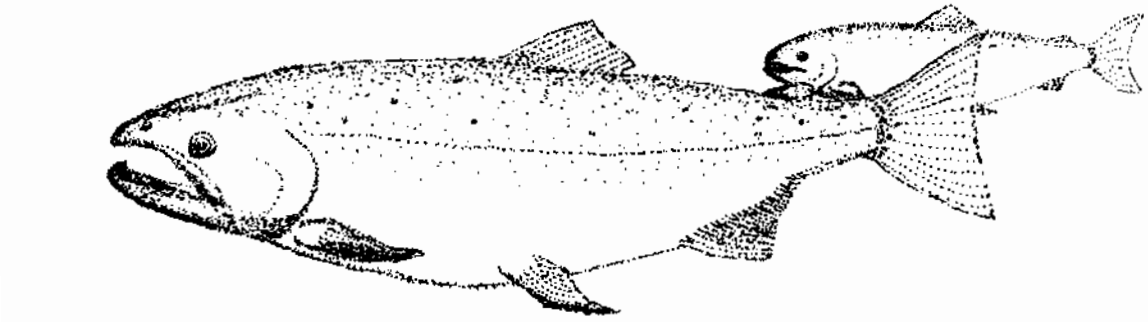
Fisheries Assistance Office
Olympia, Washington

Radio Telemetry Assessment of Adult Summer Run Steelhead Behavior Following Release in the Upper Elwha River



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Radio Telemetry Assessment of Adult Summer Run Steelhead Behavior Following Release in the Upper Elwha River

by
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ABSTRACT

Most of the Olympic Peninsula's Elwha River lies within Olympic National Park. The Olympic National Park hopes to eventually restore steelhead trout, and other anadromous salmonids, to the many miles of river located above two concrete dams. The Olympia Fisheries Assistance Office examined the feasibility of releasing adult steelhead above Glines (the upper) Dam by tracking movements of six groups of radio tagged adults released above the dam. A total of 72 radio transmitters were surgically implanted in adult steelhead trapped at river mile 3.0 on the Elwha River. Approximately equal sized groups of tagged fish were released at three different sites, one at Lake Mills and two on the upper river, during July, 1983. During late August and early September, one additional group was released on the upper river and two groups were released at Lake Mills, respectively.

Aerial or boat radio tracking surveys, performed from August 1, 1983 to January 13, 1984, provided a record of individual fish movements. Tracking of many fish ended prematurely due to apparent radio transmitter failure. Circumstances prevented determination of whether any fish attempted to spawn. However, from analysis of data collected, we reached the following conclusions: (1) as many as 35% of all tagged steelhead may have fallen back over Glines Dam; (2) apparently all fish that fell back over the dam did so during periods of spill; (3) steelhead released during early September displayed the most sustained net upstream movement into the upper river; (4) mean location of steelhead groups released during July either remained in or near Lake Mills or eventually moved down to Lake Mills; (5) mean location of steelhead groups released during late August to mid-September either remained in the upper river or soon moved into the upper river and held there.

ACKNOWLEDGEMENTS

I wish to extend my sincere appreciation to Stephen Dilley and Stephen Hager for their considerable contribution to this project. Their effort during the preparation and planning stages for fish surgery and radio tracking were invaluable. Thanks are also extended to other biologists and technicians at the Olympia Fisheries Assistance Office for their participation.

Jose Ramos and Linda Tuggle, staff at the Washington Department of Fisheries Elwha Rearing Facility, deserve special thanks for offering their facility, knowledge, and assistance during the fish capture and tagging work.

We especially want to thank the Skagit System Cooperative for allowing us to borrow their radio tracking equipment.

I wish to thank Donald Cole, fishery biologist for the Olympic National Park (ONP), for his assistance in planning, coordinating and initiating this project. I also wish to acknowledge assistance provided by the following: John Aho, ONP; Richard Olson, ONP; Paul Crawford, ONP; Allen Cummingham, ONP; John Smith, Veterinarian, Tumwater, WA; Dan Kelley, Crown Zellerbach Corporation; Carl Burger, U.S. Fish and Wildlife Service; Robert Paulsen, Washington Department of Game; and the management and pilots of both Pearson Air, Olympia, WA and Eagle Air, Forks, WA.

Finally, I wish to thank Audelia McCrowell for her effort in typing this report.

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INTRODUCTION

Since 1910 anadromous salmon and steelhead trout (Salmo gairdneri) have been denied access to the Elwha River and its tributaries above river mile 5 by man-made dams (figure 1). More than 25 miles of otherwise accessible upper mainstem river remains in pristine condition within the Olympic National Park. In addition, many accessible miles of upper river tributary streams remain in a totally natural state. The Olympic National Park (ONP) recently initiated efforts to determine the feasibility of restoring salmon and steelhead runs to the upper river. As a result the Fish and Wildlife Service (FWS) Fisheries Assistance Office - Olympia (FAO) was contracted to study adult steelhead behavior after release above the upper dam.

A study design describing a procedure for implanting small radio transmitters inside adult steelhead and then tracking their movements after release was prepared by FAO and accepted by ONP. The study objectives were: (1) to determine how summer run steelhead, imprinted on the river below Elwha Dam, would distribute in the river after release at certain locations above Glines Dam; (2) to determine whether any of these fish would attempt to spawn in the upper Elwha; and (3) to determine whether different segments of the run would display different spawning tendencies upon release above Glines Dam. Information of this nature would help assess the feasibility of using adult releases to reintroduce anadromous salmonids in the upper watershed.

An agreement was reached with the Washington Departments of Fisheries (WDF) and Game (WDG) to permit FAO to obtain adult summer run steelhead trout at the WDF Elwha Rearing Channel facility, located at river mile (RM) 3. Fish would be seined in the facility's broodstock trap, radio tagged, and released in the upper river.

The study design required that adult steelhead be fitted with radio transmitters and then released during two separate periods. The first period would be during July and the second during September. The objective of having two release periods was to determine whether early and late run fish would behave differently and which release period would be preferred. The study design also sought to determine how fish would distribute if released into the upper river as opposed to release directly into Lake Mills. This release scheme would also serve to answer the question of whether fish released in the lake would tend to fall back over the dam.

METHODS

Preparations

Based upon radio telemetry research with steelhead in Alaska, performed by the FWS Alaska Field Station of the National Fishery Research Center - Seattle (Carl Burger, 1983, personal communication), we concluded that radio transmitters ("tags") must be surgically inserted into the coelomic cavity. The Alaskan studies indicated that as much as 35% of steelhead

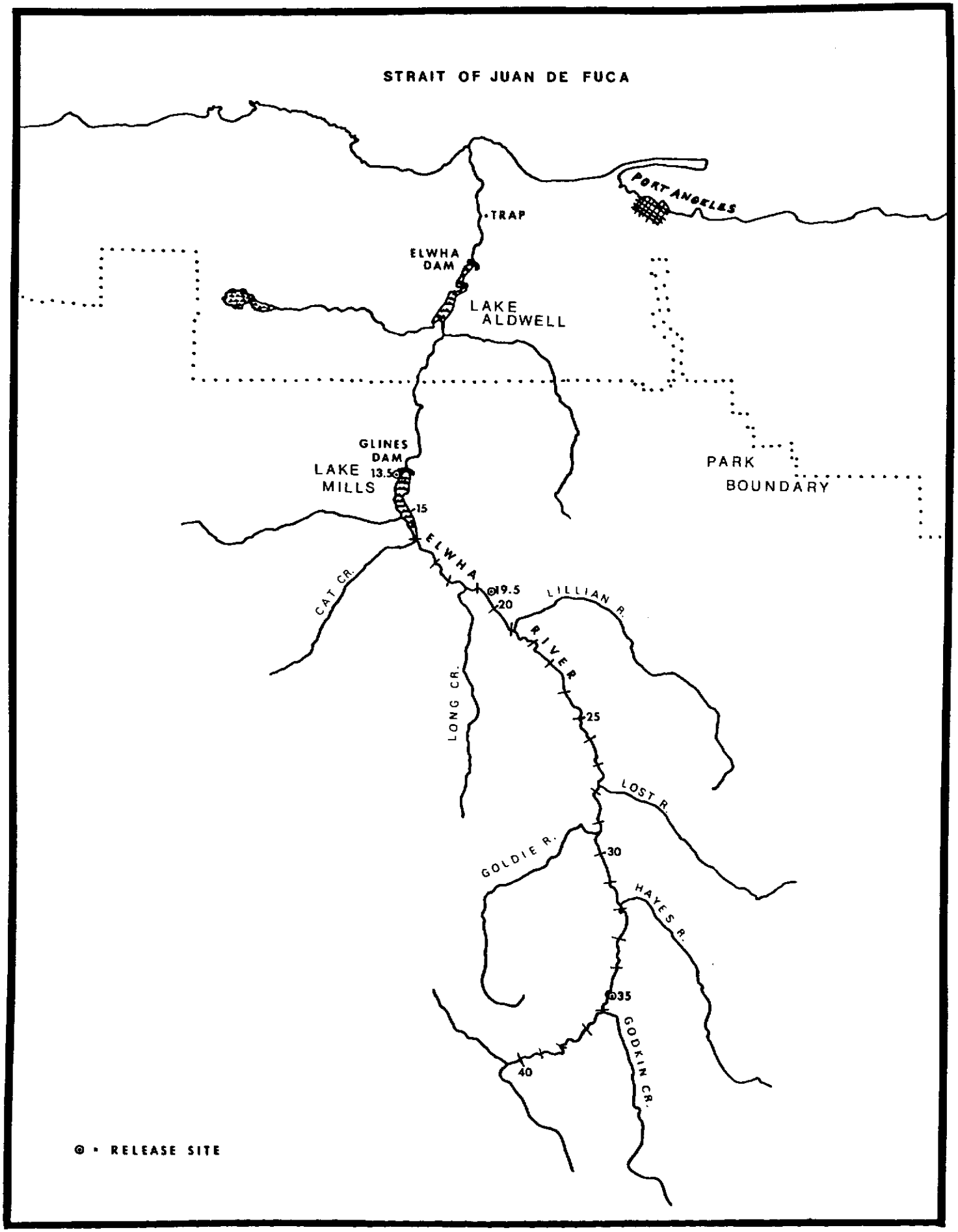


Figure 1. Elwha River System.

fitted with a radio tag in their stomach regurgiated the tag. Surgical insertion into the coelomic cavity eliminates this risk of tag loss due to regurgitation.

In order to become familiar with the surgical procedure, we arranged to practice radio tagging and the surgical procedure on summer steelhead trapped at the WDG Aberdeen Hatchery. The assistance of veterinarian John L. Smith, Tumwater, Washington, was enlisted to ensure that correct surgical technique was employed. Several fish were radio tagged and held a few weeks. These fish were then sacrificed to permit examination of their healing rate and impact on internal organs.

Equipment

We borrowed the radio receiving equipment used in this study from the Swinomish Indian Tribe. All radio-related equipment was manufactured by Smith-Root, Inc., of Vancouver, Washington. Two sizes of "P-40," cylindrically shaped radio transmitters were purchased. The larger "A" body design measured about 3.75 inches long with a 0.75 inch diameter and had an advertised battery life of 180 days. The smaller "C" body transmitters used measured about 2.0 inches long with a 0.62 inch diameter and an advertised battery life of 150 days. We determined that we could buy, distribute and detect a total of 72 transmitters, each with its own unique radio channel and signal pulse combination. All transmitters had one of four signal pulse rates per second: 0.5, 1.0, 2.0, or 3.0. All transmitters used operated within a frequency range of from 40.60 to 40.78 MHz.

Detection equipment used consisted of an "SR-40" Search Receiver modified to detect a maximum of 120 channel and pulse combinations. A second unit used, a model FDL-10ER Data Logger, accepted the receiver SR-40 detection input and made simultaneous graphic recordings on an advancing paper roll. We mounted a whip antenna beneath the aircraft wing for signal reception. A hand-held paddle antenna was used to supplement the whip antenna during boat surveys.

Tagging and Release Procedure

The general radio tagging and release procedure for July releases went as follows: (1) fish were crowded into a small area of the hatchery broodstock trap and confined by a seine while carefully selected for preferred size and condition; (2) a selected fish was then placed in an anesthetic solution for several minutes until sedated; (3) the fish was transferred to a waist high, padded tagging cradle where it was held belly up throughout the surgery; (4) using a Wescodyne-treated veterinary scalpel, and associated tools, an incision about 1.5 inches long was made through the mid-belly just anterior to the pelvic girdle; (5) an activated radio transmitter was then eased through the incision to lie in the coelomic cavity; (6) an antibacterial solution was dripped on and through the incision after which the incision was closed by tying several independent silk knots with a cutting needle; (7) the fish was returned to the trap, revived and placed inside an 8 inch diameter PVC "tube" with removable wooden end gates; (8) the tubes were then placed in the trap's slow current until they could be trucked for release; (9) four large plastic fish hauling boxes, set on a flat bed truck, were partially filled

with water from the trap; (10) a maximum of four occupied tubes were then set in place across the bottom of each box and bubbled oxygen and crushed ice were added to the water; (11) boxes were covered and tied in place and the truck was then driven either to the Lake Mills release site or to the helicopter lift site near the Elwha Ranger Station; (12) fish boxes were enclosed by nylon harnesses and then individually flown to their respective release sites where each was set down at streamside and detached from the helicopter by a ground crew; (13) fish were then released into areas of relatively slow current in the river.

Fish Capture and Tagging

Fish capture during July at the broodstock trap tagging site proceeded satisfactorily. The number of steelhead visible in the trap increased in early July and a sufficient number were trapped by mid-July to begin tagging. Chinook salmon were also present, and their numbers increased with time.

Considerable searching through the salmon was required on the final day of tagging to find sufficient steelhead. Some proportion of the steelhead always had external wounds, and whenever possible, these fish were not tagged. Fish tagged in August and September often had minor external scrapes or wounds, but their use was virtually unavoidable. We assumed that the few moments these fish were exposed to the anesthetic-fungicide solution prior to surgery would reduce the likelihood of serious subsequent fungal infection.

A few fish were injured when the scalpel blade penetrated too far into the coelomic cavity and cut the spleen, particularly on the first tagging day, July 19. If it became apparent that a fish was injured, then that tagging was aborted and the fish was surgically closed and returned to the trap pond. One such fish escaped from the trap and was caught by a sport fishermen in the lower Elwha River. Two fish, one each from the two groups to be released on July 27, at RM 19.5 and RM 35.0, were found bleeding prior to release, and were sacrificed. One of these radio tags was implanted in another fish that was then released at the Lake Mills site, on July 27. The last two fish tagged at the Lake Mills site on September 3 could not be revived, and the transmitters were recovered.

Procedure Modifications

A few procedural modifications were employed for the September releases. Risk of fish injury during surgery was reduced by slightly inclining the tagging cradle, and by inserting transmitters through the incision toward the tail. The anesthetic was replaced by an anesthetic-fungicide solution to further reduce risk of fungal infection. Perhaps most important, the surgical procedure was performed at the respective release sites rather than at the broodstock trap. This last change was made to eliminate stress on the fish and the surgical wound that occurred when they were being moved in PVC tubes.

Releases

The first twelve fish, radio tagged on July 19, were held overnight in the

broodstock trap prior to release the following morning at the Lake Mills site, RM 13.5 (Appendix 1, table 1a). All subsequent groups of tagged fish except those released at the Wilder site (RM 35.0) were released the same day they were tagged. On July 27, eleven tagged fish were released at the Humes Ranch site, RM 19.5, and eleven tagged fish were released at the Wilder site. Also, on July 27, one additional tagged fish was released at Lake Mills.

