5.0 ADULT RAINBOW TROUT MOVEMENT STUDY, KLAMATH RIVER, 2003

5.1 DESCRIPTION AND PURPOSE

PacifiCorp initiated a radiotelemetry study to provide information on the movements of rainbow trout (*Oncorhynchus mykiss*) in Klamath River during 2003. More specifically, this investigation documents the movements of rainbow trout in J.C. Boyle Development from February to September 2003. In recent years, a decline in rainbow trout use of the J.C. Boyle dam fish ladder has raised concerns that the existing ladder is ineffective, and that trout are either delayed or deterred from moving upstream of the dam.

Ineffective fish passage may reduce stream connectivity and potential genetic exchange between trout that reside upstream and downstream of the J.C. Boyle dam. Also, if fish are attempting to "home" to waters upstream of the dam, discharge from the powerhouse might be providing a stronger attraction than the J.C. Boyle bypass because of higher flows or a more concentrated homing scent, which could result in migration delay or cessation. Similar concerns also have been expressed regarding potential migration delays and passage issues for anadromous salmonids if they were re-introduced to the area.

Previous tagging studies indicate that few trout move upstream through the J.C. Boyle fish ladder during the spring spawning season. This suggests that trout may be spawning downstream of the J.C. Boyle dam either in the J.C. Boyle bypass reach and/or the peaking reach (Olson, 2002). Before this study, specific spawning activity had not been observed downstream of the dam and no apparently suitable spawning substrate had been located. However, recent fishery assessment sampling found fry in both the bypass and peaking reaches. The question remains as to where and when trout are spawning downstream of the dam. This study, along with the other aquatic studies being conducted for relicensing, will provide important information on the movement and migration of rainbow trout in the J.C. Boyle Development area.

5.2 OBJECTIVES

The objectives addressed by this study are as follows:

1. Assess adult trout passage through the J.C. Boyle fish ladder and powerhouse tailrace.

2. Evaluate potential delays in adult trout movement related to flows, Project facilities, and operations.

3. Gather information on the passage effectiveness for radio-tagged rainbow trout that use the J.C. Boyle fish ladder.

4. Document adult fish residence in the J.C. Boyle bypass reach and peaking reaches through the spawning period. Telemetry monitoring alone will not determine if trout are spawning in the reaches; however, follow-up snorkeling to observe fish may provide better information.

5. Observe longitudinal movement patterns of rainbow trout within the J.C. Boyle bypass reach, peaking reach, and associated tributaries in spring during the primary spawning migration from February through June.

6. Observe longitudinal movement patterns of rainbow trout within the J.C. Boyle bypass reach and peaking reaches and tributaries during the post-spawning period from June through August, to describe possible water quality effects on fish movement.

7. Observe rainbow trout movement during peaking operations in the J.C. Boyle peaking reach.

5.3 RELICENSING RELEVANCE AND USE IN DECISIONMAKING

The final results of this study will provide important information for use in interpreting how Project facilities and flow conditions in the J.C. Boyle bypass and peaking reaches may influence the movement patterns and habitat use of the existing adult rainbow trout populations. Results may also provide insight on how proposed protection, mitigation, and enhancement (PM&E) measures might alter these movements and habitat use in the future. In some cases, the results will be used by PacifiCorp and the Aquatic Work Group (AWG) to decide whether additional types of studies are needed to better formulate and support the proposed measures.

5.4 METHODS AND GEOGRAPHIC SCOPE

5.4.1 Geographic Scope

The Klamath River basin flows through south-central Oregon and northern California, and drains an area of approximately 12,100 square miles (Figure 5.4-1). The Klamath River flows south-west from its headwaters downstream into Upper Klamath Lake near the town of Klamath Falls, Oregon. From Link River dam, which is the outlet of the Upper Klamath Lake, the river flows about 254 miles downstream to its mouth near Klamath, California.

The focus of this study is on a portion of the Upper Klamath River that extends from the head of J.C. Boyle reservoir (RM 228.2) downstream to Copco No. 1 dam (RM 198.6) (Figure 5.4-2). Streamflows are strongly influenced by project operations from the tailrace of J.C. Boyle powerhouse (RM 220.4) downstream to Copco reservoir (RM 203.7). This section of the Klamath River is referred to as the peaking reach, and it can have typical seasonal flow and temperature patterns, as well as fluctuate on a daily basis.

The geographic scope of the Project focused on the J.C. Boyle fish ladder, powerhouse, and the bypass and peaking reaches. Tributaries were included if fish moved into such habitat. Fish in Shovel Creek will be tracked 1.5 miles up the tributary. If fish migrated through the ladder, they were tracked above the J.C. Boyle dam including such areas as the J.C. Boyle reservoir, Spencer Creek, and the Klamath River 0.5 mile upstream into the Keno reach.

Figure 5.4-1. Geographical location of the Klamath River basin in south-central Oregon and northern California.

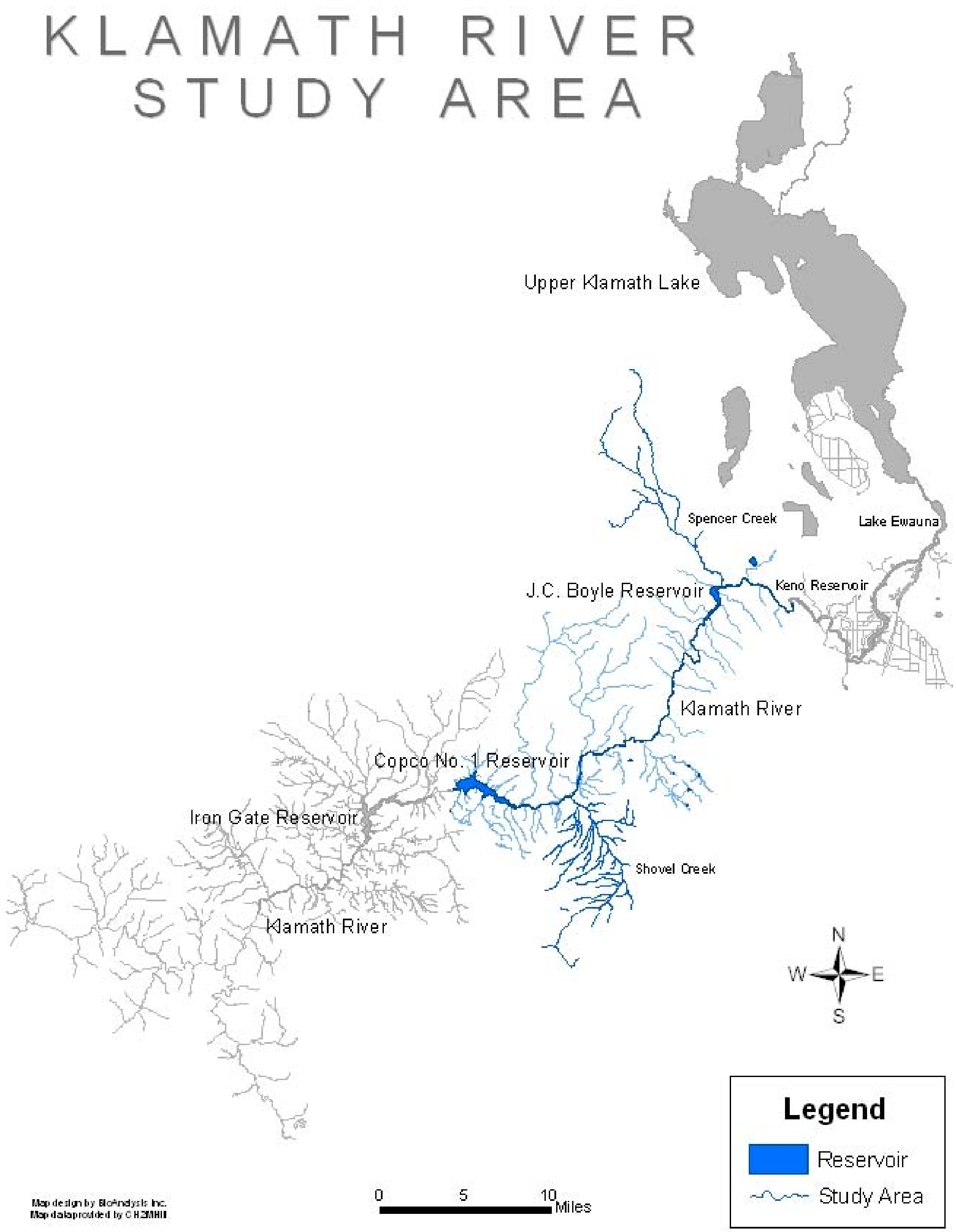

Figure 5.4-2. Study area for assessing the effects of Project operation and facilities on the movement of radio-tagged rainbow trout in the Klamath River.

5.4.1.1 Environmental Setting

During the study period, PacifiCorp operated the J.C. Boyle powerhouse under typical flow scenarios. That is, if dry conditions prevailed, the powerhouse operated under a daily peaking regime using one turbine unit. When flows increased, two units were peaked until there was sufficient flow to operate continuously (unless the river flow is near 3,000 cfs, at least one unit may peak on a daily basis). Spill at J.C. Boyle dam did not occur unless river flow was greater than 3,000 cfs, the powerhouse tripped off-line and the canal spilled into the lower bypass reach, or there was a maintenance event.

Mean daily streamflows during the study period varied from 380 to 3,850 cfs, with the highest flows occurring in the spring from mid-March to mid-June (Figure 5.4-3). Like most power peaking or load-following projects, streamflow conditions also fluctuated on a daily cycle as well (Appendix 5A).

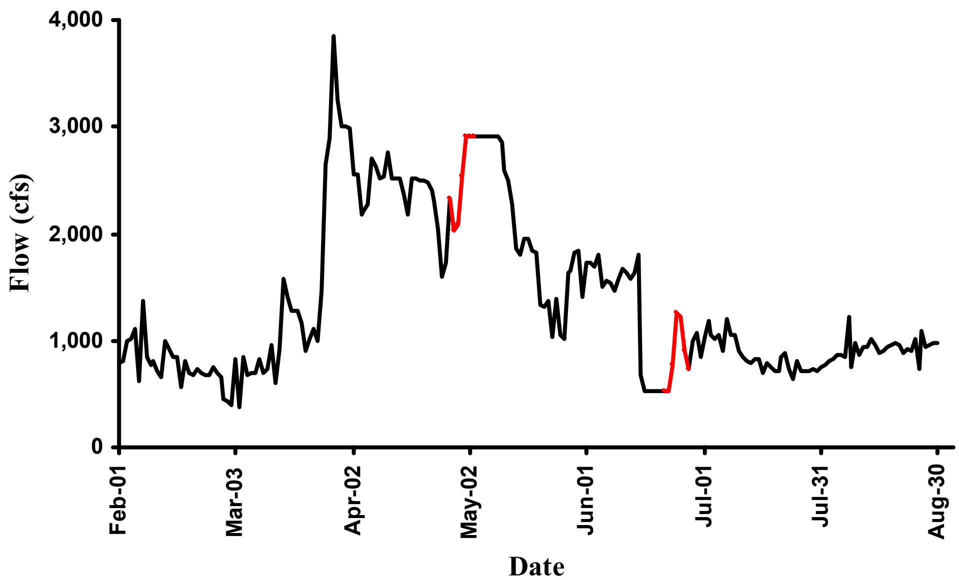

Figure 5.4-3. Provisional U.S. Geological Survey (USGS) daily mean flow (cfs) recorded for the Klamath River downstream of J.C. Boyle powerhouse (Station 11510700). Red lines from April 28 to May 2 and June 22 to 26, 2003, indicate that mean daily values were calculated from available hourly records on those dates.

Stream temperatures were monitored at seven different locations during the study period. There were two stations in the J.C. Boyle bypass reach, one each in Shovel and Spencer creeks, and three in the peaking reach. Mean daily stream temperatures measured in the upper and lower J.C. Boyle bypass reach ranged from 3.4 to 25.4°C (Figure 5.4-4). The lower station in the J.C. Boyle bypass indicates that spring water inflow to the bypass tends to moderate temperatures from winter to summer; temperatures ranged from 8 to 17°C in this section. Spencer and Shovel creeks are major spawning tributaries in the study area. Spencer Creek was colder during the winter and warmer during the summer than Shovel Creek, but the creeks had similar

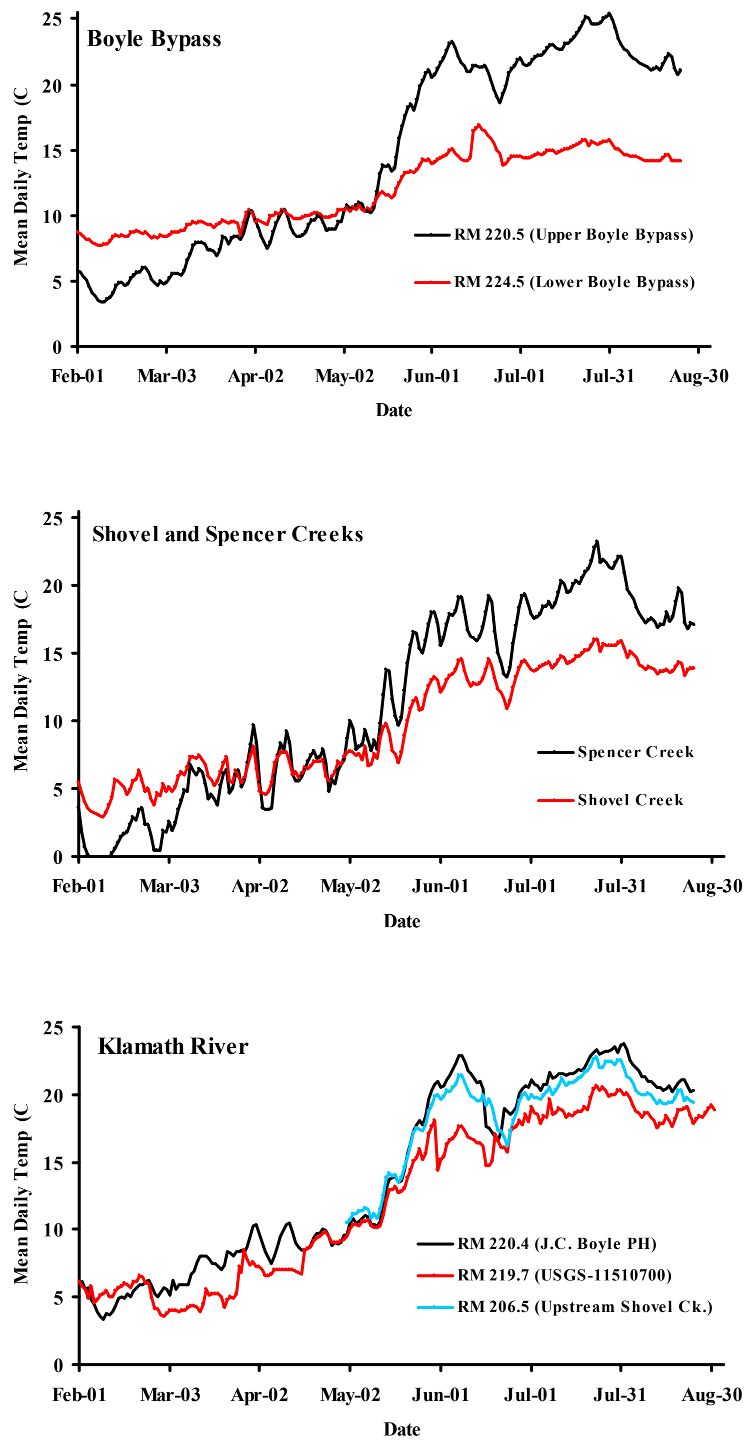

Figure 5.4-4. Stream temperature was monitored at seven different locations in the study area. There were two stations in the J.C. Boyle bypass reach, one each in Shovel and Spencer creeks, and three in the peaking reach.

temperatures during the spring spawning period. Mean daily stream temperature in the peaking reach of the Klamath River ranged from 3.4 to 23.7°C. Stream temperatures measured at the USGS station indicate that bypass reach inflow tends to moderate the temperature of water that exits the powerhouse (Appendix 5B). As expected, downstream of the USGS station, stream temperatures tend to increase in the peaking reach (Figure 5.4-4).

