them by truck around the remaining dams was initiated at Ice Harbor Dam (Ebel et al., 1973) and is now in use at Little Goose, Lower Granite, and McNary Dams.

During the winter of 1976-77, it became evident that because of low precipitation and low snow pack, extremely low river flows were probable during the spring migration of juvenile salmonids in the Snake and Columbia Rivers. Faced with the prospects of little or no spill at the dams and based on the high percentage of fish lost during a similar but less severe situation in 1973 (Ebel and Raymond, 1976), we believed that losses of downstream migrants in 1977 would be catastrophic unless a mass transportation program were carried out. Based on our estimates of the numbers of fish expected and their timing, we predicted that the collection of fish at Lower Granite Dam during the spring of 1977 would exceed our capacity to transport them by truck. Rather than return large numbers of fish to the river with little chance of survival, the NMFS and the Corps made plans to supplement the transportation capability by using barges.

The primary objective of the barging program was to transport fish collected at Lower Granite Dam to safe release sites in the Columbia River below Bonneville Dam. A second objective was to similarly transport juvenile salmonids directly from selected hatcheries (Fig. 1). This report contains detailed descriptions of the design and operation of the barges and provides a general description of the barging program carried out in 1977.

[1]Collins, G.B., W.J. Ebel, G.E. Monan, H.L. Raymond, and G. K. Tanonaka. 1975. The Snake River salmon and steelhead crisis. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. East, Seattle, WA 98112. Unpubl. rep., 30 p.

George T. McCabe, Jr., Clifford W. Long, and Donn L. Park are with the Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. East, Seattle, WA 98112.

ABSTRACT—During the spring of 1977 the National Marine Fisheries Service, in cooperation with the U.S. Army Corps of Engineers, used two cargo tank barges to transport juvenile salmonids down the Snake and Columbia Rivers (through as many as eight dams) to safe release sites in the lower Columbia River. Barge design and performance are described. The transported Pacific salmon, Oncorhynchus *sp., and steelhead trout,* Salmo gairdneri, *were continually supplied with fresh river water pumped through the barge. Fish were released in the main channel approximately 9 km (5.6 miles) below Bonneville Dam, the lowermost dam on the Columbia River. A total of 3,517,242 juvenile Pacific salmon and steelhead trout were hauled on the barges.*

Barge Design

Holding Areas

Transporting juvenile salmonids by barge is not a particularly new concept. Barging juvenile chinook salmon, *O. tshawytscha*, was first done on the

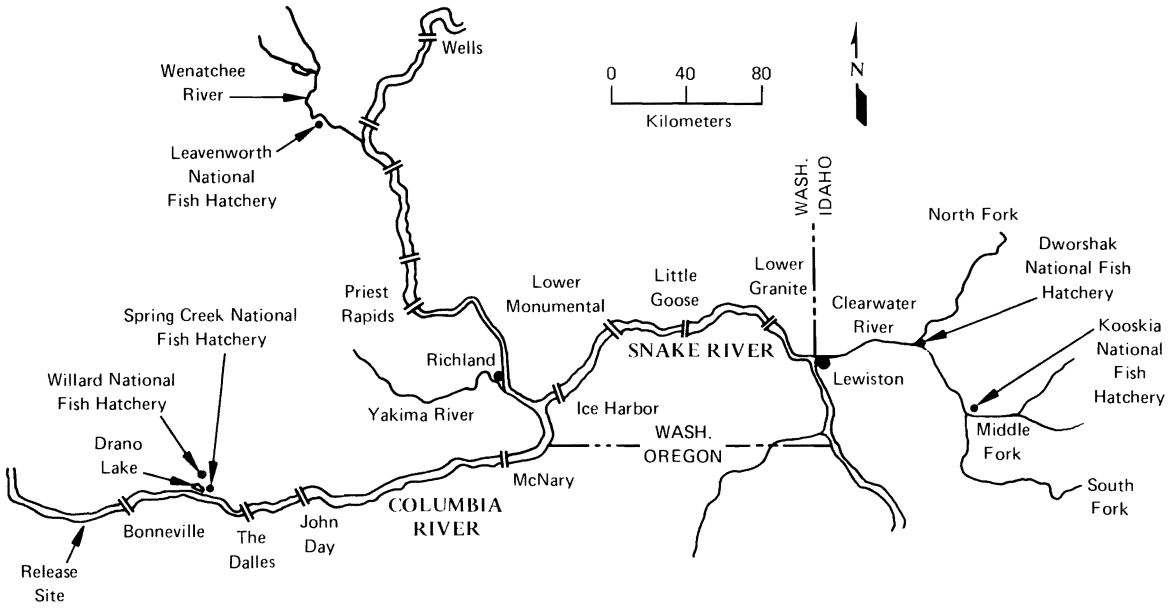


Figure 1.—Juvenile salmonids reared in Idaho streams must pass through eight dams—from Lower Granite to Bonneville—on their journey to the sea. Study map shows fish loading sites and the release site.

