8-31-2007

Ex. 280-US-406

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Spawning migration movements of Klamath largescale, Lost River, and shortnose suckers in the Williamson and Sprague rivers, Oregon, prior to the removal of Chiloquin Dam

Annual Report 2006

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Completed August 2007

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Executive Summary

The Chiloquin Dam, constructed in 1914, is located at river kilometer (rkm) 1.3 on the Sprague River near the town of Chiloquin, Oregon. The dam has been identified as a barrier that potentially inhibits or prevents the upstream spawning migrations and other movements of fish in the Sprague River. Dam removal has been recommended by a technical working group as the preferred alternative to remedy fish passage problems at the dam and is scheduled to occur in the fall of 2008. Our research objectives in 2006 were to describe adult catostomid spawning migration patterns using radio telemetry to identify and describe possible spawning areas in the Sprague River before any action is taken to improve fish passage at Chiloquin Dam. In 2006, we attached external radio transmitters to 30 Klamath largescale suckers (*Catostomus snyderi*; KLS), 32 Lost River suckers (*Deltistes luxatus*; LRS), and 28 shortnose suckers (*Chasmistes brevirostris*; SNS). These were collected from the Chiloquin Dam fish ladder and subsequently released above the dam. We also collected data from an additional 59 LRS, 70 SNS, and 1 KLS that had been radio tagged and released either in Upper Klamath Lake or at the mouth of the Williamson River. Locations of radio-tagged catostomids suggest that fish migrate to several, relatively distinct reaches of the Williamson and Sprague rivers during their respective spawning seasons. Radio-tagged KLS released in the Sprague River above Chiloquin Dam migrated to areas primarily in the Nine Mile area (rkm 13 to 46) and Beatty Gap (rkm 112 to 120). Individual KLS were also located in the Sycan River and the North Fork of the Sprague River. Radio-tagged LRS migrated to areas in the lower Williamson River (rkm 10 to 17.5), the Sprague River up to Chiloquin Narrows (rkm 0 to 10), and Beatty Gap. Individual LRS were also located in the Nine Mile area, the Sprague River Valley (rkm 60 to 107), and the Sycan River. Radio-tagged SNS migrated to areas in the lower Williamson River and the Sprague River up to Chiloquin Narrows although one individual was tracked into the Nine Mile area. Not one of the radio-tagged fish released in Upper Klamath Lake or the Williamson River was detected above Chiloquin Dam. However, one male SNS released above the dam was recorded falling back over the dam shortly after its release and then passing upstream through the fish ladder a second time. Although most radio-tagged fish were located in main-channel habitats, observations of habitat associations during radio telemetry tracking efforts in the

Sprague River above Chiloquin Dam in 2006 show an increased occurrence of radio-tagged fish in off-channel habitats compared to 2005. Despite repeated sampling with egg mats and plankton net tows, spawning was not confirmed during any of the tracking surveys in 2006. This was primarily because of deep water and high water velocities due to the above average spring runoff in 2006 and because we targeted areas where spawning was suspected but had not previously been documented. Fish were observed congregating in areas where spawning was confirmed in 2005 and the presence of catostomid larvae was documented in 2006 during a concurrent larval catostomid drift study

The removal of Chiloquin Dam is expected to allow better access for fish to spawning habitat further upstream in the Sprague River. Removal of the dam may also alleviate the problem of crowding spawning fish below the dam. This study is establishing a baseline for the existing distribution of spawning catostomids in the lower Williamson and Sprague rivers prior to the removal of Chiloquin Dam. Planned continuation of this work after dam removal will provide a means to quantify changes in spawning distributions and help natural resource managers evaluate the effects of this action.

