Evaluation of Juvenile Chinook Behavior, Migration Rate and Location of Mortality in the Stanislaus River Through the Use of Radio Tracking

December 1998

Prepared for

Tri-dam Project

Prepared by

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EXECUTIVE SUMMARY

We conducted a pilot radio tracking study with juvenile fall-run chinook salmon smolts (*Oncorhynchus tshawytscha*), in the Stanislaus River during May through July, 1998, to determine the feasibility of using radio telemetry to monitor juvenile chinook migration, mortality, and possible locations of mortality. We successfully radio-tagged and tracked 36 natural and 10 hatchery chinook subyearlings ranging in length from 101 to 117 mm. The natural chinook were captured in the Oakdale screw trap and the hatchery chinook were obtained from the Merced River Fish Facility. Tagged fish were held between 36 and 72 hours after tag implantation and released at Orange Blossom Bridge (RM 46.9) in May, and McHenry Bridge (RM 29.5) in June.

Of the 46 tagged fish released, all but one were detected through the 10 day battery life expectancy. We determined that three tagged fish died soon after release, probably the result of the marking procedure, or regurgitated tags. Of the remaining 43, only 5 (11.6%) were detected reaching Caswell State Park (RM 9). Based on the pattern and behavior of repeated tag detections, we estimated that 30 tagged fish (70%) were eaten by predators. *However, predation was never directly witnessed and therefore could not be conclusively determined.*

Fixed station receivers at three locations detected from 50.0% to 91.7% of passing tags, with the lowest detection rate at the upstream-most location and the highest detection rate at the midpoint location. We speculate that electrical interference in the urban area reduced the effectiveness of the upstream receivers. Since the fixed stations operated 24 hours per day, they provided a continuous record of chinook activity which showed peak times of movement for tagged fish were just before sunrise and just after sunset.

Daily mobile tracking surveys during May, and 2 to 5 times per week during June and July, enabled us to detect specific locations of tagged fish at any given time. Detections during mobile surveys revealed locations and habitat characteristics where fish were located. We also detected rapid movement of some tags as we approached, which indicated we were tracking a larger predatory fish that had eaten a tagged salmon.

Of the 5 tagged chinook that successfully migrated the 37.9 miles from the Orange Blossom Bridge to Caswell Park, most completed the trip in under 3 days, and the slowest fish completed the trip between 6 and 10 days. One fish traveled 28.9 miles in a 24 hour period, and distances between 11 and 20 miles per 24 hours were common for the few other fish that survived to Caswell.

Distance traveled during the night following release in May averaged 7.1 miles and ranged from 0.15 to 28.9 miles. The majority of fish migrated between 5 and 13 miles the first night. Tagged chinook released in June traveled shorter distances on the first night, averaging only 1.8 miles and ranging from -2.75 (upstream) to 7.25 miles. We found that migration rates were similar to those found in mark-recapture studies during previous years.

The only location along the river where several tagged fish stopped migrating was the backwater pond habitat at the Oakdale Recreation Area. Of 35 tagged fish released at Orange Blossom Bridge in May, 7 (20 %) halted their migration at the Oakdale Recreation Area. Most of the tagged fish that remained in the ponds at the Oakdale Recreation Area were found in calm, open water atypical of habitat preferred by juvenile chinook. All were classified as having been eaten by predators.

Radio tracking of chinook smolts proved to be feasible and effective for identifying approximate locations and probable sources of smolt mortality. Continued tracking studies with greater numbers of tagged fish, and electrofishing to recover tagged fish classified as eaten by predators are recommended. Other release locations and tracking in the San Joaquin River should be considered.

ACKNOWLEDGMENTS

There are many people that we are indebted to for their help, support and cooperation with this research project.

- Tri-Dam Board of Directors, Steve Felte, Tri-Dam Manager, Rick Martin, Manager of South San Joaquin Irrigation District, and Wayne Marcus, Manager of Oakdale Irrigation District, for their support of this project.

- We recognize and appreciate the hard work of our field staff, including: Robert Fuller, Gina Ladd, Ben Griffith, Ryan Cuthbert, Michael Justice, Tiffani Bergeron. They often worked very long hours under stressful conditions. This work would not have been possible without their dedication.

- California Department of Fish and Game, especially Jennifer Bull, Tim Heyne, Mike Cozart, and the Merced River Fish Facility crew. Throughout the season we made many trips to the hatchery for this and other projects, and our requests were always fulfilled. We are also grateful to the US Fish and Wildlife Service, including Scott Spaulding and Craig Fleming for their support of this research.

- We are again grateful to the Army Corps of Engineers, especially the staff at the Knights Ferry office. Their support and protective surveillance of our research equipment is appreciated.

- Al Chavez and the staff of the State of California Department of Parks and Recreation at Caswell Memorial State Park. They have continued to provide us access to the river and our equipment, and provided surveillance of our equipment.

- Sgt. Fred Winters with the Stanislaus County Sheriff's Office and John Doering of the Stanislaus County Office of County Counsel for their help in providing boat access to the upper Stanislaus River, where much of this research was conducted.

- Tim Ford and the Turlock and Modesto irrigation districts for their loan of equipment.

- The Oakdale Waste Treatment Facility staff, Woody Woodruff, Lovanna Brown and John Lane for their continued support, storage, and protection of our equipment.

- Michael McElhiney with the Natural Resources Conservation Service for his assistance in locating recent aerial photos of the Stanislaus River.

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INTRODUCTION

NEED AND PURPOSE

The lower Stanislaus River is 58 miles long from Goodwin Dam to the San Joaquin River. Past studies of juvenile fall-run chinook migration have indicated that mortality of outmigrants can occur at high levels within the Stanislaus River. During 1996, the number of outmigrating chinook were estimated at two points (City of Oakdale and Caswell State Park) 31.5 miles apart. Only 34% of the estimated number of smolts passing Oakdale during peak outmigration (25 April to May 10) were estimated to have passed Caswell (Demko and Cramer 1997). Prior to April 25, less than 23% of the estimated outmigrants were accounted for at Caswell, except for fry during a brief period of sharp flow increases and high turbidity (Demko and Cramer 1996). These findings raised the question of what was causing the loss of fish; an artifact of the data, or real mortality? Conventional mark-recapture techniques were ineffective in providing information about the fate of chinook between river mile (RM) 40.1 and RM 8.6. A new method of tracking juvenile chinook was needed to identify if and where mortality occurred.

Radio-tagging of chinook smolts has been used extensively in the Columbia River Basin in recent years and has provided important new information on smolt behavior, including locations and causes of mortality. These studies have primarily used fish between 110 and 150 mm fork length. Although the average smolt length is typically less than 100 mm in the Stanislaus River, many individual smolts range from 100 to 125 mm during April and May.

Our goal for the first year of study was to conduct a pilot level effort of radio tracking naturally-produced juvenile chinook in the Stanislaus River. The following information was necessary to determine the feasibility:

- Would chinook smolts survive the implantation procedure?
- Could transmitter signals be detected consistently with the tracking equipment?
- Could the fates of tagged fish be deduced from the patterns of detection over time?
- What mix of fixed and mobile tracking was needed to yield the most useful information?
- Would migration behavior of tagged smolts parallel that determined by outmigrant trapping and mark-recapture studies?

Although radio tracking is quickly becoming a popular research tool in the Pacific Northwest, relatively little work has been conducted with chinook in California. Until recently, the relatively small size of smolts was a limiting factor due to the fact that most chinook in central California migrate to the sea as sub yearlings. However, with recent developments in battery technology, equipment manufacturers have been able to reduce the size of radio transmitters, enabling implantation into smaller fish.

Prior to the initiation of field work we had a technician from the vendor of our radio tracking equipment, Advanced Telemetry Systems (ATS; Isanti, MN), visit the Stanislaus River for an on-site assessment. It was necessary to determine the following: 1) the logistical suitability for a radio tracking study and, 2) the equipment and techniques necessary for tracking juvenile chinook in the Stanislaus River. The ATS technician had extensive experience radio tracking both aquatic and terrestrial animals throughout the world; furthermore, he had considerable experience tracking fish, including salmon in moving water environments. We selected equipment types, placement, and strategy based on ATS recommendations.

A primary component of our 1998 pilot study was to evaluate the feasibility of using radio tracking to provide meaningful measures of juvenile chinook migration and points of mortality. To achieve this goal, our study was designed to complete the following four objectives.

Objective 1. Determine if radio tags implanted in chinook smolts can be tracked by fixed station receivers and mobile tracking surveys in the Stanislaus River.

Objective 2. Determine behavior and migration rates of tagged chinook.

Objective 3. Identify areas of concentrated mortality for juvenile chinook in the Stanislaus River.

Objective 4. Estimate juvenile chinook mortality between Orange Blossom Bridge (RM 46.9) and Caswell (RM 9) in the Stanislaus River and evaluate causes.

RADIO TRACKING PRINCIPLES

Because radio tracking was chosen as the primary tool for investigating uncertainties associated with juvenile chinook outmigration, we begin with a general description of the technology principles involved. Radio transmitters (hereafter often referred to as transmitters or tags) have been used to locate fish in fresh water lakes and streams for the last 25 years (Lonsdale 1968, Winter 1977). Radio telemetry provides a means of monitoring fish that are not readily visible, and to collect data with minimal influence on behavior and health. There are two units of equipment necessary to employ this technique, a transmitter and a receiver. The transmitter, which is attached or inserted into the fish emits a pulsing radio signal which is picked up by the receiver. The receiver unit consists of an antenna which picks up the signal and the radio receiver which decodes the pulsing signal, transforming it into a audible signal (frequency) heard on headphones. (If a remote system is deployed, a data-logger is necessary to record tagged fish as they pass the receiver station.) The strength, or loudness, of the audible signal indicates the proximity of the fish bearing the transmitter. This technique can be well suited for shallow, low-conductivity fresh water systems such as the Stanislaus River.

Transmitters may emit either continuous signals (whistling) or pulsing signals (beeps). Transmitters used in this study emitted pulsing signals. Pulsing signals consume less energy, and increase transmitter battery life. The pulse length (time it is "on"), pulse rate (number of pulses per minute), and pulse interval time (time between pulses), are unique for each tag, and translate into a unique frequency allowing for identification of individual fish (Winter 1996).

The distance from which radio waves can be detected in fresh water is dependent upon four factors: 1) The conductivity of the water, 2) the depth of the transmitter in the water, 3) the frequency of the radio signal, and 4) the transmitter power. As conductivity and depth increase, transmission range decreases. In low conductivity water, 50% of the surface transmitter range may be lost at a depth of 27 ft. High frequencies (150-164 MHZ) can be used in waters with very low conductivity to track fish which utilize shallow streams and rivers, as do migratory salmon. Use of high frequency tags allows the use of smaller, hand-held receiving antennas and increases detection range. The power of the transmitter also influences the detection range, with increasing power expanding the detection range.

EFFECTS OF TRANSMITTER ON FISH BEHAVIOR AND HEALTH

One obvious concern when conducting behavioral studies is that the methods used to evaluate behavior do not alter the behavior of the study subjects, or that the behavioral effects are at least minimal and known to the researchers. We reviewed laboratory research in Oregon and Washington on the effects of radio transmitters on the behavior, swimming performance, and predation rates of juvenile chinook to determine what biases may be present in our project.

One recent study examined the effects of surgically and gastrically implanted radio transmitters on the growth and feeding behavior of 192 juvenile chinook salmon ranging in size from 114 to 159 mm in fork length. The study found that although fish with transmitters placed in their stomachs grew more slowly than the fish with surgically implanted transmitters, overall health was similar among all test fish (Adams et al. 1998). Further, the study noted that both surgically and gastrically implanted fish can survive and grow. The disadvantage to surgical implantation of transmitters was the elevated stress levels of fish due to the increased handling, anesthesia, and recovery time (Adams et al. 1998).

Tests on the Snake River in Idaho indicated that fish behavior was unchanged after tag implantation (personal communication, D. Rondorf, NBS, Cook WA). On the contrary, past studies have indicated that adverse effects on physiology and behavior increased as the ratio of transmitter weight to fish weight increased (Greenstreet and Morgan, 1989; Moor et al. 1990). However, the size of the tags used in those studies was not reported. It is important to note here that given advancements in electronic and battery technology, it is possible that tags used in those studies (~10 years ago) were larger than the smallest tags available today.

Recent unpublished research has raised speculation that size of fish may play an important role in determining how well fish perform physically with both surgical and gastric transmitters (Adams et al. 1998). Adams (Unpublished 1998) found that fish less than 120 mm had reduced swimming stamina in laboratory tests, and both surgically and gastrically implanted fish were preyed upon more than untagged control fish. However, predation vulnerability was reduced by holding tagged fish for more than 24 hours following tagging. These results indicated that predation rates on tagged fish in the Stanislaus River may be higher than for untagged fish of the same size. However, our tagged fish were larger than the average smolt which undoubtedly reduced their disadvantage compared to the average size untagged fish.

STUDY AREA

The headwaters of the Stanislaus River originate on the western slope of the Sierra Nevada Mountains in central California. The Stanislaus River and its tributaries flow westerly to the confluence with the San Joaquin River on the floor of the Central Valley. The Stanislaus River is dammed at several locations for the purpose of flood control, power generation and water supply. Water uses include irrigation and municipal needs, as well as recreational activities and water quality control.

Goodwin Dam, approximately 58.4 river miles (RM) upstream from the San Joaquin River confluence, blocks the upstream migration of anadromous fish. The river below Goodwin Dam (RM 58.4) supports fall-run chinook salmon spawning from the dam downstream to the town of Riverbank (RM 34)(Figure 1). Radio tracking was conducted from RM 46.9 (Orange Blossom Bridge) to the river mouth.

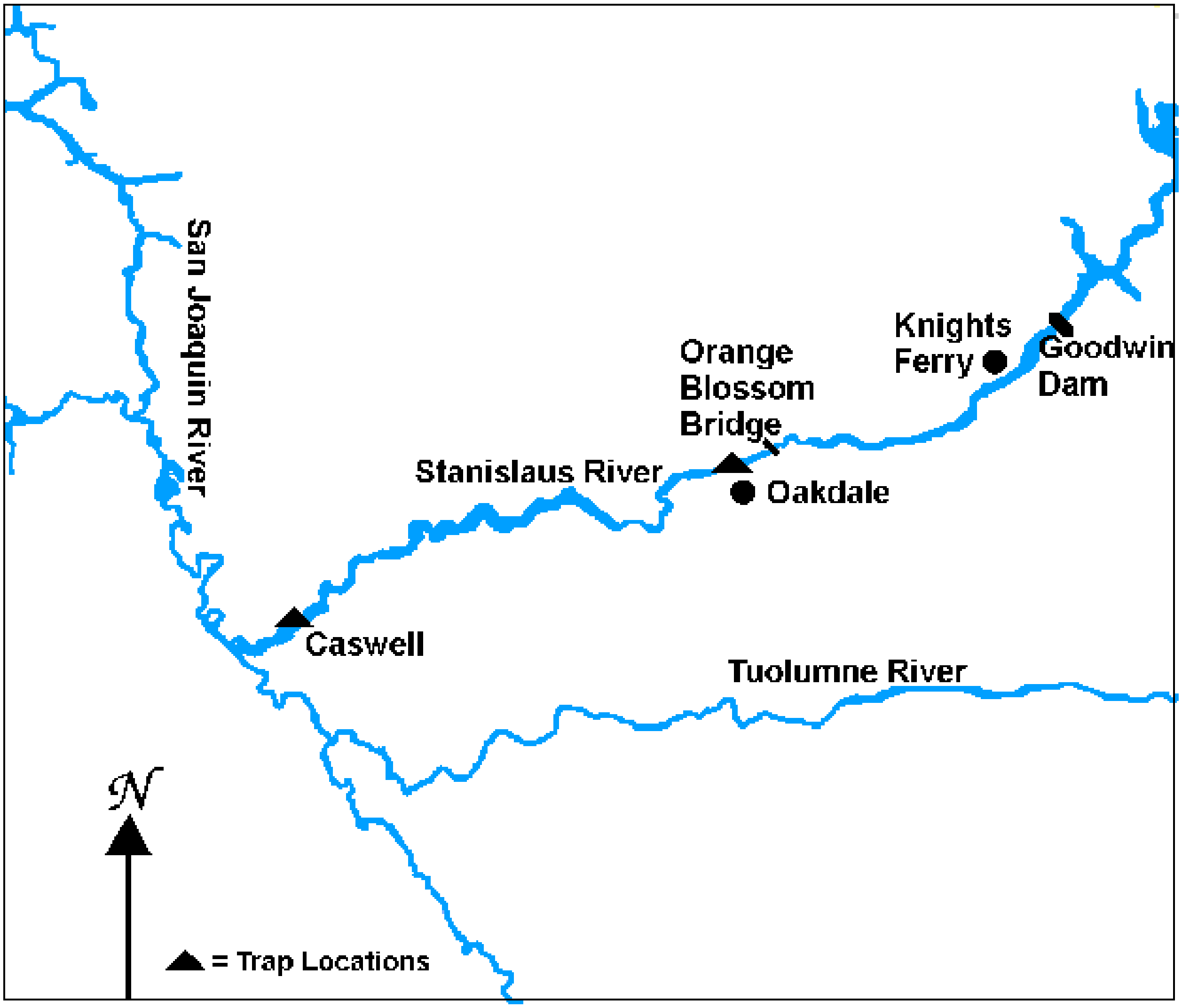

Figure 1. Location map of the San Joaquin Basin and Stanislaus River.