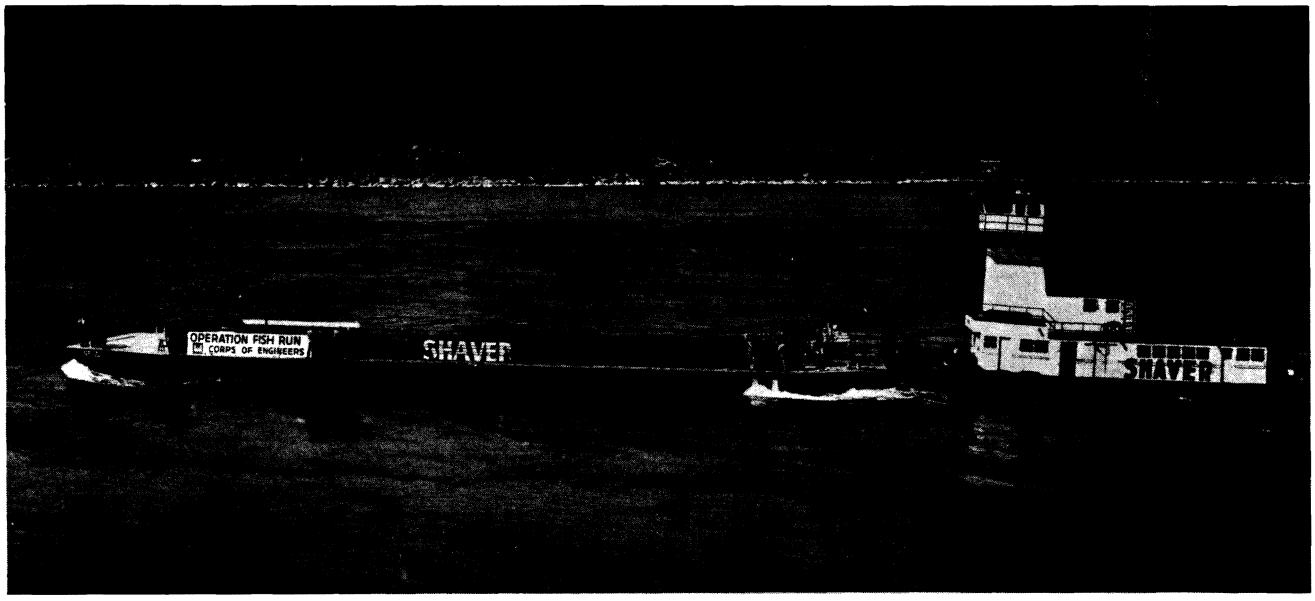


Figure 2.—A fish barge and tugboat on the Columbia River near the release site (photo courtesy of the U.S. Army Corps of Engineers).

Columbia River by the Washington Department of Fisheries in a series of experiments from 1955 to 1958. However, an open type (screened) barge was used (Ellis and Noble, 1960).

In our operation, two barges (modified for fish hauling) and a tug boat were employed. Each barge had a steel cargo tank 33.2 m (109 feet) long and 8.5 m (28 feet) wide (Fig. 2, 3). The cargo tank was divided into eight compartments by a longitudinal bulkhead

