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# The Use Of Acoustics Tags To Monitor The Movement Of Juvenile Salmonids Approaching A Dam On The Columbia River

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## ABSTRACT

This study examined the feasibility of monitoring and tracking acoustically tagged juvenile salmonids in the forebay of an acoustically noisy hydroelectric facility. Approximately 35 chinook and steelhead smolts were gastorically and surgically implanted with acoustic tags. The arrival time of the transmitted signal was used to estimate the three-dimensional position of the fish with sub-meter accuracy. The fish's three-dimensional movement pattern was tracked over time.

## INTRODUCTION

Acoustic tags have been used for monitoring fish movement for over 30 years. One of the first attempts to use acoustic telemetry was performed in 1956 by National Marine Fisheries Service on adult chinook and coho salmon fitted with a 132 kHz acoustic transmitter (Trefethen 1956). This work was followed in 1957 by studies on the Columbia River above Bonneville Dam observing the upstream migration of Pacific salmon (chinook, coho, and steelhead) in the forebay of the dam (Johnson 1960). Many acoustic telemetry studies followed and are summarized by Ireland and Kanwisher (1978), Mitson (1978), and Stasko and Pincock (1977). Although most acoustic telemetry studies with Pacific salmon have monitored adults, several studies have been performed with juvenile Atlantic salmon smolts (*Salmo salar*) as they migrate through lochs, rivers and estuaries in the United Kingdom (Lacroix and McCurdy 1996, Moore 1995, Thorpe et al. 1981).

The majority of tracking studies to date have used manually aimed directional hydrophones. A single hydrophone is generally mounted in a boat, and the boat follows a tagged fish while it migrates. The general location is recorded; however, the depth and range from the hydrophone to the fish is not known. According to Ireland and Kanwisher (1978), this method of tracking requires skill and patience, and the accuracy with which a fish's position may be determined over time left much to be desired. One investigation placed two remotely aimed hydrophones in a loch in Scotland, and used them to triangulate the position of acoustic transmitters in brown trout (Young et al. 1972). The location of tagged fish was recorded every 5 min in order to determine the activity levels of the fish, not necessarily track their specific swimming path. The most sophisticated tracking system to date was also installed in a loch in Scotland (Hawkins et al. 1974). Five omni-directional hydrophones were positioned in a small loch. By measuring the difference in arrival time of pings from acoustic tags implanted in fish, the location of each fish was determined. In this way, a location was recorded every 15 min in order to monitor the movement of fish during night and day. They concluded that if the system could be automated, a record could be made every second, and the swimming path of each fish could then be determined.

Although reports concerning the use of acoustic tags with juvenile Pacific salmon are rare, several recent studies have investigated the use of acoustic tags with juvenile Atlantic salmon smolts (*S. salar*). Saddle tags and tags that are attached to the dorsal fin or on the back of smolts, significantly affected growth of fish <180 mm in length (Greenstreet and Morgan 1989). McLeave and Stred (1975) found that both external tags and stomach-borne transmitters significantly reduced the swimming speeds of Atlantic salmon smolts, but the reduction was far less with the internal tags. Surgically implanted tags showed no affect to smolts between 120 and 190 mm in length (Moore et al. 1990).

## METHODS

In the fall of 1997, Hydroacoustic Technology, Inc. (HTI) investigated the use of acoustic tags for monitoring downstream migrating juvenile salmon and steelhead trout in the forebay of Rocky Reach Dam on the Columbia

River. Since the forebay of the dam was acoustically noisy, the initial objective of the acoustic tag study was to determine the optimal tag transmitting frequency. Once the operating frequency was determined, the next objective of the study was to investigate whether acoustic tags could be used to monitor juvenile salmonid fish movement in the forebay of Rocky Reach Dam. The final objectives were to tag, release, track, and display the results from acoustically tagged fish.