METHODS

RADIO TRACKING EQUIPMENT AND SURVEYS

We used both fixed station and mobile radio tracking procedures to monitor juvenile chinook movements in the Stanislaus River during 1998. Methods differed between these forms of tracking.

Fixed Station Radio Tracking

Fixed station receivers are designed to operate unattended, allowing for continuous monitoring with minimal personnel requirements. Stationary receivers were placed on the Stanislaus River at Oakdale (RM 42.25), Riverbank (RM 36), Del Rio Golf Course (RM 26.5), Ripon (RM 16.5), and Caswell Memorial Park (RM 9)(Table 1). The stations were designated fixed stations 1 through 5, with 5 being the most downstream location (Caswell) and 1 being the most upstream location (Oakdale). All radio tracking equipment was rented from ATS Inc. Equipment at each site consisted of a 4 element Yagi antenna connected to a Model R2000 or R4000 receiver and a DC II Model D5041 data logger. Power was provided to the receiver by two 12-V marine batteries. All equipment with the exception of the antenna was secured in a metal lock box at each station.

Table 1. Locations of fixed station receivers.

			GPS Coordinates					
Station	**Approximate Location**	**River Mile**	**N. Deg.**	**N. Min**		**W. Deg.**	**W. Min**	
1	1.5 miles above HWY 120	42.25	37	46	838	120	50	300
2	3 miles above Jacob Myers Park	36	37	45	379	120	55	301
3	1 mile below McHenry Park	26.5	37	45	78	121	1	230
4	1 mile above HWY 99	16.5	37	44	405	121	6	648
5	1 mile Above Caswell State Park	9.0	37	42	370	121	10	645

Detection range for each location was not precisely calibrated; however, we did field test radio tag detection at a preliminary site during our training period with ATS. Based on those tests, a tagged fish should have been within range of the receiver at a distance up to

0.25 miles.

Computer data loggers were utilized to store data collected by each receiver. Data collected consisted of the frequency detected and the time of detection. Data loggers were programmed to search for the specific transmitter frequencies of tags in smolts released into the river. Specific frequencies were removed from data loggers after fish had been detected downstream of the station, passed out of the system, or if transmitter batteries had died. Data was downloaded from the data loggers between one and three times per week.

Scan rate was programmed into each receiver. This is the time that the receiver scans each frequency before searching for the next frequency. The scan rate was set to check each frequency for 2 sec and then switch to the next frequency if no signal was detected. If a signal was detected in the first 2 sec then that frequency was scanned for 6 sec. As an example, 10 frequencies could be scanned in 20 sec if no frequencies were detected; conversely, a maximum time of 60 sec would be required for the same ten frequencies if all tagged fish were detected in one cycle.

The approximate location of each fixed station was selected based on several factors. First, we wanted to divide the river into units of similar lengths to evaluate chinook behavior and mortality within specific reaches. For example, by locating a fixed station receiver upstream from Oakdale (fixed station (FS) 1) and one upstream from Riverbank (FS 2), we could theoretically evaluate survival between RM 42.25 (FS 1) and RM 36 (FS 2). Although fixed stations can tell us if a fish dies within a reach, it cannot tell us where within a reach.

Once the approximate location for each fixed station was determined we had to choose specific locations. A specific location can be difficult to determine because many factors will impede the performance of the receiver, including noise from traffic and power lines, short wave radio antennas, and physical river characteristics. To provide the maximum detection distance it is best to locate a fixed station on a straight section of river, preferably about 1/4 mile in length. In such an area the antenna can be pointed directly upstream maximizing transmitter detection distance.

Because electrical noise can interfere with transmitter reception, it is desirable to locate the receivers as far away from urban settings as possible. In addition to reducing electrical interference, placing the stations away from the public also helps to minimize the risk of theft and vandalism. The equipment at each station is worth $5,000 to $8,000, and monetary loss can be considerably higher if it includes the loss of data with a data logger that has not recently been downloaded.

We attempted to minimize the risk of theft and vandalism by hiding the stations in brush. At each location equipment was placed in a lockable JoBox, which was locked to a tree with ½ inch cable. All the boxes were placed at sites which were densely vegetated. This allowed us to conceal the equipment back from the river anywhere from 10 to 30 feet. Co-axial cable ran from each box to an antenna located in a tree. Antennas were placed near or within branches such that they could not be easily seen by river users. “Radioactive” stickers were placed on each JoBox to discourage tampering. All stations remained secure through our sampling season.

Mobile Radio Tracking

Mobile tracking surveys took place daily during the first 6 weeks of the study and 2 to 5 times weekly during the last 6 weeks. Surveys started at the release sites: Orange Blossom Bridge (RM 46.9) in May and McHenry Bridge (RM 29.5) in June. Daily surveys continued downstream until all tags had been located or until the mouth of the Stanislaus River had been reached. Morning surveys took place between 0430 and 1200 hours. High flows, numerous obstacles, and constantly changing river conditions hindered safe boat navigation at night, and therefore prevented us from conducting as many nighttime surveys as desired.

We used a 20 ft jet boat powered by an 8 cylinder 4-stroke engine for the majority of the mobile tracking surveys. We chose the boat based on ATS's experience that 2-stroke engines can produce too much electrical noise to allow for proper detection of radio signals, and the need for a large, stable platform from which to work and carry equipment. Late in the season when our boat was being repaired, we borrowed an 18 ft aluminum boat with a 35 hp 2-stroke engine from the Turlock Irrigation District (TID), and although we did notice an increase in electrical noise, it did not prevent us from effectively detecting transmitter signals.

Equipment used on the boat for tracking consisted of a 4 element Yagi antenna, a R2000 receiver and set of headphones. When searching for large numbers of tags (i.e. more than 10) we used two technicians and two receivers to reduce the probability of missing tags. Boat speed ranged 5 - 10 mph depending on the number of tags being searched for. When fish were located several times in the same location during the same week, we attempt to frighten them, so that fish movement would confirm that the tag was still in a living fish (either a smolt or a predator that had eaten it).

It was important to determine the appropriate scan rate to use while tracking fish. Scan rate is the time that the receiver scans each frequency before searching for the next frequency. The receivers used in this study were capable of scanning rates between 2 sec and 16 minutes. During mobile surveys we utilized scan rates of 2 or 4 sec depending on the number of tags being searched for and the boat speed. Short scan rates allow for the scanning of more frequencies in a given period of time and a given distance covered by a moving boat. The disadvantage to short scan times is that tags only beeped every 2 sec so a tag could be missed if it did not beep within the 2 sec scan time. Long scan rates increase the chance of detecting a frequency when it is within range. In the case of mobile tracking, a frequency may not be detected in the 4 sec of one cycle. Scanning of 10 frequencies at 4 sec/frequency would require 40 sec/cycle, and the boat could move out of detection range of a tag within that time. Thus, it was very important to examine carefully the number of frequencies, the scan rate, and the boat speed during mobile surveys to insure that tagged fish did not go undetected.

For each tag located, the following information was recorded: 1) frequency of tag, 2) date and time, 3) description of location, 4) river mile, 5) GPS coordinates, 6) river depth where fish was holding (when possible), 7) description of habitat, flow conditions, position in stream channel (e.g. mid-channel, bank, etc.), cover, and the presence/absence of movement. Maps were also used to mark the daily location of each tag and estimate river mile location.

Radio Transmitters

Transmitters (6.8 mm X 12 mm, 0.5 g in water) consisted of mercury batteries, magnetic-reed switches, and a whip antenna dipped in an epoxy resin. Each tag had a different frequency ranging between 150 and 151 MHZ so individuals could be uniquely identified. The pulse rate of each tag ranged from 40-48 pulses per minute.

Tags had a guaranteed battery life of 10 days. During this study we discovered the average battery life (23 days) was considerably longer than the manufacturers guarantee, thus enabling us to track fish for longer periods.

Radio Transmitter Insertion Procedure

Prior to the initiation of the field work we had to determine how we would attach the transmitters to juvenile chinook. There are currently two accepted methods for attaching radio transmitters to juvenile chinook in the 105 to 150 mm length range. The methods are surgical and gastric (stomach) implantation (Figure 2).

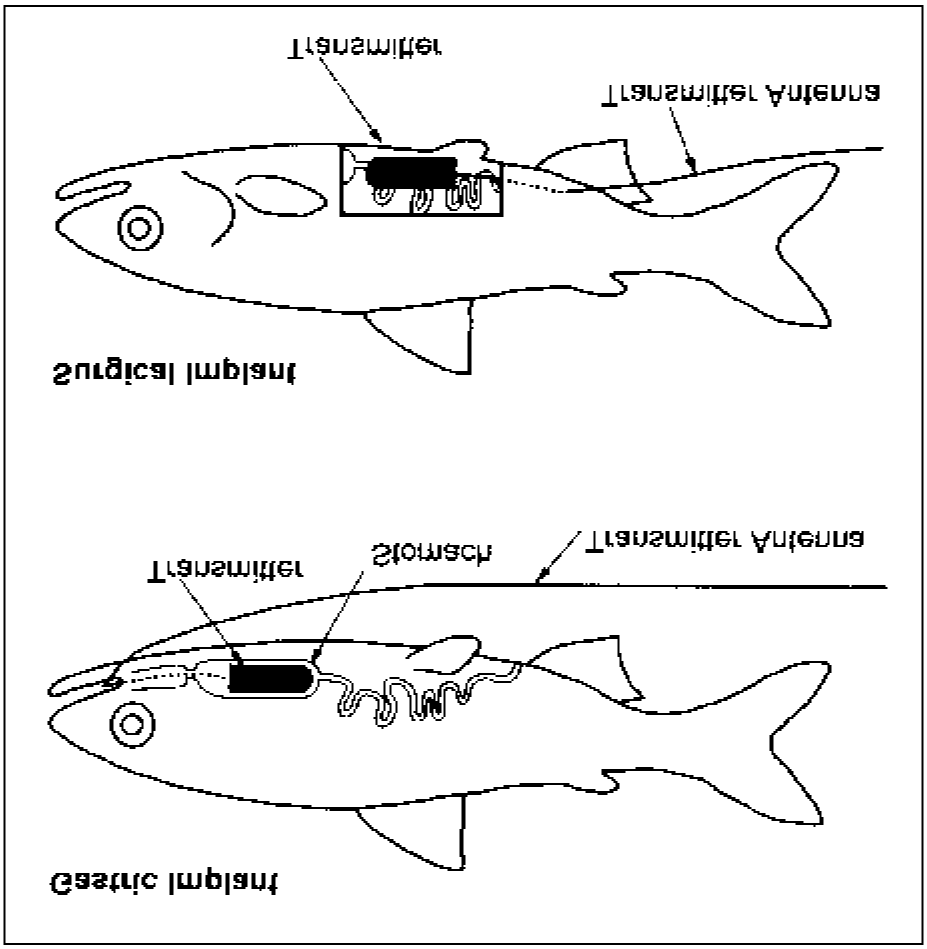

Figure 2. Drawing showing surgical and gastric radio transmitter implants in juvenile salmon (Adams et. al, 1998)

Gastric, or stomach insertion was the method chosen for this study. Because the transmitter is placed below the fish's center of gravity, a heavier tag can be used without creating balance problems (Winter 1978).

Insertion of stomach tags is quick and requires the least amount of recovery time compared to surgery. The amount of time it takes a fish to recover after implantation determined our tagging method. Since we were using fish considered to be the smallest candidates for radio tracking, we needed the smallest transmitters available. The smallest transmitters only have a guaranteed battery life of 10 days, which meant a wait of 3 to 7 days after surgery for a fish to recover would waste a majority of the transmitter's battery life. Further, with the gastric technique, we usually knew within 1 hour of the implantation procedure if a fish was not going to recover, and could easily remove the tag and implant it into another fish.

Smolts selected to carry radio transmitters were anesthetized with MS-222 in water treated with Stress Coat, a sedative, to reduce mortality due to stress. Transmitters were placed in the mouth and gently pushed past the pharyngeal bones into the abdominal cavity with a 5 mm diameter plastic probe. Insertion of tags took place under water to reduce the risk of air bubbles in the stomach cavity. The whip antenna was passed out the mouth and crimped such that it extended rearward along the fishes' lateral line. Fish were allowed to recover in a bucket with Stress Coat. Fish not recovering within a few minutes were discarded and their tags reused. Data recorded for each tagged fish was fork length (mm), origin of smolt (natural or hatchery), holding period before release, and frequency of tag (Table 2). Fish were held in the river 36-72 hours in 2 ft x 2 ft x 3 ft free standing net pens constructed of PVC and 3/16 in. Delta mesh prior to being released.

Table 2. Fish stock, length and time held prior to being released for all tagged chinook.

Release Date	Release Group	Tag Frequency	Length (mm)	Hatchery/ Natural	Held Prior to Release (h)
05/3/98	1	150.072	105	N	36
05/3/98	1	151.022	110	N	36
05/3/98	1	151.103	103	N	36
05/3/98	1	151.122	117	N	36
05/3/98	1	151.222	110	N	36
05/3/98	1	151.441	108	N	36
05/3/98	1	151.462	116	N	36
05/3/98	1	151.702	105	N	36
05/3/98	1	151.722	110	N	36
05/16/98	2	150.044	105	N	36
05/16/98	2	150.101	108	H	60
05/16/98	2	150.314	109	N	36
05/16/98	2	150.412	113	H	60
05/16/98	2	151.202	113	N	36
05/16/98	2	151.263	105	N	36
05/16/98	2	151.362	105	N	36
05/16/98	2	151.502	110	H	60
05/16/98	2	151.763	107	N	36
05/16/98	2	151.781	116	H	60
05/16/98	2	151.821	106	H	60
05/18/98	3	151.043	110	H	36
05/18/98	3	151.141	106	N	36
05/18/98	3	151.164	106	H	36
05/18/98	3	151.323	116	H	36
05/18/98	3	151.381	107	H	36
05/18/98	3	151.484	108	N	36
05/18/98	3	151.525	111	N	36
05/18/98	3	151.582	113	N	36
05/18/98	3	151.882	113	H	36
05/18/98	3	151.981	101	N	36
05/21/98	4	150.162	107	N	72
05/21/98	4	151.402	102	N	72
05/21/98	4	151.661	104	N	72
05/21/98	4	151.682	104	N	72
05/21/98	4	151.842	105	N	72
06/1/98	5	151.062	106	N	48
06/1/98	5	151.182	107	N	48
06/1/98	5	151.602	105	N	48
06/1/98	5	151.942	107	N	48
06/1/98	5	151.962	106	N	48
06/14/98	6	150.352	105	N	48
06/14/98	6	151.081	108	N	48

Release Date	Release Group	Tag Frequency	Length (mm)	Hatchery/ Natural	Held Prior to Release (h)
06/14/98	6	151.303	116	N	48
06/14/98	6	151.642	104	N	48
06/14/98	6	151.861	115	N	48
06/14/98	6	151.922	110	N	48
H = hatchery; N = Natural.					

Smolts used in this study had an average fork length of 108.5 mm (Table 3). Both natural and hatchery fish were used. All hatchery fish were from the Merced River Fish Facility. Tag insertion skills improved over the course of the study. Survival after tag insertion averaged 73% (SD=18%) and ranged 60-100% for each group. Almost all mortality observed after tag insertion was within 1 hour.

Table 3. Mean lengths (mm) and range of chinook lengths for each release group of tagged fish.

Release	Hatchery Fish		Natural Fish		Entire Group	
Group	Mean Released	Range	Mean Released	Range	Mean Released	Range
1	--	--	109.3	103 - 117	109.3	103 - 117
2	110.6	106 - 116	107.3	105 - 113	108.8	105 - 116
3	110.4	106 - 116	107.8	101 - 113	109.1	101 - 116
4	--	--	104.4	102 - 107	104.4	102 - 107
5	--	--	106.2	105 - 107	106.2	105 - 107
6	--	--	109.7	104 - 116	109.7	104 - 116

Although it was our desire to conduct controlled long-term (i.e. 2 to 3 weeks) survival tests with marked chinook in live-pens to evaluate the effects of tagging on chinook health, behavior and mortality, the lack of availability of transmitters prevented us from doing so. The demand for radio tracking equipment and transmitters is such that orders for equipment need to be placed months in advance. By the time we received approval for the project, Lotek Engineering, Inc. (Ontario, Canada) could not supply us with any tags or equipment, and ATS could only supply less than half the desired number of tags. Further, we were unable to obtain "dummy" tags (similar in size and shape to normal tags but do not operate) which are usually available for "non-tracking" tests.