5.4.1.2 J.C. Boyle Development

PacifiCorp's Klamath River Hydroelectric projects were built between 1908 and 1962 and consist of seven hydroelectric facilities and one non-generating project. Since the J.C. Boyle Development is the focus of this study, only this facility is described in this section. A more complete discussion of the other projects can found in Exhibit A of the licensing application.

J.C. Boyle dam was completed in 1958 and is located at RM 224.7 on the Klamath River. The dam is about 15 miles southwest of the City of Klamath Falls in Klamath County, Oregon. The facility is an earthen dam with three 36-foot by 12-foot tainter spill gates and a diversion intake tower. The reservoir formed by the dam has a capacity of 3,495 acre-feet (ac-ft) with about 1,507 ac-ft of usable storage. The reservoir extends upstream for a distance of 3.6 miles and has a normal water surface elevation of about 3,793 feet mean sea level (msl).

Water for power generation is drawn from the reservoir at the intake tower of the dam through four 11.5-foot-wide openings. Each opening is equipped with a vertical traveling screen to minimize fish entrainment. The four intakes combine into a single 14-foot-diameter steel pipe that extends 638 feet across the Klamath River and empties into a diversion canal. The diversion canal directs water about 2 miles downstream to the forebay of the penstock openings and canal overspill. Water flows from the forebay through a 15.5-foot-diameter, concrete-lined tunnel that splits into two 10.5-foot-diameter steel penstocks. The penstocks enter the powerhouse and water is supplied to two vertical turbine units that have a combined total hydraulic capacity of about 2,850 cfs.

The J.C. Boyle bypass reach is approximately 4.2 miles long and extends from the earthen dam downstream to the powerhouse channel. Flow in the bypass channel of the Klamath River is the combination of 100 cfs discharged from the fish ladder (80 cfs) and juvenile bypass (20 cfs). Groundwater within the bypass reach contributes an additional 220 to 250 cfs, so by the time the bypass channel reaches the confluence of the peaking reach near the powerhouse, flow is approximately 350 cfs.

Fish passage at J.C. Boyle dam is provided by a concrete pool and weir fish ladder that rises 67 feet in elevation from the base of the dam to the reservoir. The fish ladder entrance is located on the left bank, approximately 200 feet downstream of the dam and is at the farthest upstream point of the J.C. Boyle bypass reach. The fish ladder is 569 feet long and has 57 pools. The pools measure about 6 feet wide and 8 feet long, and have 3.5-foot-high weirs separating each pool. Passage upstream is accomplished when the fish jump over the weir or swim through a 4-inch by 4-inch orifice located at the bottom-center of each weir. Constant flow is maintained by an automated gate system located at the upstream end of the fish ladder. An auxiliary water supply system ensures that a total of 80 cfs are provided as attraction flow at the entrance.

Downstream passage facilities also are provided at J.C. Boyle dam. Each of the four entrances at the intake structure is equipped with Rex vertical traveling screens to prevent entrainment of fish into the power canal. High pressure spray systems keep the screens clean and free of debris buildup. In 1988, the fish screen housings were modified to allow full-year continuous operation (FishPro, 2000). In 1992, new fiberglass screens with 1/8-inch mesh replaced the previous metal screens. The bypass route is a pipe with an entrance at the south end of the intake structure with an exit at the discharge channel downstream from the spillway apron. A constant bypass flow of 20 cfs is used to convey fish through the bypass entrance.

5.4.2 Methods

To meet the objectives of this study, radio tags were inserted in 42 rainbow trout and their movements were observed using mobile and fixed-location receivers. Methods used are described below.

5.4.2.1 Site Reconnaissance and Noise Evaluation

Power production from hydroelectric facilities typically produces ambient electrical noise, which includes noise events that coincide with specific frequencies as well as codes that are similar to radio tag signals. Therefore, before conducting this radio-telemetry study, the extent and frequency of the noise within the study area were monitored. This evaluation was used to select frequencies and codes that did not coincide with ambient background noise.

Noise evaluations were conducted at J.C. Boyle, Copco No. 1, Keno, and Iron Gate dams. Ambient background noise was monitored over an approximate 24-hour period on December 2, 2002. Frequencies that are readily available for use are in the 148- to –152-MHz range in 20-kHz increments (i.e., 148.320 to 148.800 MHz). There are a total of 25 frequencies (also referred to as channels) per MHz and 212 codes available for each channel. The 148-MHz range was selected because this frequency had performed well at other hydroelectric facilities.

Background noise was evaluated at each site with an aerial telemetry system consisting of two, three-element Yagi antennas installed near the middle of the dam. Each system was monitored by a single Lotek SRX 400 receiver, programmed with all 25 possible frequencies available in the 148-MHz range. The receivers were programmed with a 5-second scan cycle, with each frequency being monitored every 125 seconds. Files from each of the projects were analyzed to identify noise events on specific channels and codes. Collectively, the results of the noise evaluation indicate that the projects produced low levels of ambient noise across the 148-MHz range. Therefore, channel 14 (148.580 MHz) and codes 01-45 were selected.

5.4.2.2 Telemetry System Design

Three fixed-station telemetry systems were installed to monitor the movements of rainbow trout during the spring spawning and migration period (February to mid-May 2003). The stations were deployed to monitor the movements of tagged fish as they encountered sensitive passage areas located at the J.C. Boyle powerhouse and fish ladder. The first and farthest downstream fixed-station site was located at the BLM boat launch (RM 220.1)[1]. The second station was located at the J.C. Boyle powerhouse (RM 220.4) to monitor the movement of fish at the confluence of the

[1] The original study plan had three fixed telemetry sites, but the equipment was stolen from the BLM site in March and was not put back in service.

powerhouse tailrace and J.C. Boyle bypass reach. Finally, the last station was placed in the fish ladder system at J.C. Boyle dam (RM 224.7) to monitor the upstream passage.

The BLM boat launch is located in the upper peaking reach of the Klamath River. A single three-element Yagi antenna fixed to a 10-foot extension mast was placed on top of the BLM building. The antenna was monitored by a single SRX 400 Lotek receiver that was supplied with power from a 12-volt recreational vehicle (RV) battery. The antenna was aimed to provide coverage of the large pool next to the building and adjusted to ensure that all radio-tagged fish that passed through this location were detected. The purpose of this system was to establish the time rainbow trout entered or exited the first large pool downstream of the powerhouse.

The fixed-station receiver located at J.C. Boyle powerhouse consisted of one aerial and two underwater antennas to monitor movement near the Project (Figure 5.4-5). The first antenna was a series of six bare coax underwater antennas combined to monitor the J.C. Boyle powerhouse tailrace. Each antenna was attached to a 5- to 8-pound (lb) weight suspended from the handrail at the powerhouse. Detection by this array established that tagged fish were near the powerhouse channel. The second antenna array was a series of two bare coax underwater antennas combined, which then were weighted and sunk to the bottom of the J.C. Boyle bypass reach. These antennas monitored tagged fish as they entered and exited the J.C. Boyle bypass reach. The last antenna was a single, three-element Yagi antenna positioned at the confluence of the powerhouse tailrace and J.C. Boyle bypass reach (Figure 5.4-6). This antenna was directed downstream to encompass the area immediately downstream of the powerhouse outfall and slightly upstream into the J.C. Boyle bypass reach. All three arrays were monitored by a single Lotek SRX unit supplied with 110-volt power supply and a 12-volt RV battery backup.

To assess passage through the J.C. Boyle fish ladder, three antenna arrays were deployed. These antennas were installed to monitor the approach, entrance, and exit of tagged fish from the fish ladder (Figure 5.4-6). The system was designed to assess passage time through the fish ladder and document if fish made several attempts to approach or enter that ladder system.

The first antenna was used to monitor the approach of tagged fish. This antenna consisted of a single bare coax antenna suspended from a rope approximately 30 feet downstream of the entrance to the ladder. The antenna was configured to detect radio-tagged fish as they approached the fishway entrance. The antenna documented the number of fish near the ladder and the number of visits.

The second antenna monitored the entrance of the fish ladder with series of three underwater antennas placed inside the ladder. These antennas were suspended in adjacent weirs and combined as one antenna to increase the detection area. This antenna recorded the entrance time into the ladder system and could be used to establish the number of attempts each fish made to ascend the ladder.

The last antenna monitored the fish ladder exit and consisted of a series of three underwater antennas suspended in alternate weirs. These antennas also were combined to increase the detection area at the fish ladder exit. This antenna established the exit time for each fish that ascended the ladder and was used to calculate total passage time. Each array was monitored as a separate antenna by a single Lotek SRX receiver. This system was supplied with a 110-volt power supply and 12-volt RV battery backup.

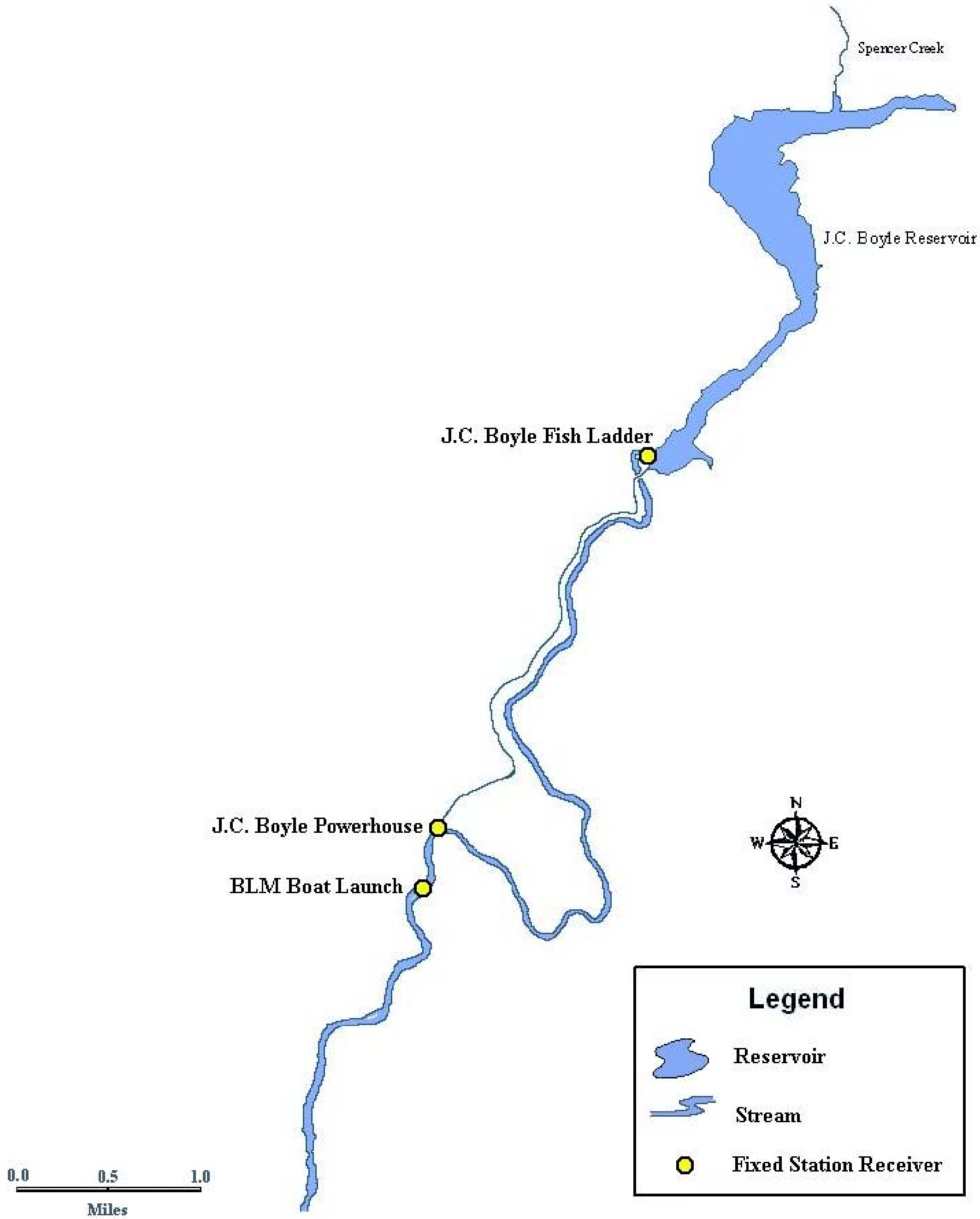

Figure 5.4-5. Locations of fixed-station telemetry receivers at the BLM boat launch (RM 220.1), and J.C. Boyle powerhouse (RM 220.4), and fish ladder (RM 224.7).

