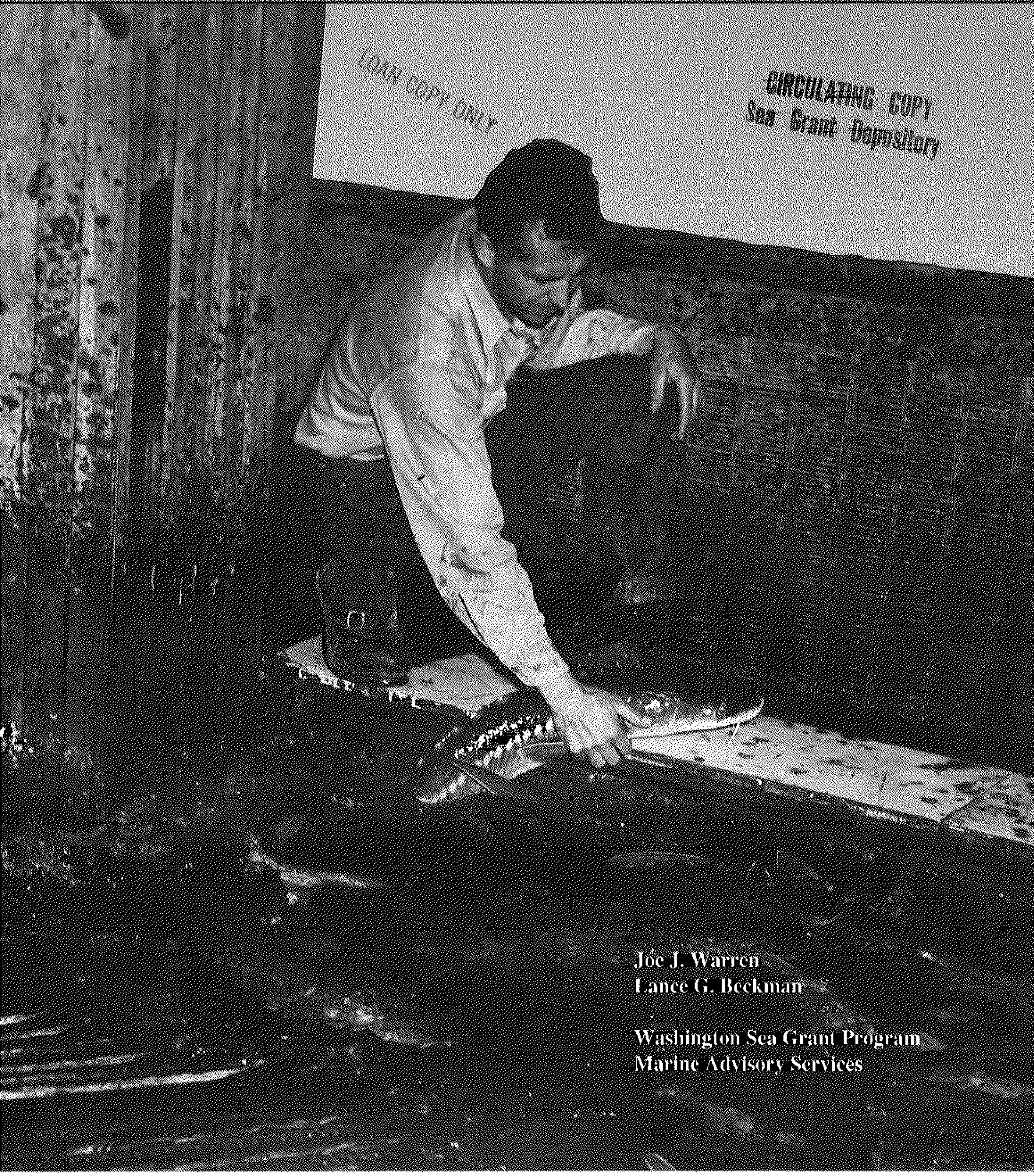
Fishway Use by White Sturgeon on the Columbia River



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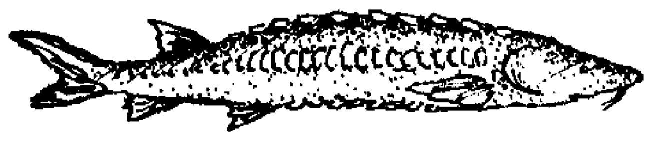


IN MEMORIAM

This publication is dedicated to the memory of Ivan J. Donaldson (1912-1989) for his perseverance in fishery programs related to fish passage at Columbia River dams. He was a leading pioneer in white sturgeon biology and expressed great concern for the continued existence of this prehistoric fish after construction of dams on the Columbia River. His accurate record-keeping of white sturgeon events provided the historical accounts addressed in this publication. Donaldson's work served as an influence in the design, construction, operation, and management of fish passage facilities at Bonneville, The Dalles, and McNary dams. His career lasted 33 years with the U.S. Army Corps of Engineers, and upon his retirement in 1973, he received the Meritorious Civilian Service award, the highest honor bestowed on civilian employees.

FISHWAY USE BY WHITE STURGEON ON THE COLUMBIA RIVER

White sturgeon *(Acipenser transmontanus)* is one of seven sturgeon species found in North America. It is also the largest freshwater fish on this continent, exceeding 1,000 pounds in weight and sometimes reaching nearly 20 feet in length. Modern relics of an ancient group of fishes, white sturgeon inhabit the larger rivers and bays of the Pacific Coast from Ensenada, Mexico, to the Aleutian Islands of Alaska. The sturgeon are distinguished from a typical bony fish (such as a salmon) by a skeleton that is mostly cartilaginous, that has a notochord (a flexible rod of cells that forms the supporting axis of the body) instead of a backbone, a primitive fin and jaw structure, and a unique digestive system. When allowed access to the ocean, white sturgeon are semianadromous—that is, they are capable of migrating regularly between fresh water and salt, spending different parts of their lives in one or both environments. Some populations of white sturgeon may spend their entire lives in fresh water, such as in the reservoirs of the Columbia River. White sturgeon can spawn several times in a lifetime, females spawning at intervals ranging from 2 to 8 years. They may spawn in areas of deep gravel riffles, in deep holes, and over rocky bottoms where swift currents exist.

Sturgeon stocks throughout the world have been depressed because of demand for their highly valued flesh and the caviar produced from their eggs. Human activities in watersheds where sturgeon live have also affected sturgeon habitat. Historically, sturgeon products have been considered valuable in Europe, Asia, and North America. The largest white sturgeon resource in North America is in the Columbia River, and yet it has never been a high priority because of concern over declining salmon stocks. During the late 1800s, white sturgeon were nearly wiped out by commercial fishing, but populations have been slowly recovering and they are now an important resource for both commercial and recreational fishermen. Angling for white sturgeon has become the most popular sport fishery below Bonneville Dam on the Columbia River.