The releases scheduled for the Wilder Site in September were eliminated as it became apparent early in the study that fish would not hold in the upper river. Instead of having a late group released at RM 35.0, an additional late group was released at the Lake Mills site. On August 31, twelve fish were tagged and released at the Humes Ranch site. On September 3, fourteen tagged fish were released in Lake Mills. And finally, on September 14, eleven tagged fish were released in Lake Mills. A total of 72 radio tagged steelhead were released (Appendix 1). As shown under the heading "Comment" in certain tables of Appendix 1, problems developed for certain tagged fish. These problems are described later in this section.

Monitoring Surveys

Monitoring of the radio tagged fish was performed principally by periodically flying over the Elwha River in a small single-engine aircraft equipped with our receiving equipment. As the pilot flew over the river or a tributary at minimum air speed, an FAO staff member would monitor either the SR-40 Search Receiver or the Data Logger. A second staff member would follow the aircraft position on a composite topographic map according to the river course and terrain viewed below. Any detected radio signal would either be manually recorded by river mile location, on the composite topographic map or assigned a river mile location on the Data Logger graph recording.

Following each survey flight, the survey record was reviewed and checked for accuracy, and fish locations were listed by river mile. In the office a computer file, listing all known radio tagged fish locations, was then updated. A complete list of all radio tagged fish locations, including releases and subsequent relocations, is presented in Appendix 2, tables 2a through 2f.

Airplane radio tracking surveys began on August 1, 1983 and ended on January 13, 1984. We attempted to perform most of the aerial surveys at two or three week intervals. However, in early November, scheduling of flights became more restricted by weather and flying conditions.

On three occasions one or two FAO staff members performed radio tracking surveys by boat and truck. This was particularly useful in locating and distinguishing similar radio signals originating from the same general area of Lake Mills. Boat access into the river above the lake was limited to a short distance due to impassible, steep riffles.

Available information suggested that the radio tagged fish would be most likely to attempt to spawn in January, with an expected peak of activity occurring in mid-January (Vince Janson, WDG Skamamia Hatchery Manager, 1984, personal communication). FAO attempted to perform a helicopter

survey in mid-January, specifically to search the upper river for signs of spawning activity. Unfortunately, this effort was thwarted by the onset of a period of heavy rainfall and hazardous flying conditions. The resultant increased stream turbidity did not decrease again until there was too little likelihood of observing spawning activity. Due to the delay, we could not justify another helicopter flight. However, one supplementary airplane flight was performed in March, but no spawning activity was observed.

Problems in Signal Monitoring

Distinguishing between different signals on the same radio channel was a significant problem encountered in the aerial surveys. Also, on some early surveys tagged fish were concentrated in certain areas, particularly in lower Lake Mills near the dam and where the river flows into the lake. At these times the receiver was usually flooded with signals as we flew over those areas. For example, when a 0.5 pulse per second (p/s) signal and either a 2 or 3 p/s signal on the same channel were received simultaneously, the slower 0.5 p/s signal was masked by the more rapid signal. This required repeat passes over the "congested" river areas, with no guarantee of signal separation and identification. Particularly in the vicinity of Lake Mills, it was either impractical or impossible to always observe the river mile locations where a signal began and ended. Therefore, the assignment of river mile relocations listed in Appendix 2 are considered accurate to within ± 0.5 mile. However, ground verification of relocations immediately below the upper dam was performed to assure that those were indeed below the dam.

The problem of signal masking was largely overcome by using the Data Logger unit, but this, in turn, led to a new detection problem. The Data Logger initiates a written recording of a signal after five consecutive pulses are detected, and it can record signals on 15 channels at once. While it does not separate recordings of simultaneously received signals on the same channel, we found that we could usually identify such overriding records on the paper roll. However, the Data Logger was unable to record a signal reception lasting less than five consecutive pulses. On several occasions we heard the audible report of the receiver or saw a channel light blink, but no recording occurred on the Data Logger. When possible, notation was added to the record to help clarify such omissions.

Figures 2 through 7 present, by release group, the continuous graphic record of each tagged fish's known river mile location. Fish locations are plotted through the time period of radio tracking. In each figure all fish location lines originate from the point of release and study day, identified as "R" on the graph. The fish numbers, connected by lines, show points of location, and correspond to the assigned fish number of the respective tracking record table in Appendix 2. While we recognize that fish may have moved more than once between particular surveys, our ability to analyze known fish movements is enhanced by simply connecting these locations, over time, with a continuous graphed line. At certain points on each graph, two or more different fish numbers are clumped together. Clumped numbers indicate that all or most of these fish occupied the same river mile at that time.

RESULTS

Lake Mills Releases, July 19

The results from releases in this group were more mixed than from any other release group. Twelve fish were released at the boat launch on July 19, and one fish was released there on July 27. As shown in figure 2, on the first two aerial surveys we found a total of eight fish located in the first mile of river above the lake (RM 16-17). Two fish, however, fell back over Glines Dam. One of these was found injured, downstream of the dam, while the other fish never again moved from upper Lake Aldwell, at RM 7.5. A third fish, number 11, in all likelihood had also fallen over the dam but was not detected there until the survey of November 25.

The two most difficult upstream reaches for an ascending fish to pass are probably in Rica and Grand Canyons, found at RM 16.5 to 17.5, and RM 20.5 to 22.2, respectively. Five fish in this release group swam beyond the lower canyon, and one swam to at least the top of the Grand Canyon. The latter fish returned to the lake by September 2.

Three additional mortalities within the group were recorded at Lake Mills during September and October. We observed one of these fish swimming aimlessly at the lake release site on September 3. This fish, number 4, had a severe head wound and was near death. We therefore caught and killed it. The other two mortalities were among five dead fish (or free tags found without a carcass) recovered around Lake Mills during the October 13 boat survey.

During the aerial survey of August 16, we found fish number 8 located about one mile upstream in Cat Creek, which empties into Lake Mills at RM 16.0. However, as was characteristic of many fish in this and other release groups, fish number 8 continued to move and was next located back in Lake Mills.

A very significant tag detection problem became evident in October. In September, we realized that use of the Data Logger should enable us to maintain a relatively high rate of radio tag detection. Its first use on the September 9 aerial survey helped increase the rate of tag detection from 73% to 86% (table 1). But, as shown in table 1, a steady decline in the tag detection rate began in late September and continued until the study was terminated in mid-January, 1984. We concluded that the most likely reason for decline in the detection rate was premature transmitter failure. This explanation appeared to be confirmed with each additional survey.

Humes Ranch Releases, July 27

Four of the 11 fish released July 27 at the Humes Ranch site, RM 19.5, swam upstream (figure 3). Fishes number 2 and 10 swam up beyond the upper canyon. However, 17 days later fish number 2 had dropped back 11 miles to the lake while fish number 10 had returned to the area of its release. Fish number 2 was found dead on October 13, during a boat survey.

Figure 2. Known movements of steelhead released July 19,1983, at RM 13.5 (Lake Mills site).

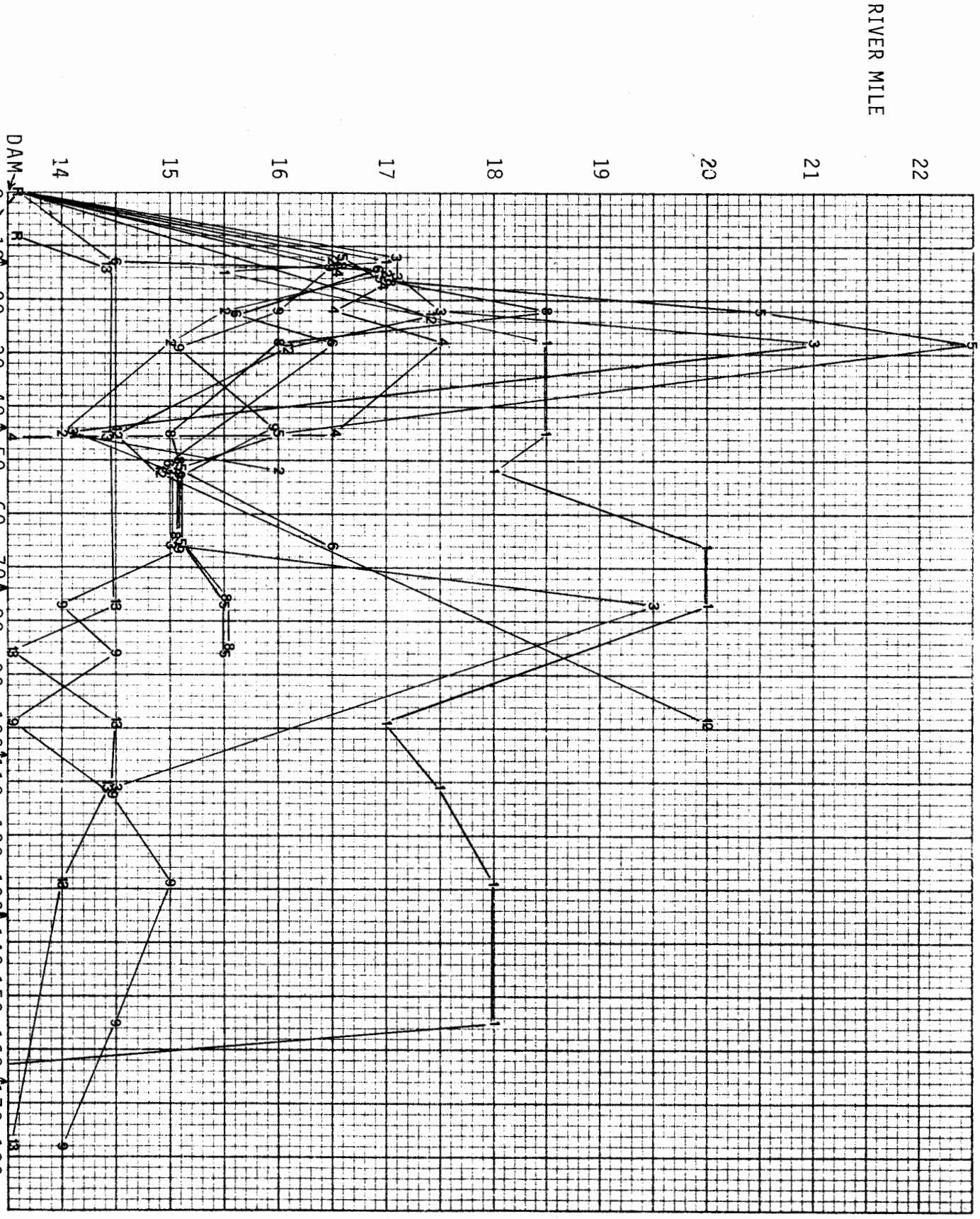


Table 1. Rate of detection of radio tagged fish in the Elwha River, from August 1, 1983, to January 13, 1984.

	Aug				Sep			Oct		Nov		Dec	Jan
	1	3	10	16	2	9	23	4	26	7	25	21	13
Assumed Number of Operative Transmitters in River	35	34	34	34	45	59	69	69	64	64	64	63	63
Known Number of Inoperative/Removed Transmitters		1	1	1	2	3	3	3	8	8	8	9	9
Number of Detected Transmitters	19	28	33	31	33	51	56	48	34	31	21	19	15
Percent of Operative Transmitters Detected	54	82	97	91	73	86	81	70	53	48	33	30	24

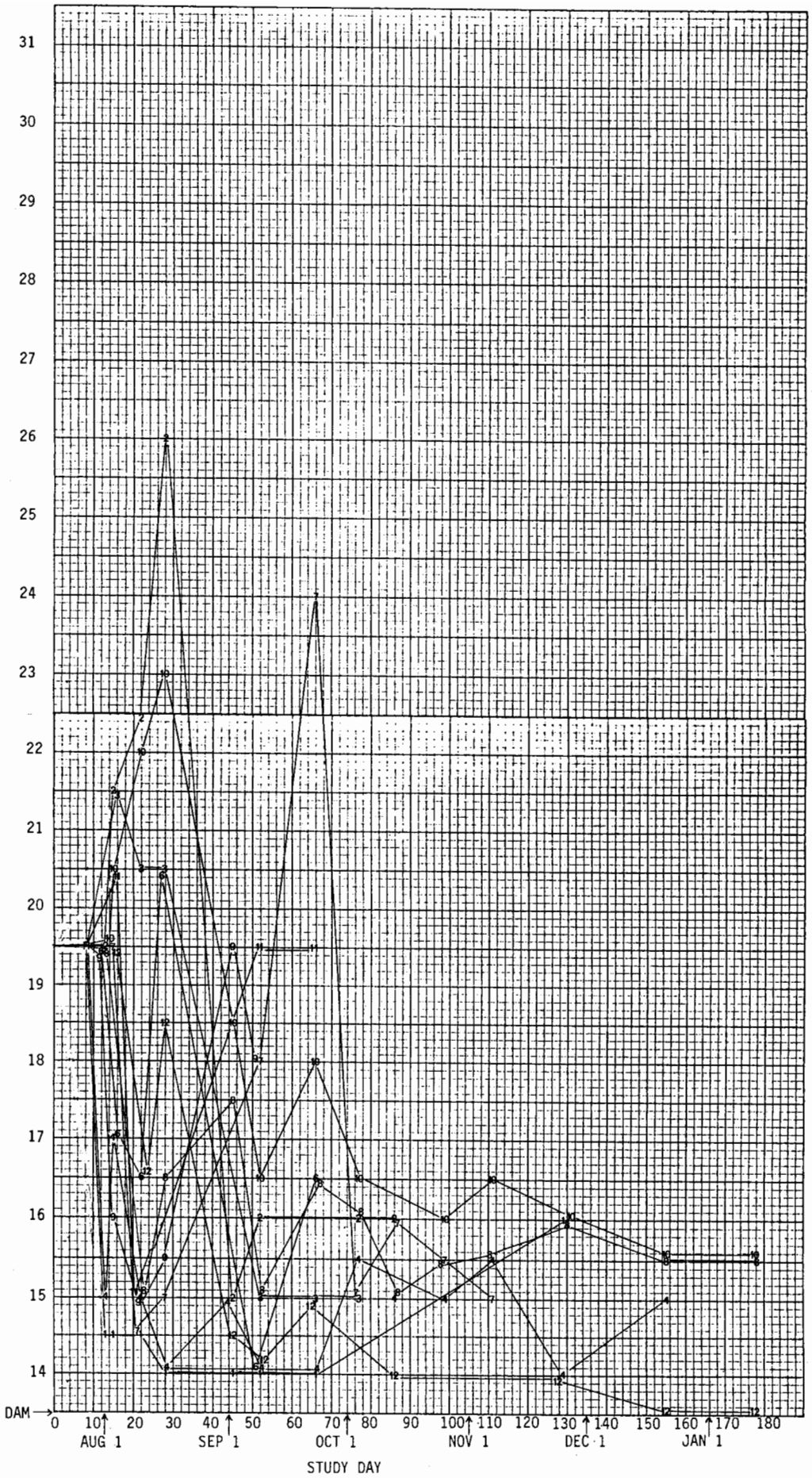


Figure 3. Known movements of steelhead released July 27, 1983, at RM 19.5 (Humes Ranch site).

Seven fish swam downstream within the first few days after release, and five entered Lake Mills. The general response of fish in this group was to move downstream. Only fish numbers 6, 9, and 11 were at points above the lake when last located. Of this release group of 11 fish, seven were lost from the study due to apparent premature transmitter failure.

Wilder Releases, July 27

With few exceptions, the fish released at the Wilder site (RM 35) soon moved far downstream (figure 4). Three fish, however, displayed a willingness to enter tributary streams. Fish number five, the only one to initially move upstream, moved at least two miles upstream before dropping back to RM 36, where it entered and ascended at least one mile into Godkin Creek. However, six days later it had moved a total of 16 miles downstream. Fishes number 4 and 9 soon moved down to RM 29.4, entered and ascended Goldie River and held there for at least six days before again moving down the Elwha River.