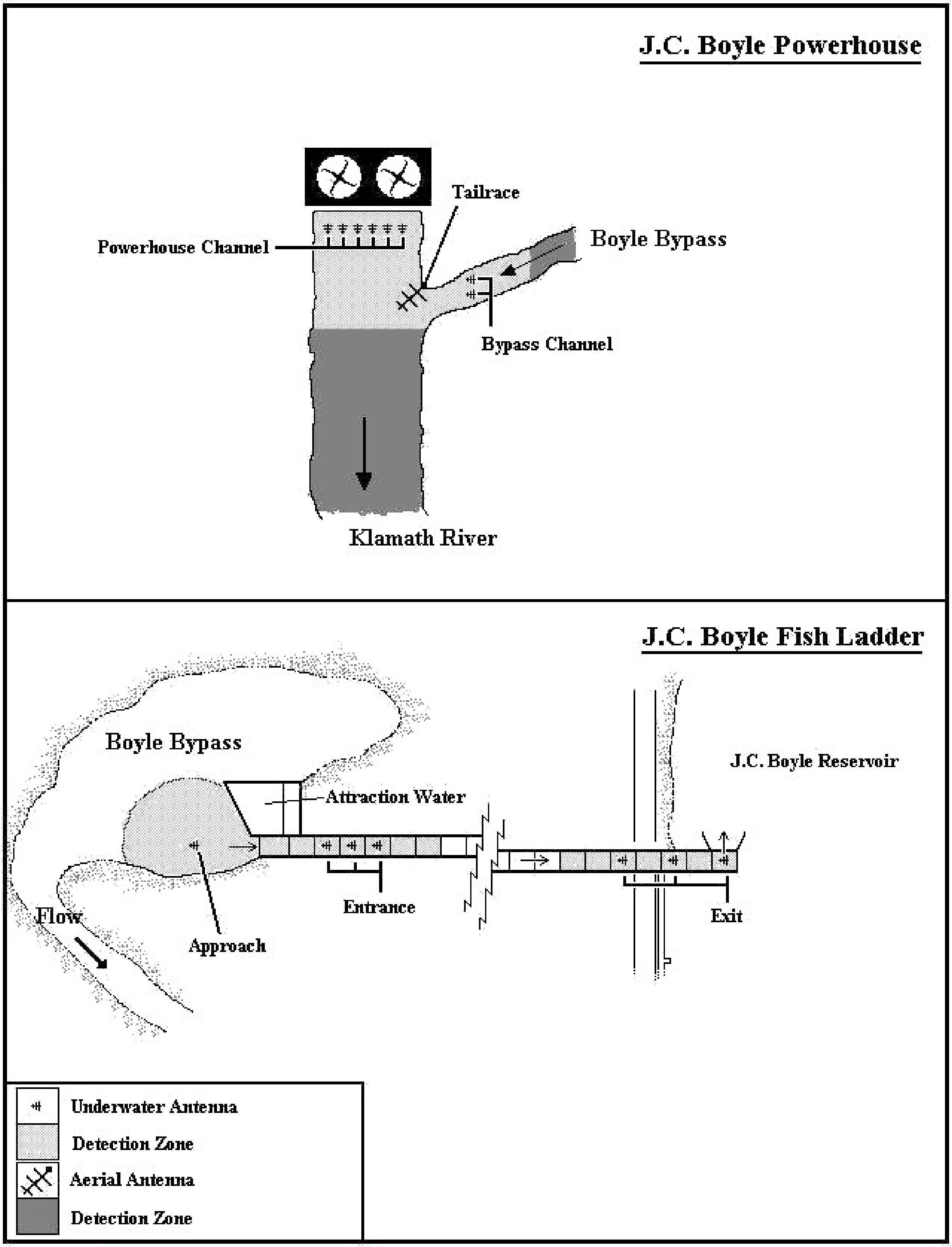

Figure 5.4-6. Telemetry systems deployed at the J.C. Boyle powerhouse and fish ladder to monitor movement of radio-tagged rainbow trout, 2003.

5.4.2.3 Collection, Radio-Tag Selection, and Surgical Procedures

A total of 42 rainbow trout was tagged in three sections of the Klamath River from February 3 to February 21, 2003. Fourteen rainbow trout were tagged in three principle areas: the J.C. Boyle bypass reach (RM 220.4-224.7), Klamath River upper peaking reach (RM 212.0-220.4), and Klamath River lower peaking reach (RM 205.2-212.0) (Figure 5.4-7).

Collection

To collect and tag rainbow trout in the Klamath River, collection permit guidelines were followed, as set by the ODFW and CDFG. Those guidelines stipulated hook and line methods, no-bait, and barbless hook. Fish were captured with rod and reel techniques using either fly or spinning reel gear. In accordance with the collection permit, artificial flies and lures with a single-barbless hook were used to reduce injury and stress to captured trout. In areas with adequate river access, a submerged polyvinyl chloride (PVC) holding pen was placed in the river at a central location during the collection process. After capture, fish were placed in 5-gallon buckets and transported to the holding pen. In the least accessible areas, individual fish were held in 5-gallon buckets for transport, anesthesia, and recuperation. In such instances, fish were tagged immediately after they were captured to minimize handling time.

Radio-Tags

Selection of the transmitter type was based on size, weight, and tag longevity. Winter (1983) identified a criterion of 2 percent ratio of transmitter to body weight (in air) as being acceptable. For transmitters used in this study, that criterion would allow the tagging of trout equal to or greater than 225 grams. However, more recent information suggests that a radio transmitter that is as much as 5 to 10 percent of the fish's body weight will not adversely affect fish behavior (Adams et al. 1998). A previous study indicated that an upstream migrant in Shovel Creek at 2 percent body weight would have to weigh 225 grams and would be about 277 millimeter (mm) FL (approximately 11 inches) (Beyer, 1984).

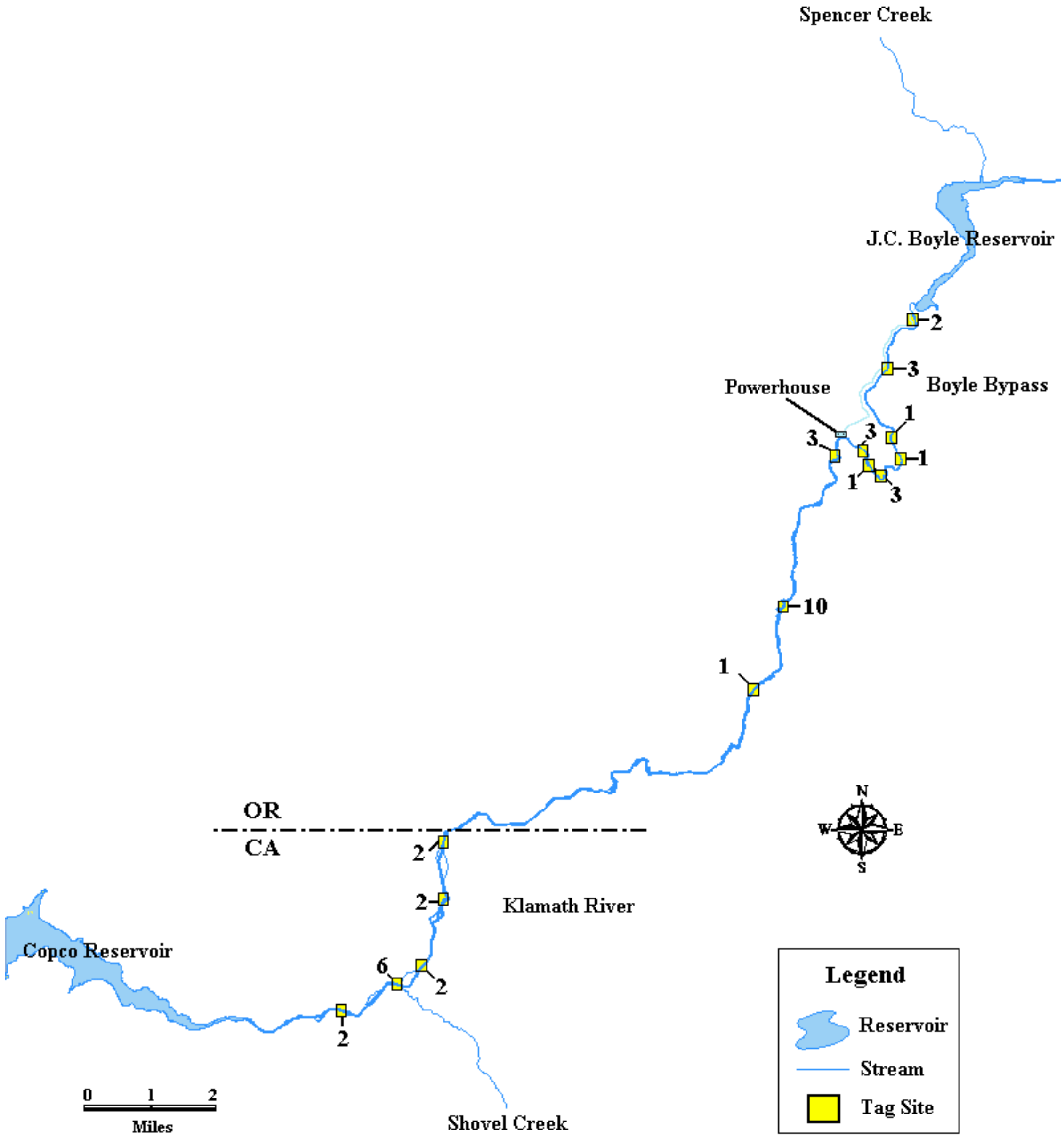

Figure 5.4-7. Tag site locations for rainbow trout radio-tagged in the Klamath River. Numbers beside each box indicate the number of trout radio-tagged.

Taking a conservative approach (based on Adams et al., 1998), it was decided to tag only those fish for which the transmitter did not exceed 5 percent of the body weight. When this criterion was applied to Beyer's (1984) length-weight data, this equated to fish that were about 205 mm FL (about 8 inches) or weighed about 87 grams. Based on this information, adult rainbow trout were implanted with digitally encoded transmitters developed by Lotek Engineering. The transmitter, model NCT-6-2, was 9.1 mm in diameter, 30.9 mm long, and weighed 4.5 grams. With a 5.0-second burst rate, the estimated life of the transmitter was 199 days[2]. Based on the noise evaluation conducted in the Project area, a frequency of 148.580 MHz (channel 14) and codes 01-45 were selected to identify individual fish.

Surgical Procedures

Transmitters were surgically implanted in 42 rainbow trout following procedures outlined in Summerfelt and Smith (1990). Fish were anesthetized in a solution of 80 milligrams per liter (mg/L) tricaine methanesulfonate (MS-222) until they lost equilibrium. Fish were weighed (grams) and measured (mm), and those fish that had external injuries, excessive scale loss, or were less than 205 mm FL were released after they recovered from anesthesia.

During surgery, the fish was placed on a V-shaped cradle and supplied with anesthetic water with a large bulb-type syringe (turkey baster). The incision site was swabbed with iodine and the body of the fish was sprayed with a diluted solution of Pro-polyaqua (synthetic fish mucous). The radio-tag was implanted through a 2.0-centimeter (cm) incision between the pectoral and pelvic fins slightly off the mid-ventral line. A 16-gauge hypodermic needle sheathed within a Teflon tube (to protect internal organs) was then inserted into the body cavity of the fish. The needle was positioned at a 45-degree angle to the medial line of the fish and pierced through the body wall of the fish. After the needle was inserted into the fish, the Teflon sheath was removed and the transmitter antenna was inserted into the needle. The hypodermic needle then was removed and the transmitter was inserted into the body cavity of the fish. The incision was closed with three to four internally knotted absorbable sutures and swabbed with iodine. Scalpel, hypodermic needle, and tweezers were immersed in isopropyl alcohol following each fish's surgery. Radio-tagged fish were held in 5-gallon buckets or in the live cage until each fish recovered from the anesthetic. The fish were released back into the river after recovery from the anesthetic. A global positioning system (GPS) waypoint was assigned to each fish upon release.

5.4.2.4 Mobile Tracking

From mid-February to September 2003, mobile surveys in the study area were used to document the location of radio-tagged fish. The study area was separated into three survey reaches: J.C. Boyle bypass reach, the upper peaking reach (Oregon), and the lower peaking reach (California). The survey reaches outline the general locations of where fish were tagged to assess movement in the Project area. Typically, the J.C. Boyle bypass and upper peaking reaches were surveyed on the same day, and the lower peaking reach was surveyed on alternate days.

To assess movement during the spring spawning period, mobile telemetry surveys were conducted 4 days per week from February 3 to May 15. Mobile surveys in Oregon and California alternated every other day to provide complete coverage of the study area. On Mondays and

[2] Minimum tag life was originally estimated at 226 days at a 5-second burst rate but the manufacturer found that the batteries installed in these tags were only projected to last 199 days.

Wednesdays, surveys were conducted in Oregon from J.C. Boyle dam downstream to RM 211.0 on the Klamath River. On alternate days, the California section was surveyed from near the Oregon border downstream to the Copco bypass area. From May 15 to September 15, surveys were conducted approximately twice per week, covering each portion of the study area once. Surveys ended the second week of September 2003 when radio tags could no longer be detected. The Klamath River was inaccessible by vehicle from about RM 210.5 to 211.5.

Radio-tagged fish were detected using a single whip antenna mounted to the roof of the vehicle and a hand-held, three-element Yagi antenna. The initial detection of tagged fish was from the mounted whip antenna as the vehicle traveled slowly along the roadway. As the signal became stronger, a hand-held Yagi antenna was used to obtain a more precise location by walking along the road or stream. A GPS unit documented the location of each fish, and the waypoint, date, time, tag code, receiver power rating, and river habitat (i.e., pool, riffle, glide, etc.) were recorded. After the survey was complete, the numbers of tagged fish detected versus total number tagged were tabulated. If there were several fish that were not detected during a mobile survey, it became necessary to expand the area surveyed. Field data were entered into computer spreadsheets and GPS data were downloaded at least once per week. A geographic information system (GIS) was used to plot all fish positions in the study area (Appendix 5C).

5.4.2.5 Stream Temperature and Flow

Stream temperatures were monitored continuously throughout the study period at seven locations and flow was monitored at the USGS station downstream of J.C. Boyle powerhouse. There were three stations in the Klamath River, two in the J.C. Boyle bypass reach, and one each in Shovel and Spencer creeks (Figure 5.4-8). In the Klamath River, the stations were located just upstream of Shovel Creek (RM 206.5), at the USGS station (RM 219.7), and at the J.C. Boyle powerhouse (RM 220.4). Stream temperatures in the J.C. Boyle bypass reach were recorded at two sites: downstream of the dam (RM 224.6) and at the lower end of the bypass just upstream of the powerhouse (RM 220.5). In Shovel and Spencer creeks, stream temperature was recorded in the lower 1 mile of stream.

Stream temperatures for each station were recorded from February to September, except for the Klamath River station just upstream of Shovel Creek, where the station began monitoring stream temperature in April 2003. The USGS station recorded both flow (cfs) and stream temperature (°C) every 0.5 hour. All other stations recorded stream temperature every hour and were downloaded at least twice during the study period. Flow and stream temperature in contrast with fish movements are displayed in Appendices 5A, 5B, and 5D.