Much of the research literature on white sturgeon in the Columbia River has stated that the dams are migration barriers to white sturgeon, causing *isolated* or *land-*

locked populations (meaning that they are unable to migrate up or down the river to the ocean, but rather are confined to reservoirs). It is suggested that fish ladders at the dams are inadequate for sturgeon use and that passage is minimal at best. However, biologists have seemed unaware that annual reports from the U.S. Army Corps of Engineers indicate that white sturgeon passage does occur at Bonneville, The Dalles, John Day, McNary, and Priest Rapids dams. On the Columbia River, dams from Bonneville Dam all the way upstream to Wells Dam were constructed with fishways (fish ladders) to allow salmon and steelhead passage upriver to their spawning grounds (Fig. 1). These fish ladders were not designed with white sturgeon in mind, and yet these fish have been observed moving past the fish counting stations. Use of fishways by white sturgeon is highly variable among the dams, however.

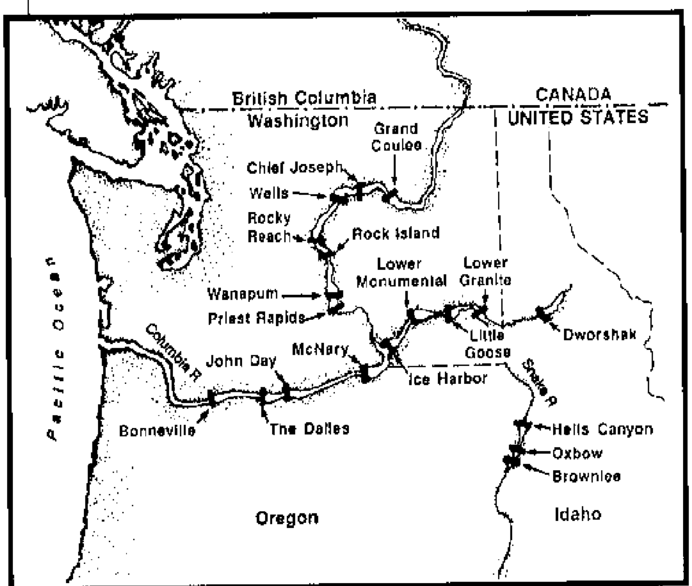


Figure 1. Columbia and Snake River dams

Fish Ladder Design

The purpose of fish ladders, of course, is to enable fish to migrate past natural or man-made barriers. First introduced in Europe over 300 years ago with the aim of passing water around or through an obstruction, fish ladders are engineered so as to dissipate the energy in the water sufficiently to permit fish to ascend without undue stress.

Since the construction of Bonneville Dam, however, fish ladders have undergone many design improvements as new biological knowledge has become available. Because of the complexity of fish ladder design, this publication describes only the general characteristics of the fish ladders at Bonneville, The Dalles, and John Day dams, where white sturgeon passage has been observed most frequently.

Photo 1. Restricted weirs

Fish ladders on the lower Columbia River dams are primarily overflow weir-types that gradually ascend from downstream (the tailrace) to upstream (the forebay) of the dam. The weirs act as barriers in the ladder to control water flow and to form a series of steps and pools. Typical weirs range from 24 to 30 feet in width and 6 feet in height. They are spaced 10 to 16 feet apart and have a minimum one-foot vertical drop between each pool. Weirs can be either "full width" ones, which allow water to flow evenly over the entire width, or "restricted" ones, which allow water to flow over only a portion of the weir (Photo 1). Water flows through a fish ladder at a rate of approximately 8 feet per second.

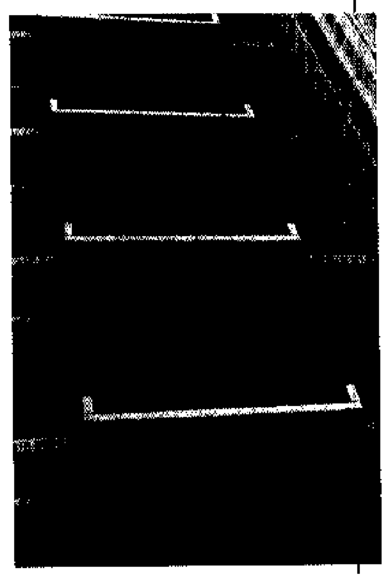


Photo 2. Restricted weir showing orifices (looking upstream at a fish ladder)

It was initially assumed that salmon and steelhead, for which the fish ladders were designed, prefer to jump from one pool to the next. However, when it was discovered that fish prefer to stay under water while moving upstream, the ladder weirs were constructed with orifices at the bottom that range from 18 to 24 inches square (Photo 2). The orifice is the most critical component that allows white sturgeon to use the fish ladders, since white sturgeon are bottom-dwellers. The relatively small size of the weir orifices could prevent very large sturgeon from using the fish ladders.

Historical Passage of White Sturgeon through Fish Locks and Ladders

Bonneville Dam, completed in 1938, was the second dam built on the Columbia River. (A second powerhouse on the Washington shore was completed in 1981.) The dam is located 145 miles from the mouth of the river, where tidal exchange has its farthest upstream influence. The dam was constructed with fish locks (elevator-like structures) and overflow weir-type fish ladders to enable migrating salmon and steelhead to bypass this man-made barrier. The fish passage facilities proved effective for these fish, but left much to be desired for the bottom-dwelling white sturgeon, which lacked the ability to negotiate waterfalls and other barriers. White sturgeon were no longer able to journey up or down the Columbia and Snake rivers; many were trapped above Bonneville Dam and it was not known how this would affect their survival without access to the ocean.

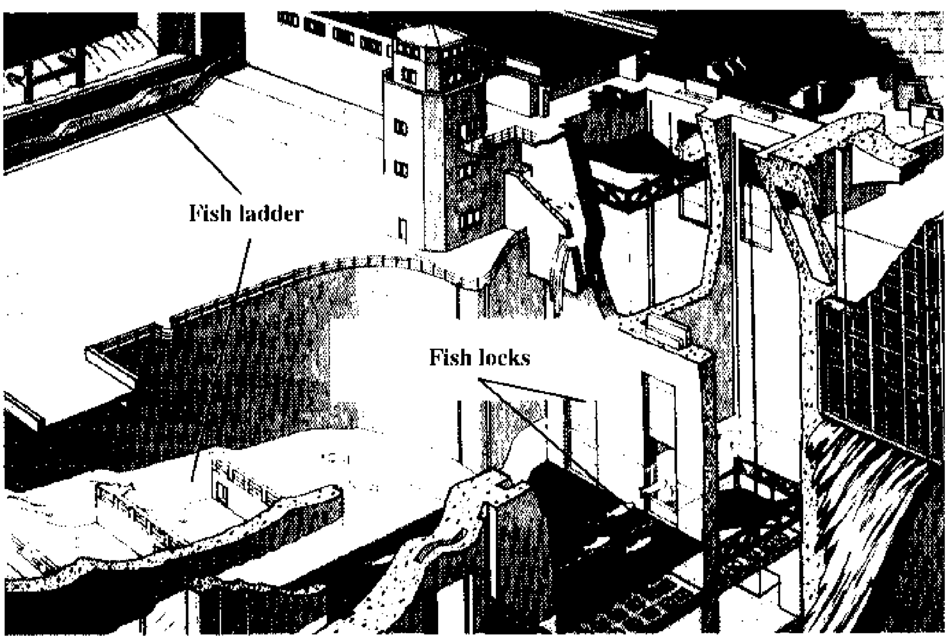
Use of Fish Locks

Bonneville Dam was constructed with three pairs of fish locks—one pair on the south end of the Oregon powerhouse (Fig. 2) and one pair on each end of the spillway. The locks measured 20 feet square and had a lift height of about 90 feet. Cables activated a grated rack to direct fish to the top. The basic operation was similar to that of a navigation lock. Fish entering the lock were trapped; water filled the lock to a level equal to that of the forebay; and then a grated floor was raised to the top of the lock, where fish could exit into the forebay. A single lock cycle took about 30 minutes to an hour, and the operator periodically conducted a lift even though there was no way of knowing exactly how many fish, if any, were trapped. Biologists from the U.S. Army Corps of Engineers would generally operate the locks to coincide with the peak timing of salmon and steelhead runs.