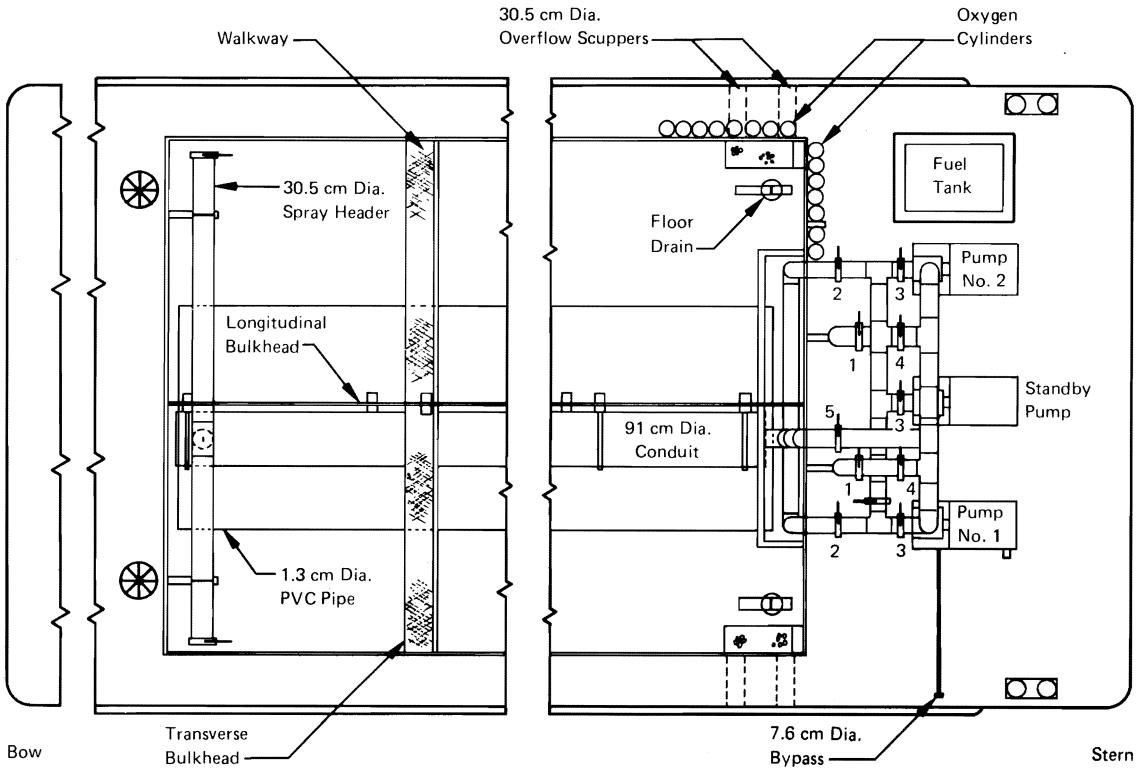


Figure 3.—Overhead view of a fish barge (modified from U.S. Army Corps of Engineers' blueprint). Key to valves: 1) Sea chest, 2) Recirculation, 3) Pump intake, 4) Back flush, and 5) Main discharge.

and three transverse bulkheads. Hinged screens, 2.7 m (9 feet) by 0.9 m (3 feet), were installed in the transverse bulkheads on each side of the longitudinal bulkhead; the six hinged screens, constructed of perforated steel plate (perforations were 4.8 mm or 0.2 inch in diameter), permitted segregation of fish into eight compartments.

Water Supply System

The basic guideline for the barge design was to simulate a modern hatchery pond (raceway) environment. The principal mode of operation was the continual pumping of river water through the barge to minimize the buildup of metabolites in the barge and to provide a continual river water experience for the fish to avoid interference with their natural homing process. A recirculation and oxygenation system served as a backup if local chemical contaminants or other factors limiting river water quality were encountered. The recirculation and oxygenation systems also minimized the cost of treating fish with salt or medication.

Water was supplied to the barge circulation system by two diesel-powered pumps (a standby pump was also available). Each pump had its own sea chest—a chamber located in the bottom of the barge providing access to an opening in the hull for intake of river water. A spoiler, a triangular metal structure placed forward of the sea chest intake and extending along the sides of the intake, was designed to prevent air bubbles (passing along the flat bottom of the hull while the barge was underway) from entering the intakes of the pumps. Air drawn into the circulation system can cause two major problems: 1) Supersaturation of the water with atmospheric gas and 2) a reduction in pump efficiency.