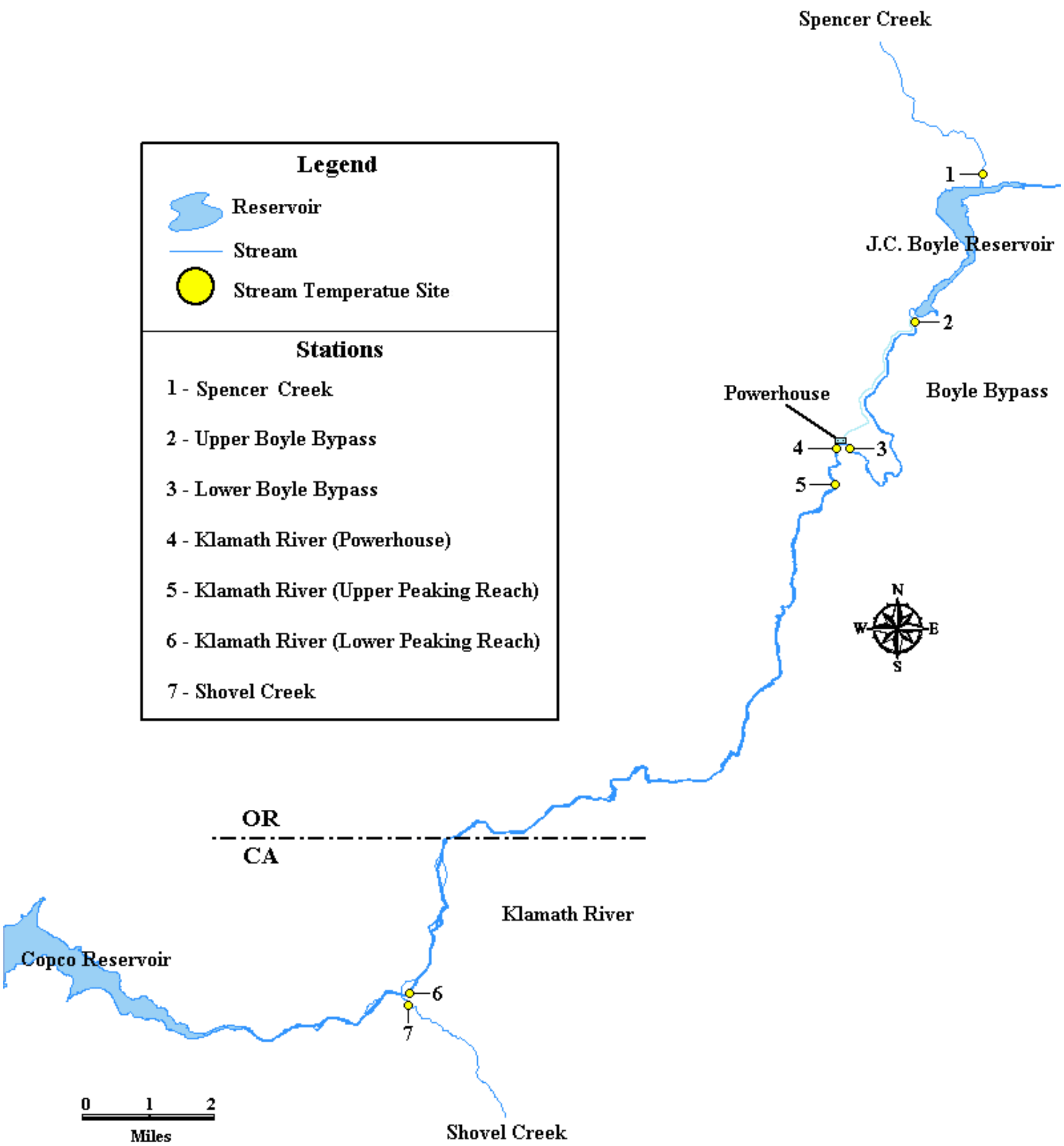

Figure 5.4-8. Location of stream temperature stations in the study area. Station 5 is USGS station 11510700, which monitors both flow and temperature.

5.4.2.6 Evaluation of Sensitive Passage Areas

To assess delay during the spring migration period, the movements of radio-tagged fish were continuously monitored at two locations from February to mid-May. A third location at the BLM site was discontinued after the equipment was stolen in March. The first location was at the J.C. Boyle powerhouse where movement was monitored near the Project tailrace at the confluence of the powerhouse and J.C. Boyle bypass reach. The second location was at the J.C. Boyle fish ladder. These sites were identified during the study development process as areas of potential delay. To assess delay in these areas, passage conditions and fish movement were evaluated to establish if there was evidence that fish were delayed or deterred in these locations. The following evaluation process was used to provide some evidence of delay or deterrence in an area:

- Encounters. The first step considered the number of fish that encountered each passage area.
- Direction of Movement and Passage Attempts. Fish that approached the powerhouse were divided into two groups: those moving upstream and those moving downstream when they entered the tailrace confluence area. At the fish ladder, the number of attempts each fish made to pass J.C. Boyle dam also was recorded.
- Passage Conditions. As the fish encountered each area, passage conditions (i.e., powerhouse operation and spill) were described.
- Passage Success. The final step was to assess the fate of the fish and determine if passage was successful. Passage time and success are important components that may provide evidence of either delay or deterrence. Clearly, several unsuccessful passage attempts meant that fish were deterred from moving through or past a particular area. Failure after several attempts excluded fish that may have been simply investigating or probing a passage area on a single occurrence. Unfortunately, there are no clear criteria for defining delay (i.e., hours, days, or weeks) that can be easily applied to resident fish behavior. However, assuming that the spring spawning and migration period is about 12 weeks (84 days), some means of comparison for the passage time through each area can be provided.

5.4.2.7 Data Retrieval and Management

Three separate types of data files were compiled in a single database to assess movement of rainbow trout. The first file contained information on the location (GPS), tag code, time of release, and length and weight for each fish tagged. The second file contained all mobile telemetry information. Waypoints used to located individual fish during mobile surveys were downloaded from the GPS into map moving software. This program allowed plotting of waypoints on electronic versions of USGS 7.5-minute (1:24,000) maps every week. This file contained GPS location, tag code and date/time. The third file contained information from fixed-station receivers that were checked approximately every other day to ensure proper operation (i.e., battery voltage, receiver time, memory status, etc.) and were downloaded at least once a week. All downloaded files were converted to ASCII format and appended to a master receiver file. At the end of the study, all fixed-station receiver files, mobile survey data, and tagging information were coded with a unique receiver number and combined into a relational database for final data analysis.

5.5 RELATIONSHIP TO REGULATORY REQUIREMENTS AND PLANS

This trout movement study is intended to provide information that, together with environmental data and the results of past and ongoing studies, can be used to assess effects of Project operations on fish resources. The data and results also will help in formulating recommendations for PM&E measures that are consistent with agency and tribal management goals. The following contain references to objectives for fisheries in the study area:

- CDFG Upper Klamath Wild Trout Management Plan
- ODFW Klamath River Basin Fish Management Plan
- U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) Endangered Species Act requirements
- Klamath River Wild and Scenic River Plan
- U.S. Forest Service Klamath River Restoration Plan
- Tribal natural resource goals and objectives and cultural values
- Long-Range Plan of the Klamath River Basin Fisheries Task Force

The results of this trout movement study will be used to help determine if current Project operations are affecting trout, and what changes to Project operations or facilities might be needed to achieve these objectives.

5.6 TECHNICAL WORKGROUP COLLABORATION

PacifiCorp has worked with stakeholders to establish a more collaborative process for planning and conducting studies needed to support Project relicensing documentation. As part of this collaborative process, an AWG was formed and meets approximately monthly to plan and discuss aquatic resource (primarily fish) study plans and results. Initially PacifiCorp had proposed conducting the trout movement study from February to May to document spawning activity. However, AWG members also expressed interest in seeing how fish move in response to changing water quality conditions. Based on collaborative discussions, the study was extended to September 2003 to document fish movement during the summer months.

5.7 STUDY OBSERVATIONS AND FINDINGS

5.7.1 Detection of Rainbow Trout

The detection of radio-tagged fish during mobile surveys of the study area remained fairly high (more than 80 percent) until the second week of July (Figure 5.7-1). Most fish (70 percent) were detected throughout the study period with only 1- or 2-week gaps in their detection history until mid-July (week 24) (Table 5.7-1). However, a few fish remained undetected throughout most of the study and it was suspected that some fish died during the study period. The following sections provide some detail on the fate of these fish, but most can be explained by: (1) predation or shed tags, (2) fish that left or were removed from the study area, or that moved to areas with limited detection, and (3) tag failure. The decrease in fish detected at the end of July (week 26) can be attributed to tag-use expiring (199 days) (Table 5.7-1).

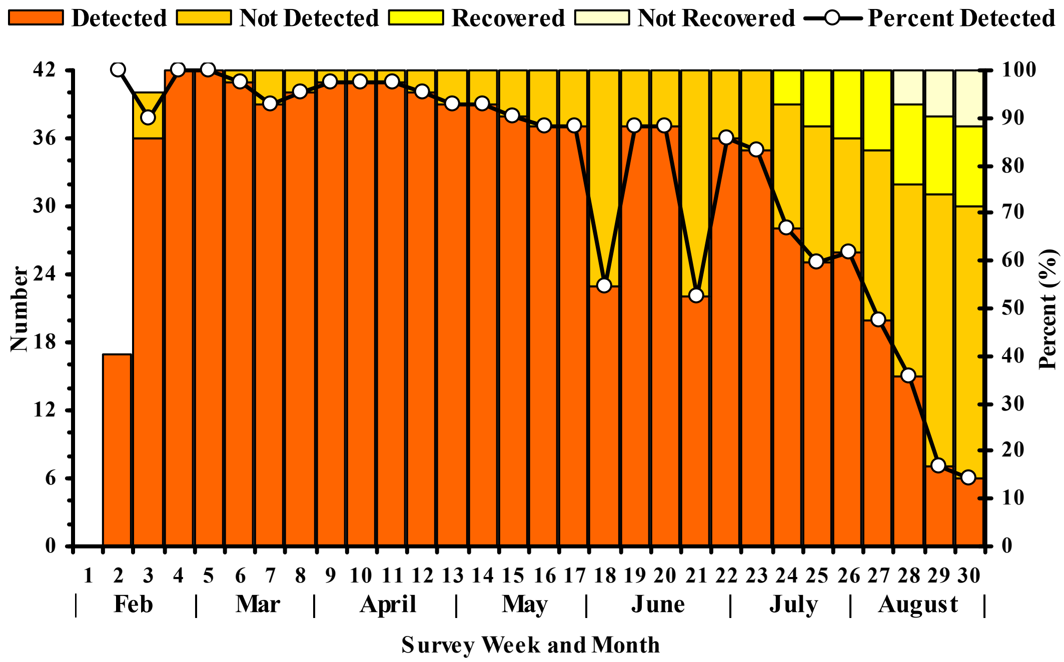

Figure 5.7-1. Number and percent displayed for fish detected during each survey week (1-30) of the study period. Plot also displays the number of fish not detected and the number of tags that were recovered or could not be recovered during the study period.

Tag Fate

Efforts were made in July and August to recover radio tags from fish that were suspected to have died or shed their tags. Seven radio tags were recovered and five others could not be recovered because of their location (Table 5.7-1). Five of the seven tags recovered were from fish that had entered Shovel Creek (the number on the tag is the same number that is assigned to the fish)(Tag No. 02, 36, 41, 42, and 45). Three of those tags were recovered in Shovel Creek (Tag No. 02, 36, 45) and two (Tag No. 41 and 42) were recovered downstream of Shovel Creek. One tag (Tag No. 45) recovered in Shovel Creek was found on the bank 6 feet above the high water mark and the other two tags (Tag No. 02 and 36) were recovered with bite marks on the antennas. Of the tags recovered downstream of Shovel Creek, one (Tag No. 41) was found about 1.3 miles downstream on the bank outside the wetted channel and the other tag (Tag No. 42) was discovered in the water of the Copco bypass.

Two tags (Tag No. 08 and 10) were recovered from fish that had not entered Shovel Creek. One tag (Tag No. 08) was recovered on the hillside about 1,000 feet from the stream channel in the lower peaking reach (RM 207.8). Interestingly, the last mobile survey before the tag was recovered suggests that the fish was about 5.5 miles upstream in the upper peaking reach (RM 213.4). The last tag recovered (Tag No. 10) was found under a tree used by great blue herons (*Ardea herodias*) along J.C. Boyle reservoir. There was obvious debris (i.e., nesting material, droppings, and feathers) underneath the tree where the tag was found. The last mobile survey before the tag became suspect suggests that the fish was about 2.5 miles downstream in the J.C.

Boyle bypass reach (RM 224.9). Because this fish was observed upstream of J.C. Boyle dam on May 19, after the fixed-station receiver was removed, it is not clear whether the fish was transported as a result of predation or whether it had passed the fish ladder system before being preyed upon.

Tags that were not recovered (Tag No. 03, 16, 18, 24 and 27) were from five fish that may have been preyed upon or shed their tags. The signal for two tags (Tag No. 03 and 16) placed the fish close to heron nest sites. Tag No. 03 was detected on numerous occasions at the same site in shallow water near the location where Tag No. 10 was found along J.C. Boyle reservoir. Similar to Tag No. 03 and 10, the signal for Tag No. 16 originated from underneath a similar roosting or nesting site, but on the hillside along Copco reservoir. This tag could not be recovered because it was located underneath a thick patch of poison oak surrounding the roosting or nesting tree. Three other tags (Tag No. 18, 24, and 27) could not be recovered because they were either in thick brush or were located in large riprap along the bank.

Table 5.7-1. Detection of rainbow trout tagged in three sections of the Klamath River during each week (1-30) of the study period. Detection of fish during each survey week of the study period (i.e., 1, 2, 3, etc.) are shaded gray. Black indicates that the tag was recovered; yellow indicates that the tag that could not be recovered. Low detection rates in June (weeks 18 and 21) were the result of limited surveys.

Study Area	Fish	February				March				April					May				June					July				August			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Lower Peaking Reach	01																														
	02																														
	30																														
	31																														
	32																														
	34																														
	35																														
	36																														
	40																														
	41																														
	42																														
	43																														
	44																														
	45																														
Upper Peaking Reach	05																														
	06																														
	08																														
	09																														
	10																														
	11																														
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	13																														
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Table 5.7-1. Detection of rainbow trout tagged in three sections of the Klamath River during each week (1-30) of the study period. Detection of fish during each survey week of the study period (i.e., 1, 2, 3, etc.) are shaded gray. Black indicates that the tag was recovered; yellow indicates that the tag that could not be recovered. Low detection rates in June (weeks 18 and 21) were the result of limited surveys.