It was discovered that at certain times of the year many white sturgeon congregated at the base of Bonneville Dam. Those measuring less than 4 feet in length were often found in the powerhouse draft tubes (the area below the turbine blades) during repair or maintenance work. More important, however, was the ability of the white sturgeon to enter the fish locks and be elevated into the Bonneville Dam forebay. Ivan J. Donaldson, resident fish biologist for the Corps of Engineers at Bonneville Dam from 1940 to 1973, was largely responsible for operating the fish locks. He wrote in a 1946 Annual Report on the Passage of Fish:

> *Few have done so, but rarely does a sturgeon ascend the ladders. The men who are most familiar with their habits are convinced that the sturgeon have a yearly period of migration in the summer months when the water is warm. In 1939, 1942, and 1946, it was demonstrated that these fish will move into the fish elevators, but the migration ceases about the first of October.*

Figure 2. Bonneville Dam fish passage facilities U.S. Corps of Engineers, Portland District



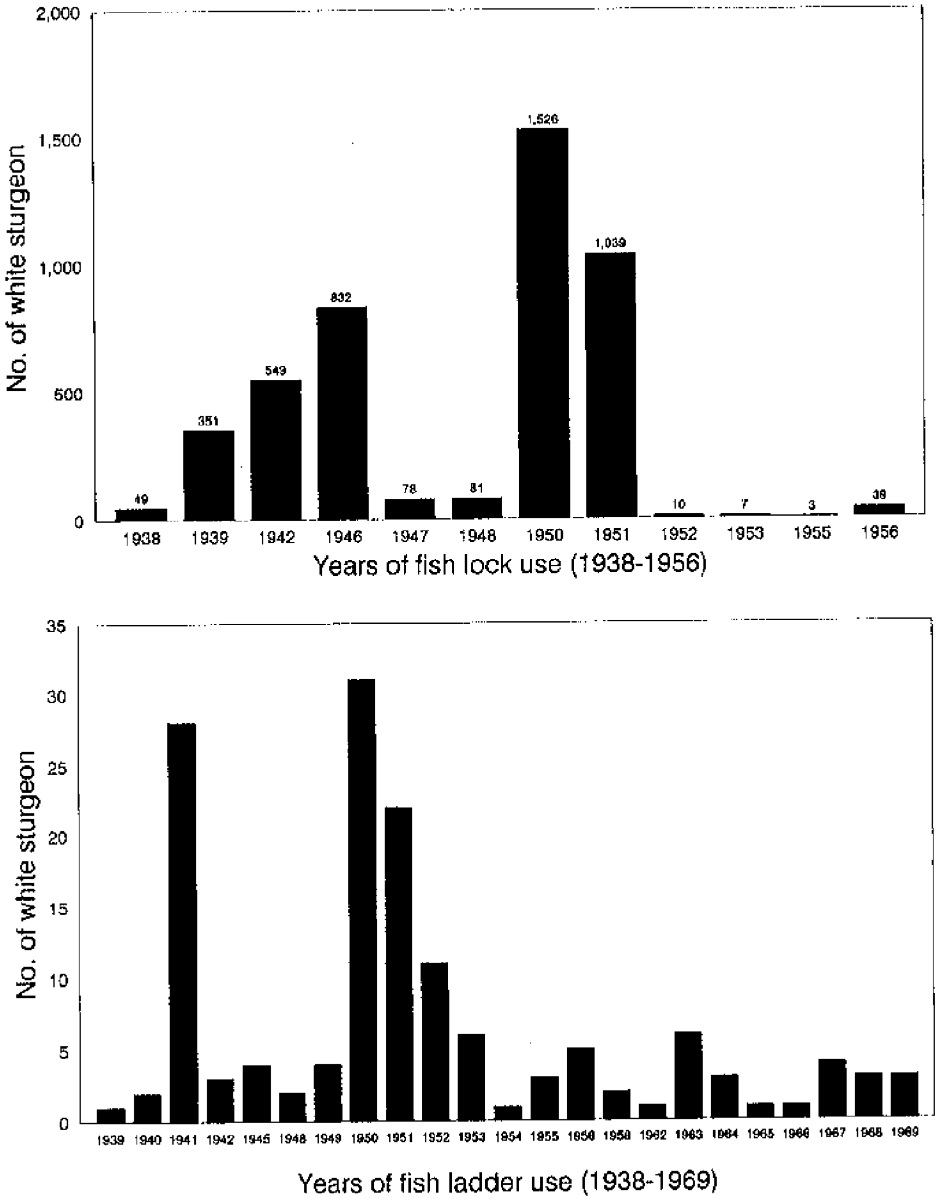


Figure 3. Historical use of fish locks and fish ladders by white sturgeon at Bonneville Dam

The fish lock was so successful, in fact, that in 1951 a record 119 white sturgeon were lifted to the forebay in one day. However, a former fish lock operator (name unknown) informed Ivan Donaldson that several hundred white sturgeon had been lifted at one time in 1938 or 1939. On the other hand, not all lifts resulted in high catches; sometimes no white sturgeon were trapped. Donaldson recorded that unsuccessful fish hauls in locks seemed to be related to water conditions at the entrance of the fish collection system: when swifter than normal flows from the fish lock collection system occurred, the catch of white sturgeon was poor.

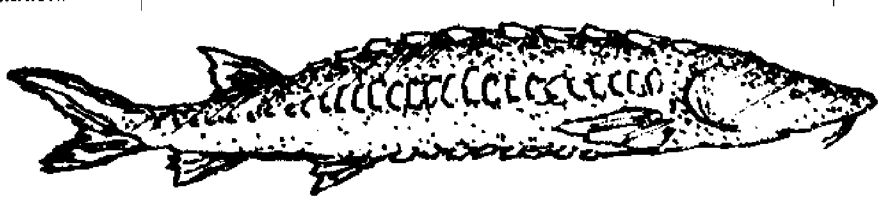
During a 31-year period (1938–1969), 4,711 white sturgeon were lifted by fish locks or ascended ladders over Bonneville Dam (Fig. 3). The fish locks were operated in only 12 of those 31 years, yet they accounted for 97 percent of the total white sturgeon that reached the forebay. White sturgeon entering the fish locks were limited to 4.5 feet or less in length because of the design of the fish collection system.