Within a period of 22 days, fish number 1 swam 21 miles downstream, entered the lake, and was found dead at RM 14.0. Only three other fish were ever relocated in the lake, and all three were eventually lost, apparently due to transmitter failure. Seven other fish were last located at scattered points in the upper river, and all of these were eventually lost due to apparent transmitter failure. Fish number 2, last located very early in the study on August 16, may have fallen victim to some other fate, such as capture and removal by a predator.

Humes Ranch Releases, August 31

The general response to release of fish in this group was encouraging, to the extent that it could be monitored. Of the 12 fish released, seven were last located at various points in the river upstream of RM 18.0 (figure 5). Fish numbers 3 and 4 swam up beyond the Grand Canyon and stayed there, at least until November 7. Fish number 2, 5, and 11 were last relocated at RM 20.5 or further upstream.

Five fish in this release group eventually dropped downstream and entered Lake Mills. While fish numbers 9, 10, and 12 were last located in Lake Mills, numbers 7 and 8 fell over Glines Dam. Fish number 8 was detected at the bridge over Little River, a small tributary several miles downstream of Glines Dam, on December 1, but was never located again despite an attempt to pinpoint it.

Apparently, only two transmitters from the remaining 10 tagged fish continued to function until the study ended. Fish number 10 was never detected after the ninth day following release. Five fish were detected through November 7, but not afterwards.

Lake Mills Releases, September 3

The general response to release of fish in this group was also encouraging. Of the 14 fish released in Lake Mills, seven ascended into the river and never were detected in the lake again (figure 6). Four other fish also left the lake but later returned. A total of 10 fish ascended beyond the

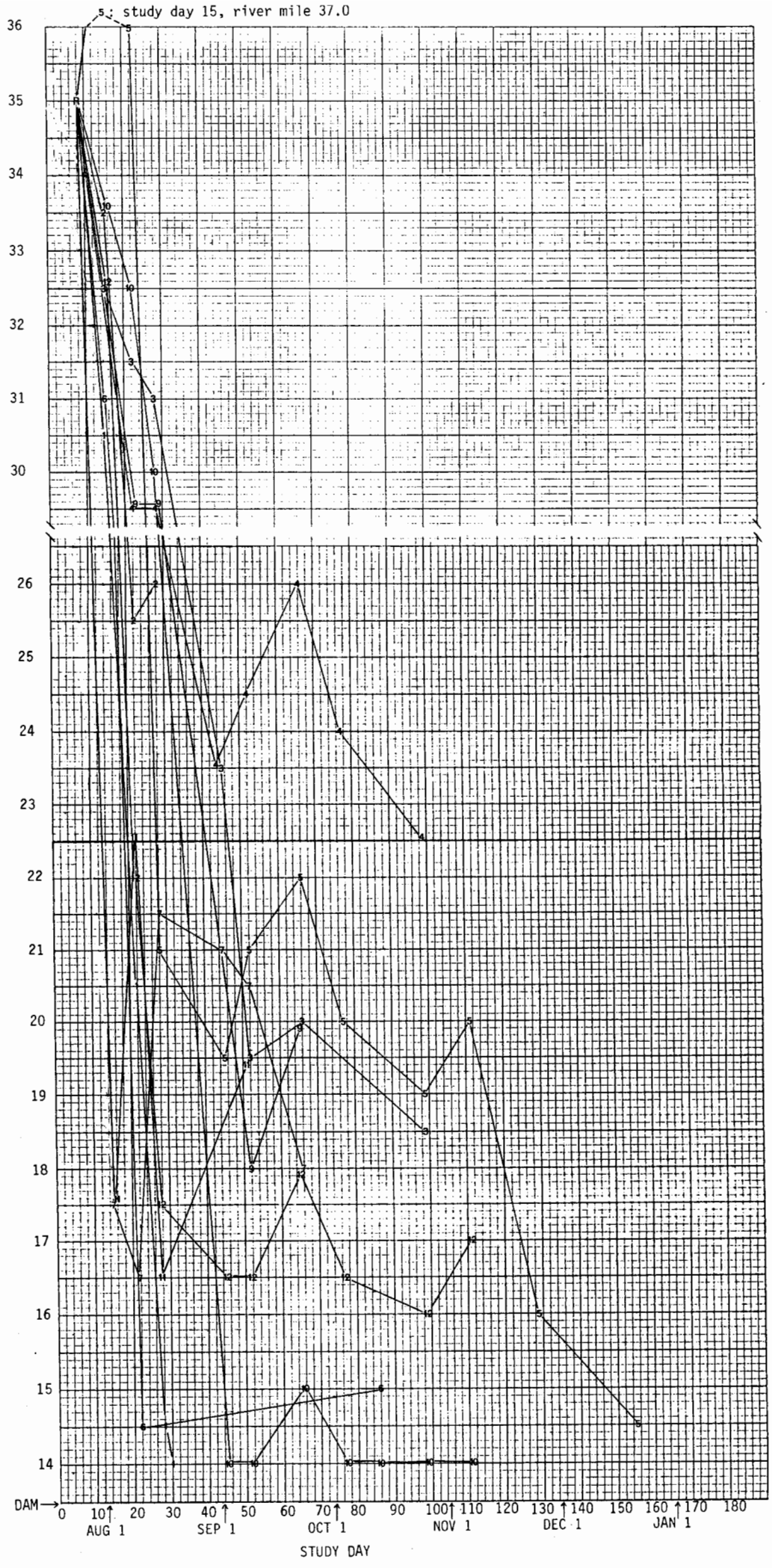


Figure 4. Known movements of steelhead released July 27, 1983, at RM 35.0 (Wilder site).

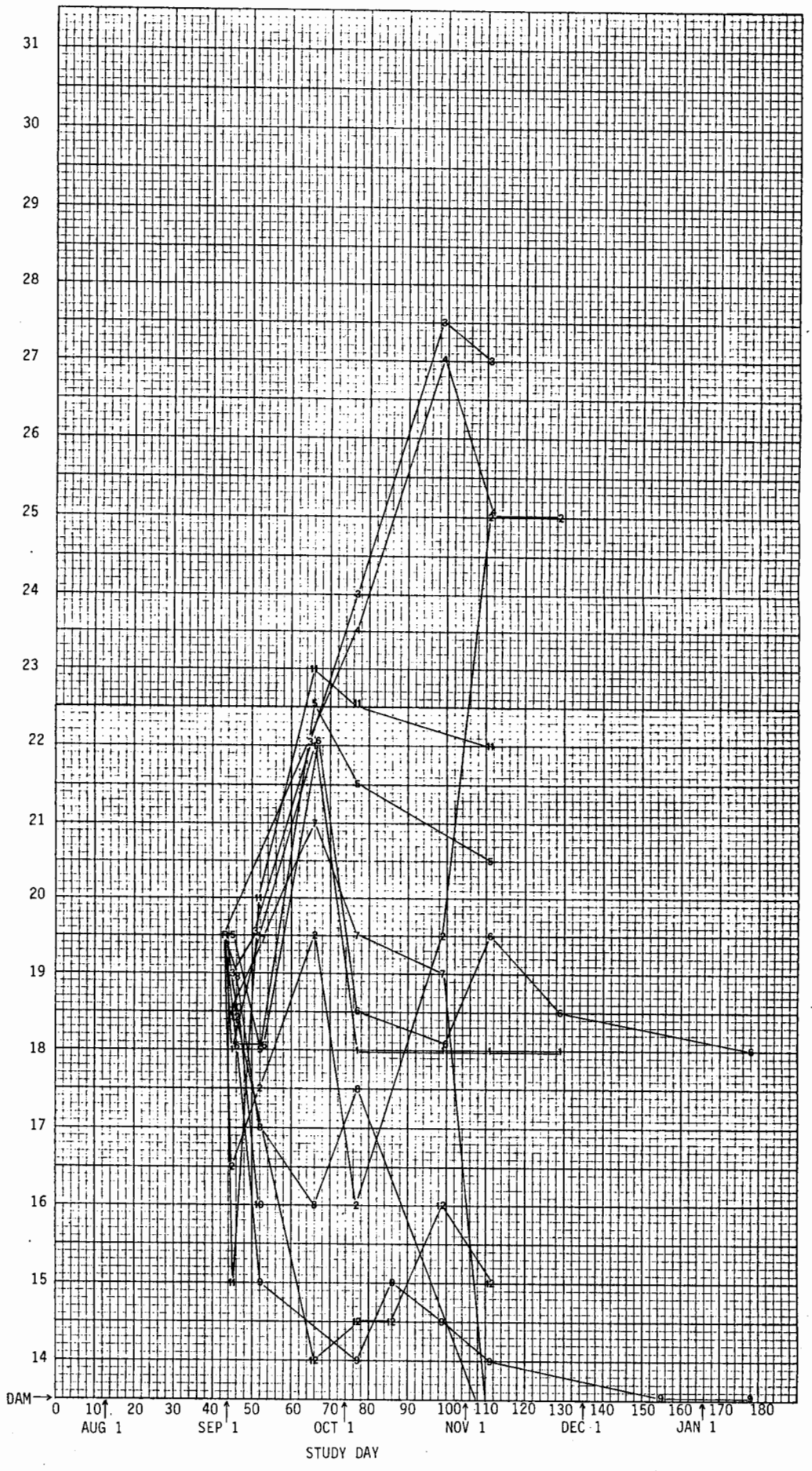


Figure 5. Known movements of steelhead released August 31, 1983, at RM 19.5 (Humes Ranch site).

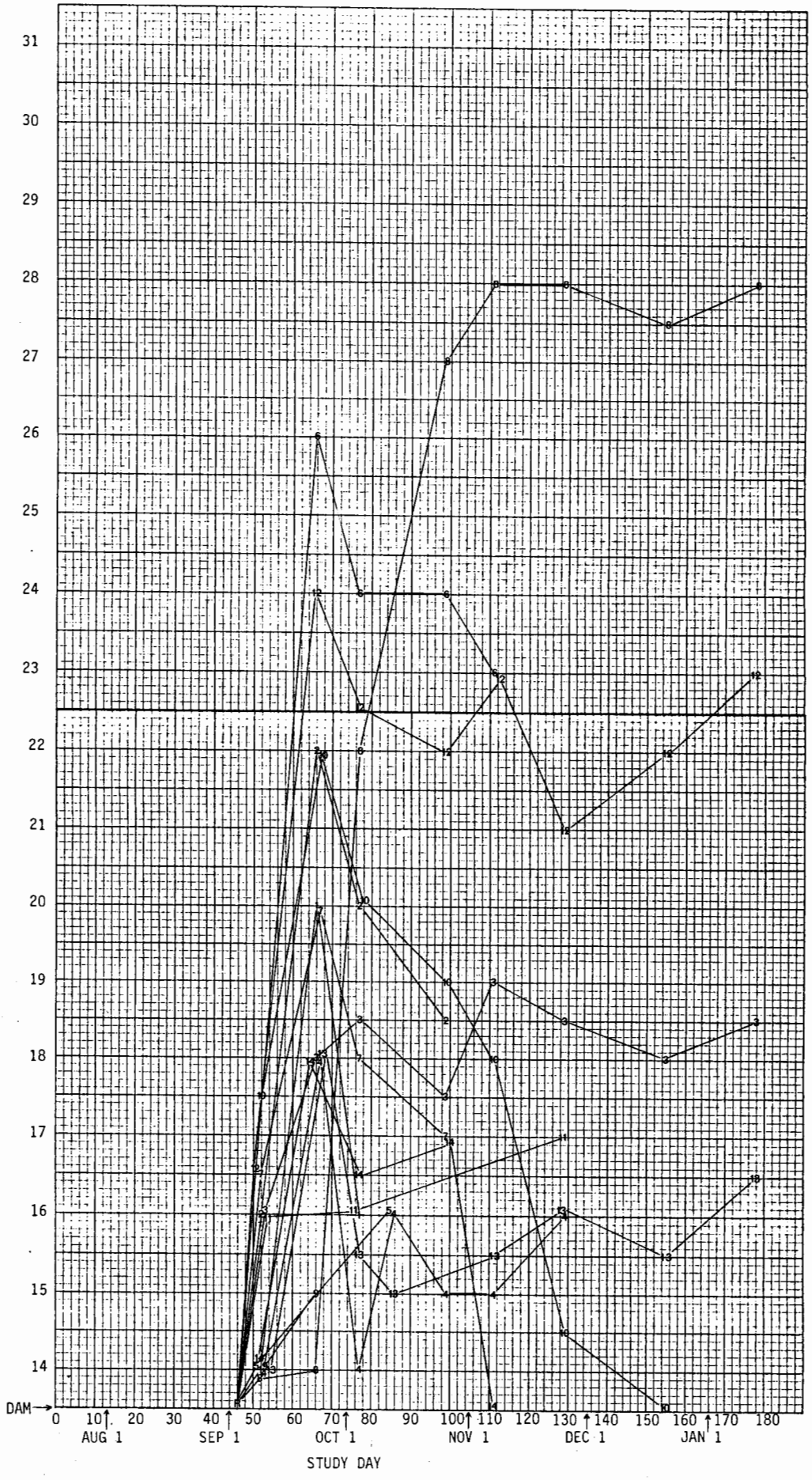


Figure 6. Known movements of steelhead released September 3, 1983, at RM 13.5 (Lake Mills site).

lower canyon reach, but five of these were last located at points downstream or in the lake. Three fish ascended and were last located above the Grand Canyon reach.

The fresh carcass of fish number 5 was recovered from an adult American bald eagle on the delta at RM 16.0. By coincidence, a boat survey was underway when the eagle suddenly took flight, leaving behind the recently killed and bleeding fish. This occurred on the 40th day following release.

Only four radio tags in this group were known to be operating when the study was terminated. One transmitter was detected for only 20 days after the fish was released.

Lake Mills Releases, September 14

The response to release of most fish in this group was good. Of 11 fish released in Lake Mills, seven were never again detected in the lake (figure 7). Six fish ascended the lower canyon reach, and only one dropped back downstream. Four fish ascended beyond the Grand Canyon, however, two of these were last located downstream between the canyons. Fish number 5 was detected in the Goldie River and apparently remained there between the October 4 and November 7 aerial surveys.

Four fish in this release group either failed to remain above Lake Mills or never ascended into the upper river. Fish numbers 10 and 11 apparently never left the lake. Fish number 4 did ascend the lower canyon, but was located below Glines Dam on December 12. One fish, number 1, was found dead in the lake during the October 13 boat survey.

Seven of eleven transmitters in this group apparently ceased to operate prematurely.

Transmitter Failures

From the preceding description it is evident that our study objectives were undermined to varying degrees by the transmitter failure problem. Unfortunately, there was no conclusive evidence available to permit identification of the problem. Tests performed on the few transmitters recovered early during the study indicated remaining battery life was normal (Smith-Root, Inc., personal communication). It was noted, however, that the external metallic finish on one of the two types of tag bodies showed signs of corrosion. Corrosion could conceivably impair performance of the transmitter's internal antenna. The manufacturer could not provide a record of tag body finishes, thus, it was impossible to relate finish type to failed transmitters.

The number of operative transmitters exhibited a distinct decline in late September (table 1). Difficulties with signal masking had been overcome when the Data Logger was used, beginning with the September 9 survey. However, surveys after September 23 showed a continuous decline in percent of operative transmitters detected. In the absence of another reasonable explanation, this kind of steady decline appears to confirm that premature transmitter failure was the source of the data loss.