Study Area	Fish	February				March				April				May					June				July				August				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
J.C. Boyle Bypass Reach	03																														
	04																														
	14																														
	15																														
	19																														
	20																														
	21																														
	22																														
	26																														
	27																														
	28																														
	33																														
	37																														
	39																														
Available		17	40	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	39	37	36	36	35	35	35
Detected		17	36	42	42	41	39	40	41	41	41	40	39	39	38	37	37	23	37	37	22	36	35	31	27	27	21	15	7	6
Percent		100	90	100	100	98	93	95	98	98	98	95	93	93	90	88	88	55	88	88	52	86	83	79	73	75	58	43	20	17

Seven tagged fish could not be detected in the study area, suggesting that the fish either were moved or transported out of the study area, or the tags failed. These fish disappeared during a 4-month period (two [Tag No. 30 and 31] in April, three [Tag No. 04, 09, and 32] in May, and two [Tag No. 05 and 23] in June) (Figure 5.7-1). Three of the fish (Tag No. 30, 31, and 32) moved into Shovel Creek and one (Tag No. 05) was at the confluence when last detected. The other three fish (Tag No. 04, 09, and 23) were last detected in the upper peaking reach. The missing fish were not located despite several surveys of Copco reservoir (including one boat survey), Copco bypass, and J.C. Boyle reservoir, and a survey of the inaccessible area of the Klamath River.

Identifying the fate of individual fish provides a more complete picture of the life history of rainbow trout in the Klamath River. Several researchers have noted that predation, angling, and shed tags are the suspected causes of tag loss (Elle, 1995; Swanberg, 1997; Chandler et al. 2001). Moreover, recent telemetry research on bull trout and rainbow trout suggests that mortality may be fairly high on spawning fish (Schill et al. 1994; Hockersmith et al. 1995; Elle, 1998). In this study, 38 percent (five of 13) of the fish that entered Shovel Creek (five tags recovered) are suspected to have died. Clearly, tags found on the bank above the wetted channel (some with bite marks) suggest some method of transport either from scavenging or predation. The inclusion of other tags found and signals that originated from suspect areas (nesting areas or hillsides) suggests that mortality may have been about 21 percent (nine of 42) for all radio-tagged fish. Although signs were posted along fishing access points in the study area requesting anglers to release tagged fish, it is possible that some fish were caught and removed. This is particularly true for fish that remained undetected during the study period.

5.7.2 Length-Weight

FL and weight (grams) of fish tagged in the Klamath River (Table 5.7-2) were measured. No fish were tagged that exceeded the 5 percent tag weight to body weight ratio and only one fish exceeded 2 percent. Rainbow trout size tended to increase downstream based on the average length and weight of fish captured in the three reaches. The largest fish radio-tagged were captured in the lower peaking reach near Shovel Creek (Table 5.7-2). Conversely, the smallest trout radio-tagged were captured in the J.C. Boyle bypass reach. As a group, radio-tagged rainbow trout varied in length from 250 to 429 mm FL with a mean of 315.5 mm (Figure 5.7-2). Weight varied from 175 to 880 grams with a mean of 384.5 grams (Figure 5.7-2). The length-weight relationship is described by the power function $W= 0.000012*L^{2.99}$ (Figure 5.7-2). This length-weight relationship is similar to that reported in Beyer (1984) for upstream migrants in Shovel Creek ($W=0.000005*L^{3.13}$).

Table 5.7-2. Summary information collected on rainbow trout radio-tagged in different reaches of the Klamath River.

Reach	Tag ID	Tag Site (RM)	Date	Fork Length (mm[1])	Weight (g[2])
Lower Peaking	01	206.4	7-Feb-03	298	320
	02	206.4	7-Feb-03	348	510
	30	206.4	10-Feb-03	405	880
	31	206.9	9-Feb-03	367	540
	32	206.9	9-Feb-03	398	720
	34	205.3	9-Feb-03	376	700
	35	208.0	8-Feb-03	375	600
	36	205.3	9-Feb-03	378	630
	40	208.0	8-Feb-03	393	680
	41	208.9	8-Feb-03	347	460
	42	206.4	7-Feb-03	334	445
	43	206.4	7-Feb-03	321	380
	44	208.9	8-Feb-03	353	460
	45	206.4	7-Feb-03	429	860
			Min	**298**	**320**
			Max	**429**	**880**
			Mean	**361**	**563**
Upper Peaking	05	217.3	5-Feb-03	302	295
	06	220.1	5-Feb-03	313	380
	08	217.3	4-Feb-03	293	240
	09	217.3	4-Feb-03	291	270
	10	217.3	4-Feb-03	300	300
	11	217.3	4-Feb-03	328	330
	12	217.3	4-Feb-03	287	260
	13	217.3	4-Feb-03	283	255
	16	217.3	4-Feb-03	356	450
	17	217.3	4-Feb-03	342	435
	18	217.3	4-Feb-03	320	315
	23	220.1	3-Feb-03	277	250
	24	220.1	3-Feb-03	250	175
	29	215.7	20-Feb-03	276	225
			Min	**250**	**175**
			Max	**356**	**450**
			Mean	**303**	**304**

Table 5.7-2. Summary information collected on rainbow trout radio-tagged in different reaches of the Klamath River.

Reach	Tag ID	Tag Site (RM)	Date	Fork Length (mm[1])	Weight (g[2])
J.C. Boyle Bypass	03	220.9	6-Feb-03	263	200
	04	220.9	6-Feb-03	276	240
	14	221.3	18-Feb-03	265	240
	15	221.3	18-Feb-03	302	360
	19	224.3	4-Feb-03	271	226[3]
	20	221.4	19-Feb-03	265	205
	21	220.8	21-Feb-03	274	230
	22	224.3	4-Feb-03	307	327[3]
	26	223.4	13-Feb-03	303	300
	27	222.2	18-Feb-03	268	220
	28	221.1	19-Feb-03	254	200
	33	223.4	13-Feb-03	312	315
	37	223.4	13-Feb-03	287	280
	39	221.7	18-Feb-03	266	230
			Min	**254**	**200**
			Max	**312**	**360**
			Mean	**281**	**254**

[1] mm = Millimeter.

[2] g = Grams.

[3] Weight was estimated on the basis of the length-weight relationship.

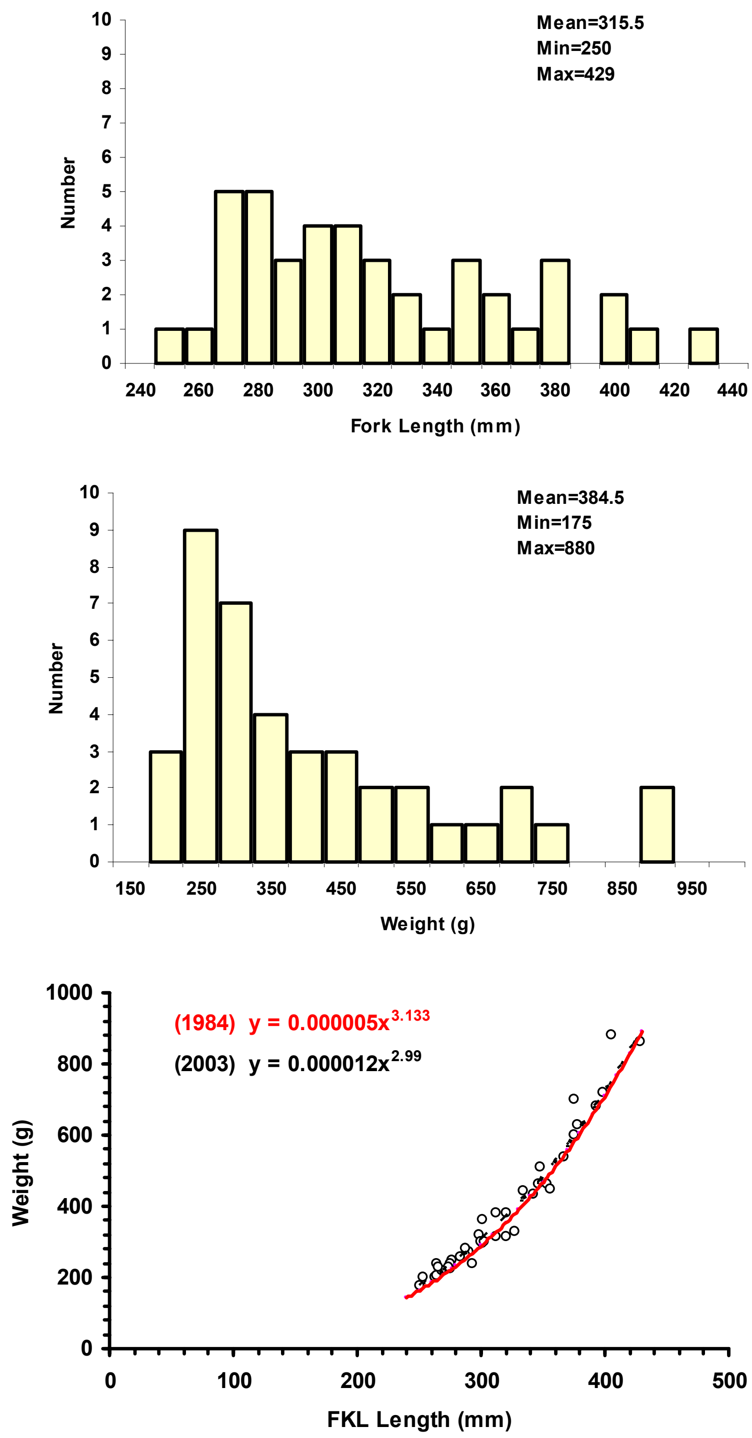

Figure 5.7-2. Length and weight distribution and relationship observed for rainbow trout radio-tagged in the Klamath River, 2003. The red line in the bottom plot represents the length-weight trend for upstream migrants captured in lower Shovel Creek, 1984 (Beyer, 1984).

5.7.3 Migration and Movement

To assess movement patterns of rainbow trout, the observed movement for each week of the study period for fish tagged in the J.C. Boyle bypass reach, upper peaking reach, and lower peaking reach of the Klamath River was estimated. The observed movement was calculated as the distance fish traveled during each week of the study period. The estimate provided a means to compare both individual and group movements in the different reaches. The estimates help describe periods of movement, home range, and the extent of movement (mobility) for each group of fish tagged (Table 5.7-3).

Table 5.7-3. Number of fish and total movement observed during each week of study period for fish tagged in the J.C. Boyle bypass reach, and the upper and lower peaking reaches of the Klamath River, 2003.

		J.C. Boyle Bypass			**Upper Peaking Reach**			**Lower Peaking Reach**		
Month	**Week**	**Total (miles)**	**Number (fish)**	**Mean***	**Total (miles)**	**Number (fish)**	**Mean***	**Total (miles)**	**Number (fish)**	**Mean***
February	1	0.0	0	0.00	0.0	0	0.00	0.0	0	0.00
	2	0.0	0	0.00	0.0	0	0.00	0.0	0	0.00
	3	1.6	1	0.12	4.0	2	0.36	0.0	0	0.00
	4	0.8	1	0.06	0.7	5	0.05	2.4	2	0.17
March	5	0.3	2	0.02	5.2	4	0.37	2.7	5	0.19
	6	17.1	9	1.22	9.4	3	0.67	2.9	6	0.22
	7	2.1	7	0.16	20.9	14	1.61	6.8	9	0.52
	8	11.4	7	0.81	2.8	6	0.22	1.7	5	0.13
April	9	4.8	4	0.34	9.7	6	0.69	7.0	9	0.54
	10	3.7	5	0.26	2.2	4	0.16	5.8	5	0.45
	11	2.8	4	0.20	0.5	3	0.04	6.0	8	0.46
	12	1.2	2	0.09	0.8	2	0.06	6.7	6	0.56
	13	12.1	9	0.86	4.5	3	0.35	8.1	8	0.74
May	14	7.1	6	0.51	2.0	6	0.15	4.1	8	0.34
	15	1.2	4	0.09	20.5	5	1.58	1.4	4	0.12
	16	5.4	10	0.42	9.5	8	0.73	2.4	5	0.22
	17	3.5	5	0.27	6.0	4	0.46	0.2	2	0.02
June	18	1.5	7	0.12	0.0	0	0.00	0.0	0	0.00
	19	0.9	6	0.07	2.3	2	0.18	0.2	2	0.02
	20	4.5	4	0.35	4.5	2	0.35	0.4	3	0.04
	21	4.4	5	0.73	2.0	1	0.40	0.1	1	0.01
July	22	1.9	7	0.15	2.7	1	0.22	30.3	3	2.75
	23	0.7	3	0.05	0.1	1	0.01	0.2	1	0.02
	24	9.4	7	0.72	3.2	2	0.36	0.0	0	0.00
	25	6.3	5	0.48	1.3	2	0.14	0.1	1	0.02
August	26	7.0	9	0.54	7.0	4	0.78	8.8	4	1.76
	27	6.3	3	0.57	4.2	2	0.52	0.0	0	0.00
	28	0.2	2	0.02	4.2	2	0.70	0.0	0	0.00
	29	0.1	1	0.02	0.1	1	0.03	0.0	0	0.00
	30	0.1	1	0.02	1.4	1	0.70	0.0	0	0.00
Total		**118.4**	**136**	**0.34**	**131.7**	**96**	**0.41**	**98.3**	**97**	**0.37**

* Mean movement is calculated as the quotient of total miles divided by the number of fish detected in each reach.

Periods of Movement

The average distance fish traveled during each week of the study period was similar for fish tagged in the three reaches. The average distance the fish traveled varied during the study period but was typically less than one mile. Fish tagged in the J.C. Boyle bypass reach and upper peaking reach displayed two peak movements during the spring (Table 5.7-3; Figure 5.7-2). In the lower peaking reach, movements were more evenly distributed over the spring spawning and migration period. Fish tagged in the upper peaking reach had the greatest total movement during the entire study period followed by fish tagged in the J.C. Boyle bypass reach and lower peaking reach (Table 5.7-3).

Movement continued throughout the summer months and the pattern was similar for fish tagged in the J.C. Boyle bypass reach and upper peaking reach (Figure 5.7-3). However, in the lower peaking reach fish appeared to maintain their locations until the beginning of July and August when a few individuals made relatively large movements (Figure 5.7-3).

In general there were more fish actively moving in the spring than during the summer and it appears from the average distance traveled in each reach that both spring spawning and summer rearing habitat may have been available in a fairly compact area (Table 5.7-3).

Home Range and Mobility

To define the home range and mobility of fish, the position of each fish was plotted and then the amount of movement was estimated by calculating changes in location for each fish during each week of the study period. Typically, the home range of an organism is defined as the area that an organism travels during a year (Smith and Smith, 2001). In this study, rainbow trout were tracked less than 1 year (7 months) during late winter, spring, and summer conditions. These seasonal conditions may be adequate to describe their general home range and mobility if it is assumed that adult fish do not make substantial movements during the remainder of the year.

The variation in home range in each reach of the study areas was similar, although fish in the lower peaking reach were generally the smallest (Table 5.7-4). The average home range for fish tagged in the upper peaking reach was 6.4 miles followed by 5.9 miles and 4.2 miles in the J.C. Boyle bypass reach and lower peaking reach, respectively (Table 5.7-4). In general, most fish in the study area tended to travel less than 10 miles from late winter to summer. However, in each of the three reaches, there were individual fish that displayed small home ranges (less than 1.0 mile) while others ranged much farther (more than 10.0 miles).