The tracking system utilized for the 1998 Rocky Reach study used four fixed, wide-beam hydrophones with overlapping beams (Figure 1). The hydrophones were placed in known locations and were mapped within a three-dimensional grid. As an acoustic tag passed through the four beams, the difference in the arrival time of each pulse was used to triangulate the exact location of the tag.

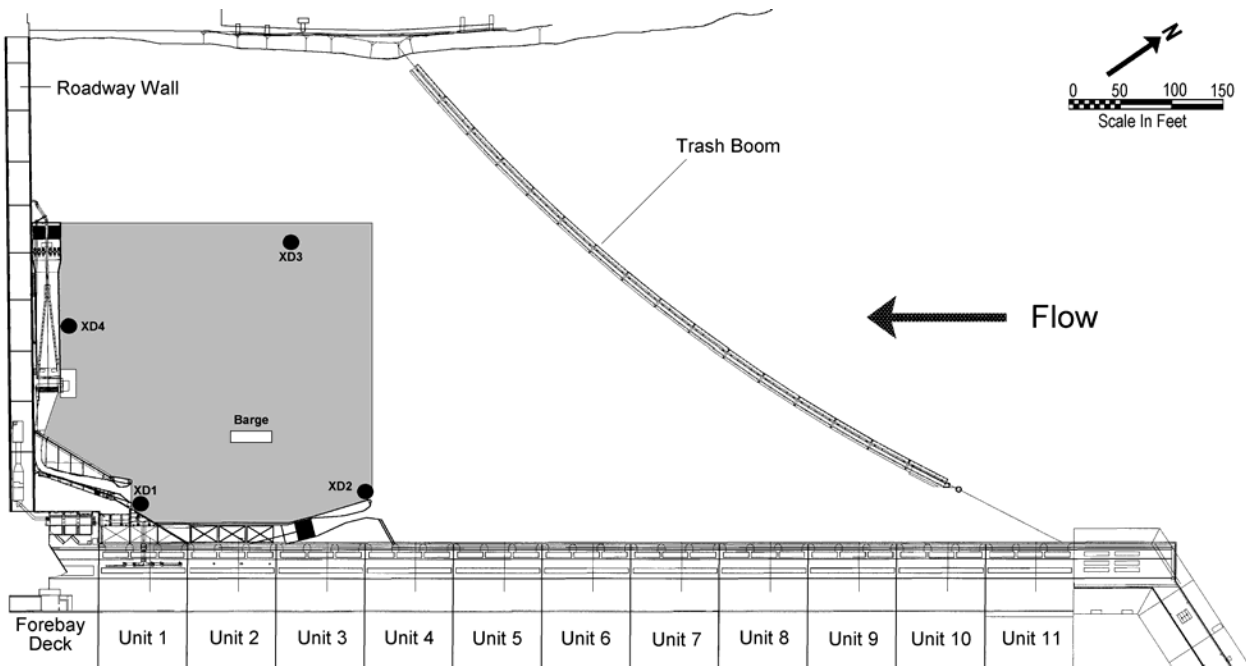


Figure 1. Plan view showing the approximate hydrophone coverage area in the forebay of Rocky Reach Dam in 1998.

Most commercial acoustic tags use frequencies between 50 and 100 kHz, and historically 74 kHz has been the most common frequency (Mitson 1978). Two major factors that affect the selection of a transmitting frequency for acoustic tags are the range of detection and size of the tag. In general, as the frequency decreases, both the size of the tag and range of detection increase.

The use of acoustic tags at Rocky Reach Dam was unique in that the frequency selection was dependent on the distribution of ambient sound near the dam. Hydroelectric projects are acoustically noisy over a broad spectrum of frequencies. In general, the ambient noise level decreases with increasing frequencies, since the sound generated at hydroelectric projects are primarily due to mechanical noise.