RELEASE PROCEDURE

Tagged smolts were transported to the release sites in ice chests filled with river water. Before release, the condition of all smolts was checked. On one occasion a tagged chinook was behaving abnormally just prior to release and as a result was not released. Smolts were released at Orange Blossom Bridge (RM 46.9) in May and McHenry Bridge (RM 29.5) in June (Table 4). Fish were released on six different dates with 5 to 11 fish released on each date. Fish were individually removed from the ice chest and placed in moderate current along the bank. No more than one minute elapsed between the release of each fish on a given date.

Table 4. Date, time and location of releases of tagged chinook released in the Stanislaus River during 1998.

Date	Group	Location	Start Time	Water Temperature (C)
03-May-98	1	Orange Blossom	1900	14.2
16-May-98	2	Orange Blossom	1945	12.9
18-May-98	3	Orange Blossom	1930	13.2
21-May-98	4	Orange Blossom	2000	14.1
01-Jun-98	5	McHenry Bridge	2000	-
14-Jun-98	6	McHenry Bridge	2030	15.7

RESULTS AND DISCUSSION

ASSUMPTIONS

In order to interpret radio tracking results, we applied several assumptions about the behavior of chinook smolts, effects of the tagging procedure, and the radio tracking equipment. The assumptions were as follows:

1. Behavior of tagged smolts was not different from that of natural smolts. This assumption was supported by our observations of tagged smolts schooling with other smolts.

2. Based on previous studies, normal behavior of outmigrating smolts between Oakdale and Caswell during May and June is daily downstream migration.

3 Upstream migration is not considered common behavior for chinook smolts. Although some chinook may migrate upstream, we believe it is more indicative of predator behavior. If a tag was regurgitated and free in the river it would remain stationary or move slowly downstream, but not upstream.

4. Given the chance that a tagged smolt was consumed by a predator and the tag ingested, the transmitter will still emit a detectible signal.

SIZE OF TAGGED AND UNTAGGED CHINOOK

One of the concerns about the feasibility of using radio tagging on juvenile chinook in the Stanislaus River, was that few smolts reached the minimum size of 105 mm required for tagging. We easily captured enough natural migrants longer than 105 mm in the rotary screw trap at Oakdale to satisfy our sample size needs for radio tagging beginning in late April. The length frequency distribution of smolts that we tagged, compared to that for chinook captured in rotary-screw trap during May, shows that our tagged fish represent the upper 10% of fish sizes among natural outmigrants (Figure 3). Because the tagged fish are larger on average than most outmigrants, they had a distinct survival advantage during outmigration, had they not been tagged. The tag likely impaired their survival, but we did not determine the net difference in survival between the larger tagged and smaller untagged fish. Although the tagged fish averaged larger than untagged fish, it was important that they were within the size range of natural migrants.

OBJECTIVE 1. DETERMINE IF RADIO TAGS IMPLANTED IN CHINOOK SMOLTS CAN BE TRACKED BY FIXED STATION RECEIVERS AND MOBILE TRACKING SURVEYS IN THE STANISLAUS RIVER.

We found radio tracking to be a viable technique on the Stanislaus River. Smolts survived the tagging procedure and appeared to behave similarly to untagged smolts. Several tagged fish were tracked for over 30 miles. Transmitter signals were easily detected and often times up to 0.25 miles away. Tagged fish remained in the Stanislaus River for a minimum of 2 days after release, and up to 30 days. We normally located all tags at large on a given day of mobile tracking, which indicated that fish were not being removed from the river by birds or water diversions.

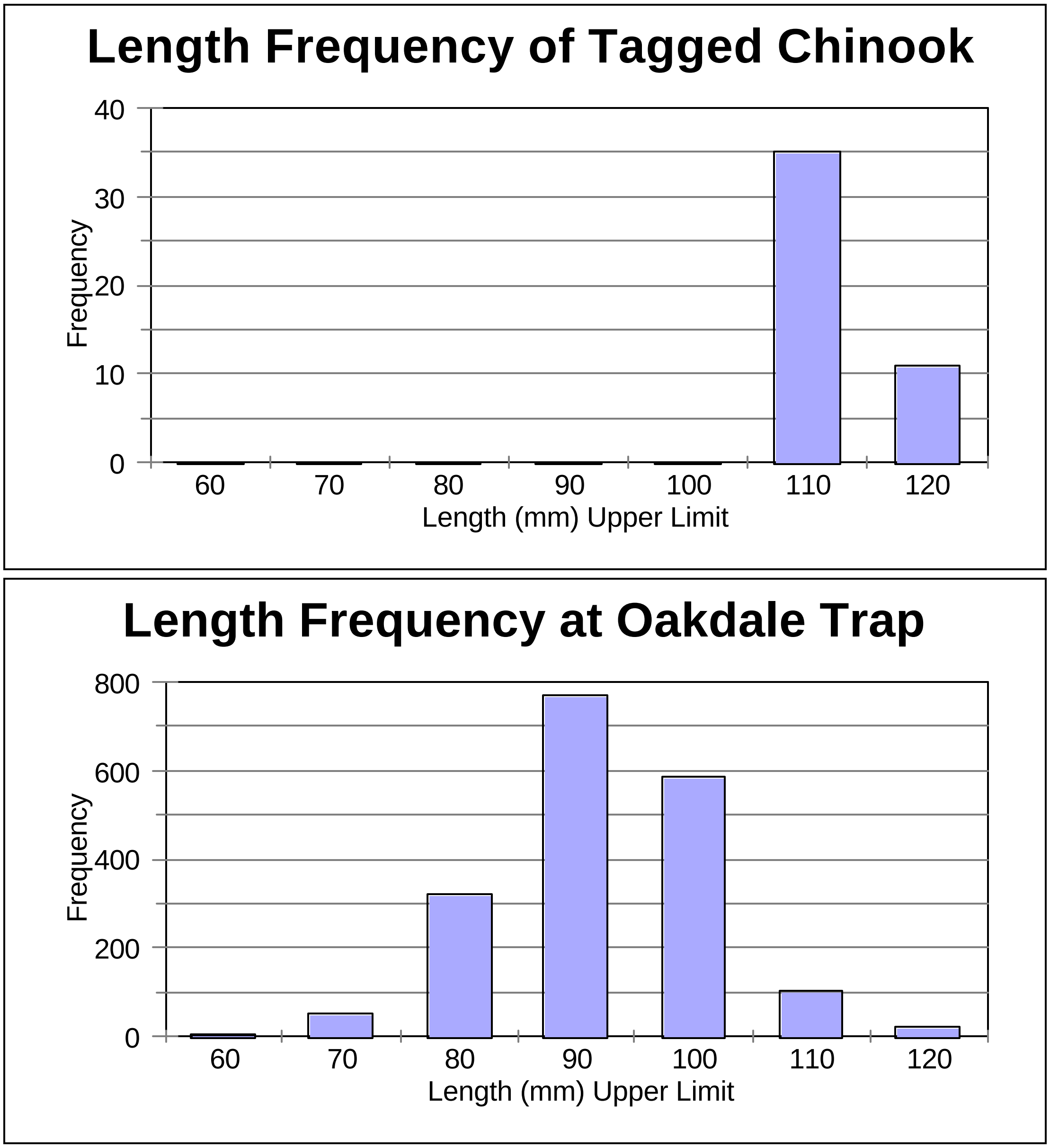

Figure 3. Comparison of the length frequency distribution of natural smolts that were radio tagged to that of all chinook captured in the Oakdale rotary screw trap from May 1 to June 14, 1998.

Fixed Station Tracking

The proportion of tagged fish detected as they passed each fixed station varied from 50% to 92% (Table 5). This was determined by comparing the number of fish detected at each station to the number known to have passed that station. Mobile tracking was successful at accounting for all tags on a daily basis; thus, we knew exactly which tags passed by each fixed station undetected. Fixed station 1 had the lowest detection rate of the functioning stations, detecting only 11 of the 22 fish that passed it (50.0%) (Table 5). Station 3 detected 11 of the 12 tagged chinook that passed it (91.7%), and station 5 detected 4 of the 5 passing fish (80%)(Table 5).

Table 5. Number of tagged chinook detected at fixed stations versus the number known to have passed based on mobile tracking detections downstream.

Station	# Tags Detected	# Tags Detected Downstream	Station Efficiency
1	11	22	50.0%
2	-	-	-
3	11	12	91.7%
4	-	-	-
5	4	5	80.0%

Five fixed station receivers were initially set up to monitor fish passage, but we had difficulties getting fixed stations 1, 2 and 4 to work properly. We ended up dismantling fixed station 2 to use the receiver to replace a malfunctioning mobile tracking receiver, and also ended up dismantling station 4 due to an inoperative receiver. As a result, we were only able to evaluate the effectiveness of stations 1, 3, and 5 (Table 5). (At the beginning of the season ATS provided us with all their remaining receivers, and no replacements were available from any vendor.)

Although we initially suspected that the more tags a station was searching for, the less effective the station would be at detecting frequencies that passed, that was not the case. Station five consistently had the most programmed frequencies but maintained a high detection efficiency. Since the number of tags appeared not to be a factor, we looked at other factors that may have affected the performance of the upstream receivers. Station 1 was situated near the city of Oakdale. Although our initial tests conducted with ATS suggested that electrical noise from the city would not interfere with our equipment, that may not have been the case. Station three was more remote than station 1, but in close proximity to the Del Rio Country club, approximately 3 miles downstream from McHenry Bridge. Of the 3 stations, station 5 was definitely the most remote site, being about 1 mile upstream from Caswell State Park. Although based on our initial electrical noise tests conducted with ATS, and the fact that electrical noise was seldom a problem during mobile surveys, we can only speculate that perhaps it affected the performance of station 1.

Mobile Tracking

We were able to detect all tags on each mobile survey and determine locations at which any tagged fish eventually stopped. The results of the mobile tracking enables us to evaluate specific locations of loss and the probable causes of loss.

Mobile tracking allowed us to determine where in the stream channel fish were located, due to the strength of the signal emitted by the radio transmitters, and the sensitivity of the receivers. On two occasions we were able to see tagged chinook (their antenna were visible) in schools of juvenile chinook in shallow water habitat. Determining precisely where fish were located served several useful purposes, including providing insight as to what types of habitat juvenile chinook utilize during their outmigration (see Habitat Utilization under Objective 2). Secondly, the patterns of movement and choice of habitat enabled us to deduce which fish had probably been eaten by a predator. This deduction was important for assessing causes of mortality to tagged juvenile chinook.

Another benefit of mobile tracking was that equipment failures were identified when they occurred, so equipment could be fixed or surveys suspended until the equipment was fixed. In the case of fixed station receivers that were only checked periodically, we sometimes found they had not been operating for up to 2 days.

The primary drawback to mobile tracking is the high cost. Although mobile surveys can be reduced from daily to 2 or 3 times a week to reduce costs, each survey requires a boat and at least two crew members. Additionally, because of the distance traveled on the river, and the time required to properly care for the equipment, each survey usually required a full day of effort. The use of a boat is also expensive; it required about 40 gallons of gas per survey, and daily maintenance of the boat was time consuming.

OBJECTIVE 2. DETERMINE BEHAVIOR AND MIGRATION RATES OF TAGGED JUVENILE CHINOOK.

Tagged chinook behavior was compared to what we know of natural chinook behavior. We only attempted to evaluate macro behavior (i.e. timing of migration, rate of migration, and habitat preferences) as opposed to micro behavior (i.e. foraging behavior, swimming ability). Overall behavior was comparable to behavior of untagged smolts observed during the screw trap studies (timing and migration rates) and in this study (habitat).

Habitat Utilization by Tagged Juvenile Chinook

During the course of our mobile tracking surveys we attempted to locate each tagged chinook as precisely as possible. Our ability to precisely determine the locations of tagged fish was dependent on several factors, most important of which was the signal strength and how close we could physically get to where the fish was located. Low signal strength only prevented us from determining precise locations a few times when tag batteries were about to die, or when we received a signal that changed locations quickly.

The Stanislaus River is a low gradient, meandering stream with low velocity between Oakdale and Caswell. The channel is deeply entrenched with a narrow floodplain and limited stream habitat complexity. The riparian corridor consists largely of farmland, which often abuts the river channel. Instream cover for juvenile salmonids consists of undercut banks, woody debris, water depth, and overhanging vegetation.

Cover was the dominant factor associated with live chinook found during daytime mobile tracking surveys. Tagged chinook were usually found along the banks, amongst either small woody debris or live brush. We also visually observed tagged smolts schooling with natural smolts among submerged brush. These habitats typically ranged from 1 ft to 6 ft in depth. Since the majority of the lower river could be categorized as glide-type habitat (i.e. wide uniform bottom, low to moderate velocities, no turbulence, uniform substrate), we could not evaluate the preference of juvenile chinook for pools riffles and glides.

Another habitat type where we suspected we might find smolts was in backwater areas where there is little or no current, and good cover near the banks. The Stanislaus River downstream from Oakdale has a significant number of “backwater” type habitat units, most of them are under approximately 200 square feet of surface area. The two largest backwater habitats are the large ponds near the Oakdale Recreation Area, and a large pond near McHenry Park. During our mobile surveys we always searched these habitats, but only found chinook in the Oakdale Recreation Area backwater. Twice we found tagged chinook utilizing other small backwater areas, and those two locations would be better categorized as eddies than backwater. As discussed later, many of the tagged fish located in the Oakdale backwaters behaved as though the fish had been eaten by a predator. We conclude that juvenile chinook make little use of backwater during their outmigration from the Stanislaus River.

Time of Migration of Tagged Chinook

Because fixed stations monitored movement of tagged chinook 24 hours per day, we were able to use data collected by the continuously operating receivers to determine the time chinook were most actively migrating. Fish movement was concentrated near dusk (between 0400 and 0759 hours) and dawn (between 1900 and 2359 hours) with peaks at 0000, 0600 and 2100 hours (Figure 4).

Of the 37 tag detections made by the fixed station recorders, only 6 detections were made during the daylight hours (from 0800 to 1800), and 4 of these could be considered periods of transitional light at dawn and dusk (0800, 0900, 1700, and 1800). Of the two fish that were detected during mid-day, one survived to Caswell, which may indicate that at least some migrating smolts move during daylight hours. During our mobile surveys we never observed a tagged chinook actively migrating during the day. Only on one occasion was an actively migrating fish tracked as it moved downstream, and it occurred shortly before dawn. The timing of smolt movement is congruent with our findings from migrants captured in rotary-screw traps. Screw trap catches of juvenile chinook in Stanislaus River since 1993 have shown that juvenile chinook are primarily captured during darkness, with peak catches occurring soon after dark and just prior to light, except during periods of high turbidity (Demko and Cramer 1993; 1995; 1996).

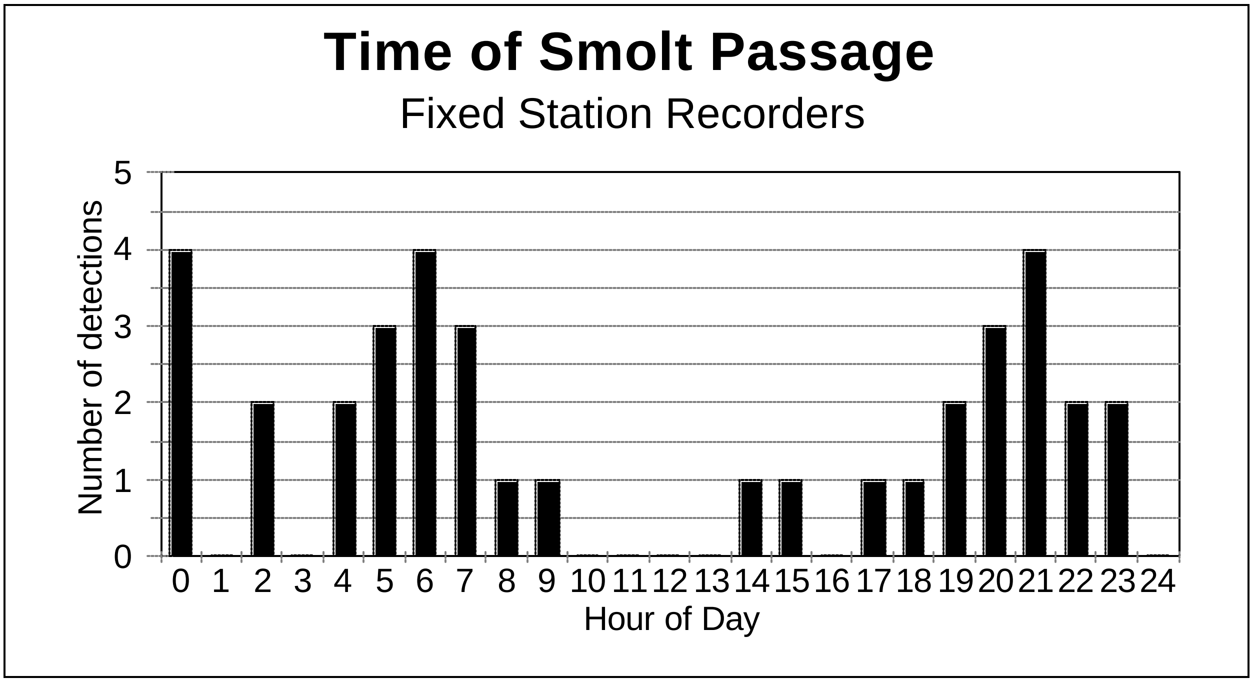

Figure 4. Diurnal pattern of smolt passage, as determined from tag detections at all fixed stations combined during 1998.