The water was pumped through 25.4-cm (10-inch) and 30.5-cm (12-inch) diameter pipes, and subsequently into a 91-cm (36-inch) diameter pipe that extended the length of the cargo space (Fig. 3, 4). Water exiting from the 91-cm (36-inch) diameter pipe flowed into a 30.5-cm (12-inch) diameter perforated pipe which served as a

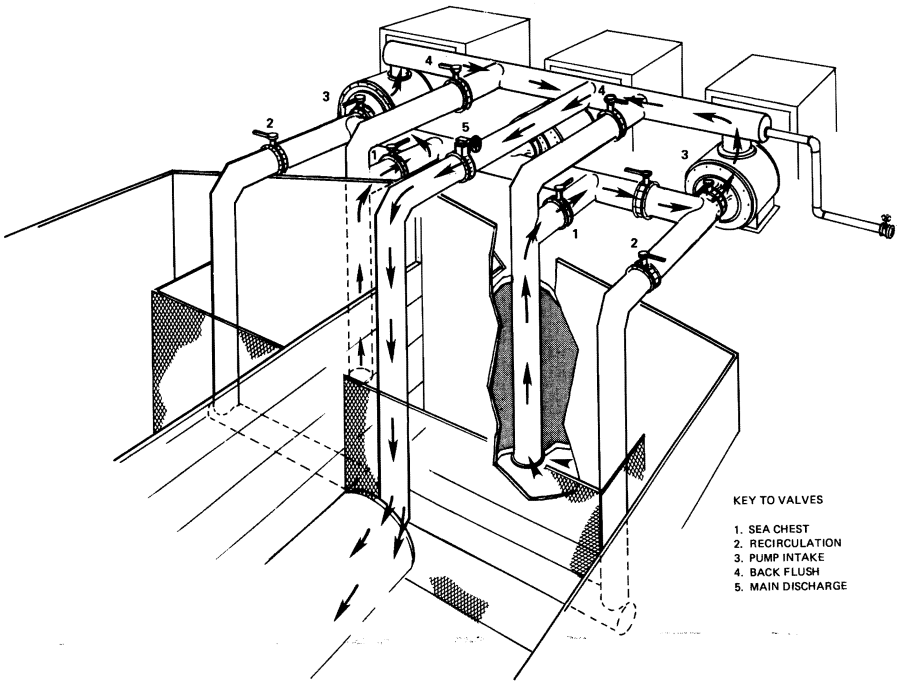


Figure 4.—Diagram of the stern plumbing on the fish barge: Arrows indicate water flow during normal circulation. Valve handles parallel to the flow indicate open valves.

spray bar and was positioned across the forward end of the cargo tank. The spray bar had 12.7-mm (0.5-inch) diameter holes on 50.8-mm (2-inch) centers; the holes were positioned in the horizontal plane on each side of the bar. A steel baffle, located aft of the bar, and the forward wall of the cargo tank helped diffuse the water.

The number and size of the holes in the spray bar were designed to create a back pressure on the pumps, thus increasing the water pressure in the 91-cm (36-inch) pipe. The increased water pressure, approximately 1.1-1.3 kg/cm (16-18 pounds/inch^2) with two pumps operating, facilitated the uptake of oxygen by the water when the system was operating in the recirculating mode. Pressure gauges on the spray bar and the discharge pipe from the pumps were used to monitor changes in the circulation system. Large pressure changes indicated a reduction in water flow; i.e., an abnormal increase signaled a plugging of the spray bar with debris.

Water flow to the spray bar could be modified by: 1) Operating either one or two pumps; 2) partially closing the main discharge valve; or 3) opening the 7.6-cm (3-inch) diameter bypass valve (Fig. 3, 4). The average outputs of one and two pumps were 12.9 m^3/minute (3,400 gpm) and 20 m^3/minute (5,250 gpm), respectively. With two pumps running it took approximately 20 minutes for one complete turnover of water in the barge.

If the intakes of the sea chests became plugged with debris, they could back flushed by opening the back flush and recirculation valves and closing the sea chest valves, thus allowing water in the pipe above the pumps to fall back through the sea chest (Fig. 4). The spray bar could be cleaned of debris by opening butterfly valves on each end.

When the water level in the center of the barge reached approximately 1.1 m (3.5 feet), water began flowing out four screened 30.5-cm (12-inch) diameter overflow scuppers located on the sides of the stern. Maximum water depth in the center of the cargo area, with two pumps operating, was approximately 1.5 m (4.8 feet). The center measurement represented an average because each barge had about 25.4 cm (10 inches) of trim.

Auxilliary Oxygen System

In addition to being able to pump water directly from the river, water could be recirculated in the barge by closing the sea chest valves and opening the recirculation valves. During recirculation, oxygen can be added to the water through three air stones—5.1 cm (2 inches) in diameter and 2.7 m (9 feet) long—installed in the aft end of the 0.9-cm (36-inch) diameter pipe.