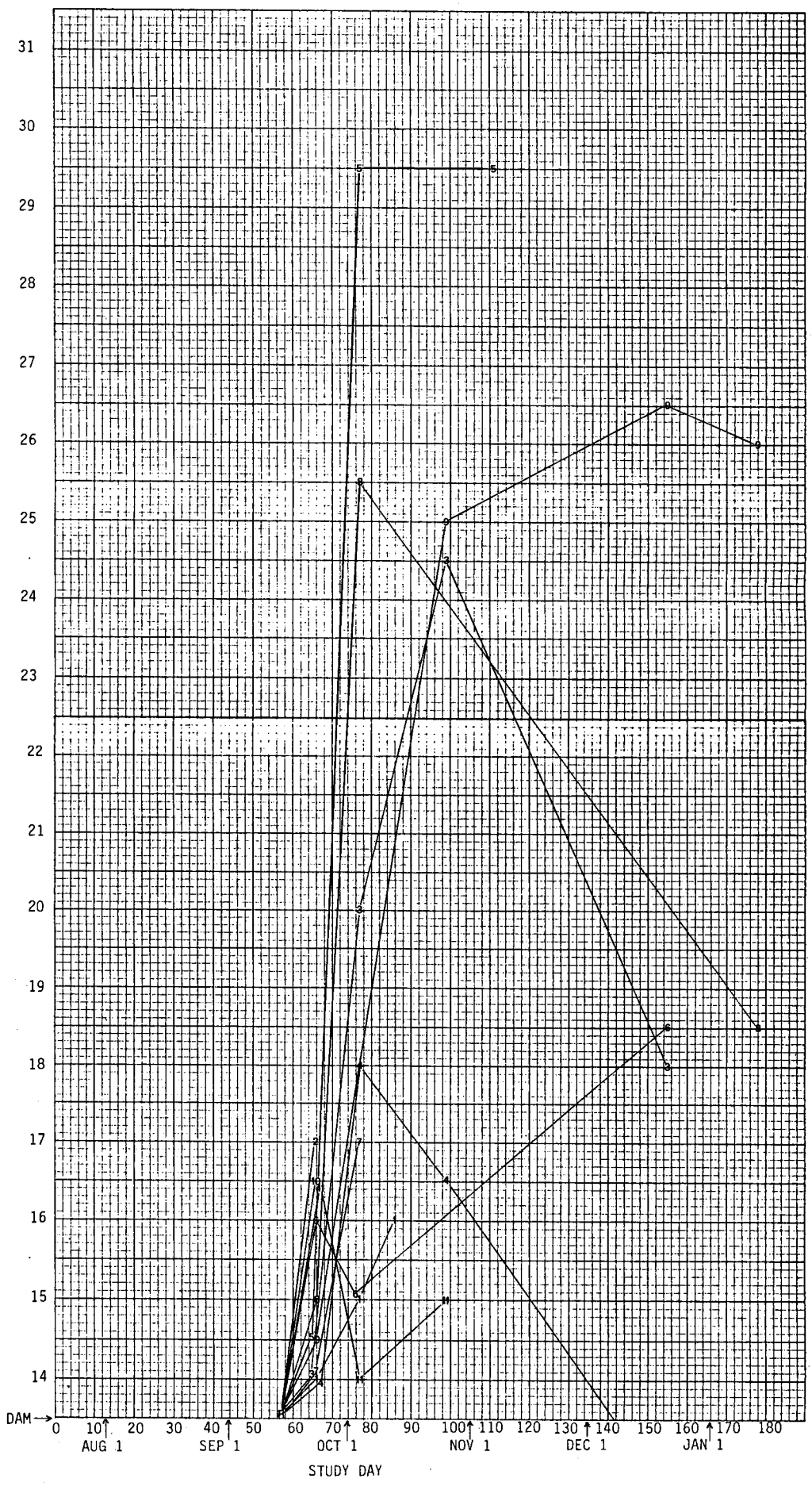


Figure 7. Known movements of steelhead released September 14, 1983, at RM 13.5 (Lake Mills site).

Fish FallBack

The problem of adult steelhead "fallback," i.e., the return of a marked fish to a point below a stream barrier following release above the barrier, has been observed by Chilcote et. al. (1983) and the Oregon Wildlife Commission (1975).

The frequency of fish fallback over or through Glines Dam, and the circumstances existing during fallback, are of primary importance in this study. Seven of the original 72 radio tagged steelhead were known to have fallen back over Glines Dam by the time the study was terminated in January, 1984. A fallback fish was caught in an Indian commerical net in the lower river on about December 20, 1983. Attempts to obtain more information regarding this fish were futile.

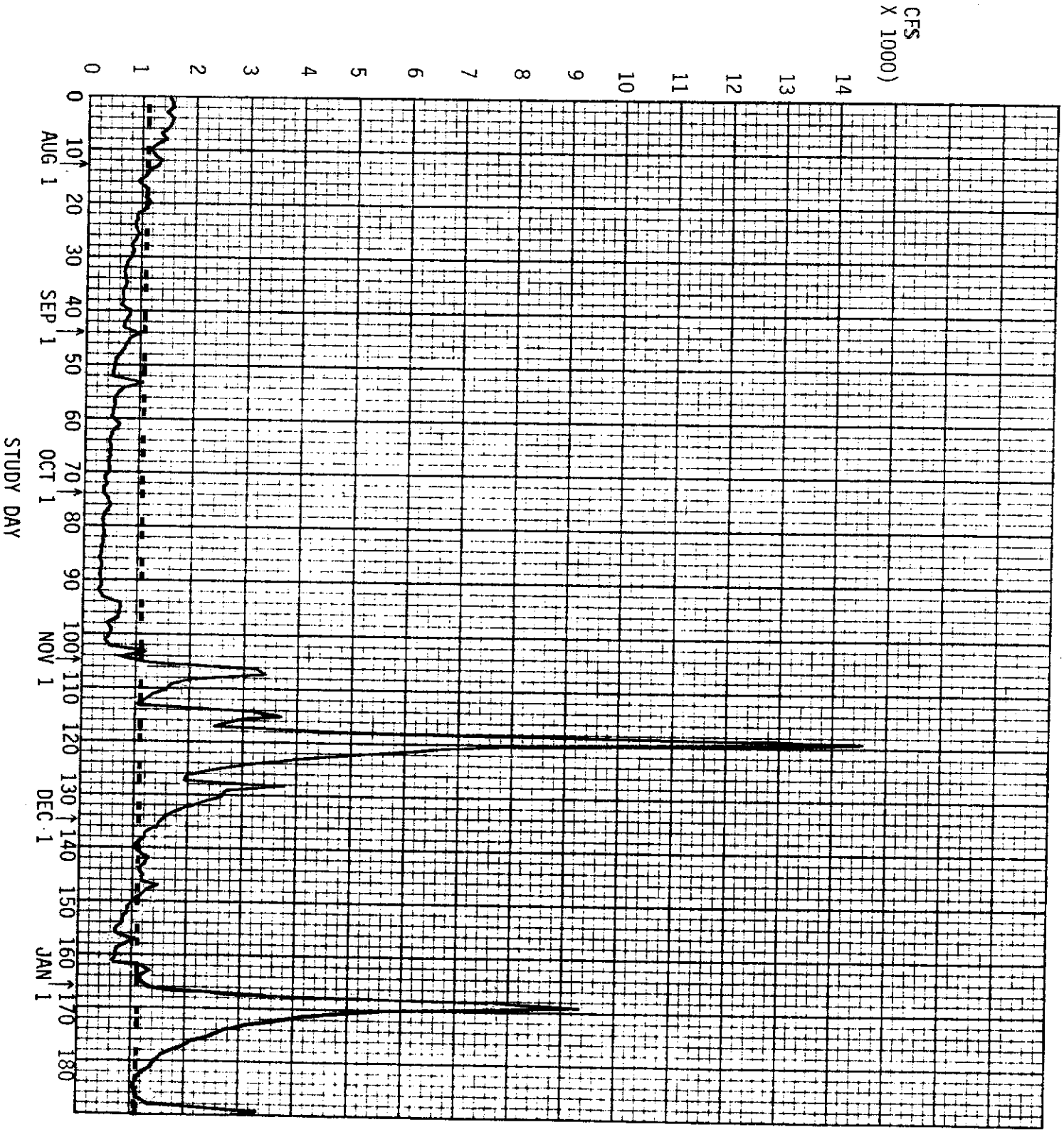
Although it is unknown whether any of the 45 fish with inoperative transmitters (by study's end) also fell back over Glines Dam, we attempted to estimate their fallback rate. Excluding seven fish among the various release groups that died above Lake Mills, a total of 20 of the remaining 65 fish were monitored above Lake Mills until the study ended or were known to have fallen over Glines Dam. The fallback rate among these 20 fish was 7, or 35% fallback. Using this fallback rate, 35% of the 45 fish with inoperative transmitters may have also fallen back over the dam. Thus, a total of 23 fish (7 known and 16 estimated) may have been fallbacks.

Fish Fallback and River Flow

River flow rate was undoubtedly a factor in the frequency of fish fallback over Glines Dam. Figure 8 presents estimated daily mean river flow at Glines Dam during the study period. Spill occurs at flows exceeding a rate of 1100 cubic feet per second (cfs) (Dan Kelley, Crown Zellerbach Corporation, personal communication). As shown in figure 8, periods of spilling occurred during late July, again during nearly all of November, and during all of January until the study ended. We determined that two or three fish from the July 19 release at Lake Mills, fell back over the dam During the earliest spill. No fallbacks were detected during the subsequent period, August 3 to the end of October, during which no spilling took place. Soon after spilling began in early November another fallback was detected. The remaining three known fallbacks also appear to have coincided with periods of spilling.

There was no evidence indicating that any fish passed Glines Dam via the turbine intake and penstock. The intake, located 65 feet below full pool elevation, seems a much less attractive route of escape to a healthy adult steelhead than the spillway's falling water at the pool surface. Only one of the seven known fallback fish was actually observed, but it had no major injuries such as are associated with adult fish passage through a power turbine. Moreover, the fish caught in the Indian net had passed both dams and was in sufficiently good condition to be purchased by a fish buyer.

Figure 8. Daily mean flow in the Elwha River, calculated from flows passed by Glines Dam (provided by Crown Zellerbach Corporation). Presented in cubic feet per second (cfs). The line (-- --) marks the flow rate above which spill occurred over Glines Dam.



Water Temperature

River water temperature data were derived from routine measurements of daily high and low temperatures at or near the WDF Elwha Rearing Facility (Greg Travers, WDF, personal communication). While temperatures ideally should have been measured in the river above Lake Mills, they were not due to logistical constraints. Water temperatures at the rearing facility and at all release sites, however, differed only by 1 or 2°F on those days when releases were made. Figure 9 presents the record of daily high and low water temperatures of the Elwha River from July 15, 1983 to January 13, 1984. These measurements should adequately represent the trends in water temperature change that radio tagged fish were subject to above the Glines Dam.

Is it possible to explain any or all release groups' movements as a factor of water temperature? We reviewed figures 2 through 7 which present the known movements of all radio tagged steelhead. No clear relationship between water temperature trends and any release group's movements is apparent. While a distinct water temperature peak occurred in late August until early September, followed by a steady temperature decline, no corresponding change in or initiation of fish movements is detectable.

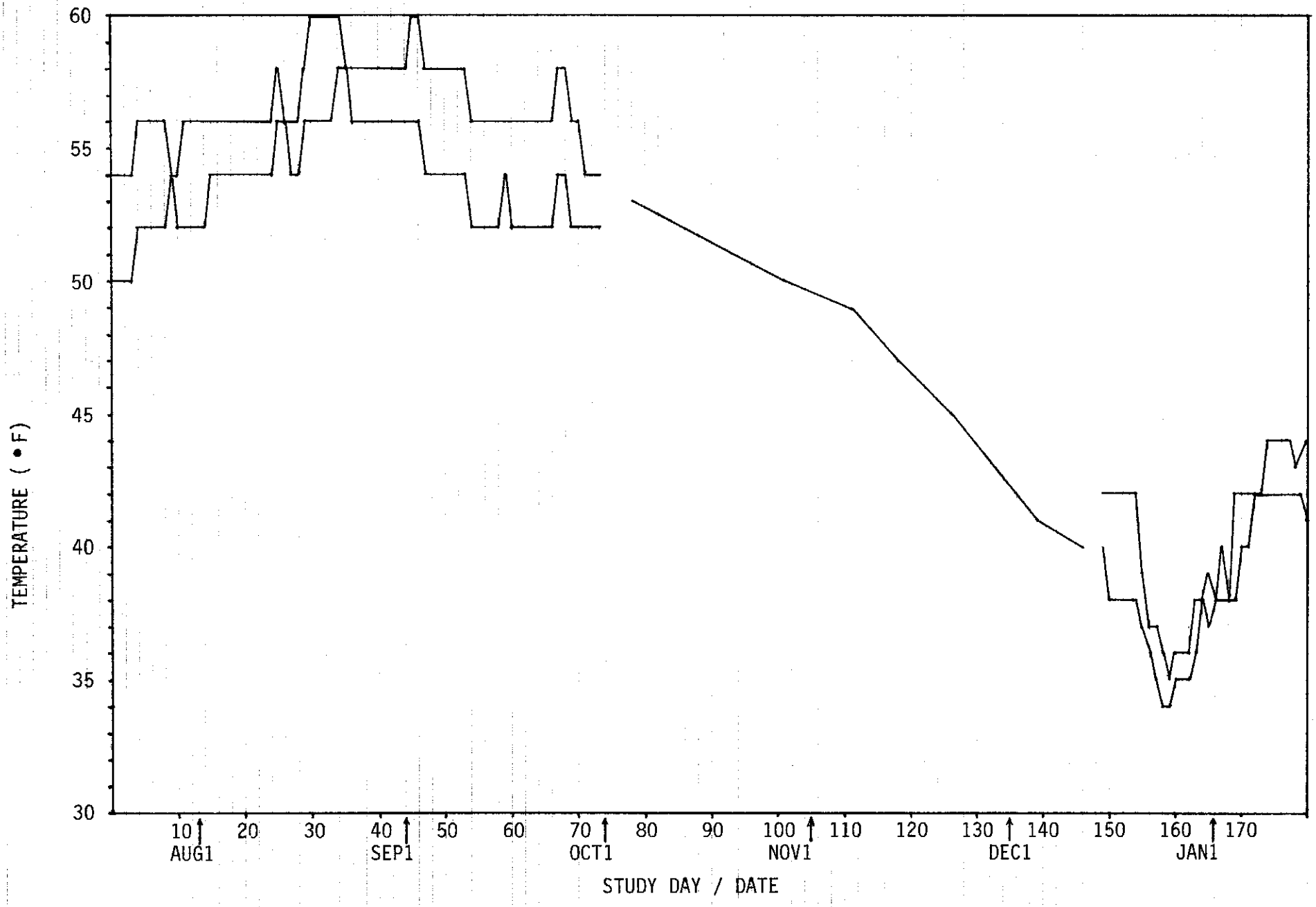


Figure 9. Maximum and minimum daily water temperature in the lower Elwha River from July 19 to September 30, 1983, and from December 15, 1983 to January 13, 1984. From Washington Department of Fisheries Elwha Facility. Graphed data for the period October 5 to December 12, 1983 was determined from single, mid-day measurements made at Elwha Tribal Hatchery.

DISCUSSION

Despite the early loss of contact with more than half of the radio tagged steelhead in this study, useful information was obtained from all release groups. The following discussion begins with a presentation of that information by major study objective.

Early vs. Late Fish Release

An assessment of mortalities and fallback fish does not conclusively favor one release period over another. However, a total of five steelhead from early releases (July) were known to have died in Lake Mills by October 13 while only two were known to have died from late releases (August and September). But, certain factors such as modified surgical techniques or change to release on the day of capture may have biased this difference. There was no significant difference in the number of known fallback fish between early and late releases. Early and late releases had four and three fish fall back, respectively. Among early releases all four fallbacks were from the first group released on July 19 at Lake Mills. Three of these fish had fallen back over the dam within two weeks of release, whereas the late release fallbacks occurred at least eight weeks after release. This difference is probably attributable to the lack of spill over Glines Dam from mid-August through late October.