The acoustic tag tracking system used for this study was an HTI *Model 290 Acoustic Tag Tracking System*. The acoustic tag receiver was designed to receive on four separate channels. One channel was assigned for each hydrophone. The received signals were synchronized in order to determine time of arrival for each detected pulse. The arrival time of the pulse at each hydrophone was used to determine the location of the tag in three-dimensions. This data was saved in digital format and a tracking program was used to track the fish in three-dimensions through the forebay.

The three-dimensional fish path was displayed with an HTI viewing program called *ACOUSTIC TAG*. The *ACOUSTIC TAG* program is an interactive display that allows the user to view individual pulses, large groups of pulses, or the entire path of each fish. The display provides a three-dimensional background showing a representation of the coverage area including some of the important structures at Rocky Reach Dam. Figure 2 provides an underwater view from within the *ACOUSTIC TAG* program with labels on the significant structures. While actively viewing fish paths within the program, the user can adjust the field of view to move spatially within the program (forward, backward, up, or down). This allows for different perspectives to be viewed for any fish path.

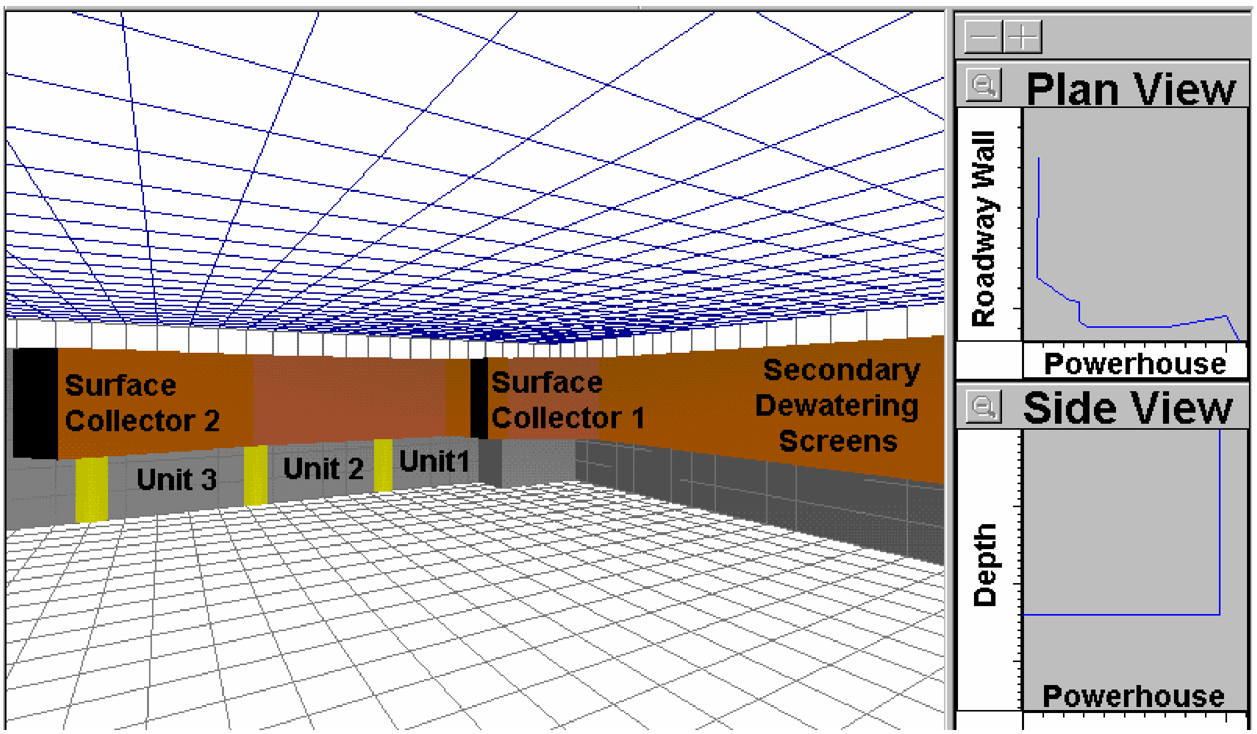


Figure 2. Typical underwater view as seen with the *Acoustic Tag* program showing the significant structures of the Rocky Reach Dam fish bypass system.