Drain Facilities

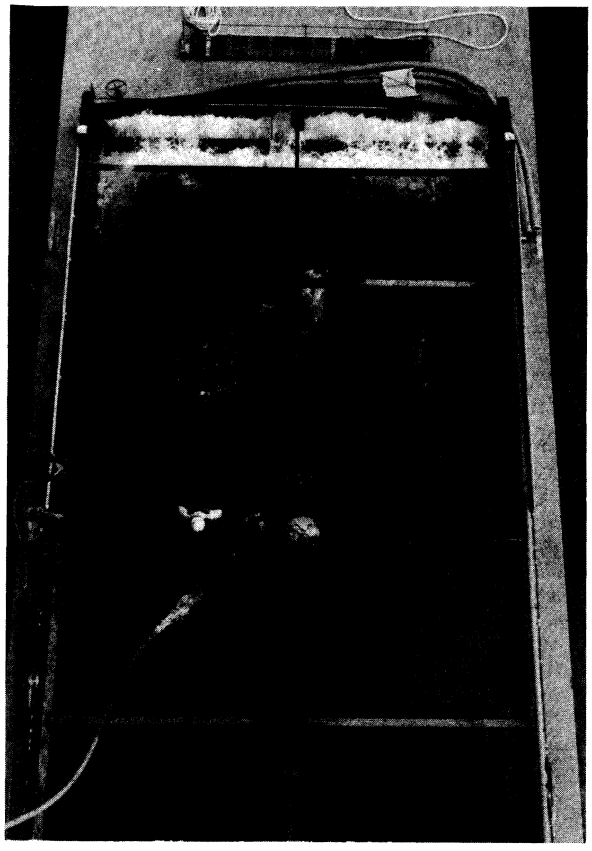
Two 25.4-cm (10-inch) diameter floor drains, located in the stern of the cargo tank, were used to drain fish and water from the barge; the fish were released underwater, taking advantage of the head of water within the barge. Water drained readily from the barge because the barges were double bottomed (the bottom of the cargo tank being approximately 0.9 m or 3 feet above the hull) and had 25.4 cm (10 inches) of trim caused by the weight of the diesel engines, fuel tank, plumbing, and oxygen cylinders located on the aft deck. As the barge drained, it rose higher in the water, thereby maintaining the head of water above river level.

Barge Operations

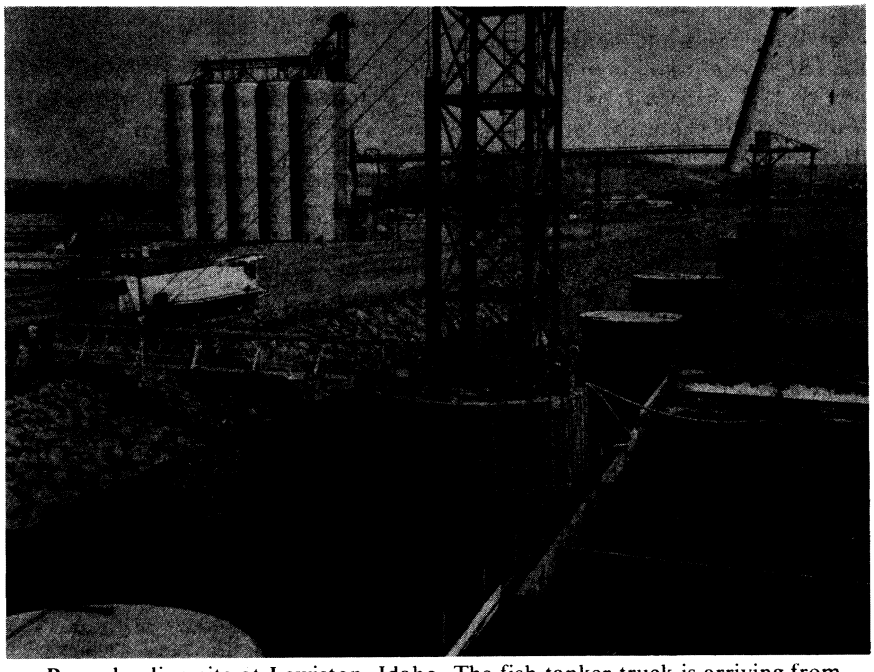
Capacity and Loading-and-Unloading Procedures

We used Cannady's table (Piper, 1970) as a guideline for computing the number of fish we could safely transport. To compute safe loading densities based on gallons per minute of flow, water temperature, elevation above sea level, species, and size of the fish were considered. We determined maximum loading capacity to be approximately 680,000 chinook salmon (20,408 kg or 45,000 pounds of fish averaging 15.2 cm or 6 inches) or 350,00 steelhead trout (26,757 kg or 59,000 pounds of fish averaging 20.3 cm or 8 inches).