The last recorded use of a Bonneville Dam fish lock was in 1971 when the fish ladder on the Oregon shore was drained for repair. The original intent of the fish locks, as already indicated, was to pass salmon and steelhead upriver and to serve as a backup when fish ladders were drained for maintenance or repair. However, the fish locks were not suitable for salmon and steelhead passage, were very time-consuming, and were labor-intensive. They were discontinued for white sturgeon use because of a lack of time and money and because few people were really interested in providing passage for white sturgeon.

It is interesting to note that the fish locks at Bonneville Dam gained attention from other parts of the world. In 1946, for example, a Russian fisheries scientist visited the dam seeking information on how to lift sturgeon above the dams being built in Russia. In 1960, French engineers planning a dam on the Sefid Ruud River, a tributary of the Caspian Sea in Iran, requested information on how to pass sturgeon over dams.

Use of Fish Ladders

Initially, it was believed that the Bonneville Dam fish ladders represented the white sturgeon's limit of physical ability, and only a small percentage (3 percent of the



total passage count) from 1938 to 1969 had used the ladders. However, white sturgeon passage over the dam improved after 1950 when all the ladder weirs were modified to provide passage by orifices at the ladder floors. This allowed white sturgeon to swim through rather than over the weirs.

White sturgeon using the fish locks and ladders to bypass Bonneville Dam led early fishery biologists to believe that a summer migration occurred in August. Although they could not explain why this seasonal migration took place, it was observed annually from 1938 to 1969 (Fig. 4).

WHITE STURGEON PASSAGE SINCE 1986

At Bonneville, The Dalles, and John Day dams from 1986 to 1991, fish ladder use by white sturgeon was greatest from May through November each year (Fig. 4), with most sturgeon being observed during July and August. This peak of fish ladder use by white sturgeon is similar to historical passage at Bonneville Dam. The typical length of white sturgeon using the fish ladder was 2 to 4 feet.

Fishery biologist Alexander D. Bajkov noted in 1951 during a white sturgeon tagging experiment that many

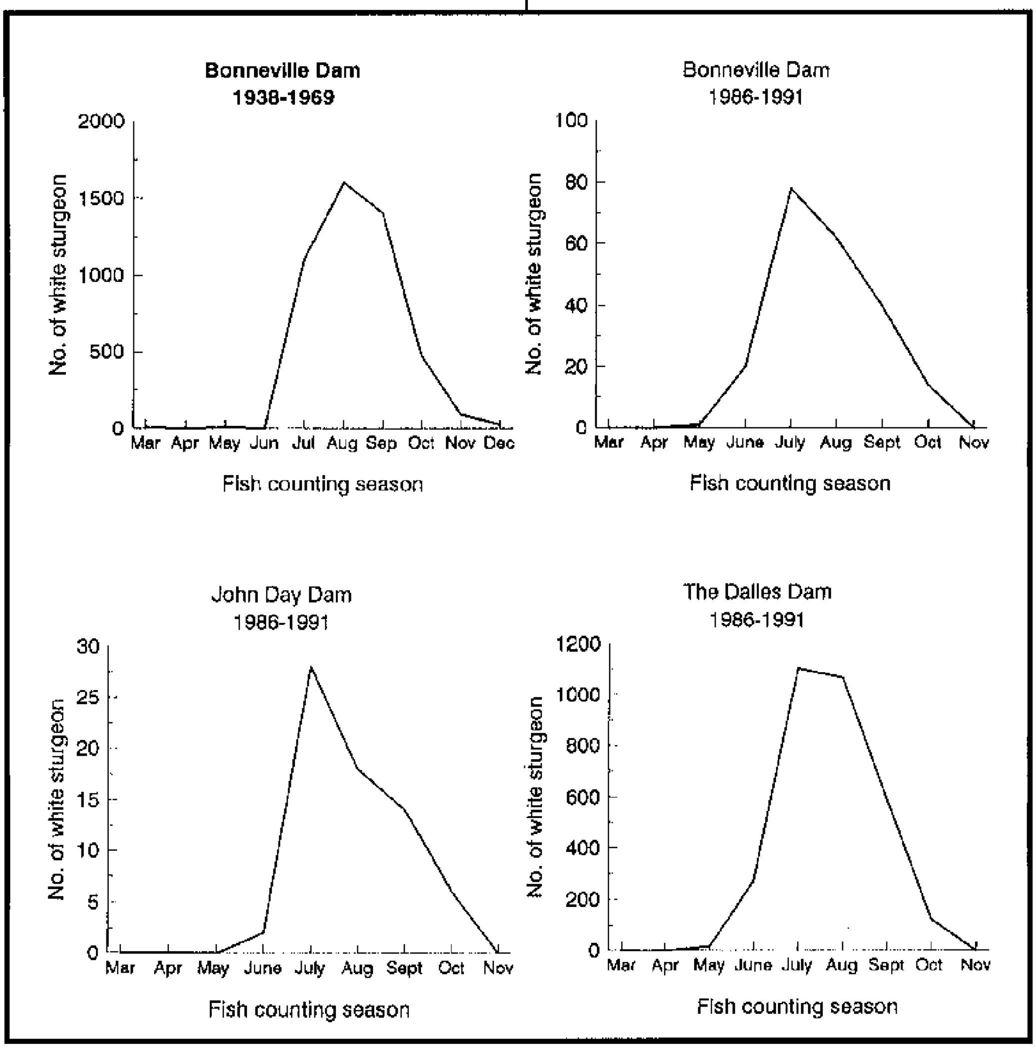
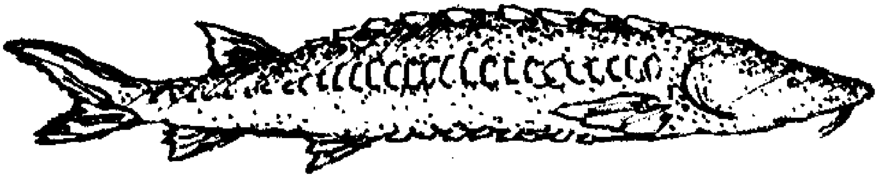


Figure 4. Peak migration of white sturgeon through fishways



Bonneville Dam							
Months	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	
Mar	0	0	0	0	0	0	
Apr	0	0	0	0	0	0	
May	0	0	1	0	0	0	
June	5	7	1	6	0	1	
July	21	5	3	23	18	8	
Aug	12	1	3	23	16	7	
Sept	3	5	8	7	11	6	
Oct	0	1	7	1	1	4	
Nov	0	0	0	0	0	0	
Total	**41**	**19**	**23**	**60**	**46**	**26**	**215**
The Dalles Dam							
Mar	0				0		
Apr	0	0	0	0	0	0	
May	1	7	5	0	2	4	
June	31	99	28	75	23	16	
July	165	165	65	141	337	230	
Aug	339	125	38	132	276	158	
Sept	206	55	50	62	119	101	
Oct	49	28	1	13	21	14	
Nov				0	0		
Total	**791**	**479**	**187**	**423**	**778**	**523**	**3181**
John Day Dam							
Mar	0						
Apr	0	0	0	0	0	0	
May	0	0	0	0	0	0	
June	0	1	0	1	0	0	
July	4	18	1	0	5	0	
Aug	7	5	1	1	4	0	
Sept	3	2	1	3	1	4	
Oct	2	3	0	0	1	0	
Total	**16**	**29**	**3**	**5**	**11**	**4**	**68**