## RESULTS AND DISCUSSION

An initial investigation was performed to determine the optimum frequency for acoustic tags in the forebay at Rocky Reach Dam (HTI 1997). The results from this phase of testing determined that the best choice for the tag frequency was 300-500 kHz, since the lowest background noise levels were measured at these frequencies. A convenient frequency, different from the active acoustic systems (200 kHz and 420 kHz) currently being used at Rocky Reach Dam, was 300 kHz. At this frequency, and using a 60° beamwidth hydrophone, the detection range was estimated to be approximately 115 m. For the 1998 tag study, 300 kHz hydrophones with 77° beam widths were used.

The tags selected for use at Rocky Reach Dam in 1998 were small, 300 kHz encapsulated, omni-directional pingers designed to be implanted orally. The tags were gastronomically inserted into the fish by placing the tag in the fish's mouth and guided past the esophagus. The tags were 23 mm long and 7 mm in diameter (0.9 x 0.3 inches). The weight in air for each tag was 4.3 g (0.2 oz) and weight in water was 2.3 g (0.1 oz). The transmit power level was approximately 143 dB uPa @ 1 m. Pulse rate was set to 1 pulse per sec with a transmit pulse width of 1 msec. The useful life of the tag, once activated, was approximately 14 days.

Tagged fish releases were scattered throughout the coverage area. Most of the releases were in areas where it was known that the fish would be detected and tracked. The tagged fish were released individually and given several hours to pass before the next fish was released. Even with these precautions, up to five fish were in the coverage area at one time and successfully tracked. Theoretically, at least 20 fish in the coverage area could successfully be tracked without confusion between the individual tags.

Tracking juvenile salmonids with sub-meter accuracy in the forebay of Rocky Reach Dam in 1998 was successful. Using a four-hydrophone array, data was collected that allowed precise three-dimensional swimming paths of the tagged fish through the forebay. The following results were by Steig et al. (1998). Figures 3 and 4 show the three dimensional track of a juvenile steelhead smolt. This fish was detected swimming in the forebay for approximately 5 hours (Figure 3) before the fish entered the Unit 1 intake (Figure 4). Figures 5 and 6 show the track of a juvenile chinook smolt. This fish was detected swimming in the forebay for 6 minutes (Figure 5) before the fish entered the Unit 1 intake (Figure 6).

Acoustic tags provided very specific information regarding the swimming paths of fish moving through the forebay at Rocky Reach Dam. This technique has the ability to document fish behavior approaching hydroelectric projects and bypass structures. In a follow up study currently in progress, additional hydrophones are being used in order to increase the sample area and cover the entire length of the powerhouse.