Migration Rates of Tagged Chinook

Of the five tagged chinook that successfully migrated to the Caswell Park (station 5 at RM 9), three completed the journey in 2 days, one in 3 days, and one took somewhere between 6 and 10 days (Table 6). One fish traveled 28.9 miles in 24 hours, and distances between 11 and 20 miles per 24 hours were observed. The fish (151.362) with the longest travel time to Caswell was the only surviving fish that halted its migration for any period of time.

Table 6. River mile and number of days after release of each detection for the five tagged fish detected passing the Caswell fixed station 5 at RM 9.

	Days After Release								
Frequency	**1**	**2**	**3**	**4**	**5**	**10**	**14**	**18**	**27**
152.122	27	9	9		9.5				8.75
150.314	33.5	9						5.25	
151.362	18	18	18	18	17	7.5	6.75	5	
151.502	36	9							
151.164	37.8	26	9						

The unique behavior of fish 151.362 indicates that although fish can stop and then restart their migration after a period of days, it may be a pattern displayed by a small percentage of outmigrants. It is possible that fish migrating quickly are less susceptible to predation, thus accounting for the rapid migration rate for most fish detected reaching Caswell. Findings of both slow and rapid migration are congruent with previous mark-recapture studies on the Stanislaus. Juvenile chinook did not generally pause for extended periods between RM 40.1 and RM 8.6, as shown by the short travel time (2 to 6 days) of marked fish and similarity in mean lengths of natural fish captured at Oakdale and Caswell. However, one recaptured fish out of 8 in 1996 (released at Oakdale) took 24 days to reach Caswell (Demko and Cramer 1996).

Rapid downstream movement by juvenile chinook was also supported by fixed station data. On most occasions fish were detected only once or twice before moving out of the receiver's range, indicating fish were actively migrating. Of the 37 tag detections (summed for all stations) 27 fish were detected only once while passing through the fixed station's range. Six tags were detected twice while passing and 4 were detected 3 to 6 times.

We calculated distance traveled on the first night after release to determine average nightly distances traveled by smolts (Figure 5). We used this measure because only on the first night did we know their exact location at the beginning of the night. Tagged chinook were also assumed to be alive the first night following release. Distance traveled the night following release for fish released in May averaged 7.1 miles and ranged from 0.15 to 28.9 miles, with the majority migrating between 5 and 13 miles. Tagged chinook released in June traveled shorter distances on the first night, averaging only 1.8 miles and ranging from -2.75 (upstream) to 7.25 miles. The cause of slower migration in June is not clear, but the consistent pattern indicates that the change in migration rate between May and June was probably real.

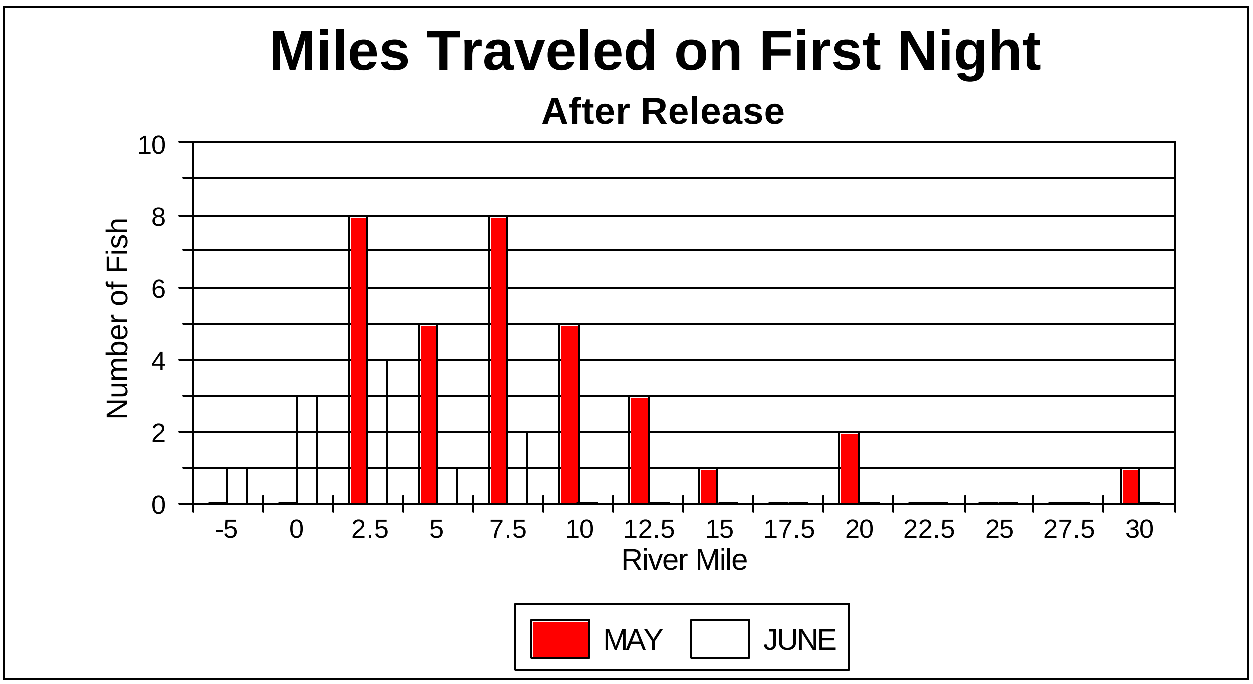

Figure 5. Distance traveled on night after release during May and June for all tagged juvenile chinook.

We compared our average mileage traveled the night following release during May (7.1

miles/night) to estimates made previously during mark-recapture experiments in 1993 through 1997 (see Demko and Cramer 1993; 1995; 1996; 1997). Fish were marked and released from Knights Ferry (RM 54.7) at night in 1995 and 1996, and recaptured at Oakdale for a total distance of 14.2 miles covered. In 1995, 70% of the recovered fish took 2 nights to complete the distance (7.1 miles/night) and another 20% took 3 nights (4.7 miles/night). This was similar to the average distance traveled during May by fish in the radio tracking study.

However, marked fish were also released at Knight Ferry in 1996, and 90% of the fish recaptured reached Oakdale the next morning, for a migration rate of 14.2 miles/night. Thus, fish traveled faster in 1996 than our tagged fish in 1998. Flow may influence migration rate, and flows were 586 cfs in 1995, 1,595 cfs in 1996 and about 2,000 cfs in 1998 during these tests. It should be noted that marked fish in previous years were released from Knights Ferry (RM 54.7) and recaptured at the Oakdale site above the ponds, whereas fish in 1998 were released at Orange Blossom Bridge and had to pass through the ponds at Oakdale Recreation Area, which may have slowed their migration. We conclude from these observations that tagged fish migrated downstream at rates that were in the range of previous observations for untagged fish.

OBJECTIVE 3. IDENTIFY AREAS OF CONCENTRATED MORTALITY FOR JUVENILE CHINOOK IN THE STANISLAUS RIVER.

Radio tracking results indicated that Oakdale Recreation Area was a potential area of high mortality. More tagged fish ended their migration at the Oakdale Recreation Area than any other location in the river (Figure 6). Of the 35 tagged chinook released at OBB during May, 7 (20%) never made it past the ponds at the Oakdale Recreation Area. The primary pond at Oakdale Recreation Area where fish were found is 7.6 miles downstream from the release location, which corresponds to the average distance traveled by smolts the first night after release.

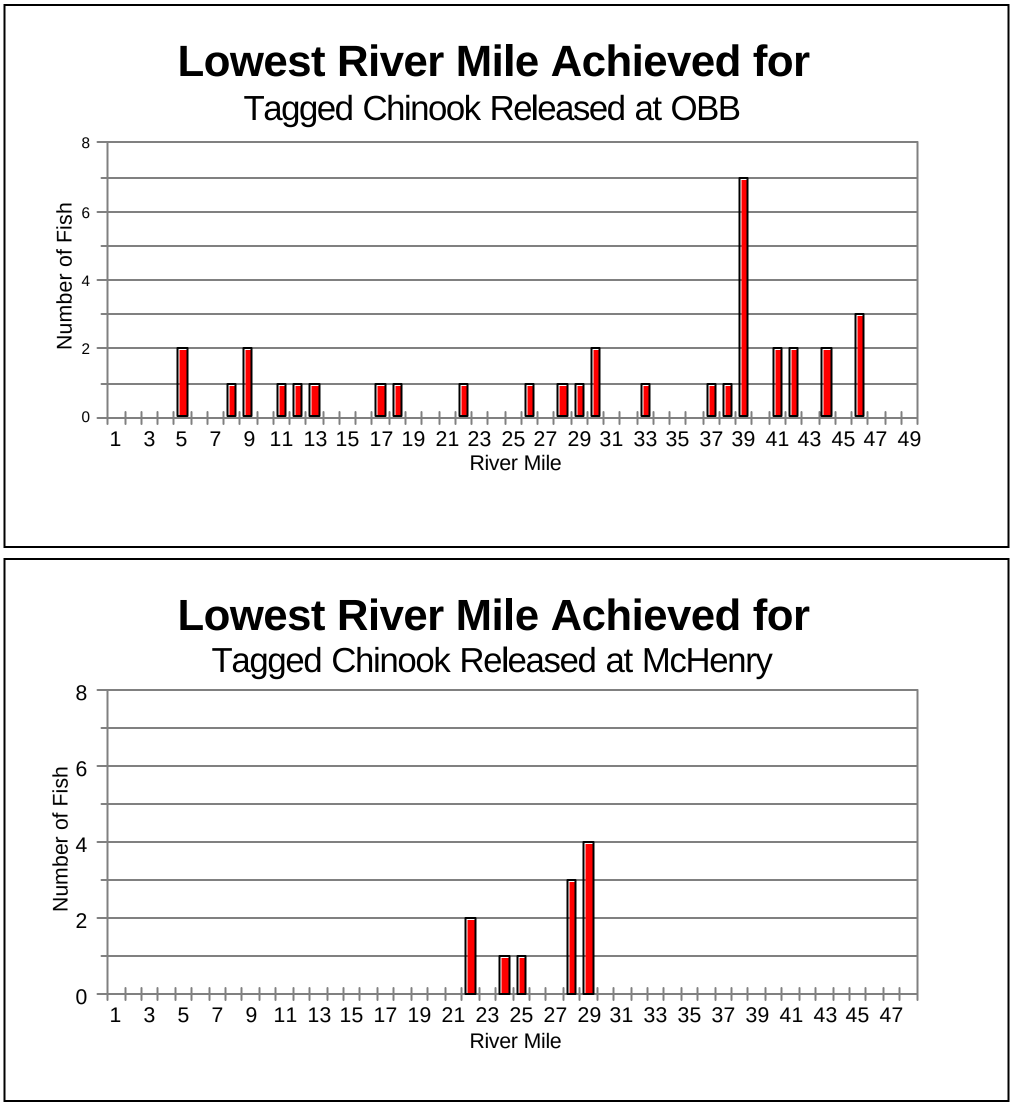

Figure 6. Frequency histogram of lowest river mile achieved by all tracked fish.

The Oakdale Recreation Area is an Army Corps of Engineers public recreation area south-west of Oakdale, located on the north side of the Stanislaus River (Figure 7). Beginning just below the site of our screw trap at RM 40.1, the Stanislaus River widens and there is a significant reduction in water velocity until approximately RM 39. The dominant substrate in the area is sand, with much of the area consisting of sandbars that are between 1 and 2 ft deep at flows of 1,500 to 2,000 cfs.

Within this area are several ponds which were created years ago by gravel mining. Although there are at least three ponds in the area connected to the river, we located all but one of the tagged fish that ended their migration in this stretch of river, in the largest pond through which a majority of the river flow is diverted. This large pond at the end of the access road is the deepest and most popular location within the recreation area for angling. The main pond averages about 8 ft deep, with a maximum depth of approximately 15 ft, and the thalweg of river current passes through the middle of the pond.

All of the tagged fish detected in the large pond were found in open water where no cover was seen. All of the tags also moved about in the middle of the pond as they were tracked. Two of the seven tags were also found near banks with cover on occasion.

Of the seven tags which stopped downstream movement in the ponds, four also moved upstream. Each of these had been previously detected in open water in the pond. This behavior would be typical of striped bass or other predatory fish and atypical of smolts. Therefore, we conclude these tagged fish were eaten by predators at the Oakdale Recreation site. We were unable to visually verify this conclusion.

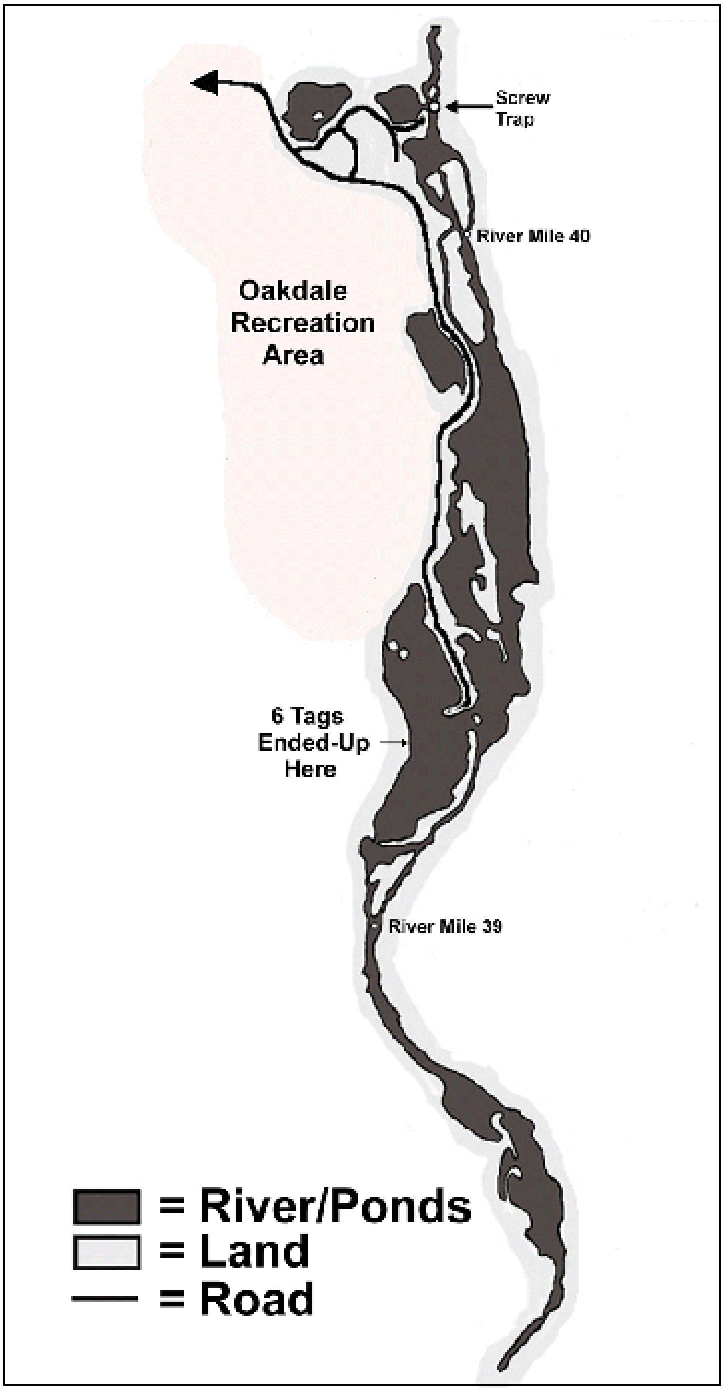

Figure 7. Location map of the Stanislaus River showing the slow-water and pond environments between RM 39 and 40.

Although Figure 6 indicates that the second highest number of tagged fish halted their migration near RM 46, one of these tagged fish never moved more than a short distance after release, and we determined it died shortly thereafter, probably the result of the tagging procedure. The two other fish exhibited significant localized movement and were occasionally found on the opposite bank, and mid-channel.

In June we conducted two separate releases downstream at McHenry Bridge (RM 29.5). Of the 11 fish released during June at McHenry Bridge, none made it to Caswell. In fact, RM 22.25 (approximately 7.25 miles downstream from release) was the lowest river mile reached by any of the fish released at McHenry Bridge (Figure 7). Two of the tagged fish never moved more than 100 yards from the release site, and we assumed they died as a result of the tagging procedure (151.062 and 150.352). Four of the 11 fish ceased migration after encountering deep holes in the river. We were unable to determine if predator concentration was higher below the release site, or if some other factor accounted for the poor performance of the fish released at McHenry. All of the fish released at McHenry in June were natural fish, and temperature and other physical variables were similar to earlier releases made at OBB.

OBJECTIVE 4. ESTIMATE JUVENILE CHINOOK MORTALITY BETWEEN OBB (RM 46.9) AND CASWELL (RM 9) IN THE STANISLAUS RIVER AND EVALUATE CAUSES.