Juvenile salmonids were loaded into



Loading spring chinook salmon from Kooskia National Fish Hatchery into barge at Lewiston, Ida. Photographs courtesy of the U.S. Army Corps of Engineers.



Barge loading site at Lewiston, Idaho. The fish tanker truck is arriving from Kooskia National Fish Hatchery to unload its cargo of spring chinook salmon into the barge. Photograph courtesy of the U.S. Army Corps of Engineers.

the barge through either 10.2-cm (4-inch) or 15.2-cm (6-inch) diameter flexible PVC hoses. All the sharp edges on hose couplings were either chamfered or covered to prevent mechanical injury to fish. When fish were unloaded from tank trucks onto the barge, we used a 3.8-cm (1.5-inch) diameter fire hose connected to the barge's circulation system to flush fish from the truck and the loading hoses. The fire hose was also used during the unloading to flush the last fish from the barge.

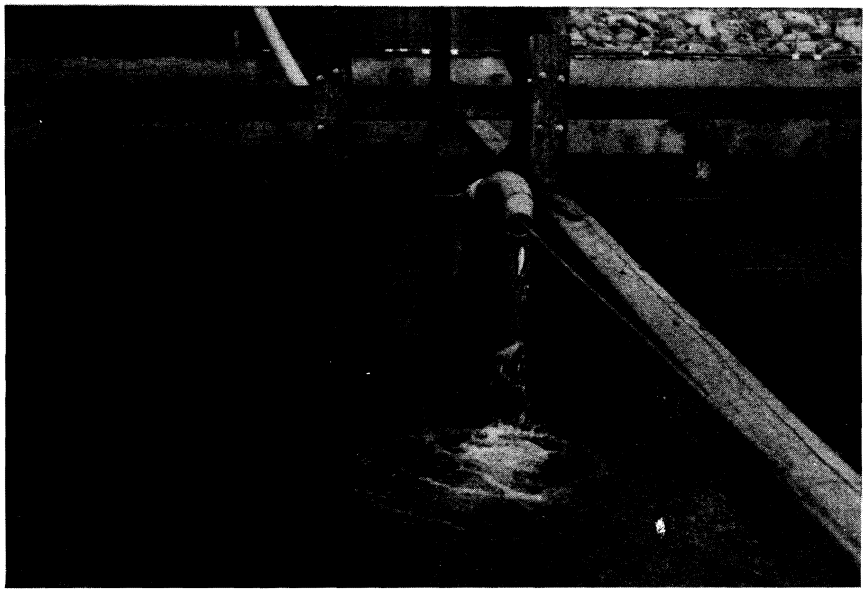
Fish were released in the middle of the main channel of the Columbia River, approximately 9 km (5.6 miles) downstream from Bonneville Dam. Predatory fish, particularly northern squawfish, *Ptychocheilus oregonensis*, are not as abundant in the fast flowing midchannel regions as they are in shoreline habitats. While fish were being discharged, the tugboat was upstream from the barge backing into the current, thereby assuring the fish weren't struck by the tug's screws. Under normal circumstances some water was pumped through the spray bar during the release, so oxygen levels remained optimal.

On 5 April 1977, two NMFS scuba divers viewed the release from underneath the barge and reported the fish appeared to be in good condition. Therefore, by direct observation we were able to determine that fish were released in a safe manner.

Chemical Treatments

A limited experiment involving transportation of juvenile salmonids in salt water was conducted during the barging program. Previous work by NMFS biologists indicated higher survival rates for chinook salmon[2] transported by truck in a 5‰ saline solution. However, the effect of using salt water during transport has not

[2]Park, D. L., E. Dawley, R. Krcma, C. Long, E. Slatick, J. Smith, and G. Swan. 1976. Evaluation of fish protective facilities at Little Goose and Lower Granite Dams and review of other studies relating to protection of juvenile salmonids in the Columbia and Snake Rivers, 1975. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112. Unpubl. rep., 50 p.