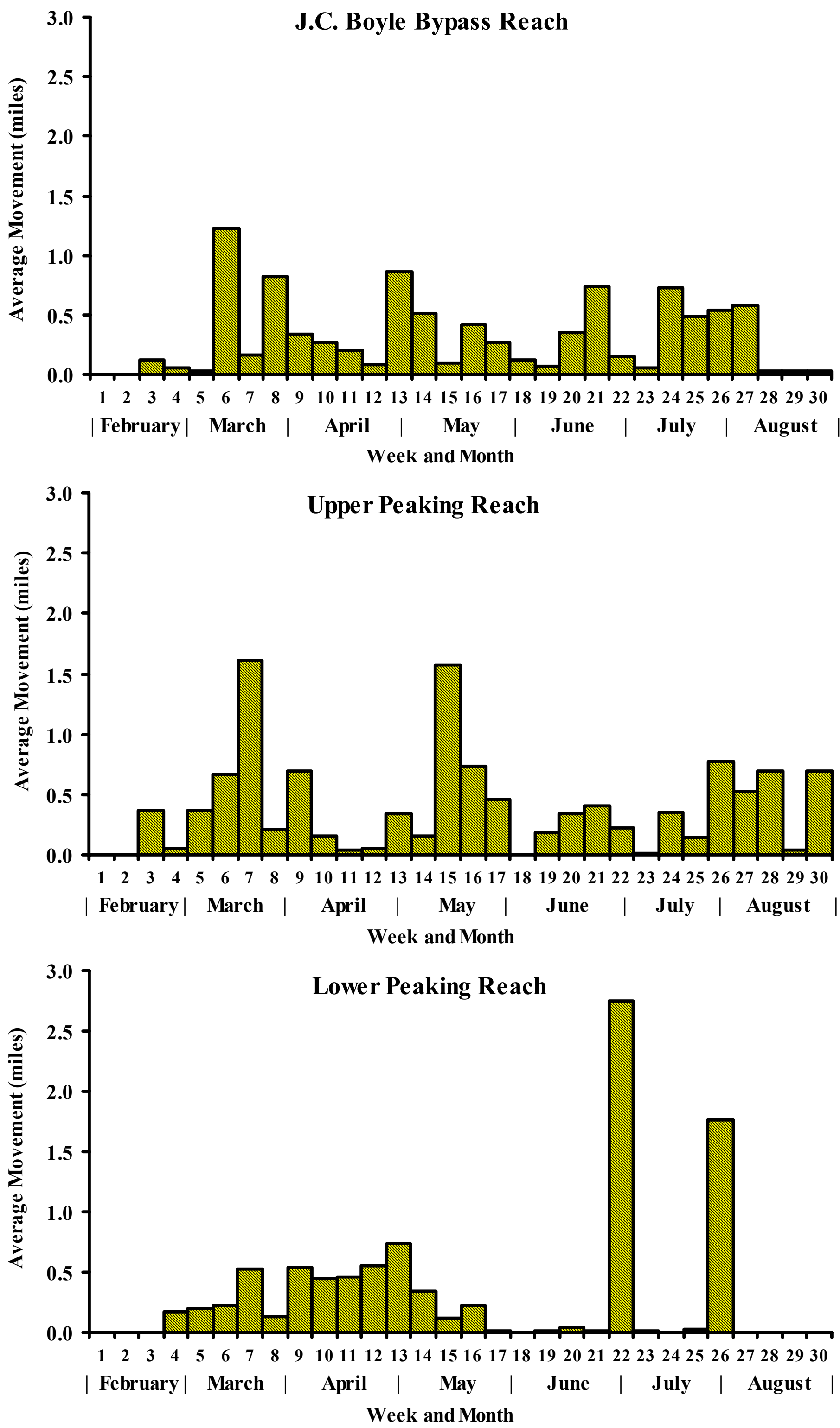

Figure 5.7-3. Average trout movement observed for each week (1-30) of the study period for fish tagged in the J.C. Boyle bypass reach, and the upper and lower peaking reaches of the Klamath River, 2003.

The extent of movement (mobility) observed within a given home range varied. For some individuals, the home range and amount of movement observed were identical (Table 5.7-4). This limited movement within the home range occurred in four of 11 fish in the J.C. Boyle bypass reach and was less noticeable in the upper and lower peaking reaches of the Klamath River. In those latter reaches, fish generally displayed more total movement within their home range (Table 5.7-4).

Most fish moved downstream after they were tagged (Figure 5.7-4). This trend is most noticeable in the J.C. Boyle bypass reach and upper peaking reach of the Klamath River (Figure 5.7-4). Nine fish in the J.C. Boyle bypass reach moved downstream to occupy stations in the upper peaking reach while only four fish moved upstream from the upper peaking reach into the J.C. Boyle bypass reach (Figure 5.7-4). Only one fish (Tag No. 34) from the lower peaking reach moved upstream into the upper peaking reach. No fish from the lower peaking reach entered the J.C. Boyle bypass reach and only one fish (Tag No. 20) from the J.C. Boyle bypass moved downstream into the lower peaking reach (Figure 5.7-4). Most of the movement in the lower peaking reach was at the confluence with Shovel Creek. This is not unexpected considering that 11 of 14 fish tagged in this reach migrated into Shovel Creek.

Table 5.7-4. Home range and total movement observed for fish tagged in the J.C. Boyle bypass, and the upper and lower peaking reaches of the Klamath River, 2003.

J.C. Boyle Bypass			**Upper Peaking Reach**			**Lower Peaking Reach**		
Fish ID	**Home Range (miles)**	**Total Movement (miles)**	**Fish ID**	**Home Range (miles)**	**Total Movement (miles)**	**Fish ID**	**Home Range (miles)**	**Total Movement (miles)**
03	4.0	4.0	05	10.5	10.7	01	0.8	2.4
04	7.3	7.3	06	1.1	1.6	02	0.4	0.7
14	2.4	3.2	08	9.6	9.8	30	0.7	0.8
15	4.5	4.6	09	4.3	5.7	31	2.6	3.6
19	10.9	18.0	10	7.6	8.2	32	7.4	10.1
20	18.1	18.7	11	5.9	5.9	34	15.8	35.4
21	4.0	10.1	12	2.8	16.0	35	1.7	2.0
22	2.6	3.9	13	3.5	8.3	36	2.6	2.6
26	1.6	2.8	16	18.9	19.5	40	4.8	11.4
27	2.2	6.5	17	0.3	0.7	41	4.1	8.0
28	1.2	1.2	18	3.6	9.7	42	9.1	9.9
33	11.1	11.1	23	3.7	8.8	43	0.1	0.2
37	12.5	24.3	24	16.1	22.0	44	6.1	7.4
39	0.5	2.7	29	1.7	4.8	45	1.9	3.8
Min	**0.5**	**1.2**	**Min**	**0.3**	**0.7**	**Min**	**0.1**	**0.2**
Max	**18.1**	**24.3**	**Max**	**18.9**	**22.0**	**Max**	**15.8**	**35.4**
Mean	**5.9**	**8.5**	**Mean**	**6.4**	**9.4**	**Mean**	**4.2**	**7.0**

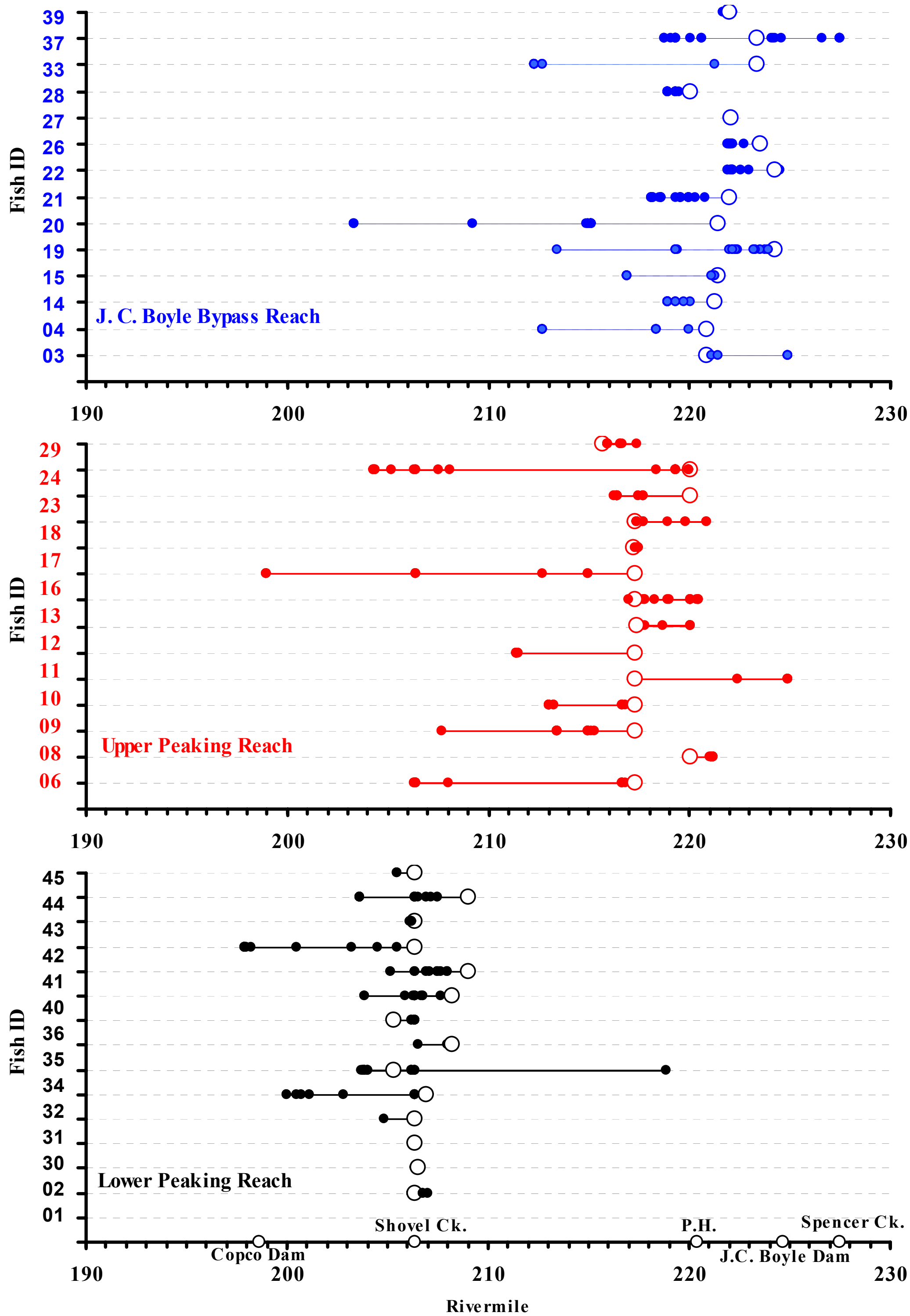

Figure 5.7-4. Home range and direction of movement observed for fish tagged in the J.C. Boyle bypass reach, and the upper and lower peaking reaches of the Klamath River, 2003. Large open circles represent tag site locations. Small dark circles represent the locations where fish were detected in the Klamath River.

5.7.3.1 Spawning

J.C. Boyle Bypass Reach

A spawning survey was conducted in a section of the J.C. Boyle bypass reach downstream from the canal spillway on April 30, 2003. The survey was conducted in a downstream manner using snorkel and bank observation. Redd locations were identified with the GPS and only one waypoint was recorded if there were numerous redds in a common area. The number and size of rainbow trout observed in the vicinity were noted. There were 56 redds in the area surveyed (RM 221.2 to 222.5) (Table 5.7-5). This is probably a minimum estimate of the total number of redds because poor visibility limited observations to the stream margin. Extensive spawning was observed in the area just downstream of the spillway (Figure 5.7-5). The number of redds diminished downstream until RM 221.9. During the survey, one tagged fish (Tag No. 6) was observed at the lower end of the spawning area. Mobile surveys in this area revealed that 12 of 14 fish tagged in the J.C. Boyle bypass reach had visited this area and two of 14 fish tagged in the upper peaking reach also visited this area.

Table 5.7-5. Number and size of rainbow trout observed near redds counted in the bypass section of the Klamath River.

	Size Range and Count (inches)				**Number**
River Mile	**< 5**	**5-7**	**8-10**	**> 10**	**Redds**
222.5	2	2		3	21
222.5	2	3		3	5
222.4					9
222.4	1	2	2	1	3
222.3					1
222.3					1
222.2					1
222.1		2			1
221.9	2	8	8	3	13
221.2		1		1	1
Totals	**7**	**18**	**10**	**11**	**56**

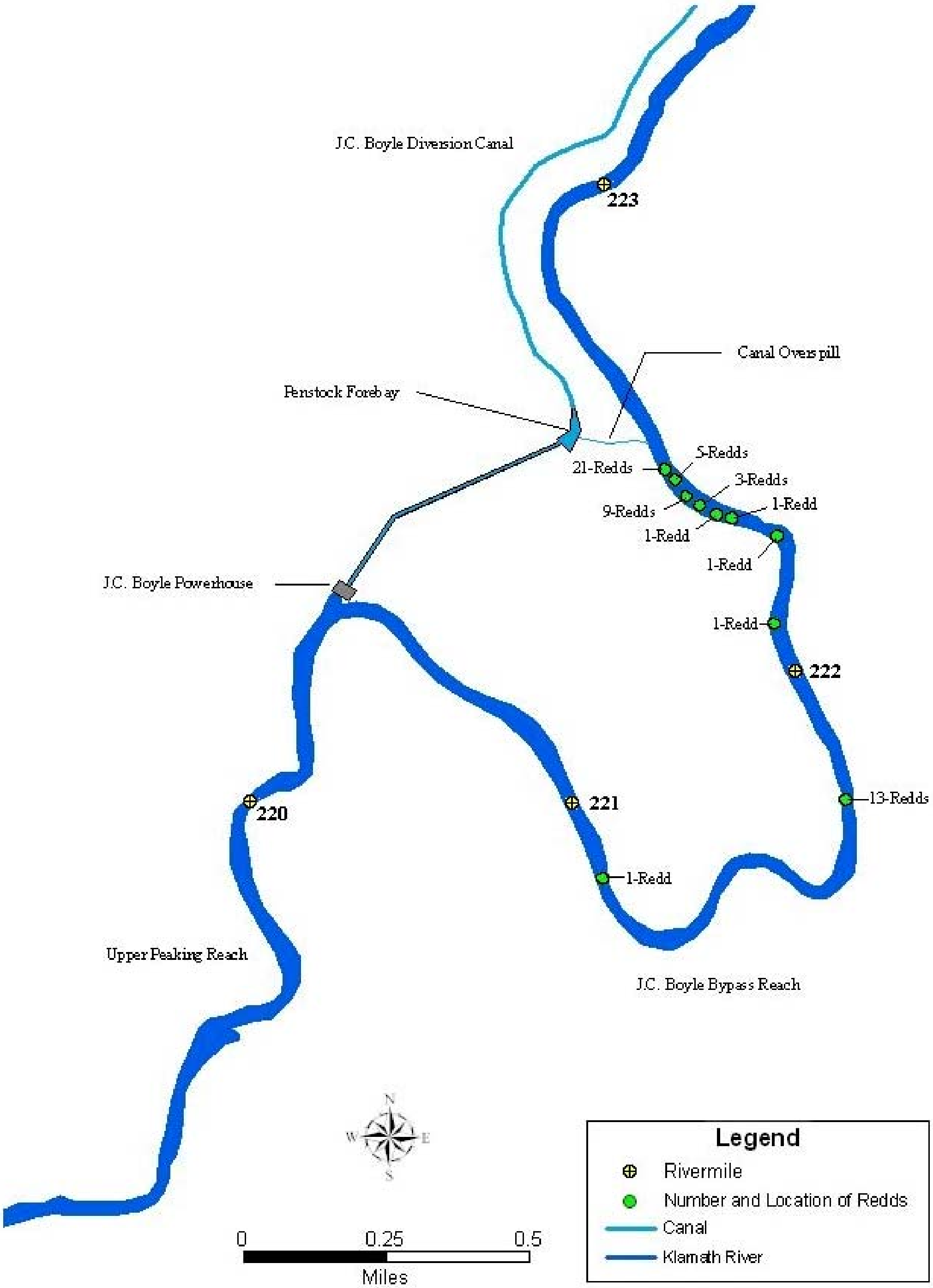

Figure 5.7-5. Location and number of rainbow trout redds observed in the J.C. Boyle bypass reach of the Klamath River, 2003.