Assessment of the factor of rate and time of movement up the river is more complex. From figures 2 - 7, it is difficult to discern any uniform movement trends among fish in a release group. During most increments of time on a given figure some fish were moving upstream, some were moving downstream, and others were unchanged. In view of the complexity of analyzing the fish movements, as presented in figures 2 - 7, a better technique was needed.

In the steelhead radio tagging analysis performed by Spence (1980) calculation of net fish movement (kilometers per day) was used to assess results. This technique is applied here to assess and compare the movement of all fish groups released from the Lake Mills site (figure 10). We believe it is most appropriate to make this comparison because: (a) more fish groups were released from this site than elsewhere; (b) this site is most important in that it offers the preferred release option, logistically; (c) the earliest and latest releases were made from this site; and (d) analysis is simplified by limiting preferred direction of movement to upstream.

Although differences in net movement were not large, figure 10 does give some indication that fish released in September had a slightly higher rate of upstream movement. Initial net upstream movement was greater in both September groups than that for fish released July 19. Net downstream movement was greater during more months for the July 19 releases than for either September release group. The September 14 releases show the most sustained net upstream movement of any release group.

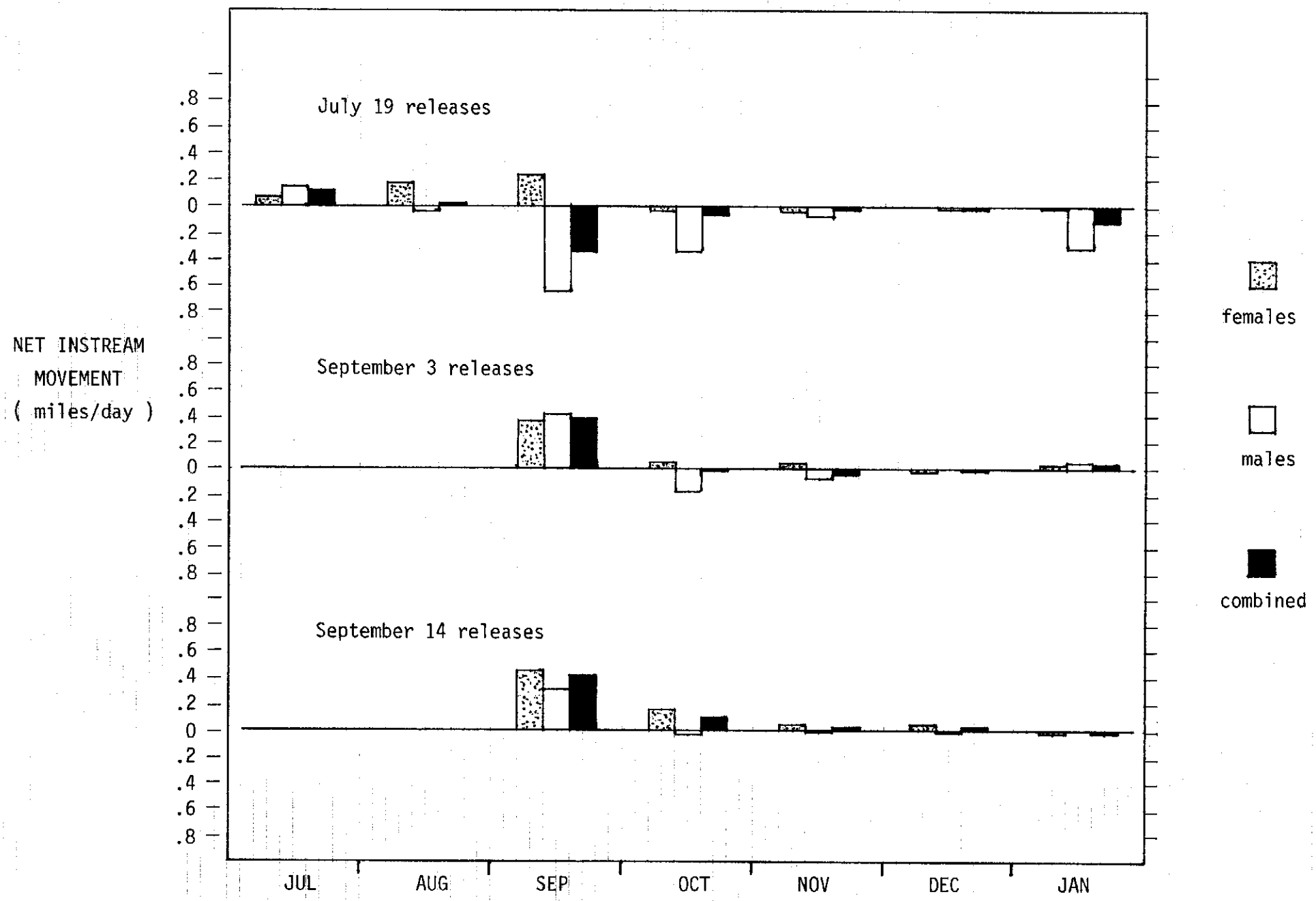


Figure 10. Net upstream and downstream movement of radio tagged steelhead groups released at Lake Mills, RM 13.5. Presented as average net miles moved per day, within each month.

If more transmitters had continued to function through the assumed period of spawning, mid-January to mid-February (Jim Nielson, WDG, personal communication) the net movement just prior to spawning might have resembled that observed in Alaskan and British Columbian research. Lough (1980), Spence (1980, 1981), and Burger et. al.(1983) all observed that radio tagged steelhead were relatively inactive while overwintering, and then began a rapid upstream spawning migration in either late April or early May.

In our final assessment of early vs. late release we compared utilization of and distribution in the upper river by all six release groups. Again faced with the complexity of the data presented in figures 2 - 7 and in the Appendix 2 tables, a simple mean river mile location is calculated for the fish location data from each aerial or boat survey, by release group (figures 11 - 16). In order to uniformly assess information in these figures we shall, somewhat subjectively, judge mean fish locations found in the river (and not in the lake) to be preferred behavior, and the further upstream they are, the more preferred their behavior.

The general trend over time in mean RM location of radio tagged steelhead in the early release groups was to either move in a downstream direction or to remain in or near Lake Mills. The Lake Mills releases of July 19 (figure 11), displayed a progressive upstream movement trend during the first four surveys. However, their mean location subsequently appeared to move back down into the lake, then up from the lake. And this sequence was repeated twice more before we observed a final mean location below Glines Dam. Both Spence (1980) and Lough (1980) observed this kind of erratic behavior by radio tagged steelhead in British Columbia. Had we been able to continue monitoring all of our fish in this group until mid-January we might have observed a mean upstream movement response to increasing water temperature, as was observed in British Columbia. However, based on the information available, this group's mean behavior is judged to be unpreferred.

The steelhead released early at Humes Ranch (RM 19.5) displayed a gradual downstream movement toward Lake Mills (figure 12). The final mean location was about five miles downstream from the release site. After September few fish in this group appear to have left the lake. Without knowing the condition of the few fish that we continued to detect in December and January, it may be presumptuous to label the preference of their behavior. However, given the criterion that a river location is preferred to a lake location, this group's behavior is found to be unpreferred.

The steelhead released at Wilder (RM 35), with respect to the behavior preference criterion, were initially given a distinct location advantage. However on almost every succeeding aerial survey their mean location moved further downstream (figure 13). On the last survey to detect more than one fish, made November 17, mean location of the group was about 18 miles downstream from the point of release. Despite the minimal detection information obtained on the latter surveys, this early release group's performance is also judged to be unpreferred.

The mean location of steelhead released late from Humes Ranch (figure 14), unlike that of the early released group (figure 12), dropped downstream and

Figure 11. Mean location of radio tagged steelhead released in the Elwha River at river mile 13.5 on July 19, 1983(one released July 27).

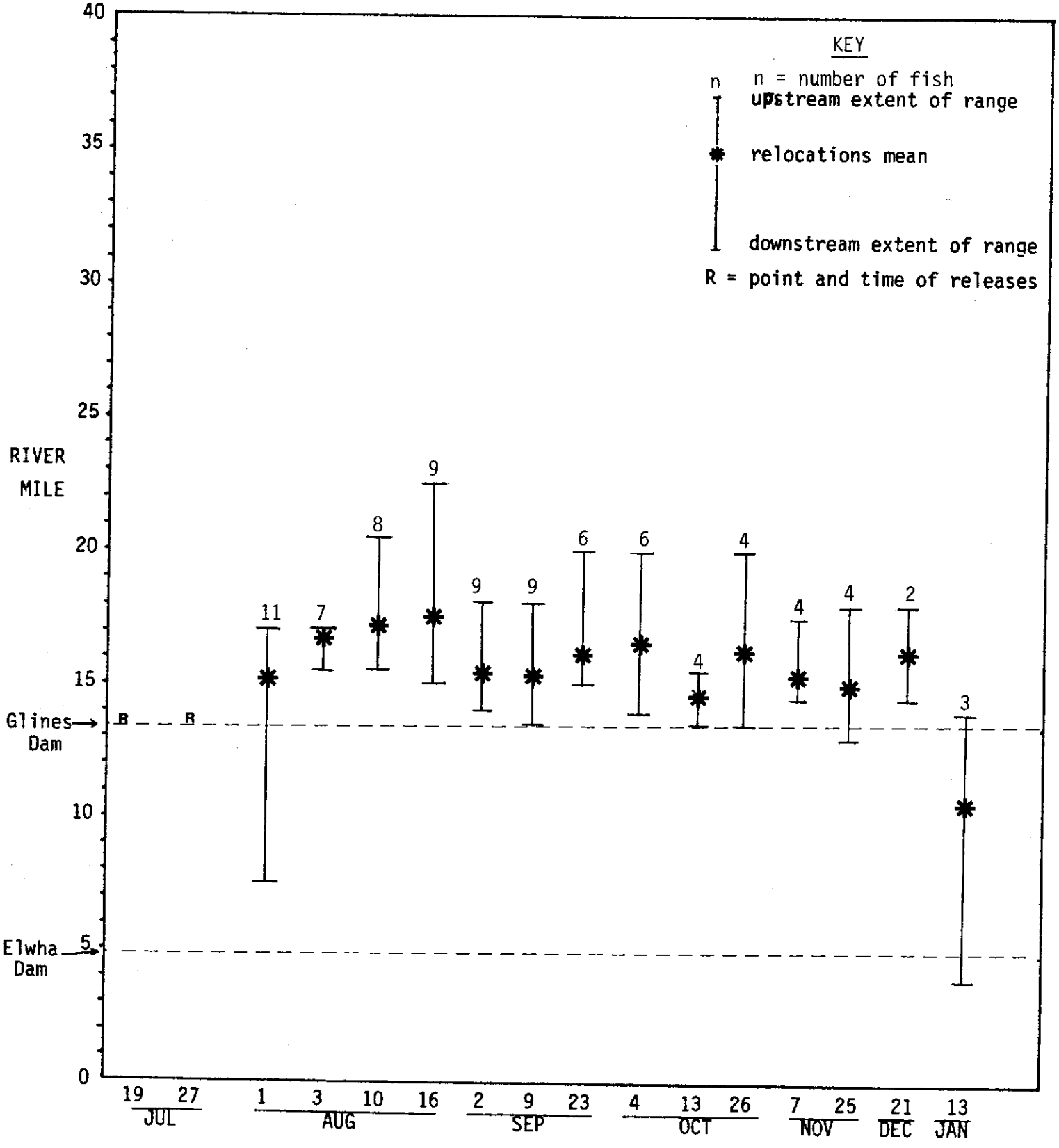


Figure 12. Mean location of radio tagged steelhead released in the Elwha River at river mile 19.5 on July 27, 1983.

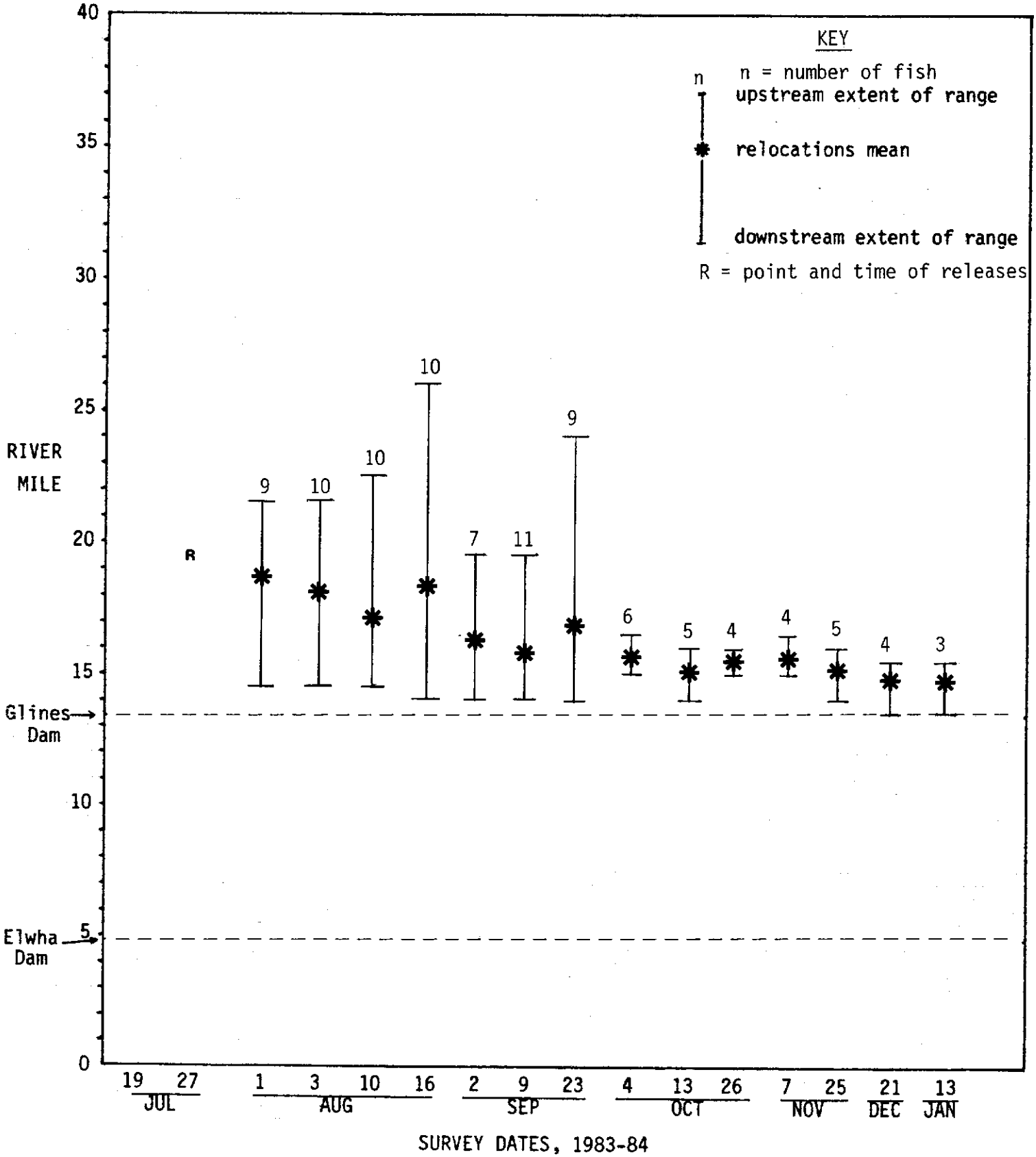


Figure 13. Mean location of radio tagged steelhead released in the Elwha River at river mile 35.0 on July 27, 1983.