Survival of Tagged Chinook to Caswell

The simplest method of estimating survival from OBB or McHenry Bridge to Caswell (RM 9) is by dividing the number of tagged fish that passed Caswell by the number of tagged fish released. Forty-six tagged fish were released but three were assumed to have died upon release. Given that 5 of 32 tagged fish released at OBB reached Caswell, average survival was estimated at 15.6%. No fish released at McHenry Bridge reached Caswell, so the survival from that site in June was estimated to be zero. We are confident that no fish reached Caswell without being detected because mobile tracking allowed us to account for all tags each day. Because of small sample size and possible modification to fish behavior by the radio tags, we cannot be confident that the estimates of mortality are representative of untagged fish. The more valuable use of this data was to identify locations of concentrated morality.

Evaluation of Tagged Chinook Mortality

We examined patterns in the data to determine if mortality of tagged fish could be linked to tagging procedure, predation, entrainment, turbidity, flow, fish size, or fish stock (hatchery/natural).

Effects of Tagging on Tagged Chinook Mortality

Three fish (frequencies 151.763 (release 2), 151.062 (release 5) and 150.352 (release 6)) were determined to have died shortly after release. These fish never moved far from the point of release. Whereas other tags that stayed in the same general location for long periods of time exhibited upstream, downstream, or lateral movement, these three fish remained in the same location for the duration of the tag life. We concluded that the fish either coughed up the tags shortly after release (this was witnessed 1 time while holding fish prior to release), or the tag remained inside the fish and the fish died. We assumed mortality was a result of the tag implantation. The three tags were subtracted from the effective release number (46) resulting in a total of 43 tagged live fish.

In addition to the mortality due to the tagging procedure there are several other factors associated with tagging that may also have influenced migration and survival rates of tagged fish. Not only were all of the fish that survived to Caswell from the first three groups, but distance traveled, and migration rates were substantially higher for the first three groups, than the last three groups (Table 7). For instance, migration rate the night after release ranged from 7.1 to 9.0 miles for the first three release groups, but from -0.1 to 4.2 for the last three groups (Table 7). Further, average total miles covered ranged from 17.9 to 19.5 miles for the first three groups, but only 0.5 to 4.8 for the last three groups.

Water temperature did not appear to be related to these differences. Average daily temperature at OBB, McHenry, and Caswell differed only slightly between releases (Figure 8). Whereas temperatures were slightly higher for groups 5 and 6, temperatures for group 1 were similar to group 5, and group 1 performed well.

We believe the duration fish were held before being tagged may have influenced their performance after release. Normally we tagged the fish most recently captured in the rotary screw trap that were large enough. As “new” fish were captured we released the old ones to ensure that we always tagged the healthiest fish available. Later in the year we caught fewer chinook that were large enough to use for radio tracking, which meant that fish were held longer prior to being tagged. The increased holding time prior to tagging, and the small increases in water temperature, may have resulted in additional stress which affected their performance after release.

Table 7. Average lengths, distances traveled and migration rates for each tag release group.

Release	Release Date	Release Location	Average Length	Average Lowest RM	Avg. Total Miles Covered	Average Migration Rate	Group Survival
1	05/03/98	OBB	109.3 (4.8)	27.6 (12.7)	19.3 (12.7)	7.3 (8.0)	12.5%
2	05/16/98	OBB	108.8 (3.8)	27.4 (16.1)	19.5 (16.1)	9.0 (8.2)	37.5%
3	05/18/98	OBB	109.1 (4.4)	29.0 (12.8)	17.9 (12.8)	7.1 (3.1)	10.0%
4	05/21/98	OBB	104.4 (1.8)	43.8 (2.8)	3.1 (2.8)	2.5 (2.8)	0.0%
5	06/01/98	McHenry	106.2 (0.8)	24.7 (2.9)	4.8 (2.9)	4.2 (3.4)	0.0%
6	06/14/98	McHenry	109.7 (5.0)	29.0 (0.6)	0.5 (0.6)	-0.1 (1.4)	0.0%

Lengths are in mm. Numbers in parenthesis are standard deviations.

Average migration rate is night after release.

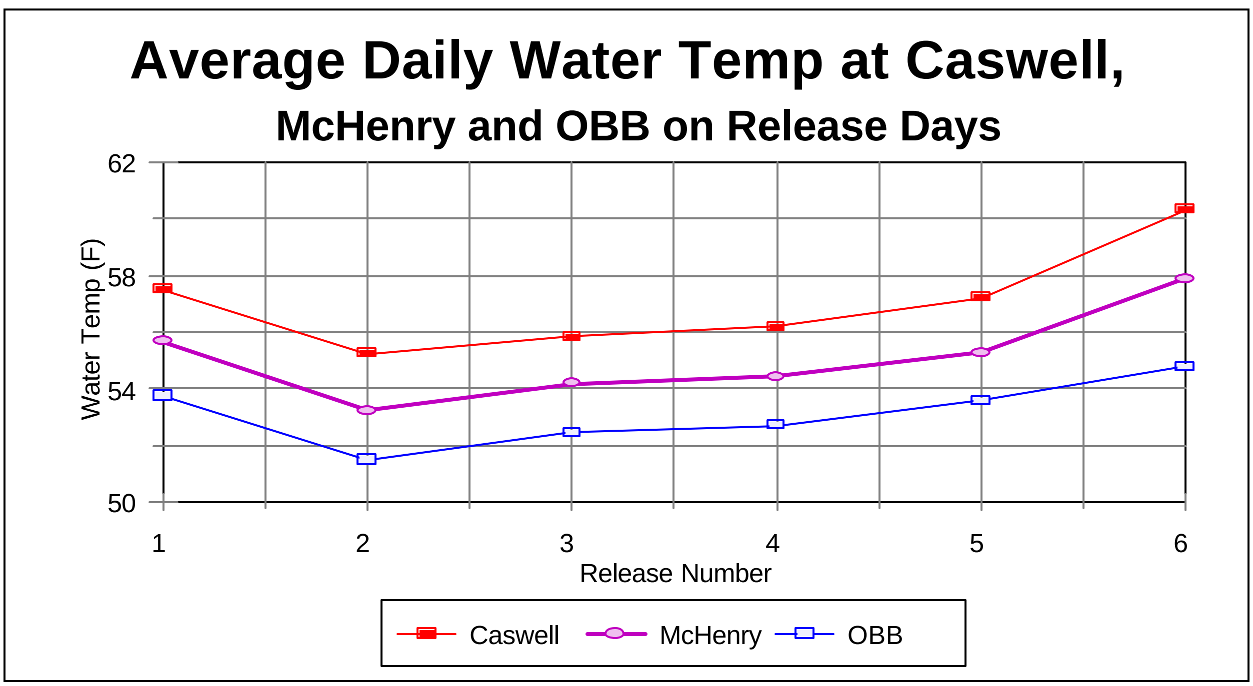

Figure 8. Average Stanislaus River temperature at OBB, McHenry and Caswell on days that tagged fish were released. Data from Onset continuous temperature recorders.

Effects of Predation on Tagged Chinook Mortality

We estimated 70% to 88% of tagged fish may have been eaten by predators. The upper estimate of 88% was calculated by including all fish whose fate we classified as "unknown" in addition to those classified as preyed upon. All classification of fish fate were based on patterns of tag movement and habitat chosen for holding, so we cannot be certain of the accuracy of these classifications. Observational characteristics that were used in this classification are described in Appendix 1.

When a fish dies or is eaten by a predator, the transmitter continues to operate until the battery expires. The extent that consumption of a tagged chinook by a predator alters the detectible signal of a tag is not known. Although changes in behavior of tagged fish we were tracking indicated they were probably eaten by predators, many of the tags seemed to remain within the stomachs of mobile predators for as long as 1 to 2 weeks. This was frequently followed by no movement (excretion or regurgitation of tag).

Behavior of 46 tagged fish were scored by the system described in Appendix 2, and their probable fate was classified based on that score (Appendix 3). Five of these 46 fish were considered to survive to Caswell, but their fate beyond Caswell was not determined Three of the 46 fish were considered to have died shortly after release. Thirty fish (70% of 43 released) were categorized eaten by predators and 8 fish were classified as unknown. Six of the unknown fish were from the first release. We were unable to track fish during their second week after release 1, because the boat had to be taken in for repair. Unfortunately we did not have another boat and were forced to suspend mobile tracking for a week. Thus we were unable to collect enough data on the fish in the first release to evaluate mortality with fates classified as unknown.

The 30 fish categorized as eaten by predators had scores ranging 3-6 (a score of 6 is the highest probability of predation). Three fish scored 3. Although 3 was considered a low score and in some cases too ambiguous, in these three fish we found other evidence to support predation. Substantial movement was documented in all three fish as recorded by differing river mileage and GPS units between days. Scores between 4 and 6 were considered the most likely candidates for predation. Although a score of four was considered low, each fish with this score showed substantial movement within a single area between days, but not downstream. We considered this behavior to be more descriptive of a predator than an outmigrating smolt.

Upstream movement was detected for 12 tagged fish. Three of these fish moved upstream within a day of release, and nine moved upstream during 5-10 days after release. Eleven of these fish eventually were classified as eaten by predators. Upstream migration ranged 0.2-6.25 miles. The dramatic change in migration strongly indicates mortality due to predation. We did not rule out the possibility that some chinook moved upstream. Our ranking system was designed for comparison to observational data. Had we seen a tag move upstream but shown no other signs of predator behavior described in ranking system, we might consider the individual to be a chinook moving upstream. We did not find this to be the case for any of the fish moving upstream.

Survival appeared higher for release groups in May when chinook abundance was higher (Figure 9). Since predation was identified as a probable cause of mortality, our observations would be consistent with a pattern of depensatory mortality. That is, if predators consume a relatively constant number of juvenile chinook, then that number represents a smaller portion of the outmigrants when their abundance is high. Survival of smolts might also have dropped if predator abundance increased. Predators such as striped bass and squawfish are migratory and their concentrations may have changed in time and space.

Predator abundances may have been higher in June than in May at the McHenry Bridge release site, but we had no data to test such a theory.

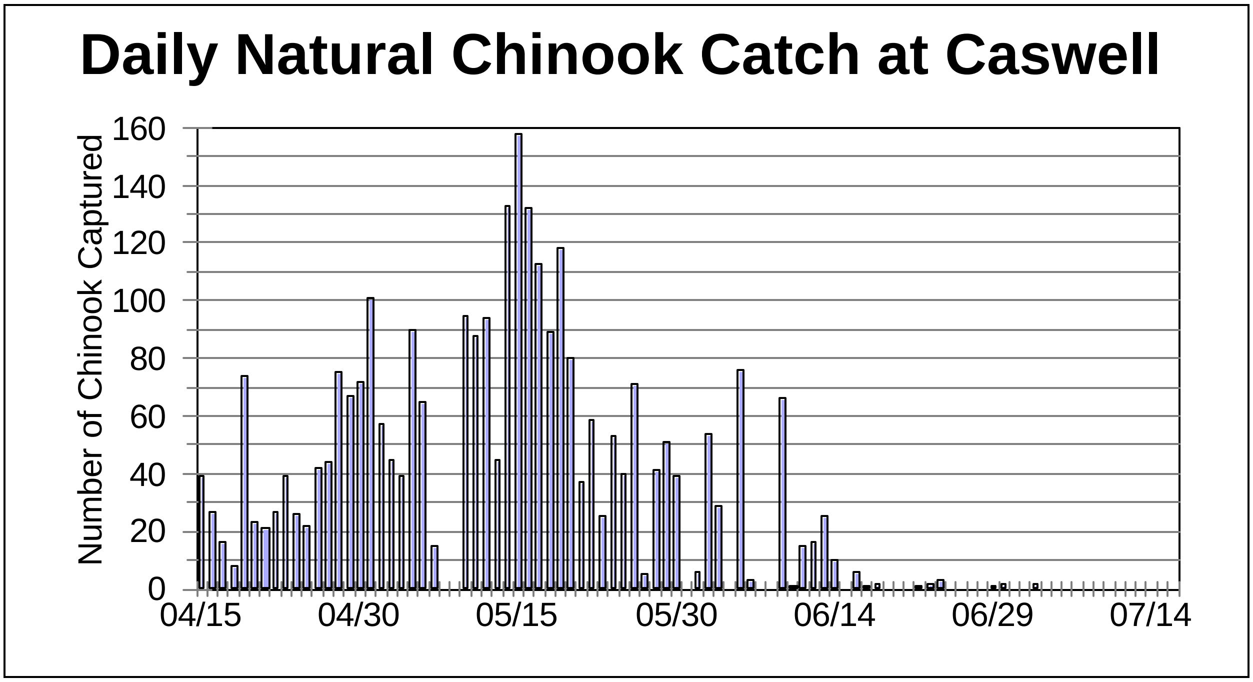

Figure 9. Daily catches of juvenile chinook in the rotary screw trap at Caswell (RM 9) after April 15, 1998.

One clear case of predation came from two tags that were apparently eaten by the same fish. These two tagged fish (150.412 and 151.525) were released on different dates (May 16 and 18, respectively). Frequency 150.412 moved slowly after release traveling only about 2 miles per day. Both tags were detected passing fixed station 1 (RM 42.25) at 0209 hr on May 21. Frequency 151.525 was next located at river mile 38 downstream of the Oakdale Recreation Area on May 21 at 1048 hr. Tag 150.412 was not located that day but may have not been scanned for before leaving the range of detection. Both tags were located

again the next day (May 22) at station 1 at 0030 hr (151.525) and 0031 hr (150.412). This means that both tags passed the station at the same time on two separate occasions. They were then found upstream at mile 44.25 where they remained until their batteries died. At river mile 44.25 both signals were observed quickly darting across the channel from bank to bank and darting to mid-channel in strong current, suggesting that
the tags were in a larger fish. Technicians also noted a change in tone of frequency 151.525. The tone, described as "muffled" and "deeper pitched," could have sounded different due to the added insulation of the predator's body.

During our daily boat trips on the river, we frequently observed anglers catching large game fish. We saw many striped bass (Morone saxatilis) that had been caught by anglers, one of about 30 pounds and most between 8 and 15 pounds. Catches were primarily during May and June, which coincided with the period of our radio tracking study. A considerable number of largemouth bass (*Micropterus salmoides*) and smallmouth bass (*Micropterus dolomieui*) were also captured, leading us to speculate that if predation losses of juvenile chinook are occurring, striped bass, largemouth bass, and smallmouth bass are probably the primary causes, especially in the Oakdale Recreation Area.

Effects of Entrainment on Tagged Chinook Mortality

We found that entrainment of tagged fish in irrigation diversions was negligible, because only one fish (151.722) disappeared from the river prior to the 10-day battery life expectancy. The one fish that disappeared was located at 0950 and 1154 hrs the day after release at RM 44.5. It was found in the middle of the river channel, and was definitely moving on both occasions, but never located again. It's possible the tag could have malfunctioned, or that the fish was eaten by a terrestrial or avian predator. Irrigation pumps are small and few in the area where the fish was last detected, so entrainment was unlikely.

It should be noted that 1998 was a high water year. Although we have no data as to the actual pumping rates, it is probable that withdrawals from the river were low relative to dry years. Additionally, the percentage of flow diverted into riparian pumps during spring of 1998 was probably small.

Entrainment of juvenile chinook into irrigation diversions has been speculated as a substantial source of mortality to chinook in the Central Valley. Research in the Sacramento River has shown that losses of juvenile chinook at irrigation diversions can be significant, but that the majority of the small diversions (i.e. less than 100 cfs) do not entrain significant numbers of salmon (Demko and Cramer 1993). That finding may explain why we did not observe entrainment in the Stanislaus River in the area between RM 47 and RM 15 where most of our tags were tracked.

Effects of Flow and Turbidity on Tagged Chinook Mortality

We examined flow at OBB and turbidity at Oakdale and Caswell for possible correlation to predation rates that we observed. River flow remained relatively constant during most of the period we were releasing and tracking juvenile chinook. Flow did drop from 2,000 cfs to 1,500 cfs for a 15 day period between June 2 and June 16 (Figure 9), which meant that both of the last two tag groups released at McHenry Bridge encountered the lower flow. However, survival was 0% for each of the last three release groups, the first of which was released 12 days prior to the drop in flow. Thus, reduced flow could not be distinguished as a factor relating to survival.

Turbidity at Caswell and Oakdale fluctuated between approximately 2 and 10 Nephelometric Units (NTU's) for most of the period, with consistently higher turbidity levels at Caswell (Figure 10). There was no trend in turbidity during our study. Thus, neither flow nor turbidity showed a correlation to our limited observations of survival. This lack of correlation could be due to small sample size and the relatively small range of variation in flow and turbidity.