Table 1. Observed sturgeon counts at mainstem Columbia River dams

small sturgeon were located in the tailrace area of Bonneville Dam from mid-August through November. He commented:

> *. . . a strong possibility that a general upstream migration of sturgeon was underway in the late summer and fall. Simultaneously the absence of sturgeon had been noticed immediately above Bonneville Dam when an experimental set line of 60 hooks failed to catch a single sturgeon during 12 consecutive days. This unusual experience strongly indicates the possibility that the entire sturgeon population moved upstream from the Bonneville lake forebay area into the upper part of the river. This theory seems to be logical because the absence of fish immediately above the dam coincided with the tremendous concentration of small sturgeon just below the dam.*

Perhaps this timing of the migration of white sturgeon is associated with their efforts to locate a suitable food supply or appropriate overwintering areas.

There is speculation also that white sturgeon enter and exit reservoirs through the navigation locks, but there has been no study to confirm the extent of movement through these locks. However, in 1961 when The Dalles navigation lock was drained for maintenance, several white sturgeon were found. Further evidence of white sturgeon movement between Columbia River reservoirs has been found in tagging studies done by the Oregon Department of Fish and Wildlife. From 1987 to 1991, 26 recaptures of tagged white sturgeon showed downstream movement between reservoirs, and one fish moved upstream.

Documentation of White Sturgeon Passage

Because of Donaldson's interest in white sturgeon at Bonneville Dam, the annual fish passage reports from 1938 to 1969 contained detailed information about this fish. He learned much about white sturgeon biology by using fish locks to lift white sturgeon over the dam and conducting his own studies (Photo 3).

From 1969 to 1980, white sturgeon passage was reported from Bonneville Dam alone; but since 1985, white sturgeon passage has been recorded and entered into annual fish passage reports from Bonneville, The

Photo 3. *A load of white sturgeon that was lifted to the top of the fish lock at Bonneville Dam.*

Dalles, and John Day dams. It should be noted that white sturgeon counts are recorded only at the convenience of the fish counter when not preoccupied by the official counts of salmonids and shad. Hence, the counts do not represent net upstream passage, nor are they adjusted for nonobservation periods. There are two fish-counting stations at each dam, one on each side of the river, and they are located on the upper end of the fish ladder near the exit into the forebay. Fish counters are in an isolated viewing room and observe fish passage through a window 5 feet wide. The fish-counting schedule at each dam ranges from March through November, and fish counters record from 5 a.m. to 9 p.m., with a 10-minute break each hour.

Bonneville Dam

Bonneville Dam is the first hydroelectric facility up the Columbia River. Its fish ladders are the second most heavily used by white sturgeon to traverse over a dam (Fig. 4). The dam has four fish ladders and there are no discernible differences in white sturgeon counts between

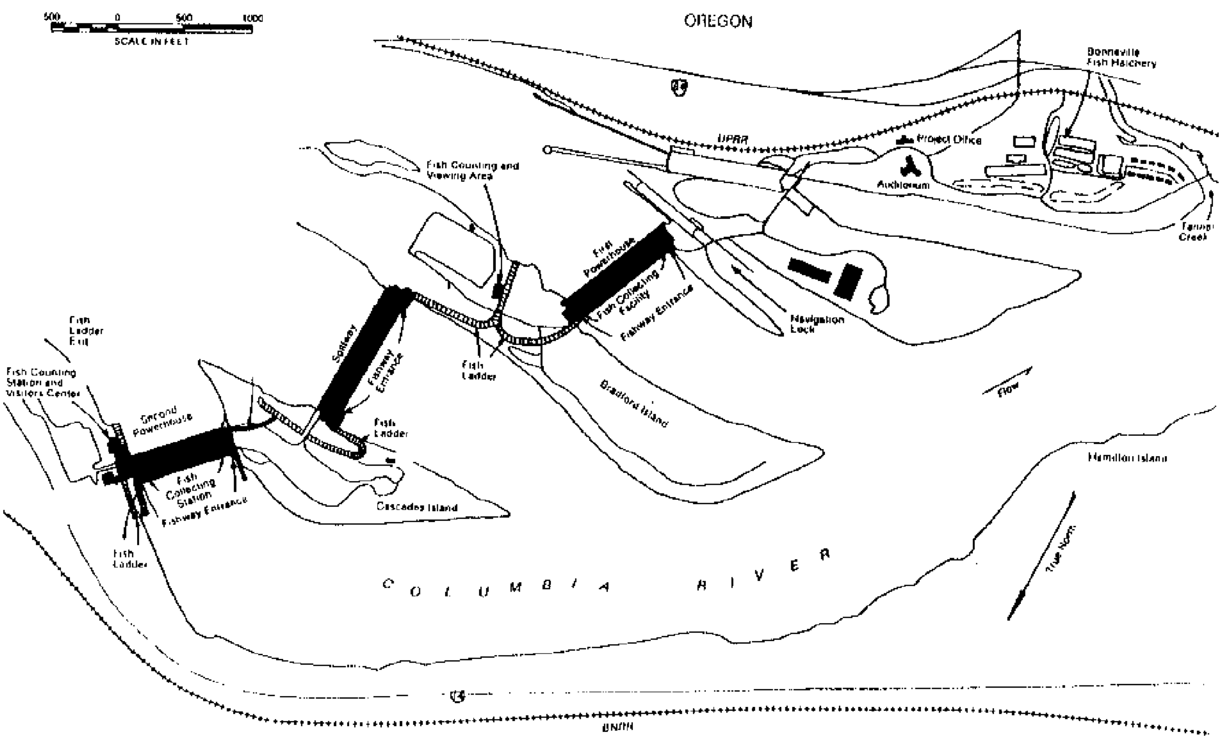


Figure 5. Bonneville Dam and fish passage facilities

Photo 4. The Dalles Dam east fish ladder

the two counting stations on the Washington shore and the two on Bradford Island (Fig. 5). During the 1986 to 1991 period, white sturgeon ranged from 1 to 7 feet in length, with most being about 3 feet. Only 13 white sturgeon were observed passing downstream, and 58 percent of the white sturgeon total was recorded during morning hours (5 to 11 a.m.).

The Dalles Dam

The Dalles Dam, completed in 1957, is the second dam up the Columbia River and is located 191 miles from the mouth. Fish passage facilities include a north and east fish ladder (Fig. 6). The east fish ladder includes a fish channel connecting the west fishway entrance and south spillway entrance and a second channel connecting with the fish collection system along the powerhouse. There is a fish lock also located near the east fish ladder, but it is inoperable and there are no records of its use to lift white sturgeon over the dam.

The Dalles Dam has the highest recorded fishway use by white sturgeon, and from 1986 to 1991, the east fishway accounted for the vast majority of sturgeon passage in the Columbia River (Table 1).