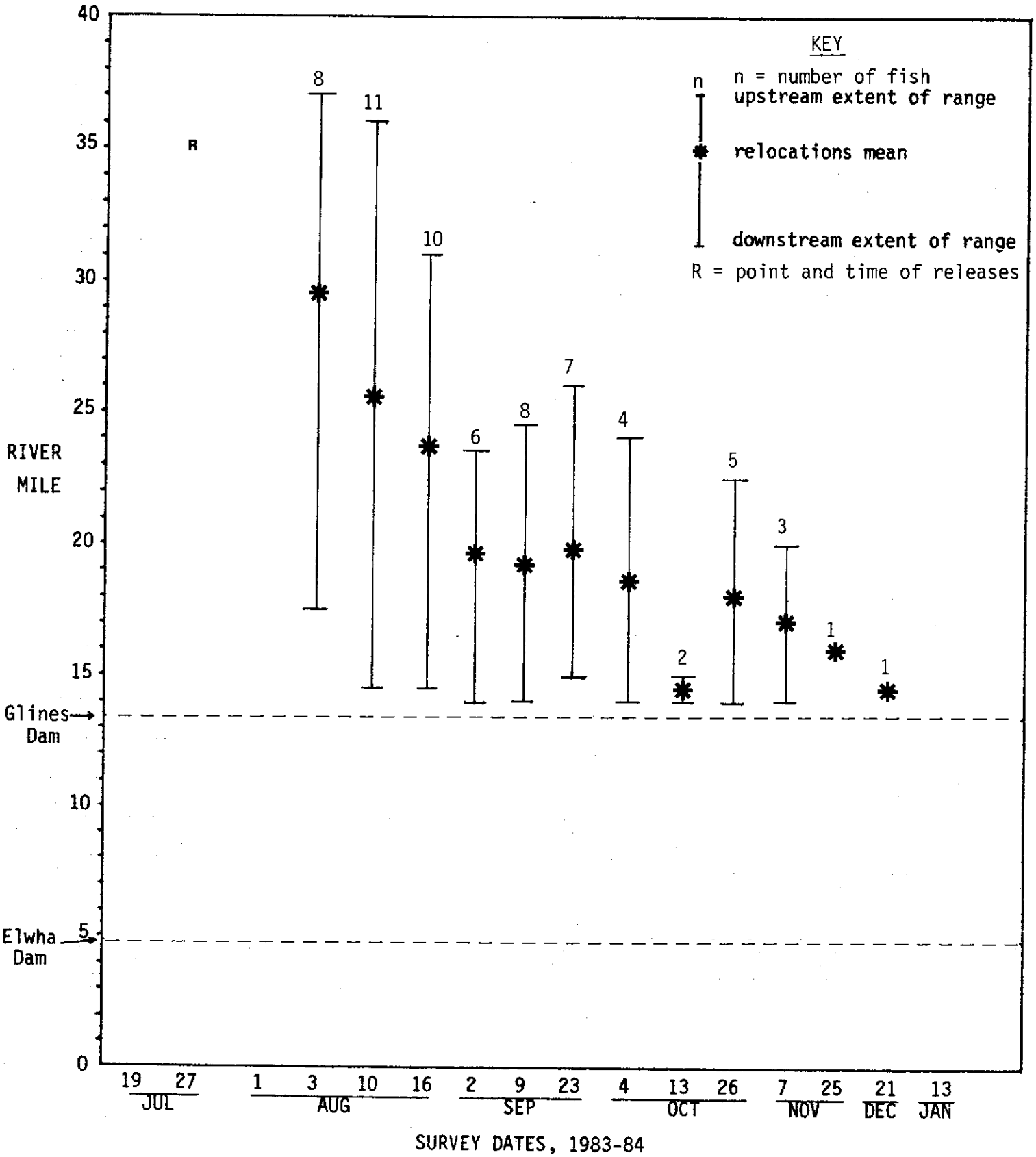
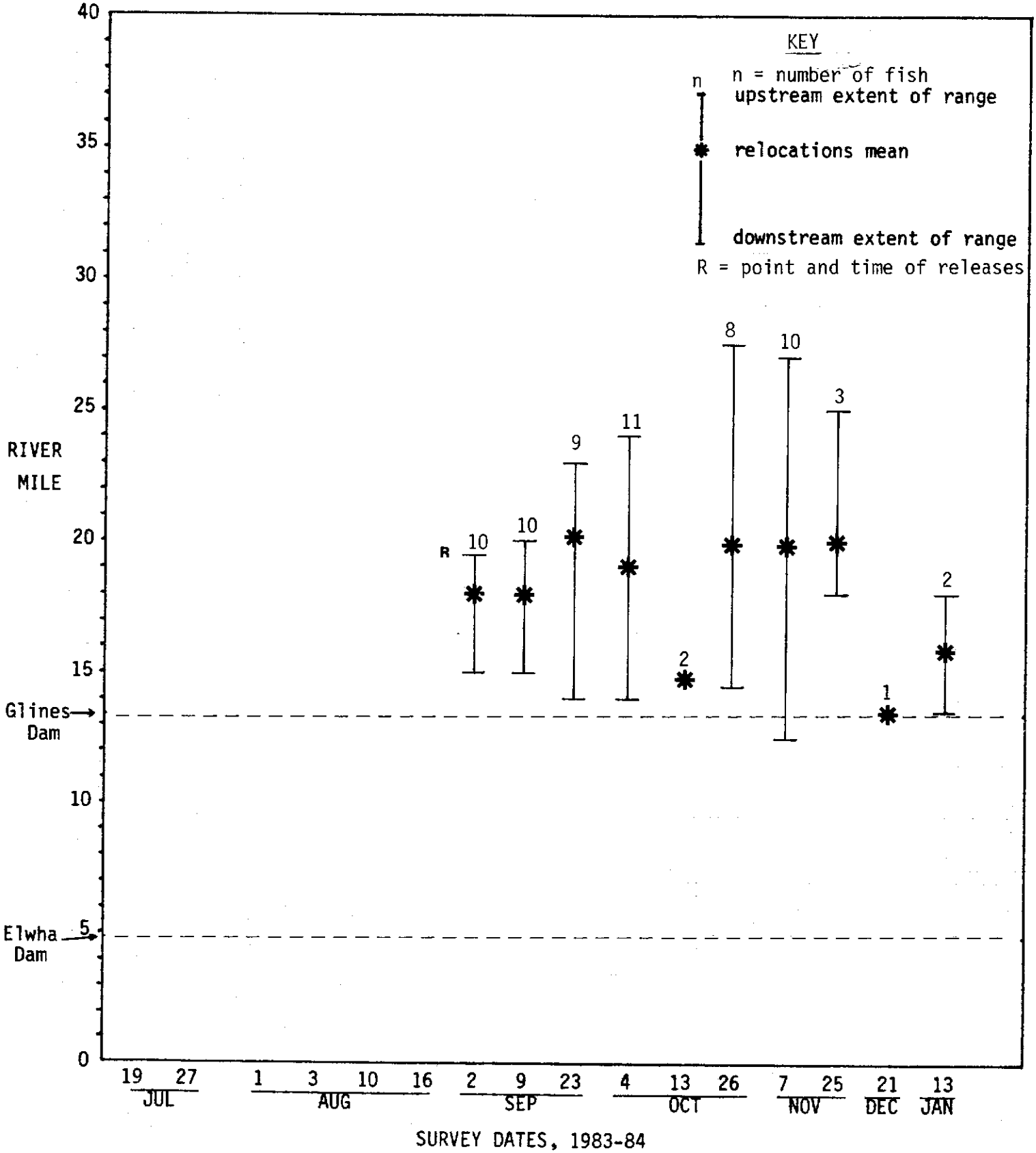


Figure 14. Mean location of radio tagged steelhead released in the Elwha River at river mile 19.5 on August 31, 1983.



after a few weeks returned to the vicinity of the release site. Their mean location remained near the release site until transmitter detection became a problem. In comparison with early release groups, this group's behavior was preferred.

Mean location of the second group released from Lake Mills on September 3, soon improved after an initial period of holding in the area of the lake (figure 15). Their mean location remained upstream of Rica Canyon, excluding the data from the October 13 boat survey, from September 23 until the study was terminated. This group's behavior, therefore, was preferred.

The final group, released from Lake Mills on September 14, behaved quite similarly to the September 3 group (figure 16). Their mean location remained in the lake a few weeks after which it was positioned above Rica Canyon. This group's behavior was also preferred.

In review, this analysis showed that while early released groups generally moved downstream or entered Lake Mills and remained there, late release groups generally moved out of the lake and held in the upper river. The latter behavior suggests that those fish were generally in better condition, and more able to respond to spawning migration instinct. Therefore, we suspect that late releases of adult steelhead are preferable to early releases.

Release Site Selection

The advantages of a successful program to trap, haul, and release adult fish that requires no air transport are obvious. Lake Mills is the preferred release site because it is the only one permitting truck transport.

The important question is whether releases of lower river imprinted adult steelhead at any release site above the upper dam will result in successful spawning in the upper river. We still do not know. If a decision were made to perform additional trial releases in attempts to observe spawning, or lack of it, in the upper Elwha, then we believe it would be most logical to use the Lake Mills boat launch as a release site. As shown in the analysis of early vs. late release, fish released from Lake Mills, particularly fish released in September, generally displayed an ability to move up the river and hold there. Whereas fish released above the lake generally dropped down into or near the lake.

Potential Fish FallBack

The phenomenon of adult steelhead trout falling back over a dam after release has been reported on only a few streams. With regard to this study's results, the most similar circumstances found elsewhere, that we are aware of, occurred at the South Santiam River in Oregon (Oregon Wildlife Commission 1975). Skamania strain summer run steelhead were introduced into the South Santiam River in 1969. Adults that returned in 1974 were trapped below the river's Foster Dam and released in the dam forebay. Steelhead that had been released below the dam as smolts fell back

Figure 15. Mean location of radio tagged steelhead released in the Elwha River at river mile 13.5 on September 3, 1983.

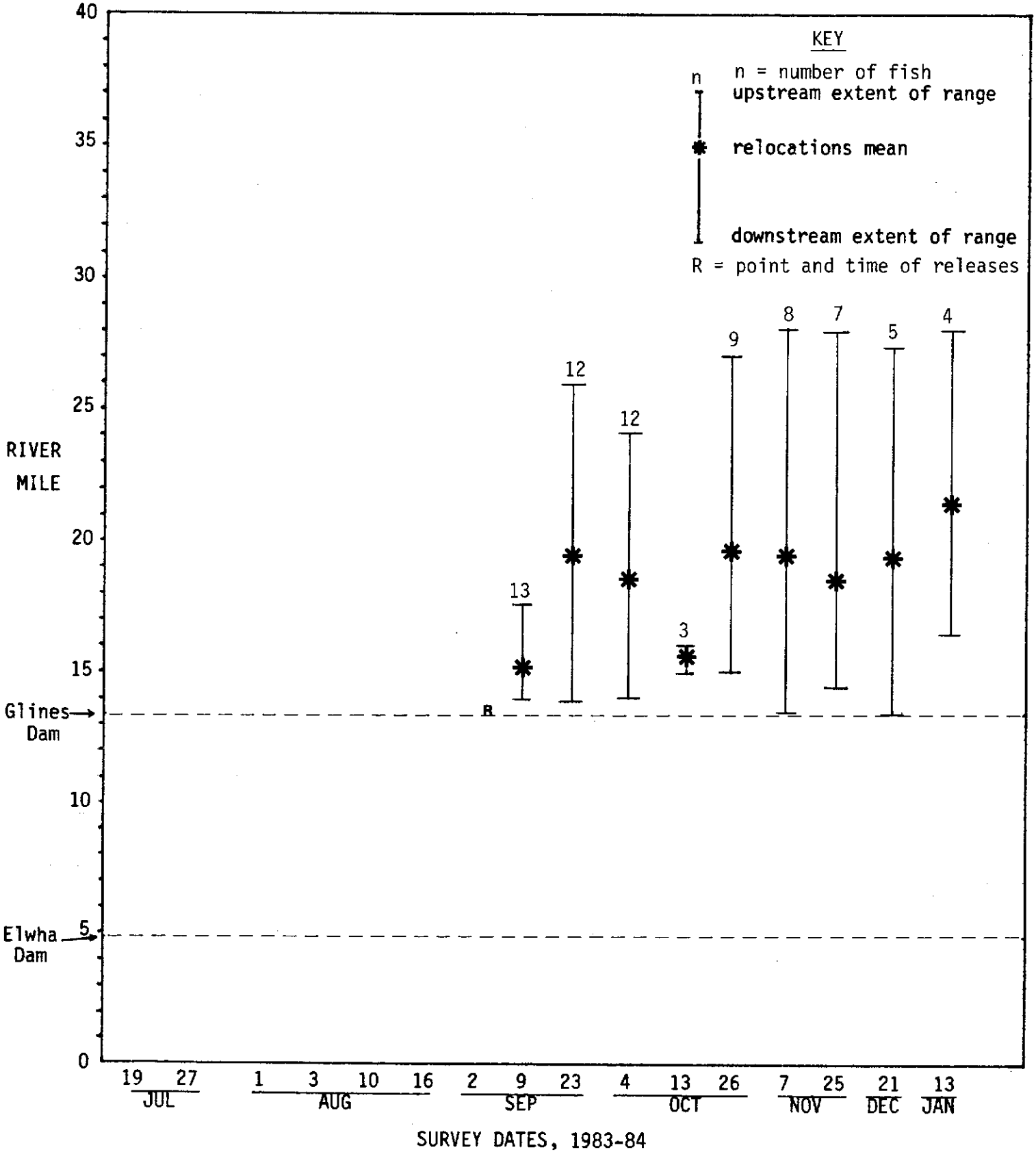
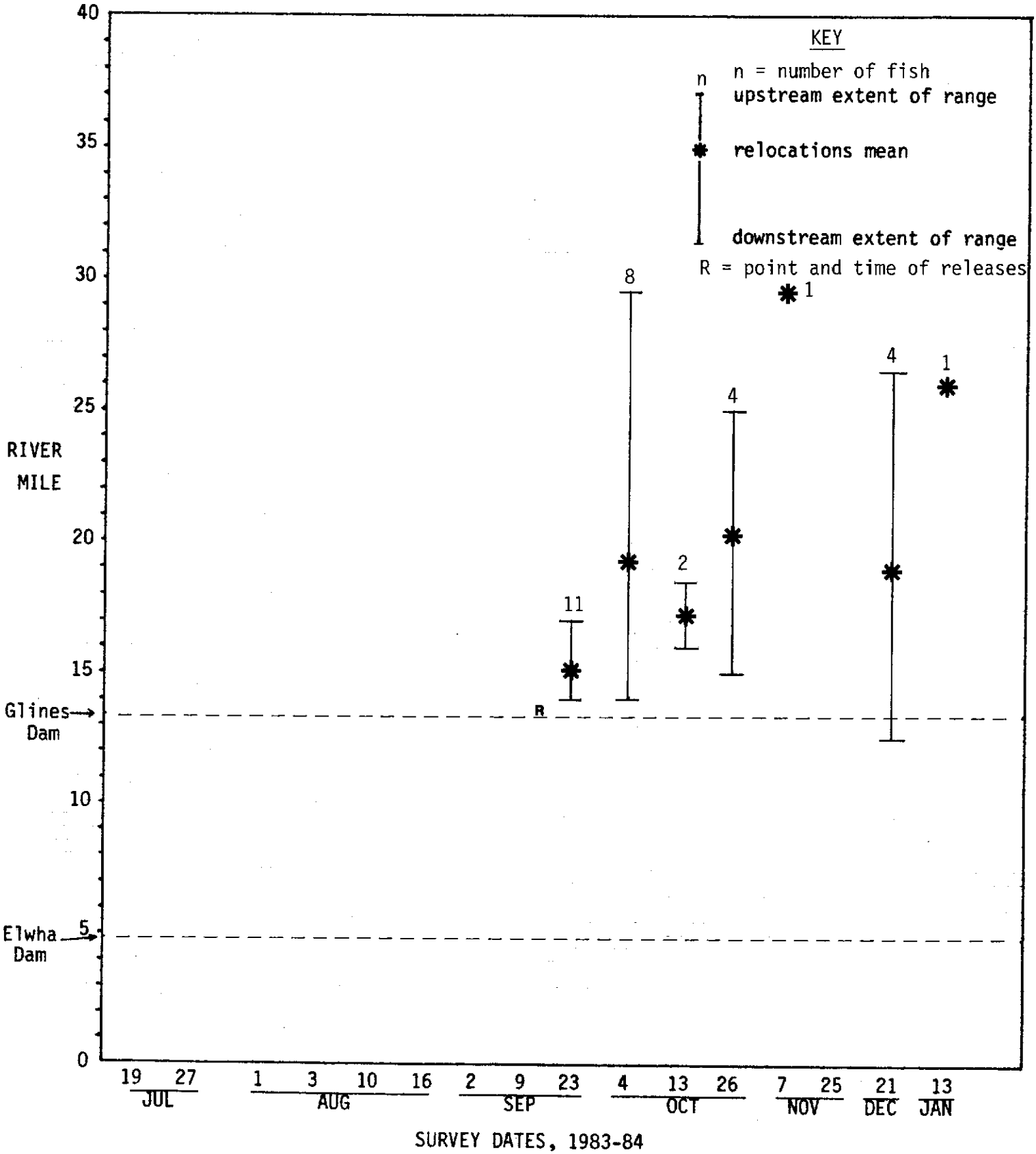