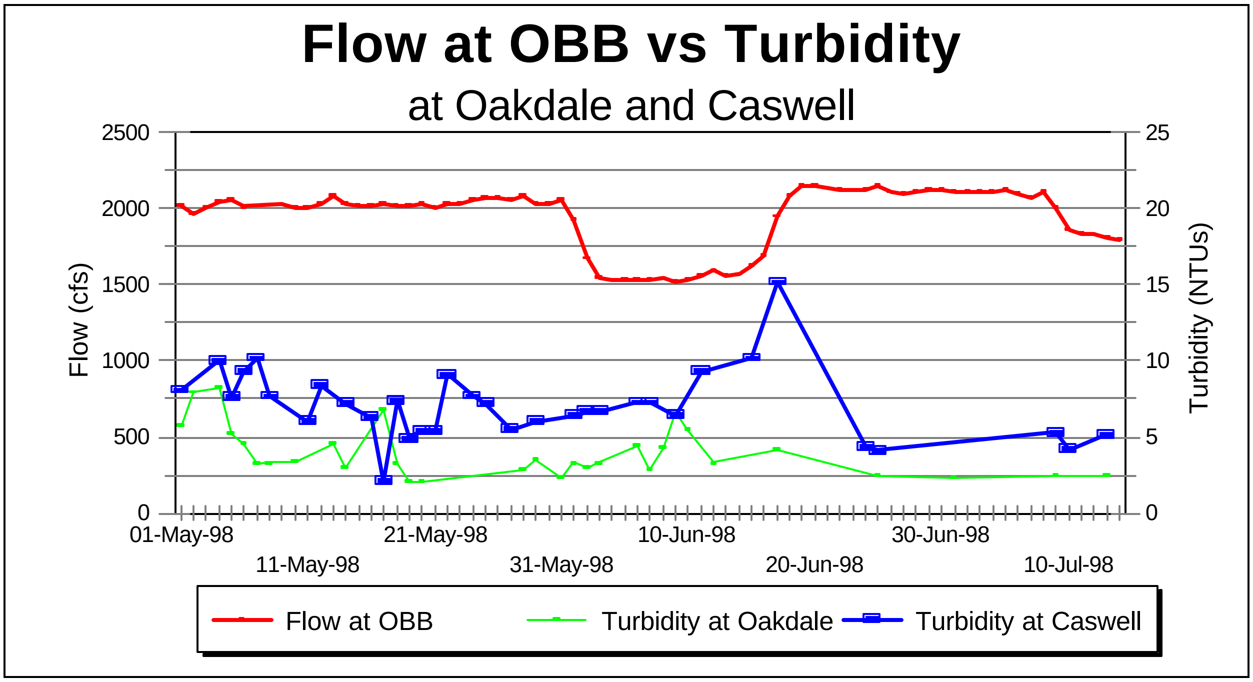

Figure 10. River flow at OBB and turbidity at Oakdale and Caswell during the radio tracking period.

Effects of Fish Size on Tagged Chinook Mortality

We found no indication within our limited data that length of tagged fish affected their survival. The individual lengths of tagged fish ranged from 101 to 117 mm fork length, with the lengths of known survivors between 105 and 117 mm. The lengths of 4 of the 5 that survived to Caswell fish fell within the average lengths of all fished released (Figure 11).

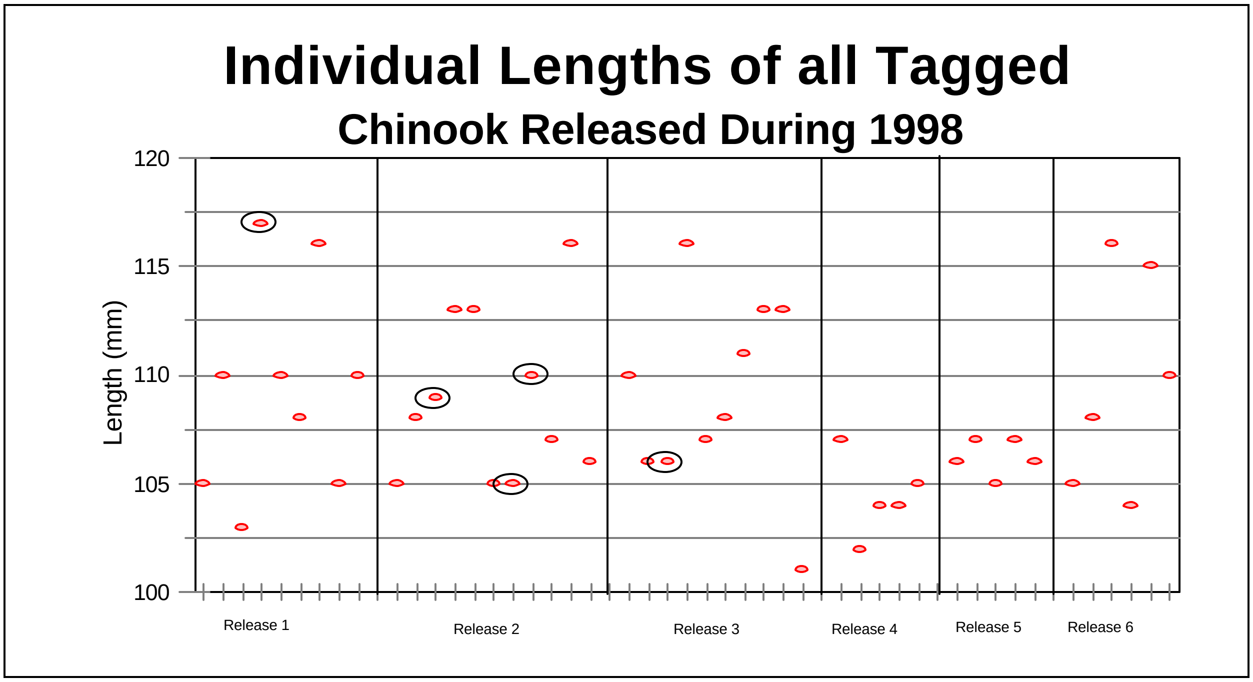

Figure 11. Individual lengths of all tagged chinook released. Circles around individual lengths indicate the fish survived to Caswell.

Effects of Fish Stock on Tagged Chinook Mortality

It appears from our limited data that hatchery fish survived at least as well as wild fish of the same size. Two of the five tagged fish that survived to the Caswell fixed station were hatchery fish, one from release 2 and one from release 3. Of the 46 tagged fish released, only 10 were hatchery fish (21.7%), 5 on release 2 and 5 on release 3 (see Table 2). The mean length of the hatchery fish was 110 mm for both releases, slightly larger than the natural fish released (see Table 2). The similar survival of hatchery and wild smolts indicates that, under the high flow conditions observed in 1998, tagged hatchery fish may be an appropriate surrogate for tagged natural fish.

CONCLUSIONS

1. Tagged smolts exhibited migratory behavior that was similar to that determined by past mark-recapture studies of juvenile chinook in the Stanislaus River.

2. Migration rates of actively migrating fish ranged from 0.15 to 28.9 miles per night. The average distance traveled the night following release was 7.7 miles for fish released in May at OBB, but only 1.8 miles for fish released in June at McHenry.

3. Mobile tracking proved effective for locating each tagged fish and determining its most probable fate.

4. The fixed station receivers were effective for determining migration timing, and can serve as backup to mobile surveys for estimating migration rates and survival to a fixed location.

5. Tagged chinook migrated downstream primarily during darkness, with peak movement just before light and soon after dark.

6. Twenty percent of the 35 tagged chinook released at OBB during May were estimated to have been eaten by predators in the ponds at the Oakdale Recreation Area. This was the only specific site where we identified a likely point source of mortality.

7. Sixteen percent of tagged chinook released at OBB survived to the Caswell fixed station recorder (RM 9).

8. We estimated that 70% to 88% of radio-tagged smolts were eaten by predatory fish.

Confirmation of actual predation was not attained, and should be verified in the future by direct sampling of predators that contain radio-tagged smolts.

9. Mortality from predation by birds or from entrainment into irrigation diversions, was insignificant or absent in the 43 chinook smolts tracked in this study.

RECOMMENDATIONS FOR FUTURE RESEARCH

These recommendations include several research projects that would provide valuable insight into causes of fish mortality. However, feasibility and costs would have to be considered in prioritizing such efforts.

1 Radio tracking of chinook smolts proved to be feasible and effective for identifying probable sources of smolt mortality. We recommend that radio tracking continue to be used as the best available tool for determining point sources of chinook mortality.

2. Valuable insights on causes of smolt mortality can be gained by expanding the radio tracking studies to include more tagged fish, and release sites at several different river miles. Points of releases should be chosen within a few miles above large in-river ponds such as that at Oakdale Recreation site. Additional release sites are needed to insure that sufficient numbers of fish are tracked as they pass areas of suspected higher rates of predation.

3. We recommend the number of fixed stations be reduced to two, with two or more receivers at each station. These monitoring stations should be somewhere around Riverbank, and another near Caswell.

4. Because our studies in 1998 indicated a likely point source of predation on smolts at the Oakdale Recreation site, predatory fish at that site should be sampled in 1999 to verify our interpretation. Direct sampling could be accomplished by electrofishing, spearfishing or angling. We could test our hypothesis that a particular tagged fish has been eaten by a predator by using electrofishing to recover the fish with the tag. Electrofishing surveys about once per week should produce sufficient sample sizes to

estimate the accuracy of our predation scoring.

5. Vulnerability of tagged fish to predators should be tested in live-cage experiments with predator species. This experiment would determine if our assumptions concerning our ability to track predators which had eaten tagged juvenile chinook are correct, and determine whether tagged chinook are more susceptible to predation than untagged (i.e. natural) chinook. It consists of two parts:

   A. *Determine if predators can be tracked, after they have eaten a tagged juvenile chinook and if so, for how long*. This experiment would entail capturing live predators from the Stanislaus River and holding them in live-cages. They would be given the opportunity to eat tagged juvenile chinook, and then monitored to determine how long after ingesting tagged chinook the tags remain in their system.

   B. *Evaluate susceptibility of tagged chinook to predation*. Although tests in the Columbia River Basin have demonstrated that juvenile chinook less than 120 mm in length can be more susceptible to predation, we need to verify whether results are applicable to conditions and types of predators in the Stanislaus River. Using natural and hatchery chinook implanted with "dummy" transmitters, we would conduct controlled experiments in live-cages to determine the extent that tagged and untagged chinook are vulnerable to predation.

Although these experiments could be conducted in a variety of in-stream cages and out-of-stream tanks, a controlled laboratory environment would be more efficient for these tests. For that reason we would seek to have a local government agency conduct these experiments.

6. The abundance of predatory fish, and their rates of predation on juvenile chinook should be tested with mark-recapture studies of predatory fish in the Stanislaus River. Boat electroshocking could be used to capture, stomach sample, tag and release predatory fish in the Stanislaus River. We used this technique in conjunction with CDFG, to estimate the consumption of juvenile chinook by squawfish in the vicinity of the fish screens at the Glenn Colusa Irrigation District. Selected habitat units between the mouth of the river and Orange Blossom Bridge would be routinely electroshocked to capture predators. Their stomachs would be pumped to determine the number of juvenile chinook eaten, and the fish would be tagged and released. By sampling over the course of the outmigration season we would be able to determine how chinook abundance, water temperature and turbidity, as well as other factors, affects predation rates in the Stanislaus River.

7. Underwater video and SCUBA observations should be evaluated as methods of detecting the ultimate fate of tagged chinook. During 1998, high water prevented us from using direct SCUBA observations to determine the ultimate fate of tagged chinook. It is plausible that under lower water and turbidity conditions we could observe 1) tagged chinook either schooling or rearing alone, 2) a large predator in the location where we detect the strongest radio signal, or 3) a dead chinook or regurgitated tag on the bottom of the river. The external antennas enable us to identify tagged chinook fairly easily, as was done twice in 1998 from observers above the water when chinook were seen in shallow water habitat. An underwater video unit could be purchased for around $3,000 and could be operated from a boat during normal mobile tracking surveys.

REFERENCES

Clark, C.W., and D.A. Levy. 1988. Diel vertical migrations by juvenile sockeye salmon and the antipredation window. American Naturalist 131(2):270-291.

Cramer, S.P. and D.B. Demko. 1993. Effects of pulse flows on juvenile chinook migration in the Stanislaus River. Annual report 1993. Prepared by S.P. Cramer and Associates for South San Joaquin Irrigation District and Oakdale Irrigation District.

Demko, D.B. and S.P. Cramer. 1997. Outmigrant trapping of juvenile salmonids in the lower Stanislaus River Caswell State Park site. Final report to U.S. Fish and Wildlife Service

Demko, D.B. and S.P. Cramer. 1996. Effects of pulse flows on juvenile chinook migration in the Stanislaus River. Annual report 1996. Prepared by S.P. Cramer and Associates for South San Joaquin Irrigation District and Oakdale Irrigation District.

Demko, D.B. and S.P. Cramer. 1995. Effects of pulse flows on juvenile chinook migration in the Stanislaus River. Annual report 1995. Prepared by S.P. Cramer and Associates for South San Joaquin Irrigation District and Oakdale Irrigation District.

Winter, J.D. 1996. Advances in underwater biotelemetry. Pages 555-587 in B.R. Murphy and D.W. Willis, editors. Fisheries Techniques, second edition. America Fisheries Society, Bethesda, MD.

Winter, J.D., V.B. Kuechle, D.B. Siniff, and J.R. Tester. 1978. Equipment and methods for radio tracking freshwater fish. University of Minnesota, Miscellaneous report 152-1978.

APPENDIX

Appendix 1. System used to score likelihood that a radio-tagged smolt had been eaten by a predatory fish.

During the coarse of the study daily observations were made on movement of the signal as well as location in the stream (i.e. inundated willows, mid channel, open water, etc.) and current. The following six categories of observation were chosen as potential indicators of predation: 1) the sudden and prolonged halt of downstream migration, 2) signal located in mid-channel where no juvenile cover observed, 3) signal located in strong current, 4) rapid movement of signal detected while tracking fish, 5) daily change in location of signal, and 6) considerable movement upstream.

Each of these characteristics was evaluated for each tag tracked. If the behavior was present, the fish was given a score of 1 and a score of 0 if the behavior was not present. Scores for all categories for each fish were summed giving each fish a rank. Fish ranked 0 to 6, with 0 representing a smolt continuously migrating downstream and no signs of predation and 6 that showed all signs possible of predation.

The halt of downstream migration was considered an indication of mortality; however, in many cases signals were still moving either within an area or upstream. Past studies in the Stanislaus River have indicated that most juvenile chinook migrate from Oakdale to Caswell about one week or less. We also considered other possibilities for a pause in migration such as death of the smolt due to the tagging procedure and tag regurgitation, and simply that a chinook had halted its migration.

Signals located mid-channel and in strong current were considered signs of predation. Mid-channel seems an unlikely resting spot for chinook smolts considering the current is normally stronger. Vulnerability to predation in mid-channel may also be increased due to a lack of cover. Larger predators are more likely to be found mid-channel, being able to withstand the current and taking advantage of an abundant food resource. Conversely, smolts are usually associated with the river banks and cover as supported by our observations where twice tagged smolts were observed in small schools of chinook in clumps of inundated willows. The presence of tags in mid-channel alone would not lead us to conclude that a chinook was predated upon because it would be unknown to the observer whether refuge from current or submerged cover existed below the surface.

On many occasions movement of signals was detected during daily radio tracking surveys. The speed of signal movement was an indicator of whether the tag was in a smolt or a predator. Tags that moved fast and far was more indicative of a predator than a live chinook. Signals sometimes moved >50m through strong current within several seconds suggesting the movement was made by a large and fast swimming fish. Signals would become louder indicating close proximity to the tag then turn faint within seconds. When tracked again the same pattern would be observed suggesting a fish was spooked by the boat engine and swimming away. This pattern was also similar to the signal of a transmitter with a dying battery; however, observations on subsequent days were used to determine if the battery was weakening. Signals that moved more slowly and stayed within the same general area or habitat, we believe, were more indicative of chinook behavior. However, the possibility also exists that we were tracking a smaller, slower predator rather than a live chinook.

Many tagged fish for which downstream migration ceased still moved within a small area from day to day. Movement between days would have indicated the tag was in a living animal although this could have been attributed to current or debris moving a regurgitated tag on the riverbed. It is unlikely that current would be responsible for the movement of a tag directly across the river or upstream. If the water was deep enough disturbance to a fish from the boat would have been minimal and incited no movement. In a similar situation if a tag was tracked to dense vegetation it would have been impossible to get very close to the signal; therefore, the fish might not have been disturbed and movement not detected. Given these situations fish movement would not have been detected until the following day when the tag was located in a different spot.

Upstream movement was also an indicator of mortality due to predation. Some of the tags moved upstream considerable distances (up to 6 miles) in a relatively short period of time. Although conditions may have been optimal this year for river rearing the energetic costs of extensive upstream movement for small fish are great, and therefore considered unlikely. However, we can not discount the possibility of smolts moving short distances (<1 mile) upstream.

Appendix 2. Observational comments, scores, and locations for each tracked tag.