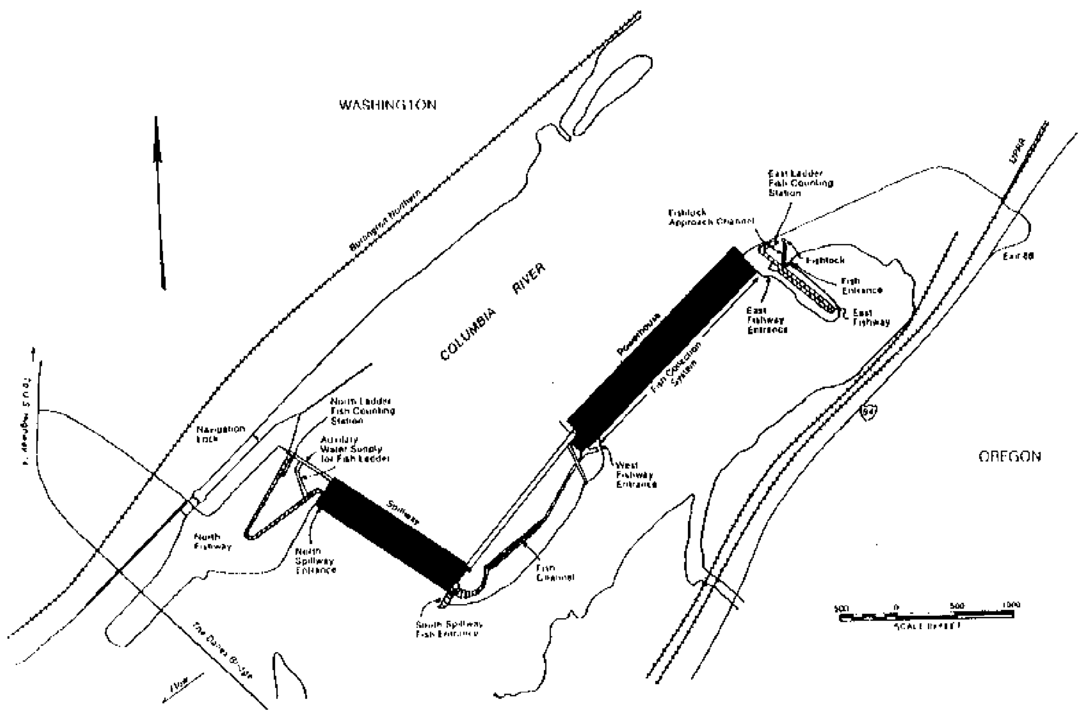


Figure 6. The Dalles Dam and fish passage facilities

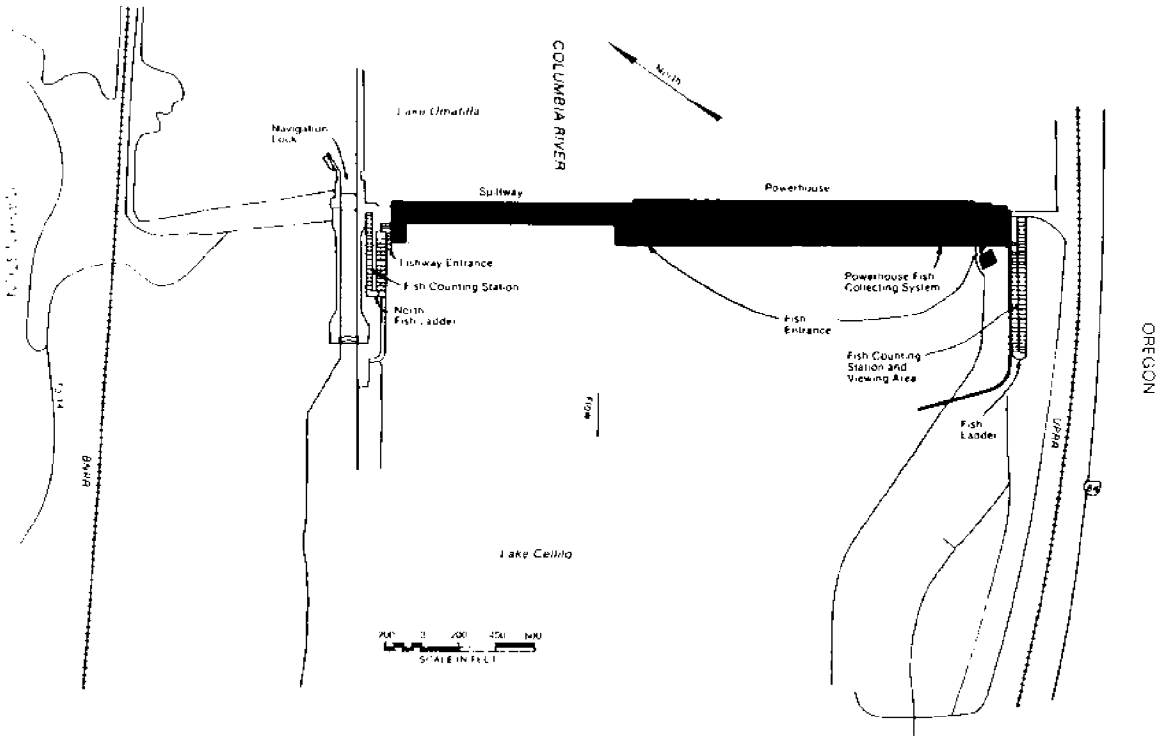


Figure 7. John Day Dam and fish passage facilities

White sturgeon as long as 11 feet have ascended or descended the east ladder, and an individual fish counter noted that extremely large white sturgeon tilted sideways to squeeze by the viewing window. In the 1986 to 1991 period, the most frequent size class observed was about 3 feet. Observations at The Dalles Dam, unlike those at Bonneville Dam, showed little difference in the timing (a.m. *vs.* p.m.) of white sturgeon passage. Only 8 percent of the white sturgeon were noted to have descended past the viewing window.

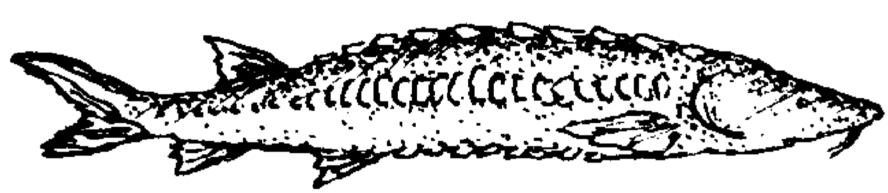
It is interesting to note that counts for other species such as walleye and northern squawfish are also consistently higher here than at other dams. Why white sturgeon and other species use the east fish ladder so much more than others is unknown, since the design of the east fish ladder is similar to that of other Columbia River fish ladders.

John Day Dam

Located at river mile 215, John Day Dam became operational in 1969 and has two fish ladders, one each on the Oregon and Washington sides (Fig. 7). No fish locks were included in the fish passage facilities. The total white sturgeon passage from 1986 to 1991 was 68 fish, the lowest number observed of the dams under consideration, with the Washington side accounting for 59 of the total. The size of white sturgeon ranged from 2 to 5 feet in length, with 3 feet again being the most common size. Nine white sturgeon were observed passing downstream, and 43 white sturgeon were recorded during the p.m. counting hours (12 noon—9 p.m.).