Introduction

The USGS Klamath Falls Field Station was contracted to investigate spawning run movements of Klamath largescale sucker (*Catostomus snyderi*; KLS), Lost River sucker (*Deltistes luxatus*; LRS), and shortnose sucker (*Chasmistes brevirostris*; SNS) in the Williamson and Sprague rivers prior to the removal of Chiloquin Dam. The objectives of this study are to describe the timing of spawning migrations, the duration that individuals spend in the Williamson and Sprague rivers during their spawning runs, and the locations of existing spawning and holding areas used by these fishes during their spawning seasons. Limited fish passage at Chiloquin Dam to upstream spawning habitats has been identified as one of the primary factors limiting the recovery of the federally-listed endangered LRS and SNS populations in Upper Klamath Lake (USFWS 2002, National Research Council 2004). Additionally, these fish passage issues at Chiloquin Dam probably affect the migratory patterns of other fishes associated with the Sprague River drainage including KLS, redband trout (*Oncorhynchus mykiss* ssp.), and several species of endemic lamprey (*Lampetra* spp.). The U.S. Bureau of Reclamation was authorized to study the feasibility of improving fish passage at Chiloquin Dam by a provision in the 2002 U.S. Farm Bill. Through this provision, a technical working group with representatives from federal, state, and local agencies and organizations was formed and reached consensus that dam removal was the recommended fish passage alternative. Although existing data suggest some fish may be able to successfully negotiate the fish ladder at the dam under certain flow and temperature conditions, removal of the dam will likely improve access for all fish species in the Sprague River to upstream spawning and rearing habitat. The amount of suitable habitat and the extent that fish will use spawning and rearing habitat upstream of the dam, however, remains largely unknown.

Chiloquin Dam is located at river kilometer (rkm) 1.3 on the Sprague River and approximately 19 rkm upstream of Upper Klamath Lake (Figure 1). The dam was constructed in 1914 to serve as a diversion structure to supply irrigation water for the Modoc Point Irrigation District. Since its construction, the dam has been fitted with three fish ladders to aid in fish passage, only one of which is currently functional. This fish ladder was built in 1966 and has since been modified with baffle boards in an attempt to provide better passage for catostomids. The ladder consists of a series of 10 concrete pools with an average drop of approximately 0.3 m between each pool. The ladder has been periodically sampled by state, federal, and tribal agencies for the presence of migrating catostomids since 1975.

The upper Klamath Basin has several endemic fish species, two of which, LRS and SNS, were listed under the Endangered Species Act in 1988 (USFWS 2002). A third catostomid, KLS, also an upper Klamath Basin endemic, has been identified by the U.S. Fish and Wildlife Service (USFWS) as a species of concern (Oregon Natural Heritage Information Center 2004). Like other lakesuckers of western North America (i.e., cui-ui *Chasmistes cujus* and June sucker *Chasmistes liorus*), the LRS and SNS are long-lived (up to 30 to 40 years) obligatory lake dwellers that use the primary tributaries of the lakes they are found in for spawning (Koch 1973; Scoppettone 1988; Scoppettone and Vinyard 1991; Moode and Muirhead 1994; Cooperman and Markle 2003). Most LRS and SNS entering the Williamson River during their spring spawning migrations are believed to spawn on the shallow riffles in the lower Williamson River from the fish weir up to the confluence with the Sprague River and in the Sprague River up to Chiloquin Dam (Figures 1 and 2). Some movement of LRS and SNS through the Chiloquin Dam fish ladder has been documented and catostomid eggs and larvae tentatively identified as belonging to these species have been collected from reaches above the dam (Perkins et al. 2000; C. Bienz, The Nature Conservancy, personal communication; USGS, unpublished data). Unlike LRS or SNS, KLS are believed to be more of a riverine species, although they can be found in Upper Klamath Lake as well (Moyle 2002). They too display an upstream migratory behavior in the early spring that is believed to be associated with a spawning migration from the lower reaches of the Williamson and Sprague rivers to the upper reaches of the Sprague River drainage. Spawning migrations and distributions of KLS, LRS, and SNS in the Sprague River above Chiloquin Dam, however, remain poorly understood.

In 2000, the U.S. Geological Survey (USGS) implemented an intensive routine sampling program at the Chiloquin Dam fish ladder to monitor the composition, timing, and relative abundance of the catostomid spawning runs in the Sprague River as part of a larger effort to monitor adult LRS and SNS populations in the Upper Klamath Basin (Shively et al. 2001). Regular sampling of the fish ladder has shown that numbers of

KLS, LRS, and SNS entering it can be highly variable between years. Perkins et al. (2000) suggested that increasing water temperature may be an important cue for migrating fish in the Sprague and Williamson rivers. Instream flow conditions and length of daily photoperiod may also influence these migrations (USGS, unpublished data). The efficiency of the Chiloquin Dam fish ladder in passing catostomids and the extent they are able to find, enter, and negotiate the ladder under various flow and temperature conditions, however, is still largely undetermined.