Freq.	Date	Time	RM	Disposition Rating	Comments
150.044	05/16/98	1945	47	3	Release
150.044	05/18/98	630	39.75		Seems to move
150.044	05/21/98	1030	39.75		Open water middle of pond, moving target
150.044	05/22/98	1450	39.75		
150.044	05/23/98	610	39.75		3 m from submerged willows, moved from open water
150.044	05/29/98	635	39.75		Near emergent veg that divides channel and pond
150.044	06/03/98	655	39.75		Debris and logs 3 meters from bank, same location for a few days
150.044	06/13/98	735	39.75		Near submerged logs near bank between side channel and pond
150.072	05/03/98	1900	47	3	Release
150.072	05/04/98	645	39.75		Vegetation and overhangs on shore, to shallow precise location
150.072	05/04/98	810	39.75		
150.072	05/05/98	652	27		
150.072	05/05/98	1220			Thick vegetation along bank
150.072	05/06/98	835	23		Shallow water emergent vegetation
150.072	05/07/98	930	23		Has not moved, presumed dead.
150.072	05/08/98	915	23		Same location last 3 days
150.072	05/30/98	845	11.75		Near mid-channel, medium and small targets on fish finder.
150.101	05/16/98	1945	47	1	Release
150.101	05/17/98	414	36		
150.101	05/17/98	740	34		Fish seems to move in response to boat
150.101	05/17/98	1935	34		Some emergent vegetation, slow water, right bank upstream facing
150.101	05/18/98	745	34		Seemed to be under brush then on the opposite bank
150.101	05/19/98	1145	34		Overhanging tree with dead submerged woody debris
150.101	05/20/98	1449	34		Overhanging tree, next to swift current, submerged dead logs next
150.101	05/21/98	1122	34		Overhanging tree, hasn't moved 3 days
150.101	05/22/98	1520	34		
150.101	05/23/98	539	34		Hasn't moved
150.101	05/25/98	520	34		Hasn't moved
150.101	05/29/98	605	33.75		Open water, near bank between trees
150.101	06/03/98	730	33.75		Between overhanging tree and dead tree
150.162	05/21/98	2000	47	5	Release
150.162	05/22/98	1405	44		
150.162	05/25/98	607	44		Overhang with some submerged veg., strong current
150.162	05/27/98	815	44		Mid channel, main flow
150.162	05/29/98	750	44.25		Mid channel, signal moved across channel to veg. on bank
150.162	06/01/98	1020	44		
150.162	06/03/98	605	44		Partially submerged dead limb, strong current
150.162	06/13/98	940	44		Behind debris pile

Freq.	Date	Time	RM	Disposition Rating	Comments
150.314	05/16/98	1945	47	1	Release
150.314	05/17/98	1110	33.5		Depth taken as close as possible
150.314	05/17/98	1915	33.5		6-8 ft out from bank near overhanging vegetation
150.314	05/18/98	629	27		
150.314	05/18/98	1010			In live branches with high velocity passing
150.314	05/18/98	1556	16.75		
150.314	05/18/98	2014	9		
150.314	06/03/98	950	5.25		Strong current, debris pile
150.352	06/14/98	2030	29.5	4	Release
150.352	06/15/98	900	29.5		Overhanging veg. next to strong current, signal moved
150.352	06/16/98	835	29.5		Targets seems to be moving mid channel, strong current
150.352	06/17/98	855	29.5		Mid channel, just above rope swing
150.352	06/20/98	743	29.5		1 m from overhanging veg, moderate current
150.352	06/21/98	704	29.5		Signal has not moved, clump of brush next to fast current
150.352	06/24/98	700	29.5		Has not moved since shortly after release, brush on river bank
150.352	06/26/98	720	29.5		Same spot since first day, dead brush inside of river, fast current
150.352	06/28/98	730	29.5		Clump of dead brush, hasn't moved
150.352	06/29/98	732	29.5		Clump of brush, hasn't moved
150.352	06/30/98	740	29.5		Brush on bank, hasn't moved
150.352	07/03/98	704	29.5		2 m from dead brush, moved 1 m
150.352	07/07/98	700	29.5		Tried to scare, did not move
150.352	07/10/98	650	29.5		Hasn't moved
150.412	05/16/98	1945	47	5	Release
150.412	05/17/98	940	46		Fish holding in same position but moving between bank and submerged tree
150.412	05/20/98	1228	44		Overhanging live vegetation with submerged veg. slow moving water
150.412	05/21/98	209	42.5		
150.412	05/22/98	31	42.5		
150.412	05/27/98	840	44.25		Mid channel, strong current
150.412	05/29/98	750	44.25		Behind debris in log jam but darted across channel
150.412	06/03/98	550	44.25		Signal seems to move, open water with submerged snag, current slow.
151.022	05/03/98	1900	47	3	Release
	05/04/98	515	47		Saw tagged fish in school with ~150 others
151.022	05/04/98	1130	46		Close to overhang
151.022	05/05/98	1134	28.5		Near banks in emergent vegetation
151.022	05/05/98	2131	27		
151.022	05/06/98	812	26.5		Emergent veg. shallow sand bar
151.022	05/07/98	900	26		Near channel center, lots of targets on fish finder
151.022	05/08/98	1200	26		Out from overhang but not mid-channel, large target on fish finder.
151.022	05/30/98	1205	26.5		Between south bank and mid-channel in faster flow.
151.043	05/18/98	1930	47	6	Release
151.043	05/18/98	2128	42.5		
151.043	05/19/98	1313	41.5		Slow water, submerged log and aquatic plants on sandy bottom, out of main

Freq.	Date	Time	RM	Disposition Rating	Comments
					channel
151.043	05/19/98	1625	41.5		Backwater, pool type area but target moved into main flow, signal weak
151.043	05/20/98	1300	41.4		Near submerged log in slow moving water but close to mid channel
151.043	05/21/98	955	41.4		Open water, mid channel, fast current
151.043	05/23/98	650	41.4		Same spot for 3 days
151.043	05/25/98	555	41.4		Has move upstream to new spot, signal weak
151.043	05/29/98	720	41.5		Mid channel
151.043	06/01/98	1035	41.4		
151.043	06/03/98	630	41.4		open water next to submerged snag, slow water
151.043	06/13/98	910	41.4		backwater area close to flow
151.062	06/01/98	2000	29.5	4	Release
151.062	06/02/98	710	29.5		2 meters out from bank moderate current, medium size targets on fish finder.
151.062	06/03/98	755	29.5		Signal seems to move, 4 meters out from bank, moderate current
151.062	06/04/98	700	29.5		Mid-channel, slow to moderate current, seems to move
151.062	06/12/98	845	29.5		Hasn't moved since release
151.062	06/14/98	1302	29.5		1 m from bank, not under veg.
151.062	06/26/98	725	29.4		Submerged willows moderate current may have moved a little but not much
151.081	06/14/98	2030	29.5	6	Release
151.081	06/15/98	1300	30		Small eddy, submerged dead trees, slow water, has moved since yesterday
151.081	06/16/98	955	30		Target moves in mid channel, strong current
151.081	06/20/98	732	30		Mid channel, fast current, strong signal next to eddy
151.081	06/21/98	700	30		Signal has moved, under overhanging tree next to strong current
151.081	06/24/98	655	29.75		Mid channel, strong current, has moved
151.081	06/26/98	717	29.75		2 m from submerged willows in moderate current
151.081	06/28/98	727	29.75		Mid channel, moderate current
151.081	06/29/98	728	29.75		3 m from submerged willows, hasn't moved
151.081	06/30/98	733	29.75		Mid channel
151.081	07/03/98	659	29.75		3 m from submerged willows open water, moderate current
151.081	07/07/98	650	29.75		Tried to scare, did not move
151.103	05/03/98	1900	47	4	Release
151.103	05/04/98	545	45.5		Moving fish, followed
151.103	05/04/98	600			
151.103	05/04/98	605			
151.103	05/04/98	830	39.75		Fish followed earlier, now in thicket/overhang
151.103	05/05/98	1025	39.75		Same location, different position
151.103	05/06/98	640	39.75		Same location as yesterday
151.103	05/07/98	715	39.75		Moved since yesterday
151.103	05/08/98	550	39.75		Does appear to be moving
151.122	05/03/98	1900	47	3	Release
151.122	05/04/98	505	27		
151.122	05/05/98	2030	9		
151.122	05/06/98	542	9		
151.122	05/06/98	1000	9		Just off the bank with emergent vegetation

Freq.	Date	Time	RM	Disposition Rating	Comments
151.122	05/08/98	1119	9.5		Mid channel, extremely large target on fish finder
151.122	05/30/98	915	8.75		Mid-channel, strong current, flat bottom, resident fish moves in same general area.
151.141	05/18/98	1930	47	2	Release
151.141	05/19/98	1225	37.75		Dead woody vegetation submerged and above water in back water area
151.141	05/19/98	1720	37.75		
151.141	05/20/98	1558	28.5		In main current , no cover
151.141	05/21/98	1150	28.5		Under overhanging trees next to current picture
151.141	05/24/98	520	28.5		In close to bank and overhanging veg, strong current
151.141	05/26/98	730	28.5		
151.141	05/30/98	710	28.25		Same spot for last week, overhanging tree
151.141	06/03/98	800	28.5		Overhanging vegetation, moderate current.
151.141	06/05/98	855	28.5		Same spot for a couple of weeks
151.141	06/14/98	1307	28.5		Same location, signal sounds different
151.164	05/18/98	1930	47	2	Release
151.164	05/18/98	2359	42.5		
151.164	05/19/98	1231	37.8		Open water mid-channel but not main current, seems to move
151.164	05/20/98	840	27		
151.164	05/20/98	843	27		
151.164	05/20/98	1640	26		Live veg., North bank, depth could be inaccurate, PICTURE
151.164	05/21/98	1245	18.5		Steep wall of blackberry brambles dropping into main current
151.164	05/21/98	2048	9		
151.164	05/21/98	2100	9		
151.182	06/01/98	2000	29.5	3	Release
151.182	06/02/98	735	24.5		Overhanging trees and vines next to strong current, fish moved in response to boat, chased upstream then down
151.182	06/03/98	1140	25.5		Signal seems to move, moderate current, dead brush overhanging water
151.182	06/04/98	715	25.5		2 meters out from overhanging and submerged vegetation, moderate current
151.182	06/05/98	915	25.5		Signal seems to be moving, mid channel
151.182	06/12/98	900	26		Strong signal, mid channel, same location as before
151.182	06/14/98	1330	26		1.5 m from bank and overhanging veg, doesn't move
151.202	05/16/98	1945	47	4	Release
151.202	05/17/98	850	39.75		Moving in response to boat, in open water
151.202	05/17/98	2032	39.75		Deep water, middle of pond
151.202	05/18/98	615	39.75		Good signal, seems to move
151.202	05/19/98	620	39.75		Open water, signal not strong, seems to move
151.202	05/20/98	1350	39.75		Open water, 50 m from bank, signal seems to move and fade
151.202	05/21/98	1018	39.75		Mid channel, 15 m from bank, no cover, picture
151.202	05/22/98	1435	39.75		Moved from boat, signal weak
151.202	05/23/98	620	39.75		Weak signal, seemed to move
151.202	05/29/98	650	39.75		Open water
151.202	06/03/98	705	39.75		Signal moves, open water
151.202	06/13/98	740	39.75		Center of pond towards island

Freq.	Date	Time	RM	Disposition Rating	Comments
151.222	05/03/98	1900	47	0	Release
151.222	05/04/98	901	27		
151.222	05/05/98	1300	21.5		Overhanging trees and emergent vegetation
151.222	05/07/98	1000	18		Deep water, many fish on fish finder
151.222	05/08/98	945	18		Could not obtain satellites for GPS, all sizes of targets on fish finder
151.263	05/16/98	1945	47	4	Release
151.263	05/17/98	830	40		Could not get close enough to bank for accurate depth
151.263	05/17/98	2040	39.75		Deep, open water, strong signal
151.263	05/20/98	1421	38		North bank, submerged and overhanging willows in low flows
151.263	05/21/98	1101	38		Partially submerged willows very dense, ~3 m from swift current, moved across stream, pictures
151.263	05/22/98	1505	38		
151.263	05/23/98	555	38		4 m out from submerged willows in main current
151.263	05/25/98	530	38		
151.263	05/29/98	625	37.25		Near south bank in emergent veg.
151.263	06/03/98	1220	37.5		Different bank than previous day, couldn't get a location, signal moves or fades in and out
151.303	06/14/98	2030	29.5	5	Release
151.303	06/15/98	935	28.5		Signal moved from deep hole on bend to S. bank and back to hole, strong current
151.303	06/16/98	855	28.5		Overhanging tree w/ limbs in water, moderate current
151.303	06/20/98	802	28.5		Big bend, probably deep hole, signal moved from overhanging tree to bend
151.303	06/21/98	720	28.5		Signal moving, has moved since yesterday, next to submerged willows
151.303	06/24/98	710	28.5		1.5 m out from submerged willows in moderate current
151.303	06/26/98	740	28.5		2 m from submerged willows on bank, fast flow, same spot as last time
151.303	06/28/98	740	28.5		About 15 m from previous location, mid channel, strong current
151.303	06/29/98	747	28.5		Moved around midchannel
151.303	06/30/98	750	28.5		Mid channel, moderate current
151.303	07/03/98	715	28.5		Mid channel, moderate current, has moved
151.303	07/07/98	715	28.5		Scared, seemed to move, but maybe not
151.303	07/10/98	658	28.5		Weak signal, battery dying
151.323	05/18/98	1930	47	5	Release
151.323	05/18/98	2213	42.5		
151.323	05/19/98	1245	40		Submerged and emergent willows, midstream island with high flows on either side
151.323	05/19/98	1640	40.25		Could see fish schooling with others, behavior did not seem to be impaired
151.323	05/20/98	1500	33		Moving target, mid channel w/ moderate flow
151.323	05/21/98	608	27		
151.323	05/21/98	1215	24.5		Fast moving water , mid channel but 3m from submerged willows
151.323	05/24/98	545	23.25		Mid channel, weak signal, not precise location
151.323	05/26/98	802	23.5		Mid channel, fast current, seems to move
151.323	05/30/98	740	23.25		Mid-channel strong current, been here a few days
151.323	06/03/98	835	22.75		Mid channel, strong to moderate current, has moved since previous day.
151.323	06/05/98	950	23.25		Mid-channel, strong current, has moved downstream a little.

Freq.	Date	Time	RM	Disposition Rating	Comments
151.323	06/14/98	1355	22.75		Mid channel, no cover, strong current, has moved
151.362	05/16/98	1945	47	1	Release
151.362	05/17/98	423	27		
151.362	05/17/98	1730	18		Large pile woody debris, strongest signal along bank not mid channel
151.362	05/18/98	510			
151.362	05/18/98	1040	18		North bank, fast water, live brush
151.362	05/19/98	940	18		Submerged and overhanging vegetation next to fast current
151.362	05/20/98	1730	18		Inundated willows next to main current, close to pump
151.362	05/21/98	1251	17		Over hanging and submerged willows,2 m from main current
151.362	05/26/98	950	7.5		Small backwater area, partially submerged willows, low flows
151.362	05/30/98	1000	6.75		Mid-channel, different location in same area
151.362	06/03/98	955	5		Moderate current, mid-channel, no cover
151.381	05/18/98	1930	47	5	Release
151.381	05/19/98	1215	37.5		Overhanging tree submerged woody debris, fast current
151.381	05/19/98	1735	38		
151.381	05/21/98	1110	36.5		Partially submerged willows very thick, next to main current, moved across stream
151.381	05/22/98	1500	39		Overhanging veg.
151.381	05/23/98	729	27		
151.381	05/24/98	610	17		Dead tree in water w/ no branches for cover- 5 m from bank
151.381	05/26/98	825	17.5		1 m from dead tree, partially submerged in fast current
151.381	05/30/98	810	17		Has move in same general area mid-channel, away from dead tree where originally found.
151.381	06/03/98	900	17.25		Mid-channel, strong current, 4 meters from bank
151.381	06/05/98	1025	17		Strong current no cover, targets on fish finder.
151.402	05/21/98	2000	47	5	Release
151.402	05/22/98	1345	46		
151.402	05/23/98	717	46		Submerged tree, very strong signal mid channel
151.402	05/25/98	621	46		Signal seemed to move, initially strong, under overhanging willow
151.402	05/26/98	1936	42.5		
151.402	05/27/98	810	44.5		Overhanging tree, swift current
151.402	05/29/98	745	43.75		Overhanging fig tree, strong current
151.402	06/01/98	1025	43.75		
151.402	06/03/98	610	43.75		Overhanging tree, strong current
151.402	06/13/98	935	43.75		Under overhanging fig tree, N. bank
151.441	05/03/98	1900	47	2	Release
151.441	05/08/98	732	30		Big fish on fish finder
151.441	05/30/98	655	30		Under overhanging and emergent vegetation next to main current
151.441	06/03/98	1200	30.25		In clump of brush, next to strong current.
151.441	06/05/98	835	30.25		Strong current, 1 meter from partially submerged shrubs
151.462	05/03/98	1900	47	1	Release
151.462	05/04/98	505	47		Opposite bank of release