Figure 16. Mean location of radio tagged steelhead released in the Elwha River at river mile 13.5 on September 14, 1983.



at a mean rate of about 26%. Steelhead that had been released as smolts in the reservoir fell back at the rate of 13%. Research biologists studying this behavior eventually concluded that their summer steelhead fallback problem could not be remedied (David Buchanan, Oregon Department of Fish and Wildlife, personal communication).

While we were aware of a 9.7% known fallback rate at Glines Dam, the estimated total rate was 35% fallbacks. The fallback rate among steelhead released as smolts below Foster Dam is a comparable rate. Fish in both instances were released as smolts below the respective dam (Elwha steelhead were originally released below the lower dam). Fish in both instances were Skamania strain summer run steelhead, trapped below the respective dam and released above it. Although unconfirmed, a fallback rate approaching 35% of released adult steelhead could have a significant impact on a program of restoration above Glines Dam. However, if run restoration is based on returned adults that have imprinted and smolted above Glines Dam, then their fallback rate could be much lower.

Another factor that should favor increased chances for success of adult releases above Glines Dam is the lower level of handling and stress upon the fish. We assume that all radio tagged steelhead in our study suffered varying levels of stress due to handling, especially the surgery. A few fish presumably died as a result of stress or trauma related to the surgery. However, a carefully executed program of trap, haul, and release of adults could minimize handling and stress which should increase survival.

We believe the fallback risk can be minimized at Glines Dam by avoiding releases when water is spilled over the dam. Spill during September is less likely than during the early portion of the run, in July, according to USGS hydrologic records.

There was evidence that some radio tagged fish that fell over Glines Dam were not injured by the fall and therefore could eventually spawn in habitat between the two Elwha dams. Two steelhead were observed swimming just above the lower dam on April 25. In addition, the fish caught in an Indian net below the lower dam must have fallen over both dams, and yet it apparently was in good health. Fish which fall back between the dams may spawn there successfully. WDF (1971) estimated that sufficient spawning habitat exists there to accommodate about 500 chinook spawners, and the WDG (1973) accepted such spawning habitat as generally suitable for steelhead also.

Presmolt Planting

An alternative to releasing adult steelhead above Glines Dam to initiate their reestablishment is the planting of presmolt-sized fish at various locations throughout the upper river. These fish would be imprinted to the upper river, thus their drive to return to and redistribute in the upper river as spawning adults would be stronger. This approach, however, would be quite expensive and would also involve a significant risk. The resident

trout population in the upper Elwha is generally reputed to be quite healthy. Competition for food and habitat from greater numbers of rearing resident trout could significantly reduce growth and survival of planted steelhead. If this were the case, there might be no practical means of assuring that the initial number of migrant smolts would be large. Also, improvements in the structures at the dams for passing downstream migrants would need to be in place to avoid additional losses.

Size of planted steelhead would be a critical factor in their survival. If fry were used, they should be larger than resident trout fry present in the river in order to better compete for food and cover (David Buchanan, Oregon Department of Fish and Wildlife, 1984, personal communication). On Vancouver Island, British Columbia, steelhead ranging in size from small fry to fingerlings were released into Englishman Creek, which contained resident rainbow trout (Jeremy Humes, British Columbia Fish and Wildlife, 1984, personal communication). Combined results showed that steelhead survival and condition increased directly as their size at release increased. Moreover, it was observed that best steelhead survival resulted from an even distribution of released fish throughout the habitat. A planting density of about 0.5 fish per square meter produced optimum survival.

Radio Telemetry

Transmitter failures significantly limited our ability to meet the study goals, but we are confident that this or a similar project can be performed properly, with the correct equipment. Recent information indicates that the Smith-Root, Inc. transmitters were inadequately shielded to prevent water leakage (Radio Telemetry Seminar, Woodland Park Zoo, Seattle, WA, 1984, personal communication). Transmitters shielded by an external coating of biologically inert wax, similar to beeswax, have functioned properly for many months under conditions similar to those in this study. In addition, transmitters apparently are available with additional capabilities, such as alteration of a transmitter's signal pulse when a fish dies or a transmitter is regurgitated. This would have been useful in this study.

CONCLUSIONS

Based upon the results we've described, and their analysis, we believe that two of the three study objectives were met. Results indicate that adult steelhead can and will ascend the upper Elwha River if released in lower Lake Mills or at RM 19.5. However, this behavior appears to be related to time of release, as our findings indicate that relatively late release, during September, increases the likelihood of distribution into upper river habitat. This observation also answers another study objective, to determine if different segments of run timing would display different spawning tendencies upon release above Glines Dam. The remaining objective, to determine whether released adults will spawn in the upper Elwha, remains unanswered.

The steelhead fallback rate over Glines Dam may have been as high as 35%. While we consider this factor to be a potential threat to success of a trap, haul and release approach to upper river run reestablishment, it appears that this risk can be reduced. If the majority of steelhead were released in late summer when the likelihood of spill over Glines Dam is minimal, then fewer fish would probably fall back over the dam.

The question of whether steelhead will spawn in the upper Elwha probably could be answered by an additional and improved radio tagging study that would profit from knowledge gained in this study.

Our review of research investigating success of steelhead fry plants in streams inhabited only by resident trout points to a potentially reliable means of initiating a cycle of steelhead production. However, the greater expense of aerial transport and the question of suitable fry availability may preclude this option.

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APPENDIX 1

RADIO TAGGING GROUP DATA, BY RELEASE SITE

1. a. Lake Mills release, July 19, 1983

Fish Number	Fork Length (cm)	Sex	Assigned Transmitter			Comment
			Channel	Pulse Per Second	Body Type	
1	93	M	15	2	A	-
2	75	F	6	2	A	-
3	73	F	7	2	A	-
4	76	M	1	2	A	Transmitter reused on 9-3-83
5	77	M	9	2	A	-
6	72.5	F	13	2	A	-
7	89	M	8	2	A	Transmitter reused on 9-3-83
8	74	M	12	2	A	-
9	86	M	3	2	A	-
10	74	F	14	2	A	-
11	73	M	10	2	A	-
12	74	F	11	2	A	-

1. b. Humes Ranch release, July 27, 1983

Fish Number	Fork Length (cm)	Sex	Assigned Transmitter			Comment
			Channel	Pulse Per Second	Body Type	
1	76	F	1	1	A	-
2	71	F	2	1	A	-
3	72	M	12	1	A	-
4	71	F	14	1	A	-
5	77	M	13	1	A	Bleeding, sacrificed; trans, reused 9-3-83
6	72	F	8	1	A	-
7	70	M	10	1	A	-
8	79	M	9	1	A	-
9	74	F	6	1	A	-
10	75	F	4	1	A	-
11	75	F	5	1	A	-
12	75	M	11	1	A	-
13	74	F	9	0.5	A	Released at Lake Mills

1. c. Wilder release, July 27, 1983

Fish Number	Fork Length (cm)	Sex	Assigned Transmitter			Comment
			Channel	Pulse Per Second	Body Type	
1	75	M	2	3	A	Transmitter reused on 9-14-83
2	76	F	10	3	A	-
3	72.5	F	5	2	A	-
4	73.5	F	13	3	A	-
5	79	M	14	3	A	-
6	83	F	4	2	A	-
7	75	M	2	2	A	-
8	76	F	11	1	A	Bleeding; sacrificed; trans. reused 7-2783
9	78	M	5	3	A	-
10	72	F	15	1	A	-
11	72	M	3	1	A	-
12	76	F	7	1	A	-

1. d. Humes Ranch release, August 31, 1983

Fish Number	Fork Length (cm)	Sex	Assigned Transmitter			Comment
			Channel	Pulse Per Second	Body Type	
1	70	M	15	3	C	-
2	73.5	F	6	3	C	-
3	72	F	6	.5	C	-
4	73.5	M	4	3	C	-
5	73	F	11	3	C	-
6	74	F	8	3	C	-
7	66	M	7	3	C	-
8	69	M	5	.5	C	-
9	77.5	F	14	.5	A	-
10	71.5	M	9	3	C	-
11	74	M	12	3	C	-
12	71	M	2	.5	C	-

1. e. Lake Mills release, September 3, 1983

Fish Number	Fork Length (cm)	Sex	Assigned Transmitter			Comment
			Channel	Pulse Per Second	Body Type	
1	78	M	8	2	A	-
2	71	M	4	.5	C	-
3	74	F	7	.5	A	-
4	75	M	1	2	A	-
5	70	F	3	3	C	-
6	68.5	F	1	3	C	-
7	67	F	1	.5	C	-
8	71	F	15	.5	A	-
9	74	F	13	1	A	-
10	72.5	M	8	.5	A	-
11	75.5	M	11	.5	A	-
12	73	M	10	.5	A	-
13	89	M	12	.5	A	-
14	74.5	M	3	.5	C	-
15						Fish died due to stress
16						Fish died due to stress

1. f. Lake Mills release, September 14, 1983

Fish Number	Fork Length (cm)	Sex	Assigned Transmitter			Comment
			Channel	Pulse Per Second	Body Type	
1	86	F	13	.5	A	-
2	81	F	16	3	C	-
3	73	F	16	1	C	-
4	75.5	M	18	2	C	-
5	75	F	17	2	C	-
6	75	M	17	3	C	-
7	60	M	18	3	C	-
8	83	M	16	2	C	-
9	65	F	17	1	C	-
10	72	F	2	3	A	Tag operating erratically at release
11	69	F	18	1	C	-

APPENDIX 2

TAGGED FISH RELOCATIONS, BY RELEASE SITE

2a. Mills Lake release, July 19, 1983 (see column heading key below).

C	P	DATE			S	R	L	FISH NUMBER
15	2.0	7	19	83	1	13.5	13.5	
		8	1	83	13		17.0	
		8	3	83	15		15.5	
		8	16	83	28		18.5	
		9	2	83	45		18.5	1
		9	9	83	52		18.0	
		9	23	83	66		20.0	
		10	4	83	77		20.0	
		10	26	83	99		17.0	
		11	7	83	111		17.5	
		11	25	83	129		18.0	
		12	21	83	155		18.0	
		1	13	84	178		4.0	
6	2.0	7	19	83	1	13.5	13.5	
		8	1	83	13		16.5	
		8	3	83	15		17.0	
		8	10	83	22		15.5	
		8	16	83	28		15.0	2
		9	2	83	45		14.0	
		9	9	83	52		16.0	
7	2.0	7	19	83	1	13.5	13.5	
		8	1	83	13		17.0	
		8	3	83	15		17.0	
		8	10	83	22		17.5	
		8	16	83	28		21.0	
		9	2	83	45		14.0	
		9	9	83	52		15.0	3
		9	23	83	66		15.0	
		10	4	83	77		19.5	
		11	7	83	111		14.5	
9	2.0	7	19	83	1	13.5	13.5	
		8	1	83	13		16.5	
		8	3	83	15		17.0	
		8	10	83	22		20.5	
		8	16	83	28		22.5	
		9	2	83	45		16.0	5
		9	9	83	52		15.0	
		9	23	83	66		15.0	
		10	4	83	77		15.5	
		10	13	83	86		15.5	
13	2.0	7	19	83	1	13.5	13.5	
		8	1	83	13		14.5	
		8	3	83	15		17.0	
		8	10	83	22		15.5	
		8	16	83	28		16.5	6
		9	9	83	52		15.0	
		9	23	83	66		16.5	
8	2.0	7	19	83	1	13.5	13.5	
		8	1	83	13		13.0	7

2a.(continued)

C	P	DATE			S	R	L	FISH NUMBER
12	2.0	7	19	83	1	13.5	13.5	
		8	1	83	13		16.5	
		8	3	83	15		17.0	
		8	10	83	22		18.5	
		8	16	83	28		16.0	8
		9	2	83	45		15.0	
		9	9	83	52		15.0	
		9	23	83	66		15.0	
		10	4	83	77		15.5	
		10	13	83	86		15.0	
3	2.0	7	19	83	1	13.5	13.5	
		8	1	83	13		16.5	
		8	10	83	22		16.0	
		8	16	83	28		15.0	
		9	2	83	45		16.0	9
		9	9	83	52		15.0	
		9	23	83	66		15.0	
		10	4	83	77		14.0	
		10	13	83	86		14.5	
		10	26	83	99		13.5	
		11	7	83	111		14.5	
		11	25	83	129		15.0	
		12	21	83	155		14.5	
		1	13	84	178		14.0	
14	2.0	7	19	83	1	13.5	13.5	
		8	1	83	13		7.5	10
10	2.0	7	19	83	1	13.5	13.5	
10	2.0	11	25	83	129	13.5	13.0	11
11	2.0	7	19	83	1	13.5	13.5	
		8	10	83	22		17.5	
		8	16	83	28		16.0	
		9	2	83	45		14.5	12
		9	9	83	52		15.0	
		10	26	83	99		20.0	
9	0.5	7	27	83	8	13.5	13.5	
		8	1	83	13		14.5	
		9	2	83	45		14.5	13
		10	4	83	77		14.5	
		10	13	83	86		13.5	
		10	26	83	99		14.5	
		11	7	83	111		14.5	
		11	25	83	129		14.0	
		1	13	84	178		13.5	
1	2.0	7	19	83	1	13.5	13.5	4
		8	1	83	13		16.5	
		8	3	83	15		17.0	
		8	10	83	22		16.5	
		8	16	83	28		17.5	
		9	2	83	45		16.5	
		9	3	83	46		13.5	