Early radio telemetry studies have provided some descriptions of catostomid spawning migrations within the Williamson-Sprague river system (Buettner and Scoppettone 1990, C. Bienz, The Nature Conservancy, personal communication). Most radio-tagged LRS and SNS entering the Williamson River from Upper Klamath Lake were located in the lower Williamson River up to the confluence with the Sprague River (rkm 9.5 to 17.5) and in the lower Sprague River below Chiloquin Dam (rkm 0 to 1.3). These studies documented some movement of catostomids through the Chiloquin Dam fish ladder and some radio-tagged individuals were found migrating as far upstream as Beatty Gap but did not provide the needed detail to meet the objectives of determining changes in spawning distribution after the removal of Chiloquin Dam.

During the 2004 and 2005 spawning seasons, we fitted a combined total of 51 KLS, 45 LRS, and 35 SNS captured from the Chiloquin Dam fish ladder with radio transmitters and released them above the dam (Tyler et al. 2007, Ellsworth et al. 2007). Tracking efforts were extended to the 2006 spawning run with the same objectives and using most of the same protocols with some slight modification to improve tag retention and tracking ability as mentioned below. Findings from this study are expected to help assess changes in distribution and migratory behavior of catostomids in the Sprague River following the removal of Chiloquin Dam.

Methods

<u>Site Description</u>

Upper Klamath Lake is a remnant of the Pleistocene Lake Modoc located on the east side of the Cascade Mountain Range in south-central Oregon. At full capacity Upper

Klamath Lake has a surface area of 259 km^2, making it one of the largest freshwater lakes in the western United States (Dicken 1980). Although Upper Klamath Lake is relatively shallow with an average depth of only 2.4 m, it does have numerous pockets of deep water along a narrow trench on the western shore ranging in depth from 3 to 15 m. Historical records indicate that Upper Klamath Lake had been eutrophic prior to early Anglo-settlement (Wood et al. 2006); however, it has since become hypereutrophic primarily due to high nutrient loading from various land-use practices (USFWS 2002). This is a condition that promotes high production of the blue-green alga *Aphanizomenon flos-aquae* which leads to subsequent deterioration of water quality and occasional fish kills.

The Sprague River originates to the east of Upper Klamath Lake in the Gearhart and Quartz mountains draining an area of approximately 4,092 km^2. The Sprague River is a low gradient river (approximately 0.4m/km) and is characterized by broad valleys with extensive riverine meanders interspaced with low canyons or gaps created by uplifts or block faulting geology. Associated with these uplifted areas is an upwelling of groundwater which recharges the Sprague River as it cuts through these formations (Gannett et al. *In press*). The Sprague River is the principal tributary of the Williamson River which also originates east of Upper Klamath Lake in the Yamsay Mountains. Combined, the Williamson and Sprague rivers provide approximately 50 percent of the annual inflow to Upper Klamath Lake (Kann and Walker 2001). Both rivers typically exhibit a spring snowmelt hydrograph.

Fish Collection, Radio Tags, and Surgical Procedures

During the spring of 2006, 30 KLS, 32 LRS, and 28 SNS were collected at the Chiloquin Dam fish ladder (Table 1), fitted with external radio transmitters, and released approximately 100 m upstream of the dam (Figure 1). Each fish was identified to species, sex, and spawning condition, measured for fork length, and inserted with a 134 kHz passive integrated transponder (PIT) tag prior to the attachment of a radio transmitter. Species and gender determination for each fish was based on morphological characteristics as described in Markle et al. (2005). A sample of fin tissue was also collected from each fish so a genetic analysis could be conducted at a later date should it be deemed necessary to do so. Adult-size catostomids captured in the Chiloquin Dam fish ladder were assumed to be on an upstream migration. We also assumed, based on known life history characteristics for these species and other closely related species, that upstream movement of these fish during this time of year is associated with spawning activity (Moyle 2002). As an additional way of confirming spawning activity, a concurrent USGS project was conducted to monitor larval catostomid drift in the Sprague and lower Williamson rivers to determine if larvae were emigrating from the reaches where we located adult fish. Data on larval drift collected during 2006 will be presented in a separate report.

One additional KLS was tagged and released at the mouth of the lower Williamson River using the same methodology described above (Table 1, Figure 1). High flows and a heavy debris load in the lower Williamson River prevented the capture of additional fish for tagging at this location; however, 43 LRS and 60 SNS that had been fitted with radio transmitters as part of another concurrent USGS study on Upper Klamath Lake were also detected entering the Williamson River and crossing upstream of the fish weir during the 2006 spawning season (Table 2). These fish were tracked to analyze the movements of catostomids as they crossed the fish weir and approached Chiloquin Dam on their spawning migrations.