Freq.	Date	Time	RM	Disposition Rating	Comments
151.462	05/04/98	1015	46.5		Finder showed multiple (100+) small targets, school?
151.462	05/04/98	1120	46.5		Same position as earlier
151.462	05/06/98	615	42.75		On bank in overhanging trees and debris caught in snag
151.462	05/07/98	800	42.5		South bank, hasn't moved
151.462	05/08/98	641	42.75		Could not obtain satellites, used previous day's GPS
151.462	06/03/98	735	30.25		Slow current, shallow grassy area on sandy substrate
151.484	05/18/98	1930	47	4	Release
151.484	05/19/98	530	36		
151.484	05/19/98	728	36		
151.484	05/19/98	1750	37.5		Moved a lot in response to boat, moved north bank to south bank, veg. on both banks
151.484	05/20/98	1740	17		Overhanging vegetation, willows next to current, signal moving
151.484	05/21/98	1312	14		1.5 m out from submerged willows on point of curve, fast moving water, strong signal
151.484	05/26/98	900	13.75		Mid channel, fast current, no cover
151.484	05/30/98	837	12.5		Mid-channel, strong current
151.484	06/03/98	925	12.5		Submerged brush, moderate current, signal moving to mid-channel
151.484	06/05/98	1050	12.5		Mid-channel, strong current
151.484	06/14/98	1555	13.25		3 m from bank, not quite mid channel, no cover, strong current
151.502	05/16/98	1945	47	0	Release
151.502	05/17/98	815	39.5		Emergent vegetation and elodea beds, got as close as possible to bank
151.502	05/17/98	2020	38		Back water area, overhanging dead vegetation
151.502	05/17/98	2102	36		
151.502	05/18/98	619	27		
151.502	05/18/98	1701	9		
151.525	05/18/98	1930	47	5	Release
151.525	05/21/98	209	42.5		
151.525	05/21/98	1048	38		Overhanging tree, submerged veg. next to swift current, signal sounded weird picture(2)
151.525	05/22/98	209	42.5		
151.525	05/29/98	755	44.25		Moved across stream from north to south bank, submerged tree, no small branches
151.525	06/03/98	600	44.25		Submerged brush mid-channel
151.525	06/13/98	940	44.25		Behind debris pileup, near. S. bank
151.582	05/18/98	1930	47	6	Release
151.582	05/19/98	1300	41.4		Mid channel, fast moving water, target seemed to move between slow and fast water
151.582	05/19/98	1620	41.4		Backwater, pool type area but target moved into main flow, signal weak
151.582	05/19/98	1947	42.5		
151.582	05/19/98	1947	42.5		
151.582	05/20/98	1255	41.4		Middle of channel, fast moving water

Freq.	Date	Time	RM	Dispositio n Rating	Comments
151.582	05/20/98	1842	42.5		
151.582	05/21/98	945	43		Overhanging trees submerged willows next to swift current, PICTURE
151.582	05/23/98	655	43		Very strong signal, clear water, gravel substrate
151.582	05/25/98	600	43		Very strong signal, clear water, gravel substrate
151.582	05/29/98	737	42.5		Mid-channel, fast current
151.582	06/01/98	1030	42.5		
151.582	06/03/98	617	42.5		Overhanging vegetation at first, then moved to open water.
151.582	06/13/98	925	42.5		Elodea patch- sand/gravel substrate, fairly swift current, shallow water
151.602	06/01/98	2000	29.5	3	Release
151.602	06/02/98	800	22.25		Same spot as 151.962
151.602	06/03/98	845	22.5		Deep pool, bend in river
151.602	06/04/98	735	22.75		Deep pool in bend on river, moderate current
151.602	06/05/98	1000	22.5		Fish has been here for three days, deep hole in river bend, no cover
151.602	06/12/98	920	22.5		Mid channel, has moved downstream from deep hole
151.602	06/14/98	1405	22.5		Upstream from 151.962, different spot, mid channel
151.642	06/14/98	2030	29.5	5	Release
151.642	06/15/98	910	28.75		Submerged dead veg, very thick, some emergent willows, next to strong current, signal moves
151.642	06/16/98	845	29.5		Target is moving from bank to mid channel and back, strong current
151.642	06/17/98	910	29		On shore in light brush just above submerged tree
151.642	06/20/98	750	28.75		Small backwater area, 2m from bank, no current
151.642	06/21/98	711	28.75		Signal has moved, hard to pinpoint, close to submerged willows near midchannel
151.642	06/24/98	725	29		Mid channel, strong current under tree downed across river
151.642	06/26/98	730	29		Mid channel, under downed tree, same spot as last time
151.642	06/28/98	735	29		Has moved slightly downstream, mid channel, strong current, no cover
151.642	06/29/98	737	29		Moved slightly upstream since previous survey
151.642	06/30/98	742	29		Under tree across river, has moved
151.661	05/21/98	2000	47	5	Release
151.661	05/22/98	1350	46		
151.661	05/23/98	720	46		Mid channel, main flow, 3 m from bank and submerged veg.
151.661	05/25/98	620	46		Submerged tree and shrub but no emergent veg.
151.661	05/27/98	825	46		Submerged shrub/tree, mid channel, main flow
151.661	05/29/98	810	46.25		Signal seems to move, mid channel, strong current
151.661	06/01/98	1010	46.25		Near south bank
151.661	06/03/98	545	46.25		In same submerged snag as 5/28, has changed location
151.661	06/13/98	1000	46.25		Towards main current and slightly downstream of submerged tree near S. Bank
151.682	05/21/98	2000	47	5	Release
151.682	05/22/98	59	42.5		
151.682	05/22/98	1425	39.75		Moved in response to boat, first located near willows
151.682	05/23/98	625	39.75		Open water, strong signal
151.682	05/27/98	710	40		Strong signal ~2 m from overhanging tree in main flow, has moved upstream
151.682	05/29/98	700	40		Mid-channel

Freq.	Date	Time	RM	Disposition Rating	Comments
151.682	06/01/98	1100	40		Mid-channel
151.682	06/03/98	645	39.75		Open water, moderate current, 3 meters from partially submerged willows.
151.682	06/13/98	840	40		Out from veg. near N. bank, Elodea bed
151.702	05/03/98	1900	47	5	Release
151.702	05/04/98	710	39.75		Signal disappeared, moving fish?
151.702	05/04/98	850	39.75		Open water, moved around the boat while tracking
151.702	05/05/98	1030	39.75		
151.702	05/06/98	705	39.75		Probably fish food, not in same area when scanned earlier
151.702	05/07/98	730	39.75		Weak signal, could be some distance from recorded location
151.702	05/08/98	606	40		Could not obtain satellites for GPS
151.702	05/29/98	650	39.75		Open water
151.702	06/03/98	707	39.75		Open water
151.722	05/03/98	1900	47	1	Release
151.722	05/04/98	950	44.5		Mid-channel, medium size fish on fish finder
151.722	05/04/98	1154	44.5		Moved around boat, same position as earlier
151.763	05/16/98	1945	47	1	Release
151.763	05/17/98	1000	46.75		On downstream side of sand bar under downed tree
151.763	05/17/98	2140	46.75		Overhanging tree, right bank facing upstream, swift water outside of brush
151.763	05/19/98	530	46.75		Overhanging downed tree, woody debris
151.763	05/20/98	1205	46.75		Overhanging vegetation, submerged dead wood over shallow water
151.763	05/21/98	925	46.75		Same as yesterday
151.763	05/29/98	824	46.75		Overhanging tree over shallow sand bar
151.763	06/01/98	1000	46.75		Near south bank in emergent and overhanging vegetation.
151.763	06/03/98	535	46.75		Same exact spot for weeks
151.763	06/13/98	1010	46.75		Hasn't moved
151.781	05/16/98	1945	47	3	Release
151.781	05/17/98	11	42.5		
151.781	05/17/98	705	36		
151.781	05/17/98	755	34.25		Tracked while moving downstream to bum's campsite
151.781	05/17/98	1930	34.5		Fast moving water (food path?) moving target, not in vegetation but main channel, very strong signal, Doug took picture
151.781	05/18/98	820	29.75		Fish near brush, south bank
151.781	05/18/98	1411	27		
151.781	05/19/98	910	20.75		Submerged cluster of dead branches next to fast flow
151.781	05/20/98	1700	22.75		Margin of small eddy edge of calm and current near emergent veg.
151.781	05/21/98	1230	22.5		Submerged thick woody veg. and emergent veg.
151.781	05/24/98	550	22.5		No movement
151.781	05/26/98	855	14.5		Main flow mid channel next to rip rap bank, no cover...weak signal
151.781	05/30/98	825	13.25		about 2 meters out from bank, without cover, slow moving water
151.781	06/03/98	915	13.25		Strong current, mid-channel, little signal movement, has moved since last tracking
151.781	06/05/98	1040	13		1 meter from cover, strong current

Freq.	Date	Time	RM	Disposition Rating	Comments
151.821	05/16/98	1945	47	4	Release
151.821	05/16/98	2250	42.5		
151.821	05/17/98	915	40		Fished out later by Tiffani and Ryan
151.821	05/17/98	2054	40		Fast moving water next to pile of woody debris and small backwater area, good signal but hard to get on top of with boat
151.821	05/17/98	2307	36		
151.821	05/18/98	717	36		Not a good signal, false alarm
151.821	05/18/98	850	29		Fish in mid river , more notes
151.821	05/20/98	1535	29		Mid channel, rip rap bank, strong current
151.821	05/21/98	1140	29		Target moved around the area
151.821	05/24/98	641	29		Signal moves
151.842	05/21/98	2000	47	4	Release
151.842	05/22/98	1340	46.5		
151.842	05/25/98	630	46.5		Open water, mid channel, strong current, very strong signal
151.842	05/27/98	830	46.5		Mid channel, strong current
151.842	05/29/98	816	46.5		Signal moving. strong current, no cover
151.842	06/01/98	955	46.75		
151.842	06/03/98	537	46.5		Same exact spot for more than 1 week.
151.842	06/13/98	1005	46.5		Hasn't moved
151.861	06/14/98	2030	29.5	6	Release
151.861	06/15/98	1310	32.25		Signal moved from bank to mid channel
151.861	06/16/98	1000	30.25		Along bank, overhanging brush, shallow water, little current
151.861	06/17/98	840	30.3		Partially submerged and overhanging willows
151.861	06/20/98	725	30.25		Signal moving, between midchannel and veg. bank
151.861	06/21/98	655	30.25		Signal seemed to move, close to submerged willows to midchannel
151.861	06/24/98	650	30.25		Mid channel, strong current, has moved since 3 days ago
151.861	06/26/98	705	30.25		Mid channel, same location last time
151.861	06/28/98	720	30.25		Mid channel, moderate current, same location
151.861	06/29/98	723	30.25		Mid channel, moderate current, hasn't moved in 3days
151.861	06/30/98	730	30.25		Mid channel
151.861	07/03/98	650	30.25		Mid channel, moderate current, signal moving
151.882	05/18/98	1930	47	6	Release
151.882	05/18/98	2140	42.5		
151.882	05/19/98	630	39.75		Open water, strong signal
151.882	05/19/98	1700	39.75		
151.882	05/20/98	1335	39.75		10 m from bank open water, very strong signal
151.882	05/21/98	1028	39.75		Open water, strong but moving signal
151.882	05/22/98	1440	39.75		Moved from boat
151.882	05/29/98	645	39.75		Open water
151.882	06/01/98	1105	39.75		
151.882	06/03/98	708	39.75		Strong signal then weakened, signal may be moving
151.882	06/13/98	845	40		Out from veg. near N. bank in swift current

Freq.	Date	Time	RM	Disposition Rating	Comments
151.922	06/14/98	2030	29.5	4	Release
151.922	06/15/98	1240	28.5		Very weak signal, hard to get close to, under large overhanging tree
151.922	06/16/98	900	28.25		Overhanging brush and trees, moderate current
151.922	06/20/98	813	28.25		Signal not very strong, in dense thicket of partially submerged willows, has moved since previous day
151.922	06/21/98	722	28.4		Has moved upstream, next to submerged willows, moderate current
151.922	06/24/98	715	28.4		Mid channel, moderate current
151.922	06/26/98	745	28.4		Mid channel, moderate current, has moved since last time
151.922	06/28/98	745	28.4		Has moved slightly downstream, mid channel, by submerged log, moderate current
151.922	06/29/98	750	28.4		Moved since yesterday, mid channel
151.922	06/30/98	754	28.4		Has moved downstream, moving around, mid channel
151.922	07/03/98	718	28.4		Mid channel, slow current
151.942	06/01/98	2000	29.5	4	Release
151.942	06/02/98	720	28.25		Overhanging tree, partially submerged willows next to strong current, same location as 151.141
151.942	06/03/98	815	27.5		Overhanging tree lots of submerged brush, slow current
151.942	06/04/98	720	25.4		1 meter from overhanging and partially submerged willow, slow current, near small backwater area.
151.942	06/05/98	930	25.25		No cover, small backwater type area aside from main flow
151.942	06/12/98	906	25.25		Mid channel, strong current
151.962	06/01/98	2000	29.5	4	Release
151.962	06/02/98	755	22.25		Deep pool on bend main current, medium to small targets on fish finder.
151.962	06/03/98	848	22.25		Signal definitely moving, originally under overhanging tree
151.962	06/04/98	745	22.75		Moved a lot, was mid-channel at one point, moved upstream slightly from yesterday's location.
151.962	06/05/98	955	22.5		Target is moving across river, mid-channel, strong current
151.962	06/12/98	925	22.5		Mid-channel, almost same location as 151.602
151.962	06/14/98	1402	22.5		Mid channel, no cover, strong current, 3m from bank w/ brush
151.962	06/26/98	807	22.5		Weak signal, hard to pinpoint exact location
151.981	05/18/98	1930	47	6	Release
151.981	05/19/98	1705	39.75		
151.981	05/20/98	1340	39.75		Open water, 50 m from bank middle of pong, strong signal
151.981	05/21/98	1008	40		Mid-channel, no cover
151.981	05/23/98	639	40		Mid channel open water, strong signal
151.981	05/25/98	545	40		Mid channel, strong current, strong signal
151.981	05/29/98	710	40		Mid channel
151.981	06/01/98	1050	40		Mid-channel
151.981	06/03/98	640	40		Open water, slow current
151.981	06/13/98	855	40		Mid channel, main current, sandy substrate

Appendix 3. Results of scoring system for each tracked tag.

Freq.	Downstream migration halted	mid channel	strong current	signal movement detected	change in location from previous day	upstream movement	pond	Score	Determination
151.502	0	0	0	0	0	0	0	0	Survive
151.222	0	0	0	0	0	0	0	0	Unknown
151.722	0	0	0	1	0	0	0	1	Unknown
151.362	0	1	0	0	0	0	0	1	Survive
150.314	0	0	1	0	0	0	0	1	Survive
151.164	0	0	1	1	0	0	0	2	Survive
151.781	0	1	1	0	1	0	0	3	Dead
151.462	1	0	0	0	0	0	0	1	Unknown
150.101	1	0	0	0	0	0	0	1	Unknown
151.763	1	0	0	0	0	0	0	1	Tag
151.441	1	0	1	0	0	0	0	2	Unknown
151.141	1	0	1	0	0	0	0	2	Unknown
151.602	1	1	0	0	1	0	0	3	Dead
151.182	1	1	0	1	0	0	0	3	Unknown
151.022	1	1	1	0	0	0	0	3	Unknown
150.072	1	1	0	1	0	0	0	3	Unknown
150.044	1	1	0	1	0	0	0	3	Dead
151.962	1	1	1	1	0	0	0	4	Dead
150.352	1	1	1	1	0	0	0	4	Tag
151.942	1	1	1	0	1	0	0	4	Dead
151.122	1	1	1	0	0	1	0	4	Survive
151.103	1	0	0	1	1	0	1	4	Dead
151.484	1	1	1	1	0	0	0	4	Dead
151.821	1	1	1	1	0	0	0	4	Dead
151.263	1	0	1	1	1	0	0	4	Dead
151.842	1	1	1	1	0	0	0	4	Dead
151.202	1	0	0	1	1	0	1	4	Dead
151.922	1	1	0	1	1	0	0	4	Dead
151.062	1	1	0	1	1	0	0	4	Tag
151.661	1	1	1	1	1	0	0	5	Dead
151.702	1	0	0	1	1	1	1	5	Dead
151.682	1	1	0	0	1	1	1	5	Dead
151.303	1	1	1	1	1	0	0	5	Dead
151.323	1	1	1	1	1	0	0	5	Dead
150.162	1	1	1	1	1	0	0	5	Dead
150.412	1	1	1	1	1	0	0	5	Dead
151.381	1	1	1	1	1	1	0	6	Dead
151.642	1	1	1	1	1	0	0	5	Dead
151.525	1	1	0	1	1	1	0	5	Dead
151.402	1	1	1	1	0	1	0	5	Dead

Freq.	Downstream migration halted	mid channel	strong current	signal movement detected	change in location from previous day	upstream movemen t	pond	Score	Deter-mination
151.582	1	1	1	1	1	1	0	6	Dead
151.981	1	1	1	0	1	1	1	6	Dead
151.043	1	1	1	1	1	1	0	6	Dead
151.081	1	1	1	1	1	1	0	6	Dead
151.861	1	1	1	1	1	1	0	6	Dead
151.882	1	0	1	1	1	1	1	6	Dead