Loading spring chinook salmon from Kooskia National Fish Hatchery into barge at Lewiston, Idaho. Photographs courtesy of the U.S. Army Corps of Engineers.

been fully evaluated based on returning adults subjected to the treatment as juveniles. Consequently, only the first barge load of chinook salmon and steelhead trout transported from Lower Granite Dam was subjected to a salt treatment.

The fish were exposed to a 9.5‰ salt solution (sodium chloride) for 1 hour. The salinity was monitored with a YSI salinometer and was achieved by pumping a concentrated salt solution, prepared in a brine tank on shore, to the barge. The fish collected at Lower Granite Dam that were treated in the salt solution appeared to tolerate the increased salinity well. Benefits from the salt treatment will not be known until adults return in 1978-81.

On three occasions we considered it prudent to disinfect the barges because of the possible contamination by diseased hatchery fish that had been transported. To disinfect, we used calcium hypochlorite (65 percent strength) to achieve a chlorine concentration of 18.9 ppm. Water was recirculated for at least 2.5 hours while disinfecting; the residual chlorine was then neutralized with sodium thiosulphate before draining the water.

Oxygen and Temperature Monitoring

Oxygen levels and temperatures in the barge were monitored with a YSI model 51B dissolved oxygen meter. Water directly below the spray bar and near the overflow scuppers in the aft compartments was checked periodically for dissolved oxygen.

Oxygen levels under the spray bar were typically near 100 percent saturation. The lowest oxygen value recorded in the aft compartment was 7.8 ppm at 13°C (55°F). A simultaneous reading in the forward compartment under the spray bar was 10 ppm at 13°C (55°F). The barge was loaded with 153,596 steelhead trout at the time of the 7.8 ppm reading. Oxygen values at different depths did not vary significantly—surface reading and measurements 0.5 m (1.5 feet) above the bottom were generally within 0.2 ppm. In all transports by barge there was no increase in the water temperature between the forward and aft compartments.

Potential Problem Areas

The general performance of the barge was excellent. However, there were some minor problems involving the pumping system and the unloading procedures that merit mention. During periods of rough water on the river, the efficiency of the pumps was reduced. When large waves struck the barge the flow to the spray bar was briefly decreased, indicating that perhaps the pumps were sucking air for a short time. These circumstances were rare and had little effect on transport operations.

On several occasions the holes in the spray bar became partially plugged with river debris, primarily small wooden sticks, and the bar had to be cleaned. The plugging did not create a serious problem; however, the need to monitor pressure change in the pipe was demonstrated to avoid plugging and serious reduction of flows.

Although most of the fish were easily discharged from the barge, the last several hundred fish of a load often were reluctant to leave. Sometimes fish would hide under the 91-cm (36-inch) diameter pipe that extended along the length of the barge. Fire hoses proved useful in flushing these remaining fish toward the aft drains.

The Transport Program

A total of 3,517,242 juvenile salmonids were transported from 5 April to 5 June 1977 (Table 1); breakdown by species was: Coho salmon, *O. kisutch*, 21,777; chinook salmon, 3,111,159; and steelhead trout, 384,306. The longest hauls were made from Lewiston, Idaho, to below Bonneville Dam — 520 km (323 miles). Lower Granite Dam fish were transported 468 km (291 miles). Transport times from Lewiston, Idaho, and from Lower Granite Dam to the release sites were about 34 and 30 hours, respectively.

When hatchery fish were barged, we estimated the mortality associated with loading, transporting, and unloading to be less than 0.5 percent. The estimated mortality rates of chinook salmon and steelhead trout from Lower Granite Dam were 3.6-7.5

[3]Reference to trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Table 1.—Juvenile salmonids transported by barge from various sources and loading sites on the Columbia and Snake Rivers in 1977.