## ACKNOWLEDGMENTS

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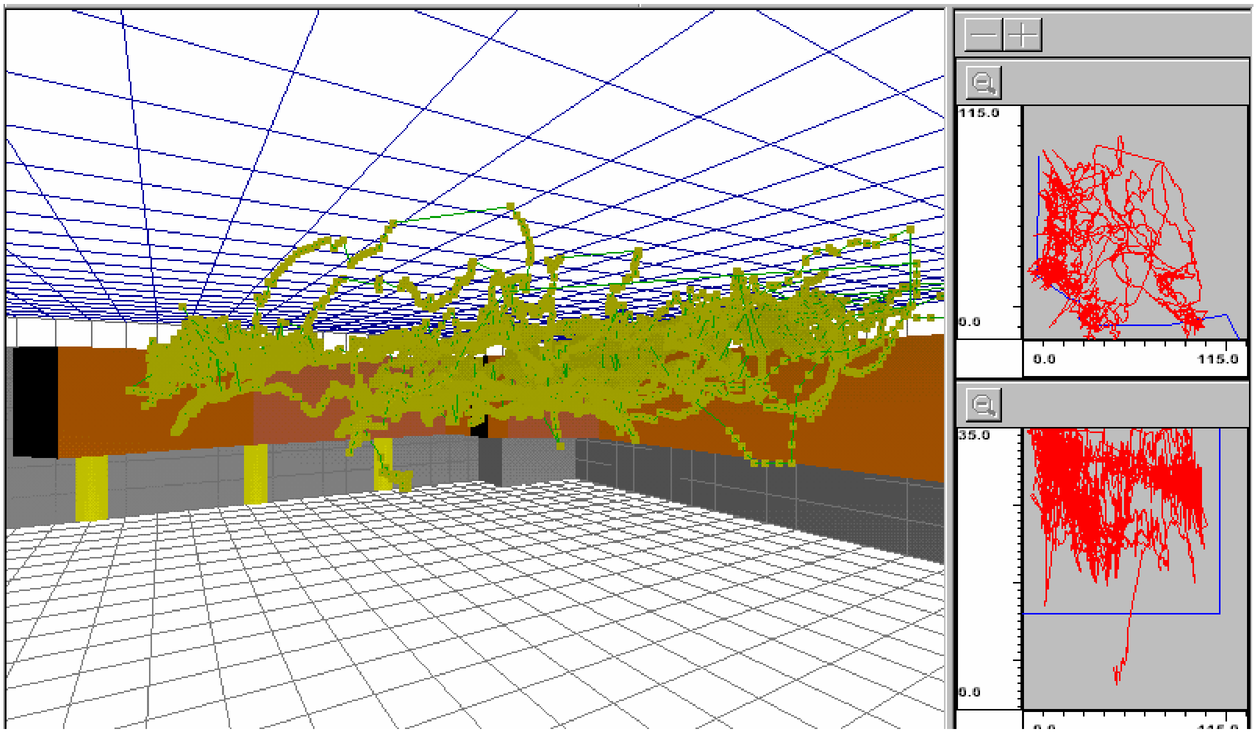


Figure 3. The three-dimensional view of Fish 1 (steelhead smolt released at 1309 h on May 20) showing the entire track (Rocky Reach Dam, 1998).