STURGEON IN RUSSIA

American rivers are not the only ones faced with man-made obstructions causing sturgeon migration problems. In Russia, where sturgeon are also highly valued, hydroelectric facilities inhibit sturgeon migration as well. Although the power dams are constructed with traditional fish ladders, they are impractical for large adult sturgeon to use. Therefore, fish elevators much like the once-used fish locks at Bonneville Dam were specially built for them. Two fish elevators were installed at the Volgograd power dam on the Volga River, a tributary to the Caspian Sea. These elevators lift sturgeon during the main spawning migration of three species—beluga sturgeon, *Huso huso* (twice the size of white



sturgeon), Russian sturgeon, *Acipenser gueldenstaedti*, and stellate sturgeon, *A. stellatus*. The results have been highly successful, allowing approximately 23,000 sturgeon a year to bypass the dam.

BENEFITS OF STURGEON PASSAGE

In September of 1942, Ivan Donaldson wrote to Captain R.B. Cochrane, Area Engineer at Bonneville Dam, this one of many recommendations concerning the fisheries problem at Bonneville Dam:

> *Look ahead to the building of Umatilla and be willing to build a pair of locks for salmon and for sturgeon. I suggest that they also be designed for bottom traveling fish which do not like to rise over any wall. The design should be such that sturgeon can enter from a level with the bottom of the deepest hole at the dam. I would like to think that we have demonstrated, by cutting holes in the bottom stoplogs, which regulate the fish entranceway elevation to the ladder collection bays, that sturgeon will then enter the collection bays (some will anyway) and be lifted over the dam. . . .We may find in the future that sturgeon must migrate to some extent.*

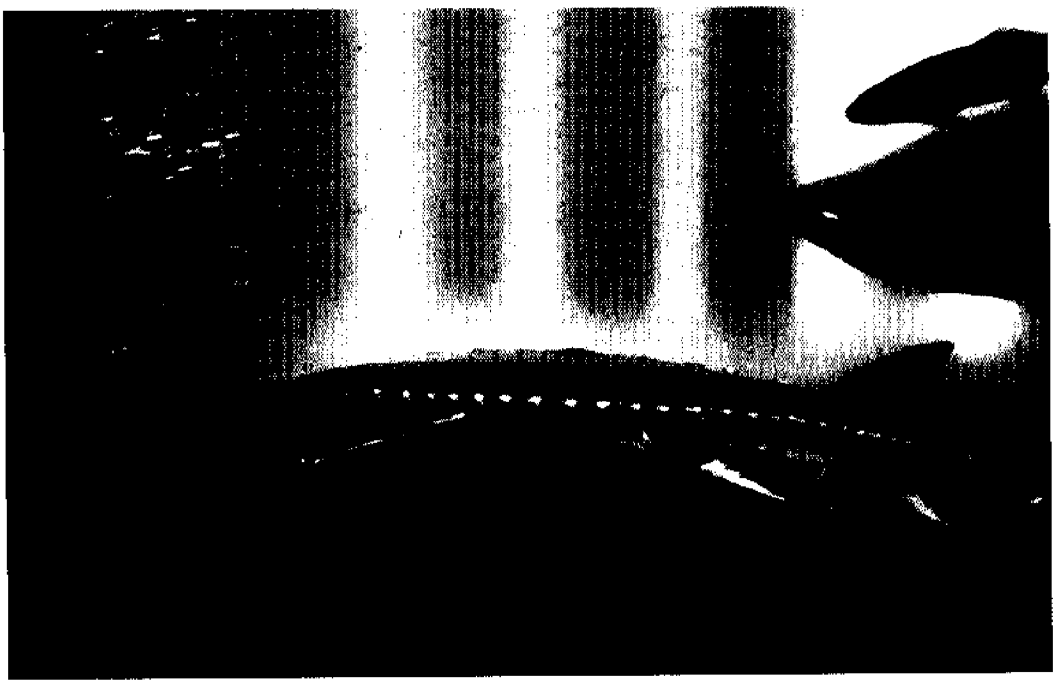
Even though the use of fish locks has ceased, fish ladders continue to allow limited passage of white sturgeon at some of the Columbia River dams. Fishway use by white sturgeon at The Dalles Dam east fish ladder has ranged from 187 to 791 white sturgeon per year since 1985. If it were known why more white sturgeon use the east fish ladder, then perhaps other fishways could be changed to improve white sturgeon passage.

If passage facilities for white sturgeon on the Columbia River were to be improved, several benefits might accrue:

- recruitment of white sturgeon to upper reservoirs where populations are sparse (resulting in more spawning adults and larger populations);
- migration of white sturgeon to more suitable habitat for feeding and/or spawning;
- improved genetic diversity.

In the meantime, white sturgeon are still making efforts to maintain their migratory instincts with limited use of fish ladders to bypass Columbia River dams. How much we are willing to help them by improving passage possibilities remains to be seen.

Photo 5. White sturgeon passing the counting window of a fishway



SUGGESTED READINGS

Bajkov, A.D. 1951. Migration of white sturgeon *(Acipenser transmontanus)* in the Columbia River. Oregon Fish Commission Research Briefs 3(2):8–21.

Beamesderfer, R.C., J.C. Elliot, and C.A. Foster. 1989. Status and habitat requirements of white sturgeon populations in the Columbia River downstream from McNary Dam. Pages 5–52 *in* A.A. Nigro, editor. Annual Progress Report to Bonneville Power Administration. Portland, OR.

Beamesderfer, R.C., T.A. Rien, C.A. Foster, and A.L. Ashenfelter. 1990. Status and habitat requirements of white sturgeon populations in the Columbia River downstream from McNary Dam. Pages 6–37 *in* A.A. Nigro, editor. Annual Progress Report to Bonneville Power Administration. Portland, OR.

Clay, C.H. 1961. Design of fishways and other fish facilities. Department of Fisheries of Canada. Ottawa, Canada. 301 pp.

Conte, F.S., S.I. Doroshov, P.B. Lutes, and E.M. Strange. 1988. Hatchery manual for the white sturgeon *(Acipenser transmontanus)*, with application to other North American Acipenseridae. Publications Division, Agriculture and Natural Resources, University of California. Oakland, CA. Publication 3322. 104 pp.

Coon, J.C., R.R. Ringe, and T.C. Bjornne. 1977. Abundance, growth, distribution, and movements of white sturgeon in the mid-Snake River. Contribution No. 97, Forest, Wildlife, and Range Experiment Station. University of Idaho, Moscow, ID.

Corps of Engineers. *Fish Passage Facilities.* Visitor Center Interpretive Display, Fish Viewing Room. Bonneville Dam, OR.

Corps of Engineers. *A Continuing Program of Fishery Research.* Visitor Center Interpretive Display, Fish Viewing Room. Bonneville Dam, OR.

Duke, S.D., T.J. Underwood, G.M. Asbridge, R.G. Griswold, M.J. Parsely, and L.G. Beckman. 1990. Status and habitat requirements of white sturgeon populations in the Columbia River downstream from McNary Dam. Pages 78–148 *in* A.A. Nigro, editor. Annual Progress Report to Bonneville Power Administration. Portland, OR.