Fish selected for tagging were all in prespawn condition (no expression of gametes when lightly squeezed) and were unmarked in USGS adult monitoring efforts as indicated by a lack of a PIT tag. Minimum fork length for fish selected for tagging was 350 mm. Fish were tagged and released over the duration of each species' spawning migration through the Chiloquin Dam fish ladder. Each fish was fitted with a small submersible external radio transmitter (Grant Systems Engineering Pisces tag) measuring approximately 30 x 10 x 10 mm. The internal components of each tag were sealed in a foam epoxy resulting in a nearly neutrally buoyant tag weighing approximately 2.0 g in air but only 0.2 g in water. The foam epoxy surrounding the tags was colored grey to mimic the dorsal coloration of the fish. Battery life of each tag was estimated by the manufacturer to be approximately eight to ten weeks with a signal burst set at every 3.0 seconds during the day and every 5.0 seconds at night. Tags were programmed to transmit on four different frequencies ranging from 164.290 MHz to 164.340 MHz and each tag was set to generate a unique coded identifier. Field tests for these tags showed that codes could be received at a distance of approximately 100 m at ground level and approximately 600 m from a plane flying at 300 m elevation. External radio transmitters were selected instead of internal radio transmitters for this study in an effort to minimize additional stress placed on these fish during their spawning migrations.

Each fish to be fitted with a radio transmitter was first lightly anesthetized by placing it in a mixture of 0.1 g Tricaine Methane Sulfonate (MS-222) to 1 liter river water. The radio transmitters were attached externally to the fish at the dorsal fin by threading anchor material (18-lb test nylon-coated, seven-strand stainless steel wire) through the dorsal pterygiophores with a 15.2 mm, 14-gauge Rosenthal needle. The anchor material was passed through each fish twice for a double-posted attachment technique. One end of the anchor material was crimped with a brass sleeve behind a 6.4-cm^2 plastic backer. The other end of the anchor material was crimped with a piece of inferior wire behind a similar backer with the expectation of this crimp eventually corroding, thereby causing the tag to release from the fish. The nylon coating on the anchor material was removed with a butane torch prior to applying the crimps to make a good metal-to-metal connection with each crimp. Each tagged fish was allowed to recover in a holding tank with a dilute amount of StressCoat® solution for 30 to 60 minutes prior to being released.

<u>Fish Tracking and Data Collection</u>

Fish locations were determined using remote telemetry stations, weekly aerial surveys, and weekly ground surveys. Remote telemetry stations were located on the Williamson River at rkm 0 (mouth of the Williamson River) and rkm 9.5 (Williamson River fish weir); on the Sprague River at rkm 0.5 (Chiloquin), rkm 1.3 (Chiloquin Dam), rkm 13.0 (Braymill fish hatchery), rkm 47.1 (the lower end of S'Ocholis Canyon), and rkm 111.4 (the lower end of Beatty Gap); and on the Sycan River at rkm 3.6 (Figure 1). A Grant Systems Orion receiver/data logger was used at each remote telemetry station to detect and record fish movements past each station. The reception of each receiver was tested by lowering a weighted radio tag to the bottom of the river at various locations near the site to ensure that a radio-tagged fish crossing the site would be detected. The hardware and location of each remote station was adjusted to maximize our ability to detect fish crossing each site. Data recorded by the data loggers were downloaded on a weekly basis to make sure they were recording data properly.

Aerial surveys were conducted on a weekly basis in a fixed-wing aircraft with two whip antennas (Model CI-177-1) attached to the aircraft's struts. A Lotek SRX_400 receiver was used during aerial surveys to search for and locate fish with tags on the four frequencies used for fish tagged at Chiloquin Dam and the lower Williamson River. An Orion receiver/data logger was also used during these surveys to record encounters with fish on the remaining 11 frequencies used for fish tagged in Upper Klamath Lake. Aerial surveys focused on the lower Williamson River up to Spring Creek, the Sprague River up to the confluence of the North and South Forks, and the Sycan River up to Coyote Bucket Canyon. When a fish was recorded passing one of our upstream remote stations, the aerial survey was extended past that station and into tributaries until the fish was located or until a fish barrier was reached.