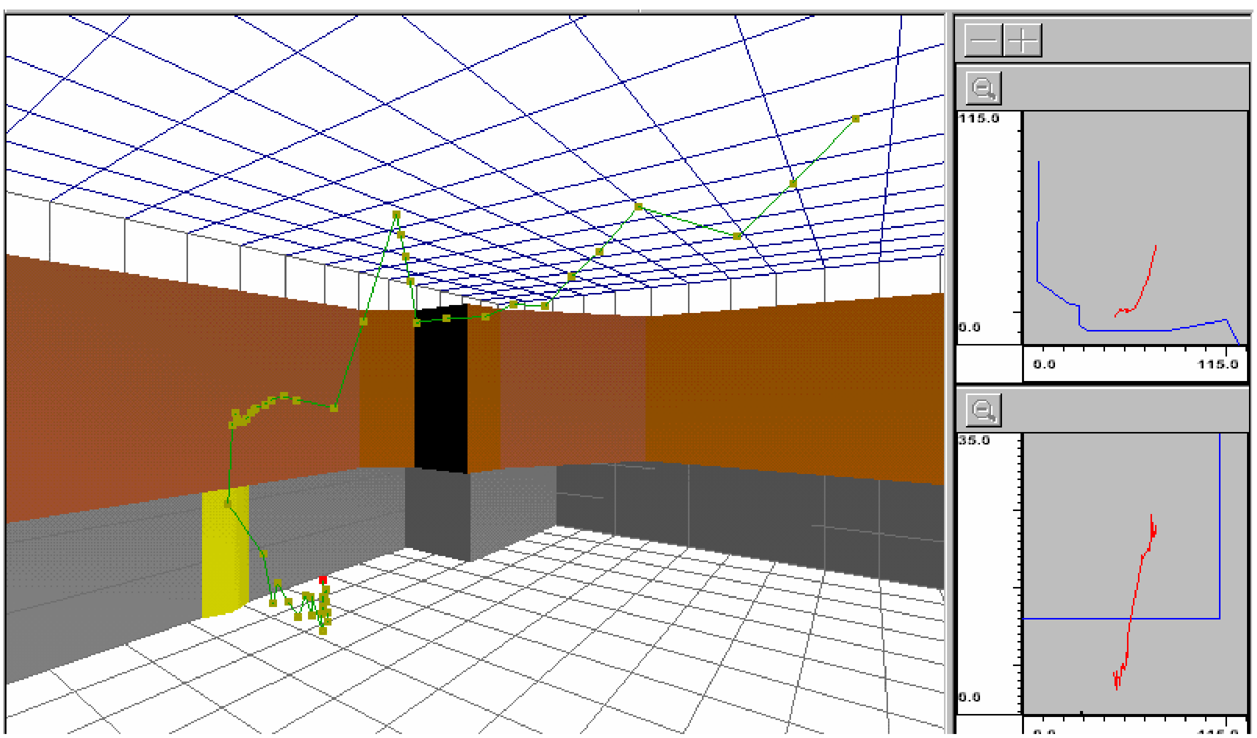


Figure 4. The three-dimensional view of Fish 1 (steelhead smolt released at 1309 h on May 20) showing the end of the track (Rocky Reach Dam, 1998).