Mullan, J.W., M.B. Dell, S.G. Hays, and J.A. McGee. 1986. Some factors affecting fish production in the mid-Columbia River, 1934–1983. U.S. Fish and Wildlife Service Report No. FRI/FAO–86–15: 69.

Rieman, B.E., and R.C. Beamesderfer. 1990. White sturgeon in the lower Columbia River: Is the stock overexploited? North American Journal of Fisheries Management 10:388–396.

Rien, T.A., A.L. Ashenfelter, R.A. Farr, J.A. North, and R.C. Beamesderfer. 1991. Pages 6–44 *in* A.A. Nigro, editor. Annual Progress Report to Bonneville Power Administration. Portland, OR.

Rochard, E., G. Castelnaud, and M. Lepage. 1990. Sturgeons *(Pisces: Acipenseridae)*: Threats and prospects. Journal of Fish Biology 37(A):123–132.

U.S. Army Corps of Engineers. 1948–1969. Daily Fishway Reports. Bonneville Dam, OR.

U.S. Army Corps of Engineers (Portland and Walla Walla District). 1986-1991. Annual Fish Passage Report. Columbia and Snake River Projects.

War Department. 1938–1947. Daily Fishway Reports. Office of Resident Engineer. Bonneville Dam, OR.

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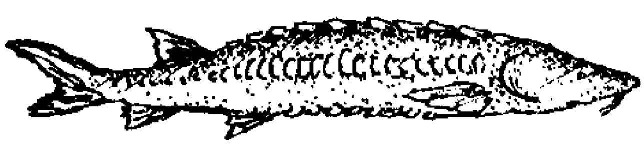

About the Authors:

Joe J. Warren worked for the U.S. Fish and Wildlife Service from 1989 to 1990 with the endangered cui-ui sucker on Pyramid Lake, Nevada. He has been engaged since 1990 on a USFWS white sturgeon research project on the Columbia River downstream from McNary Dam. He received his education in Animal Science at the University of California-Davis.

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Credits:

Cover: Ivan Donaldson at Bonneville Dam fish lock in 1950, from the collection of Mrs. Ivan Donaldson; taken by Les Ordeman
Photos 1, 2, and 4: Joe Warren, 1991
Photo 3: Ivan Donaldson, 1950
Photo 5: Sally Jones, Fisheries Field Unit, Bonneville Dam
Figures 2, 5, 6, and 7: U.S. Army Corps of Engineers, Portland and Walla Walla Districts
Figure 8: Calvin R. Sprague
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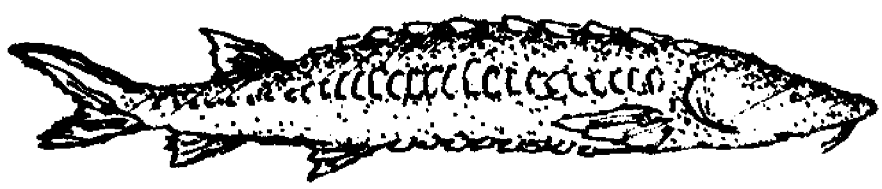

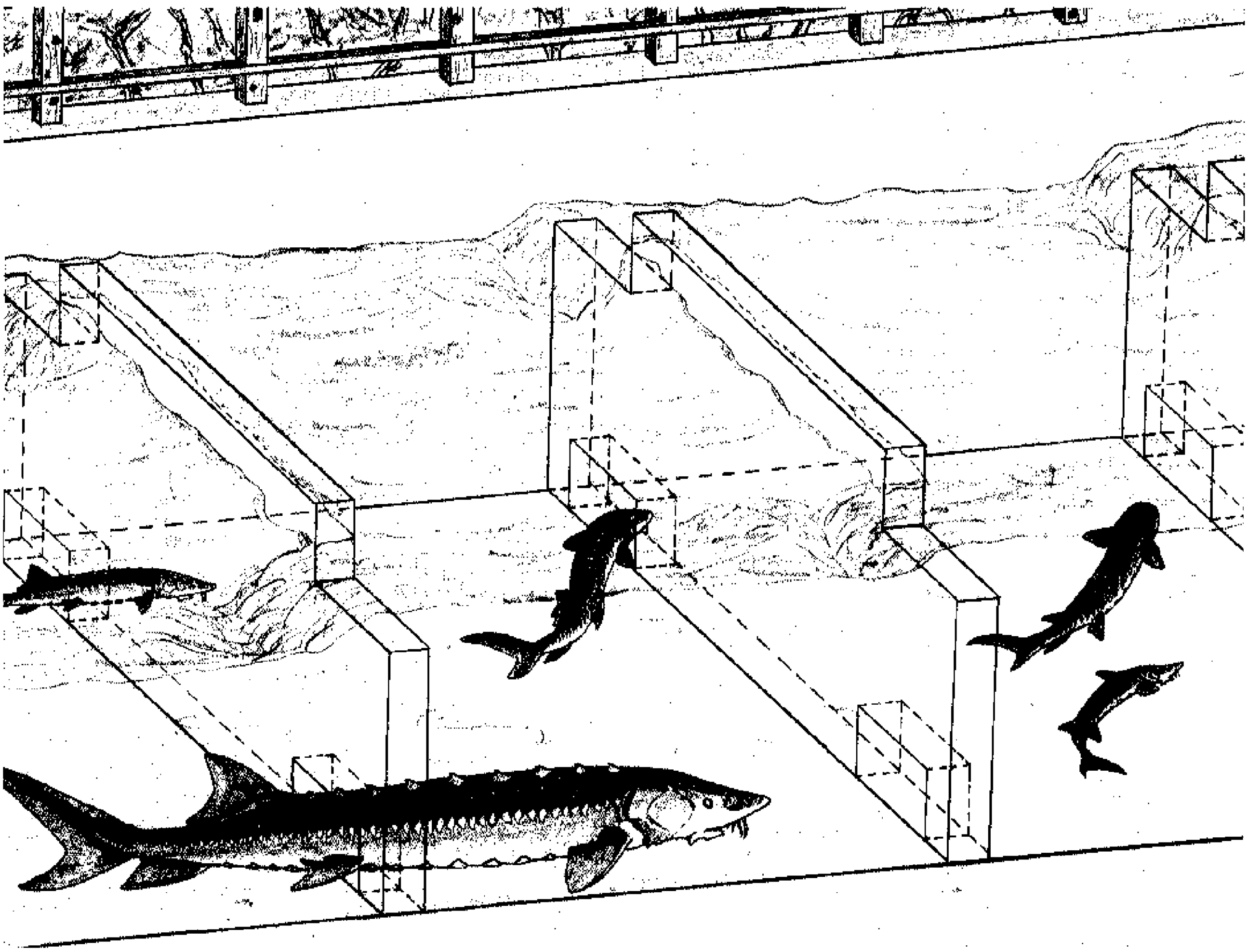

Figure 8. Schematic drawing of white sturgeon entering orifices of fish ladder weirs

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