Date loading started Mo/day	Species	Number Unmarked	Number Marked	Source	Loading site	Remarks
4/5	Fall chinook salmon	50,160		Spring Creek National Fish Hatchery	Spring Creek National Fish Hatchery	
4/11	Fall chinook salmon	935,939	76,057	Spring Creek National Fish Hatchery	Spring Creek National Fish Hatchery	
4/12	Fall chinook salmon	999,575		Spring Creek National Fish Hatchery	Spring Creek National Fish Hatchery	
4/19	Spring chinook salmon	329,430	31,200	Kooskia National Fish Hatchery	Lewiston, Idaho	Loaded barge remained in Clearwater River for 14 hours.
4/22	Coho salmon		21,777	Willard National Fish Hatchery	Drano Lake, Wash.	
5/4	Chinook salmon	103,200	10,510	Collector at Lower Granite Dam	Lower Granite Dam	
	Steelhead trout	70,118	10,115			
5/5	Steelhead trout	155,148	17,178	Dworshak National Fish Hatchery	Lewiston, Idaho	All fish, except last load of 28,200 remained in Clearwater River for 12 hours.
5/26	Chinook salmon	24,498	10,198	Collector at Lower Granite Dam	Lower Granite Dam	
	Steelhead trout	36,695	10,097			
6/1	Fall chinook salmon	241,000		Priest Rapids spawning channel	North Richland, Wash.	
	Steelhead trout		48,455	Leavenworth National Fish Hatchery		Originally, fish came from Chelan Hatchery
	Summer chinook salmon	133,876	99,113	Wells spawning channel		
6/2	Chinook salmon	55,483	10,920	Collector at Lower Granite Dam	Lower Granite Dam	An additional 110 adult steelhead (spawned out) were also transported.
	Steelhead trout	26,382	10,118			
		3,161,504	355,738			

percent and 2.2-5.3 percent, respectively. The apparent reason for the increased mortality among fish collected at Lower Granite Dam was that fish arriving at the dam were observed to be debilitated, probably because of low stream flows which caused a laborious migration.

No sea gulls took any fish out of the barge while enroute to the release site, although sea gulls (10-20 birds) were sometimes noted feeding near the release point.

Fish barging should not be viewed as a replacement to the trucking of fish, but as a complementary method of fish transport. Barging is best used when large numbers of fish (i.e., greater than 100,000) have to be transported from collection facilities. Moreover, barging can be efficiently employed in transporting large numbers of fish from hatcheries. Trucks are necessary during the time periods (often several weeks) before and after the peak of the juvenile salmonid migrations. Tanker trucks carry a small fraction of a barge's capacity; therefore, they are well suited for use during the pre- and post-peak migrations of juveniles.

Biologists of the NMFS (Ebel et al., 1973) have demonstrated that the homing ability of adult salmonids, captured as juveniles while they were actually migrating downstream and then transported in trucks, has not been seriously impaired; therefore, it is reasonable to assume that the homing ability of barged fish should not be reduced. It is also theorized that the continual exposure of the fish to river water throughout the downstream barge journey might ensure homing success with fish transported directly from hatcheries.

The success of the barge as a useful transport mode will be fully evaluated when adults return in 1978-81. Because releases of truck-transported fish were made concurrently with barge releases, a direct comparison between barge and truck transport systems can be made. Adults returning from all experimental releases will be recorded at Lower Granite Dam, at hatcheries, on natal spawning grounds, and in commercial and recreational fisheries.

Acknowledgments

We thank personnel from the U.S. Army Corps of Engineers for their major roles in the preparation of the fish barges and the loading site at Lower Granite Dam. The project was financed by the U.S. Army Corps of Engineers. Financial assistance was also provided by Chelan, Douglas, and Grant County Public Utility Districts for the barge operation from Richland, Wash., on 1 June 1977.

Literature Cited

Chaney, E., and L. E. Perry. [1976.] Columbia Basin salmon and steelhead analysis: Summary report 1 September, 1976. Pac. Northwest Reg. Comm., Vancouver, Wash., 74 p.

Ebel, W. J., D. L. Park, and R. C. Johnsen. 1973. Effects of transportation on survival and homing of Snake River chinook salmon and steelhead trout. Fish. Bull., U.S. 71:549-563.

Ebel, W. J., and H. L. Raymond. 1976. Effect of atmospheric gas supersaturation on salmon and steelhead trout of the Snake and Columbia Rivers. Mar. Fish. Rev. 38(7): 1-14.

Ellis, C. H., and R. E. Noble. [1960.] Barging and hauling experiments with fall chinook salmon on the Klickitat River to test effects on survivals. Wash. Dep. Fish., 70th Annu. Rep., p. 57-71.

Piper, R. G. 1970. Know the proper carrying capacities of your farm. Am. Fishes U.S. Trout News 15(1):4-6, 30.