Tributaries

One-third (14 of 42) of the radio-tagged fish migrated to Spencer and Shovel creeks. One fish from the J.C. bypass reach migrated to Spencer Creek during the first week of April and 13 fish migrated into Shovel Creek from March to May. Eleven of the fish that migrated into Shovel Creek were tagged in the lower peaking reach and the other two were tagged in the upper peaking reach. Most of the fish (12 of 13) in Shovel Creek entered the tributary from the beginning of March to mid-April. The last fish entered Shovel Creek at the end of May. Tributary residence ranged from 1 to 6 weeks in Shovel Creek, with most fish exiting between mid-April to first week of June. Residence in Spencer Creek was about 4 weeks with the fish exiting near the end of April. The one fish that entered Spencer Creek was detected just downstream of Clover Creek (RM 3.5), and between RM 0.9 and RM 1.2. In Shovel Creek, most of the fish were detected in the lower 1.5 miles of the stream. A spawning ground survey in Shovel Creek conducted on April 22, 2003, revealed 43 redds in the index area (RM 0.6 to 0.9). Spawning activity appeared to be past its peak because redds were beginning to fade and fish numbers had diminished.

Post-spawning movement revealed that most of the fish (seven of 13) that entered Shovel Creek selected new locations downstream in the Klamath River or Copco reservoir when they were last detected. Two fish moved upstream after leaving Shovel Creek, but then moved back downstream past Shovel Creek. The tags for three fish were recovered in Shovel Creek and one fish was last detected in Shovel Creek before it disappeared. The fish that entered Spencer Creek moved back downstream through J.C. Boyle reservoir, passed through the powerhouse, and established a new residence in the upper peaking reach of the Klamath River.

Klamath River

In addition to spawning areas observed in tributaries and the J.C. Boyle bypass reach, semi-permanent stations in the Klamath River were plotted to help define potential adult rainbow trout spawning and rearing areas (Figure 5.7-6). The plot depicts areas of the Klamath River where at least one fish was detected on at least two consecutive surveys during the spring (March through May). Fish positions recorded in late February were eliminated to allow fish at least 1 week of recovery and redistribution from their tag site locations. The areas were further refined by eliminating fish (14 of 42) that entered Shovel or Spencer creeks, presumably to spawn.

The plot shows two major fish areas in the lower J.C. Boyle bypass reach, one as a known spawning location. In the peaking reach of the Klamath River, there were numerous semi-permanent adult stations, but most were concentrated in the upper peaking reach. Undoubtedly, many of these areas were simply adult holding or rearing areas. However, these areas may provide a template for future research if conditions in the mainstem become favorable enough to conduct snorkel surveys.

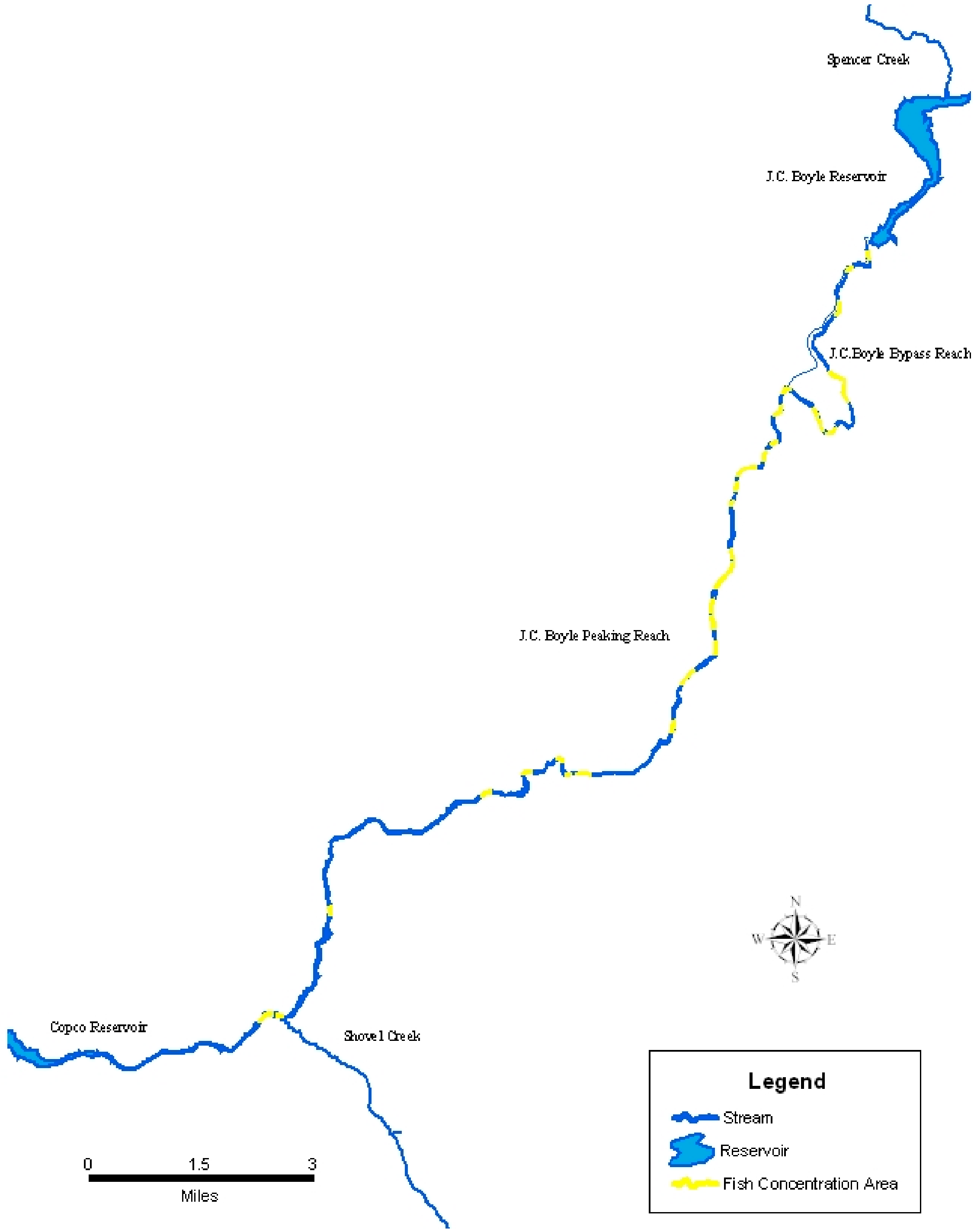

Figure 5.7-6. Semi-permanent stations occupied by radio-tagged rainbow trout from March to June in the Klamath River, 2003.

5.7.3.2 Passage Areas

J.C. Boyle Fish Ladder

Fish passage at J.C. Boyle dam was monitored from February to mid-May 2003. During that time, only one of 42 (2.3 percent) radio-tagged fish in the Klamath River approached or ascended the fish ladder. The fish (Tag No. 37) was tagged in the J.C. Boyle bypass reach (RM 223.4) on February 13 and remained near the tag site for about 1 month. Later, on March 10, the fish was detected upstream (RM 224.3) during a mobile survey, about 0.3 mile downstream of the fish ladder. The fish returned downstream to the tag site by March 17, but subsequently moved back upstream again and was detected near its former upstream site on March 26. The fish moved upstream to the fish ladder on March 29 and was detected on the approach antenna for 1.3 hours (Table 5.7-6). On March 29, the fish also was detected sporadically at the entrance of the fish ladder. Three days later, on April 1, the fish again was detected near the fish ladder for about 0.5 hour, but did not enter. The fish passed the Project on April 2, ascending the ladder (entrance antenna to exit antenna) in about 3.5 hours. This equates to about 3.7 minutes per pool and weir to ascend the fish ladder.

Table 5.7-6. Detection history for a single fish (Tag No. 37) that approached, entered, and passed at J.C. Boyle fish ladder.

	Antenna Detections						Time Intervals (hours)		
	Approach		Entrance		Exit		Approach Only	Approach to Entrance	Entrance to Exit
Date	First	Last	First	Last	First	Last			
3/29/03	1:37 p.m.	2:55 p.m.	1:41 p.m.	2:54 p.m.	---	---	1.30	0.07	---
4/1/03	5:34 a.m.	6:02 a.m.	---	---	---	---	0.47	---	---
4/2/03	2:56 a.m.	3:04 a.m.	3:10 a.m.	3:51 a.m.	6:16 a.m.	6:35 a.m.	0.13	0.23	3.5

It is not clear if the movement and passage of this fish (Tag No. 37) was related to spill. The Project began spilling in the J.C. Boyle bypass reach on March 27 (4 p.m.) and continued for approximately 43 hours until it was down-ramped on March 29 (10 a.m.) (Figure 5.7-7). Approximately 3.5 hours later, on March 29, the fish was detected at the fish ladder near the entrance (Table 5.7-6; Figure 5.7-7). However, the fish did not pass until 3.5 days later on April 2. After ascending the ladder, the fish migrated upstream through J.C. Boyle reservoir and was detected in Spencer Creek.

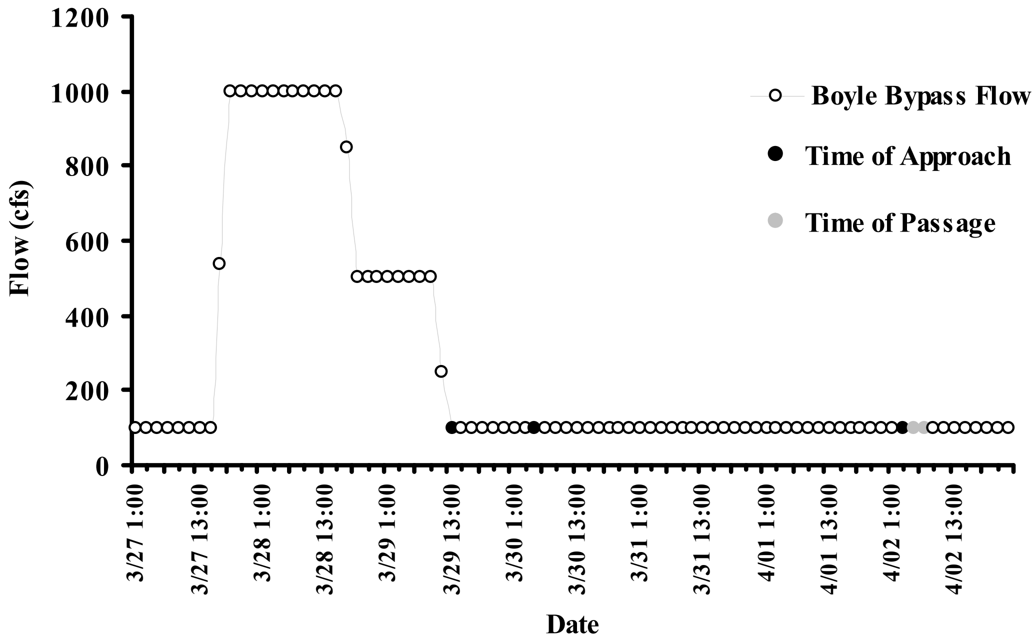

Figure 5.7-7. Comparison of the time Fish No. 37 approached and passed the J.C. Boyle fish ladder with flow (cfs) in the bypass during a spill event.

However, no other radio-tagged fish were observed moving in response to the spill event. In fact, the two fish (Tag No. 19 and 22) located closest to the fish ladder remained at the same station before and after the spill event. It also appears that no fish in the upper peaking reach responded to the spill event by migrating into the J.C. Boyle bypass reach. Therefore, the successful passage of this fish (Tag No. 37) indicates that it was not delayed or deterred from passing the Project after it entered the fish ladder.

J.C. Boyle Tailrace Confluence Area

To assess potential delays associated with operation of J.C. Boyle powerhouse, the movements of radio-tagged fish were monitored near the tailrace. More specifically, the tailrace was monitored at the confluence of the powerhouse and J.C. Boyle bypass reach. Less than a third (13 of 42) of the fish actually moved into the passage area (Table 5.7-7). There were 29 fish that did not encounter the passage area (i.e., fish that did not move into the tailrace) (Table 5.7-7). Fifteen distinct passage events resulted from the 13 fish that encountered the confluence area One fish (Tag No. 28) accounted for three passage events as it moved both upstream and downstream through the confluence area.

Table 5.7-7. Information on rainbow trout that were detected in the tailrace confluence area of the powerhouse and J.C. Boyle bypass channels.

Number Tagged	Encountered Passage Area		Direction of Movement	Fish ID	System Operation (Yes or No)	Successful Passage (Yes or No)	Passage		Delay		
							Date	Hours	Yes	No	?
42	Yes	13 (31%)	Upstream (5)	06	Yes	Yes	Mar-12	0.47		X	
				13	Yes	Yes	May-03	212.86			X
				10	NA	Yes	May-19	NA			X
				18	Yes	Yes	Apr-29	24.37		X	
				28	Yes	Yes	Apr-29	3.08		X	
			Downstream (9)	04	Yes	Yes	Feb-09	2.88		X	
				14	No	Yes	Mar-06	0.05		X	
				15	Yes	Yes	Apr-28	0.07		X	
				19	NA	Yes	Jul-16	NA			X
				20	Yes	Yes	Mar-11	1.75		X	
				21	Yes	Yes	Feb-25	0.43		X	
				28	Yes	Yes	Feb-23	0.63		X	
				28	Yes	Yes	May-01	0.07		X	
				33	Yes	Yes	Mar-12	0.01		X	
				37	Yes	Yes	Apr-30	17.23		X	
	No	29 (69%)	No Delay								

NA (Not Available)—Specific information on the passage time and conditions are not available for these fish because they moved through the area after the fixed-station receiver was taken down (mid-May). Passage dates reflect the first survey date that fish were detected either upstream or downstream from the confluence of the powerhouse and J.C. Boyle bypass reach.