2b. Humes Ranch release, July 27, 1983

C	P	DATE			S	R	L	FISH NUMBER
1	1.0	7	27	83	8	19.5	19.5	
		8	1	83	13		14.5	
		8	3	83	15		14.5	1
		8	10	83	22		14.5	
		8	16	83	28		14.0	
		9	2	83	45		14.0	
		9	9	83	52		14.0	
		9	23	83	66		14.0	
		11	25	83	129		16.0	
2	1.0	7	27	83	8	19.5	19.5	
		8	1	83	13		19.5	
		8	3	83	15		21.5	
		8	10	83	22		22.5	
		8	16	83	28		26.0	2
		9	2	83	45		15.0	
		9	9	83	52		16.0	
		10	4	83	77		16.0	
		10	13	83	86		16.0	
12	1.0	7	27	83	8	19.5	19.5	
		8	3	83	15		21.5	
		8	10	83	22		20.5	
		8	16	83	28		20.5	
		9	9	83	52		15.0	3
		9	23	83	66		15.0	
		10	4	83	77		15.0	
14	1.0	7	27	83	8	19.5	19.5	
		8	1	83	13		15.0	
		8	3	83	15		17.0	
		8	10	83	22		15.0	
		8	16	83	28		14.0	4
		9	2	83	45		15.0	
		9	9	83	52		14.0	
		9	23	83	66		14.0	
		10	4	83	77		15.5	
		10	13	83	86		15.0	
		10	26	83	99		15.0	
		11	7	83	111		15.5	
		11	25	83	129		14.0	
		12	21	83	155		15.0	
8	1.0	7	27	83	8	19.5	19.5	
		8	1	83	13		19.5	
		8	3	83	15		17.0	
		8	10	83	22		16.5	
		8	16	83	28		20.5	6
		9	9	83	52		14.0	
		9	23	83	66		16.5	

2b.(continued)

C	P	DATE			S	R	L	FISH NUMBER
10	1.0	7	27	83	8	19.5	19.5	
		8	3	83	15		19.5	
		8	10	83	22		14.5	
		8	16	83	28		15.0	7
		9	9	83	52		18.0	
		9	23	83	66		24.0	
		10	4	83	77		15.0	
		10	13	83	86		16.0	
		10	26	83	99		15.5	
		11	7	83	111		15.0	
9	1.0	7	27	83	8	19.5	19.5	
		8	1	83	13		19.5	
		8	10	83	22		15.0	
		8	16	83	28		16.5	8
		9	2	83	45		17.5	
		9	9	83	52		15.0	
		9	23	83	66		16.5	
		10	4	83	77		16.0	
		10	13	83	86		15.0	
		10	26	83	99		15.5	
		11	7	83	111		15.5	
		11	25	83	129		16.0	
		12	21	83	155		15.5	
		1	13	84	178		15.5	
6	1.0	7	27	83	8	19.5	19.5	
		8	1	83	13		19.5	
		8	3	83	15		16.0	
		8	10	83	22		15.0	9
		8	16	83	28		15.5	
		9	2	83	45		19.5	
		9	9	83	52		18.0	
4	1.0	7	27	83	8	19.5	19.5	
		8	1	83	13		19.5	
		8	3	83	15		20.5	
		8	10	83	22		22.0	
		8	16	83	28		23.0	10
		9	2	83	45		18.5	
		9	9	83	52		16.5	
		9	23	83	66		18.0	
		10	4	83	77		16.5	
		10	26	83	99		16.0	
		11	7	83	111		16.5	
		11	25	83	129		16.0	
		12	21	83	155		15.5	
		1	13	84	178		15.5	
5	1.0	7	27	83	8	19.5	19.5	
		8	3	83	15		20.5	
		8	10	83	22		15.0	11
		9	9	83	52		19.5	
		9	23	83	66		19.5	
								52

2b.(continued)

C	P	DATE			S	R	L	FISH NUMBER
11	1.0	7	27	83	8	19.5	19.5	
		8	1	83	13		19.5	
		8	3	83	15		19.5	
		8	10	83	22		16.5	12
		8	16	83	28		18.5	
		9	2	83	45		14.5	
		9	9	83	52		14.0	
		9	23	83	66		15.0	
		10	13	83	86		14.0	
		11	25	83	129		14.0	
		12	21	83	155		13.5	
		1	13	84	178		13.5	

2c. Wilder release, July 27, 1983

C	P	DATE			S	R	L	FISH NUMBER
5	2.0	7	27	83	8	35.0	35.0	
		8	3	83	15		32.5	
		8	10	83	22		31.5	
		8	16	83	28		31.0	3
		9	2	83	45		23.5	
		9	9	83	52		19.5	
		9	23	83	66		20.0	
		10	26	83	99		18.5	
10	3.0	7	27	83	8	35.0	35.0	
		8	3	83	15		33.5	
		8	10	83	22		25.5	2
		8	16	83	28		26.0	
13	3.0	7	27	83	8	35.0	35.0	
		8	10	83	22		29.5	
		8	16	83	28		29.5	
		9	2	83	45		23.5	
		9	9	83	52		24.5	
		9	23	83	66		26.0	4
		10	4	83	77		24.0	
		10	26	83	99		22.5	
14	3.0	7	27	83	8	35.0	35.0	
		8	3	83	15		37.0	
		8	10	83	22		36.0	
		8	16	83	28		21.0	5
		9	2	83	45		19.5	
		9	9	83	52		21.0	
		9	23	83	66		22.0	
		10	4	83	77		20.0	
		10	26	83	99		19.0	
		11	7	83	111		20.0	
		11	25	83	129		16.0	
		12	21	83	155		14.5	
4	2.0	7	27	83	8	35.0	35.0	
		8	3	83	15		31.0	
		8	10	83	22		14.5	6
		10	13	83	86		15.0	
2	2.0	7	27	83	8	35.0	35.0	
		8	3	83	15		17.5	
		8	10	83	22		16.5	
		8	16	83	28		21.5	7
		9	2	83	45		21.0	
		9	9	83	52		20.5	
		9	23	83	66		18.0	
5	3.0	7	27	83	8	35.0	35.0	
		8	10	83	22		29.5	
		8	16	83	28		29.5	9
		9	9	83	52		18.0	
		9	23	83	66		20.0	

2c.(continued)

C	P	DATE			S	R	L	FISH NUMBER
15	1.0	7	27	83	8	35.0	35.0	
		8	3	83	15		33.5	
		8	10	83	22		32.5	
		8	16	83	28		30.0	10
		9	2	83	45		14.0	
		9	9	83	52		14.0	
		9	23	83	66		15.0	
		10	4	83	77		14.0	
		10	13	83	86		14.0	
		10	26	83	99		14.0	
		11	7	83	111		14.0	
3	1.0	7	27	83	8	35.0	35.0	
		8	3	83	15		17.5	
		8	10	83	22		22.5	11
		8	16	83	28		16.5	
		9	9	83	52		19.5	
7	1.0	7	27	83	8	35.0	35.0	
		8	3	83	15		32.5	
		8	10	83	22		22.0	
		8	16	83	28		17.5	12
		9	2	83	45		16.5	
		9	9	83	52		16.5	
		9	23	83	66		18.0	
		10	4	83	77		16.5	
		10	26	83	99		16.0	
		11	7	83	111		17.0	
2	3.0	7	27	83	8	35.0	35.0	
		8	3	83	15		30.5	1
		8	10	83	22		20.5	
		8	16	83	28		14.5	
		8	18	83	30		14.0	

2d. Humes Ranch release, August 31, 1983

C	P	DATE			S	R	L	FISH NUMBER
15	3.0	8	31	83	43	19.5	19.5	
		9	2	83	45		18.0	
		9	9	83	52		19.5	
		9	23	83	66		22.0	
		10	4	83	77		18.0	1
		10	26	83	99		18.0	
		11	7	83	111		18.0	
		11	25	83	129		18.0	
6	3.0	8	31	83	43	19.5	19.5	
		9	2	83	45		16.5	
		9	9	83	52		17.5	
		9	23	83	66		19.5	2
		10	4	83	77		16.0	
		10	26	83	99		19.5	
		11	7	83	111		25.0	
		11	25	83	129		25.0	
6	0.5	8	31	83	43	19.5	19.5	
		9	2	83	45		19.0	
		9	9	83	52		19.5	
		9	23	83	66		22.0	
		10	4	83	77		24.0	3
		10	26	83	99		27.5	
		11	7	83	111		27.0	
4	3.0	8	31	83	43	19.5	19.5	
		10	4	83	77		23.5	
		10	26	83	99		27.0	4
		11	7	83	111		25.0	
11	3.0	8	31	83	43	19.5	19.5	
		9	2	83	45		19.5	
		9	9	83	52		18.0	
		9	23	83	66		22.5	5
		10	4	83	77		21.5	
		11	7	83	111		20.5	
8	3.0	8	31	83	43	19.5	19.5	
		9	2	83	45		18.0	
		9	9	83	52		18.0	
		9	23	83	66		22.0	
		10	4	83	77		18.5	6
		10	26	83	99		18.0	
		11	7	83	111		19.5	
		11	25	83	129		18.5	
		1	13	84	178		18.0	

2d.(continued)

C	P	DATE			S	R	L	FISH NUMBER
7	3.0	8	31	83	43	19.5	19.5	
		9	2	83	45		18.5	
		9	9	83	52		19.5	
		9	23	83	66		21.0	
		10	4	83	77		19.5	7
		10	26	83	99		19.0	
		11	7	83	111		12.5	
5	0.5	8	31	83	43	19.5	19.5	
	0.5	9	2	83	45		19.0	
	0.5	9	9	83	52		17.0	
	0.5	9	23	83	66		16.0	8
	0.5	10	4	83	77		17.5	
	0.5	12	1	83	135		8.0	
14	0.5	8	31	83	43	19.5	19.5	
		9	9	83	52		15.0	
		10	4	83	77		14.0	
		10	13	83	86		15.0	9
		10	26	83	99		14.5	
		11	7	83	111		14.0	
		12	21	83	155		13.5	
		1	13	84	178		13.5	
9	3.0	8	31	83	43	19.5	19.5	
		9	2	83	45		18.5	10
		9	9	83	52		16.0	
12	3.0	8	31	83	43	19.5	19.5	
		9	2	83	45		15.0	
		9	9	83	52		20.0	
		9	23	83	66		23.0	11
		10	4	83	77		22.5	
		11	7	83	111		22.0	
2	0.5	8	31	83	43	19.5	19.5	
		9	2	83	45		18.5	
		9	23	83	66		14.0	12
		10	4	83	77		14.5	
		10	13	83	86		14.5	
		10	26	83	99		16.0	
		11	7	83	111		15.0	

2e. Mills Lake release, September 3, 1983

C	P	DATE			S	R	L	FISH NUMBER
8	2.0	9	3	83	46	13.5	13.5	
		9	9	83	52		14.0	1
		9	23	83	66		20.0	
		10	4	83	77		16.0	
4	0.5	9	3	83	46	13.5	13.5	
		9	9	83	52		16.0	
		9	23	83	66		22.0	2
		10	4	83	77		20.0	
		10	26	83	99		18.5	
7	0.5	9	3	83	46	13.5	13.5	
		9	9	83	52		16.0	
		9	23	83	66		18.0	3
		10	4	83	77		18.5	
		10	26	83	99		17.5	
		11	7	83	111		19.0	
		11	25	83	129		18.5	
		12	21	83	155		18.0	
		1	13	84	178		18.5	
1	2.0	9	3	83	46	13.5	13.5	
		9	9	83	52		14.0	
		9	23	83	66		18.0	
		10	4	83	77		14.0	4
		10	13	83	86		16.0	
		10	26	83	99		15.0	
		11	7	83	111		15.0	
		11	25	83	129		16.0	
3	3.0	9	3	83	46	13.5	13.5	
		9	9	83	52		14.0	5
		10	13	83	86		16.0	
1	3.0	9	3	83	46	13.5	13.5	
		9	23	83	66		26.0	6
		10	4	83	77		24.0	
		10	26	83	99		24.0	
		11	7	83	111		23.0	
1	0.5	9	3	83	46	13.5	13.5	
		9	9	83	52		16.5	7
		9	23	83	66		20.0	
		10	4	83	77		18.0	
		10	26	83	99		17.0	
15	0.5	9	3	83	46	13.5	13.5	
		9	9	83	52		14.0	
		9	23	83	66		14.0	8
		10	4	83	77		22.0	
		10	26	83	99		27.0	
		11	7	83	111		28.0	
		11	25	83	129		28.0	
		12	21	83	155		27.5	
		1	13	84	178		28.0	

2e.(continued)

C	P	DATE			S	R	L	FISH NUMBER
13	1.0	9	3	83	46	13.5	13.5	
		9	9	83	52		14.0	9
		9	23	83	66		15.0	
8	0.5	9	3	83	46	13.5	13.5	
		9	9	83	52		17.5	
		9	23	83	66		22.0	
		10	4	83	77		20.0	10
		10	26	83	99		19.0	
		11	7	83	111		18.0	
		11	25	83	129		14.5	
		12	21	83	155		13.5	
11	0.5	9	3	83	46	13.5	13.5	
		9	9	83	52		16.0	11
		10	4	83	77		16.0	
		11	25	83	129		17.0	
10	0.5	9	3	83	46	13.5	13.5	
		9	9	83	52		16.5	
		9	23	83	66		24.0	12
		10	4	83	77		22.5	
		10	26	83	99		22.0	
		11	7	83	111		23.0	
		11	25	83	129		21.0	
		12	21	83	155		22.0	
		1	13	84	178		23.0	
12	0.5	9	3	83	46	13.5	13.5	
		9	9	83	52		14.0	
		9	23	83	66		18.0	13
		10	4	83	77		15.5	
		10	13	83	86		15.0	
		11	7	83	111		15.5	
		11	25	83	129		16.0	
		12	21	83	155		15.5	
		1	13	84	178		16.5	
3	0.5	9	3	83	46	13.5	13.5	
		9	9	83	52		14.0	
		9	23	83	66		18.0	14
		10	4	83	77		16.5	
		10	26	83	99		17.0	
		11	7	83	111		13.5	

2f. Mills Lake release, September 14, 1983

C	P	DATE			S	R	L	FISH NUMBER
13	0.5	9	14	83	57	13.5	13.5	
		9	23	83	66		14.0	
		10	4	83	77		15.0	1
		10	13	83	86		16.0	
2	3.0	9	14	83	57	13.5	13.5	
		9	23	83	66		16.5	10
16	1.0	9	14	83	57	13.5	13.5	
		9	23	83	66		14.0	
		10	4	83	77		20.0	3
		10	26	83	99		24.5	
		12	21	83	155		18.0	
16	2.0	9	14	83	57	13.5	13.5	
		9	23	83	66		15.0	
		10	4	83	77		25.5	8
		1	13	84	178		18.5	
16	3.0	9	14	83	57	13.5	13.5	
		9	23	83	66		17.0	2
17	1.0	9	14	83	57	13.5	13.5	
		9	23	83	66		14.5	
		10	26	83	99		25.0	9
		12	21	83	155		26.5	
		1	13	84	178		26.0	
17	2.0	9	14	83	57	13.5	13.5	
		9	23	83	66		14.5	
		10	4	83	77		29.5	5
		11	7	83	111		29.5	
17	3.0	9	14	83	57	13.5	13.5	
		9	23	83	66		16.0	6
		10	4	83	77		15.0	
		12	21	83	155		18.5	
18	1.0	9	14	83	57	13.5	13.5	
		9	23	83	66		16.5	11
		10	4	83	77		14.0	
		10	26	83	99		15.0	
18	2.0	9	14	83	57	13.5	13.5	
		9	23	83	66		14.0	
		10	4	83	77		18.0	4
		10	26	83	99		16.5	
		12	21	83	155		12.5	
18	3.0	9	14	83	57	13.5	13.5	
		9	23	83	66		14.0	7
		10	4	83	77		17.0	

COLUMN HEADING KEY

C Transmitter Channel
P Transmitter Pulse
S Study Day
R River Mile of Release Site
L River Mile of Fish Relocation