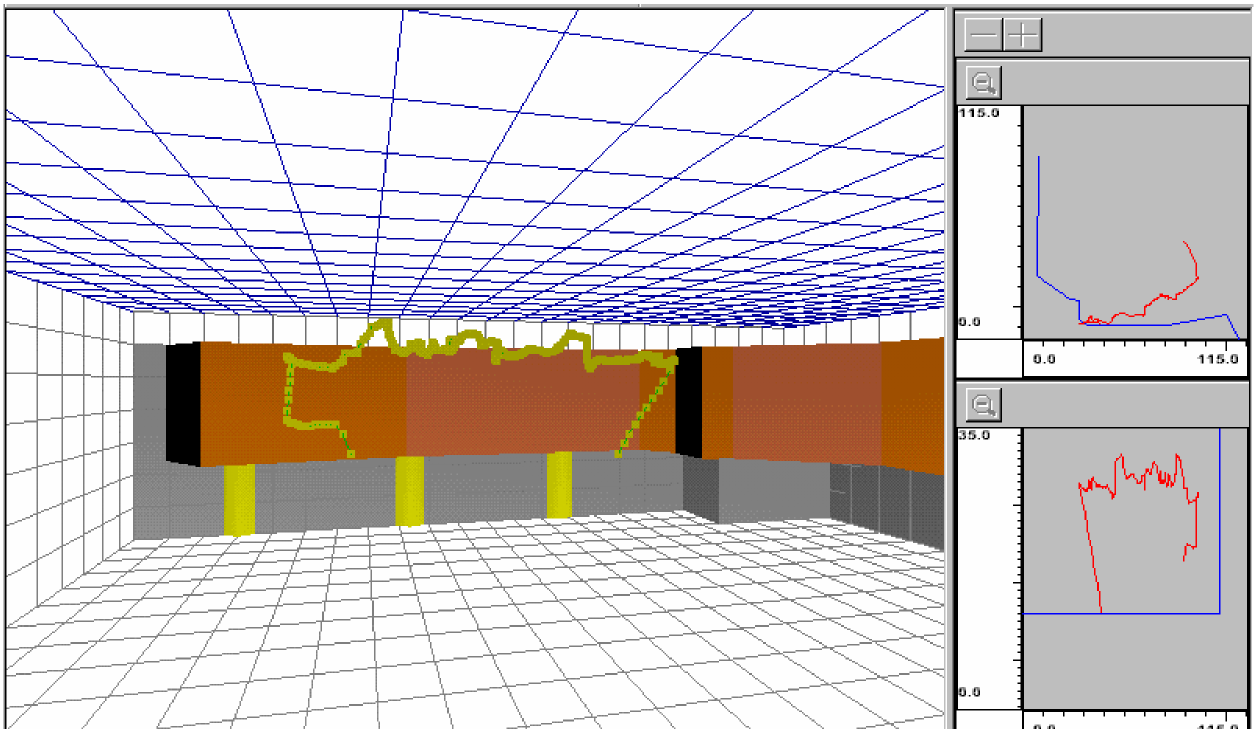


Figure 5. The three-dimensional view of Fish 7 (chinook smolt released at 1455 h on May 27) showing the entire track (Rocky Reach Dam, 1998).

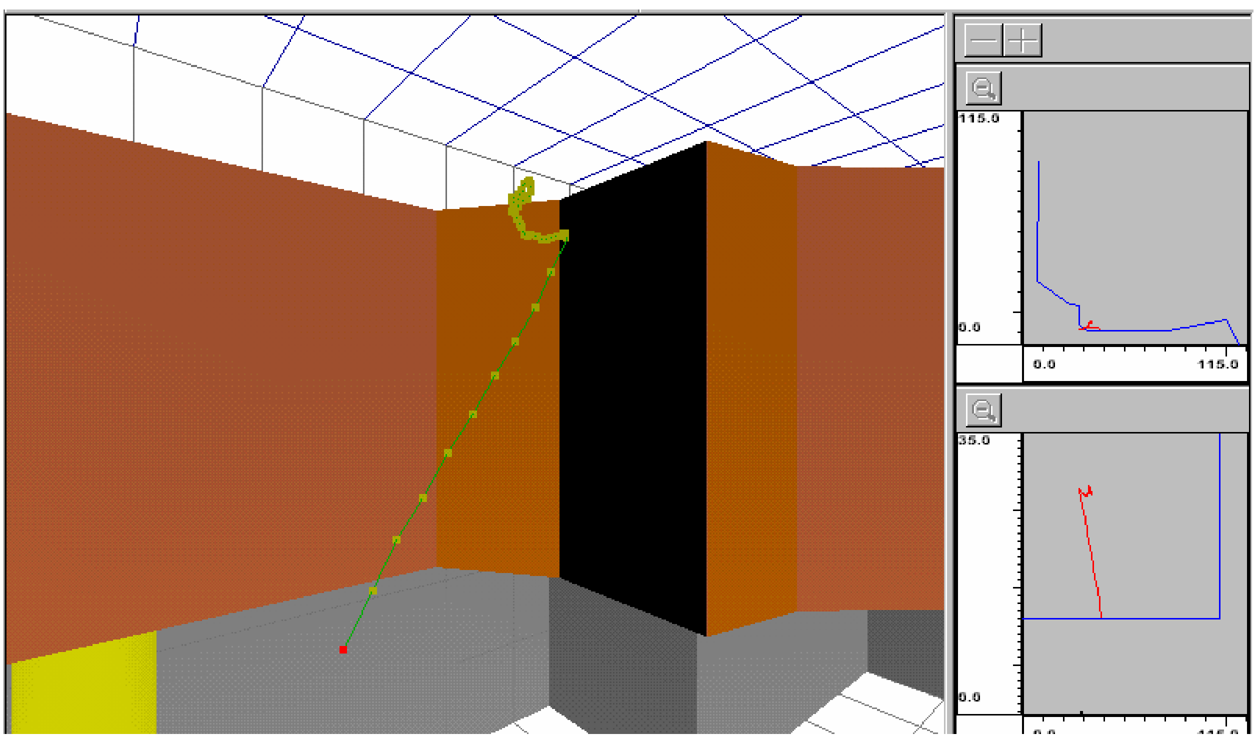


Figure 6. The three-dimensional view of Fish 7 (chinook smolt released at 1455 h on May 27) showing the end of the track (Rocky Reach Dam, 1998).

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