Most of the fish (nine of 14) moved downstream through the J.C. Boyle tailrace (Table 5.7-7). Fish moved downstream through most of the spring migration period from the J.C. Boyle bypass reach into the upper peaking reach of the Klamath River. All downstream migrants successfully passed through the tailrace area on their first attempt. Only one fish (Tag No. 14) moved downstream through the tailrace when the J.C. Boyle powerhouse was not generating. Movement downstream through the confluence area varied from 0.01 hour to 17.2 hours, with most passing through the confluence area in less than 3 hours. Fish No. 37 spent the longest time in the confluence area of the bypass reach and powerhouse tailrace. However, Fish No. 37 already had migrated to Spencer Creek and returned to the confluence area through the penstock of the powerhouse. As a point of comparison, the median passage time through the confluence area was brief (0.43 hour) compared to the spring spawning and migration period (84 days).[3] Given that all the fish moved through the tailrace confluence area successfully on their first attempt, and did so in a relatively short time, it appears that fish were not delayed or deterred as they moved downstream.

There were five fish that moved upstream through the confluence of the powerhouse and J.C. Boyle bypass reach channels. Most of these fish passed through the confluence area in late April and May from the upper peaking reach into the bypass reach. A passage time for Fish No. 10 or

[3] A median passage time of 0.43 hour through the confluence area compared to the spring spawning and migration period (84 days or 2,016 hours) is relatively small. The passage time equates to about 0.02 percent of the total spring spawning and migration period ((0.43 hour / 2,016 hours)*100) = 0.02 percent).

19 could not be provided because they passed after the fixed station was removed. Most of the upstream migrants encountered the confluence area when the powerhouse was operating, and successfully passed the area on their first attempt as they moved into the bypass reach. However, upstream movement through the tailrace confluence area varied considerably (0.5 hour to 212.9 hours).

Fish No. 6, 18, and 28 appear to have spent a relatively short time in the tailrace confluence area relative to the entire spring spawning and migration period (less than 2 percent). Fish No. 6 and 18 also were detected near the spawning area in the J.C. Boyle bypass reach during mobile surveys, and Fish No. 28 returned to the J.C. Boyle bypass reach only to move back downstream again to the upper peaking reach. This behavior suggests these fish were neither delayed nor deterred as they encountered the confluence area.

The late arrival of Fish No. 13 in the tailrace confluence area (May 3) and the fact that it spent a considerable time there seems to warrant further consideration. Fish No. 13 moved into the tailrace confluence area during an extended period of powerhouse generation (Figure 5.7-8). Approximately 24 hours after it was detected in the confluence area by the aerial antenna system, the fish had moved upstream close enough to be detected by the underwater antennas located within the J.C. Boyle bypass reach (see Figure 5.4-6). This observation was confirmed by mobile surveys on May 5 and 7 that placed the fish in the lower J.C. Boyle bypass reach. Apparently, the fish had moved through the tailrace confluence area to the J.C. Boyle bypass reach where it was detected for 188 hours. The fish had entered the J.C. Boyle bypass reach, but did not continue farther upstream. Mobile surveys during late spring and summer placed this fish back downstream near similar locations before it had moved into the confluence area. For these reasons, it is unknown whether this fish (Tag No. 13) was delayed or deterred by project operations at the J.C. Boyle powerhouse. The behavior suggests that the fish negotiated the tailrace within a day, but elected to remain close to the tailrace confluence area even though it had successfully passed to enter the J.C. Boyle bypass reach.

The passage of Fish No. 10 and 19 could not be evaluated because they moved into the J.C. Boyle bypass reach after the spring spawning and migration period. Whether these fish (Tag No. 10 and 19) were delayed at the Project remains unknown.

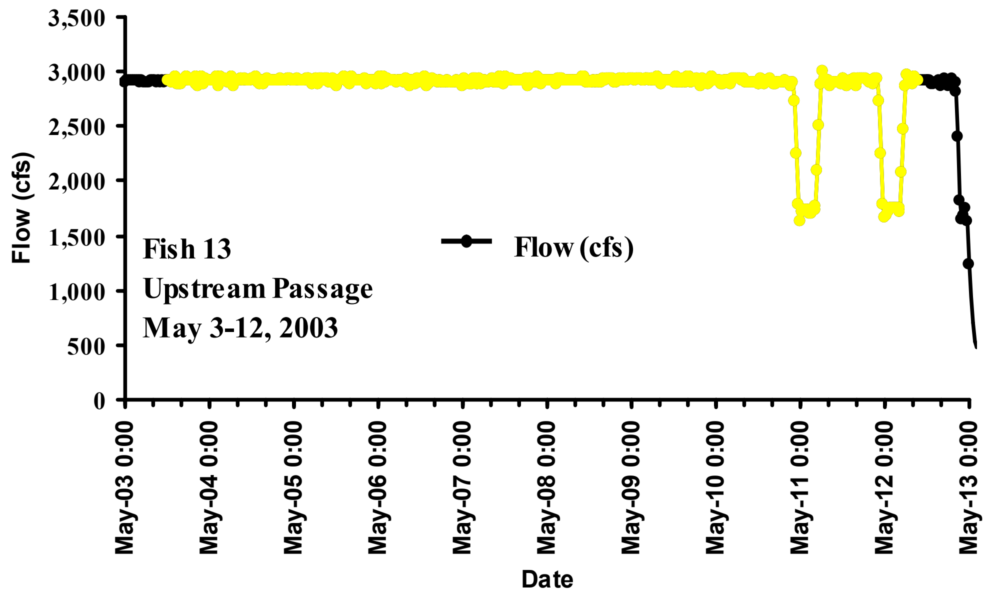

Figure 5.7-8. Passage conditions (flow) at the confluence area of the powerhouse and J.C. Boyle bypass channels for Fish No. 13. The yellow line overlaid on flow conditions indicates the period of time that Fish No. 13 resided in the evaluation area.

5.7.4 Power Peaking Observations

The effects of power peaking on movement of tagged fish were investigated to see if they would respond to changes in flow by changing there longitudinal position within the stream. First, a series of blind tests was used on two observers to determine their ability to accurately locate the position of the fish along the streambank. The tests showed that the longitudinal position of a test tag could be determined within 10 feet of the true location in the stream channel.

Twelve observations were made on four fish and movement was detected on four occasions (Table 5.7-8). Fish moved from 10 to 210 feet in response to power peaking and for all observations the fish remained within the same habitat unit; there were two observations of the fish moving downstream and two moving upstream. However, most of the observations noted that fish did not change position in response to power peaking.

A similar study on the response of rainbow trout to peaking events was conducted in the Caney Fork River in Tennessee (Niemela, 1989). In that study, total distance and maximum displacement in response to power peaking were highly variable. The total distance fish moved ranged from 0 to 1,869 feet (Niemela, 1989). Fish moved quickly to hydraulic refuges with the onset of generation and most often moved upstream or from one bank to the other to find refuge, often selecting the same refuge areas during subsequent generation cycles.

Table 5.7-8. Changes in longitudinal position for radio-tagged rainbow trout during base and peak flows in the peaking reach of the Klamath River, 2003.

Date	Code	Observations						Results	
		Base			Peak				
		Time	Habitat		Time	Habitat		Direction	Delta (feet)
7/24	1	11:30	Riffle		13:23	Riffle		Upstream	50-60
7/30	12	9:30	Riffle		15:18	Riffle		None	0
7/30	17	11:20	Riffle		15:00	Riffle		None	0
8/1	12	6:50	Riffle		11:15	Riffle		None	0
8/1	17	8:20	Riffle		10:30	Riffle		None	0
8/12	1	9:15	Riffle		12:38	Riffle		Upstream	40
8/13	12	6:55	Riffle		10:01	Riffle		Downstream	10-15
8/21	1	11:15	Riffle		13:30	Riffle		None	0
8/22	12	6:50	Riffle		9:50	Riffle		None	0
8/25	12	6:50	Riffle		15:41	Riffle		None	0
8/25	1	11:45	Riffle		13:35	Riffle		None	0
9/3	14	7:00	Run		16:18	Run		Downstream	210

5.7.5 Movement and Stream Temperature

To assess movement in relation to temperature, fish movement was plotted with the mean daily stream temperature (Appendix 5B). Spring movement into tributaries (Spencer and Shovel creeks) in the study area generally occurred when stream temperatures were between 4 to 8°C. In summer, there did not appear to be any directional movement that could be related to cooler stream temperatures being potentially available at the confluence of Shovel Creek and downstream of the J.C. Boyle bypass reach. Moreover, most fish appeared to move downstream (Figure 5.7-4) in the peaking reach of the Klamath River where stream temperatures increased (Figure 5.4-4). However, Behnke (1992) noted that redband rainbow trout may possess the hereditary basis to function at high stream temperatures. In part, this may explain their wide distribution in streams of arid lands.

5.8 DISCUSSION

The purpose of this study was to investigate and document the movements of rainbow trout in the J.C. Boyle Development area. The movement patterns of radio-tagged trout in the area are important in understanding how Project operations may aided fish movement through sensitive passage areas at the powerhouse and the fish ladder at J.C. Boyle dam. In part, this was accomplished by mobile surveys and fixed-station telemetry sites.

The detection of radio-tagged fish during the study remained fairly high (greater than 80 percent) until mid-July. A few that remained undetected throughout most of the study and it was suspected that some fish that had died. Other researchers have noted mortality and predation during the spawning period (Elle, 1995; Swanberg, 1997; Chandler et al. 2001). For spawning bull trout, Schill et al. (1994) noted a relatively high mortality (67 percent) and Elle (1998) reported a lower range of mortalities (26 to 36 percent) for spawning adult bull trout. For rainbow trout radio-tagged in the Yakima River, post-spawning mortality was 6 percent and mortality from predation was 4 percent (Hockersmith et al. 1995). In this study, 38 percent (five of 13) of the fish that entered Shovel Creek (five tags recovered) are suspected to have died (predation and post-spawning mortality). The inclusion of other tags found and signals originating from suspect areas suggest that mortality may have been about 21 percent (nine of 42) for all radio-tagged fish. None of the mortalities that occurred during this study appears to be related to J.C. Boyle operation.

One-third (14 of 42) of the radio-tagged fish migrated to Spencer and Shovel creeks. The majority of those fish (13 of 14) entered Shovel Creek. Fish that entered Shovel Creek migrated from the upper peaking reach (two fish) and lower peaking reach (11 fish) from March to May. The fish that entered Spencer Creek was tagged in the J.C. Boyle bypass reach. Post-spawning behavior revealed that most of the fish (seven of 13) that entered Shovel Creek selected new locations downstream in the Klamath River or Copco reservoir. Two fish moved upstream after leaving Shovel Creek, then moved back downstream past Shovel Creek. Three fish apparently died in Shovel Creek and one fish was last detected in Shovel Creek before it disappeared. The fish that entered Spencer Creek moved back downstream through J.C. Boyle reservoir and passed through the powerhouse to establish a new residence in the upper peaking reach of the Klamath River.

There were 56 redds counted in the lower section of the J.C. Boyle bypass reach near the penstock forebay overflow. No spawning in this area had been observed before this study. Most of the fish tagged in the J.C. Boyle bypass reach visited this area as well as two fish tagged in the upper peaking reach. A plot of semi-permanent stations occupied by tagged fish during the spring clearly defined this area. Several more areas were prominent in the upper peaking reach. Unfortunately, poor visibility in the peaking reach did not allow further investigation of these potential adult rearing and spawning areas.

Fish appeared to be actively moving throughout most of the spring spawning and migration period. In summer, most fish tagged in the lower peaking reach remained in general areas, while fish in the upper peaking reach and J.C. Boyle bypass tended to move more frequently. This general trend seems to support the mean home range size observed for fish tagged in the three reaches. Fish in the upper peaking reach had a mean home range of 6.4 miles followed by 5.9 miles in the J.C. Boyle peaking reach and 4.2 miles in the lower peaking reach. The mean home range size of fish tagged in the peaking reaches does not appear to be much different than fish tagged in the J.C. Boyle bypass reach.

Most fish moved downstream after they were tagged. More than half of the fish tagged (nine of 14) in the J.C. Boyle bypass reach moved downstream during spring and summer to occupy stations in the upper peaking reach. Four fish from the upper peaking reach moved upstream into the J.C. Boyle bypass reach and another four fish moved downstream into the lower peaking reach. Only one fish from the lower peaking reach migrated upstream to the upper peaking reach. Movement during the spring in the lower peaking reach was centered near Shovel Creek, but most fish returned downstream after the spring spawning and migration period.

The movement of fish in summer did not suggest that fish moved to locations to take advantage of potentially more suitable stream temperatures. If stream temperature prompted fish movement, more fish would have been expected to move downstream to the confluence of Shovel Creek and into the J.C. Boyle bypass reach. Archival radio-tags that record stream temperature are better suited to determine if fish are selecting stream locations based on temperature.

Movements in response to power peaking varied, were generally not extensive (10 to 210 feet), and usually occurred either upstream or downstream within the same habitat unit. From 12 observations, only four movements were noted in response to power peaking. Niemela (1989) found that fish movement in response to power peaking was highly variable (range; 0 to 1,869 feet).

There was no evidence of delay or deterrence of fish at the powerhouse or fish ladder. In fact, most fish appeared to move through the powerhouse tailrace area on the first attempt without delay. The movement of fish (13 of 42) that passed the tailrace area was from fish tagged in the upper peaking reach (four fish) and J.C. Boyle bypass reach (nine fish). No fish tagged in the lower peaking reach migrated upstream to enter the J.C. Boyle bypass reach. The majority of the fish that encountered the confluence of the powerhouse and J.C. Boyle bypass reach typically spent less than 2 percent of the spring spawning and migration period passing the tailrace area.

Only one fish (tagged in the J.C. Boyle bypass reach) of the 42 radio-tagged fish in the Project area attempted and passed the fish ladder at J.C. Boyle dam. The successful passage of this fish after it entered the fish ladder indicates that it was not delayed or deterred by the fish ladder at J.C. Boyle dam. The lack of upstream movement toward the J.C. Boyle dam observed in this study seems to support Olson's (2002) explanation for the reduction in trout use of the fish ladder. He suggested that rainbow trout probably have modified their movement behavior as an adaptive response to new conditions with the dam in place.