Weekly ground surveys were conducted during the daytime in areas where aerial surveys indicated tagged fish were concentrating (Table 3). Fish were located with a Lotek SRX_400 receiver and a hand-held 4-element Yagi antenna during these surveys. Fish locations were marked by obtaining a Global Positioning System (GPS) reading and characterized by recording the general mesohabitat type, water temperature and depth, substrate type, and average water velocity at two-thirds of the water column from the bottom and 10 cm from the bottom of the river. Substrate type was determined either visually or by probing with a wading rod.

Two additional remote telemetry stations were installed on the Sprague River in 2006, one at rkm 0.5 (Chiloquin Remote Station) and one at Chiloquin Dam (rkm 1.3; Figure 2). These remote stations were installed to monitor the movements of radio-tagged fish in the spawning areas between the Williamson River fish weir and Chiloquin Dam, and to compare these movements to detections of PIT-tagged fish migrating through the Chiloquin Dam fish ladder as well as catches in the fish ladder. The remote telemetry stations were also installed to determine how many radio-tagged fish crossing the weir reached the dam and to approximate travel and lingering times for radio-tagged fish in this reach.

Egg collection mats and plankton net tows were used to sample for eggs in areas where fish were observed congregating or holding for multiple days. The egg collection mats, which were made of 2.5-cm thick filter material (Enkamat® PF13C) fixed to a 1 x 0.75 m wire frame, were placed below the nearest riffle and checked on the following week on the next survey in that reach. Plankton nets were used to collect eggs by towing the nets behind a boat in suspected spawning areas. Water depths in 2006 precluded the use of kick nets for egg sampling.

Data Analysis

Data collected from fish tracking efforts were stored in an electronic database from which information for individual fish were extracted for processing. Migration destinations were determined from the furthest upstream detection for each individual fish. Migration patterns were grouped by species, timing of fish passage through the Chiloquin Dam fish ladder, and by destination.

Fish movements at the dam were determined primarily by analyzing the timing and duration of detections received on the two directional antennas located on either side of the dam. A fish's proximity to the dam was determined by analyzing signal strength and reception on these two antennas. A fish's approach to the telemetry station was defined as when a fish entered the area where it was detected by at least one antenna for more than 30 consecutive minutes. This time was used in calculating the first detection at the station discussed below. A fish's approach to the dam was similarly defined as when a fish entered the area where it was detected on both antennas for more than 30 consecutive minutes. This time was used in calculating the amount of time spent at the dam and for determining the number of approaches made on the dam. Departures from the dam were defined as when the fish was no longer detected on the respective antennas for more than 10 minutes. All detections of less than 30 minutes with an absentee time of more than 10 minutes were deleted to eliminate noise and code collisions as well as intermittent detections made with fish located on the fringe of the detection limit for the telemetry station.

Results

Klamath Largescale Sucker

Of the 30 KLS tagged at the Chiloquin Dam fish ladder, eight (3 females and 5 males) were tagged at the outset of the spawning run between March 27 and March 31. Seventeen KLS (11 females and 6 males) were tagged between April 14 and April 26, during which time 1764 KLS were captured in the fish ladder (Janney et al. *In review*; Figure 3). The remaining five KLS (4 females and 1 male) were tagged between May 1 and May 12. During this period, 441 KLS were captured in the fish ladder (Janney et al. *In review*). The mean (± SD) fork lengths of KLS fitted with radio tags at Chiloquin Dam were 446 ± 30 mm for males and 476 ± 40 mm for females.

Klamath largescale suckers tagged from the Chiloquin Dam fish ladder were located migrating to four general areas: Beatty Gap, the Nine Mile area, the North Fork of the Sprague River, and the Sycan River (Figure 4). We tracked six male and four female KLS to Beatty Gap (Figure 5a and 5b). Six of these fish were from the first group of KLS coming through the Chiloquin Dam fish ladder (Figure 3). The other four were tagged at later dates. Three of the earlier running male KLS that migrated up to Beatty Gap appeared to return several kilometers downstream before returning to Beatty Gap a second time. This second return coincided with the arrival of a KLS radio-tagged later in the season. The mean (± SD) upstream travel time from Chiloquin Dam to Beatty Gap was 511 ± 117 hours for male KLS and 471 ± 270 hours for female KLS. The mean (± SD) lingering time in Beatty Gap was 344 ± 262 hours for male KLS and 57 ± 43 hours for female KLS. Two male KLS were tracked downstream to the lower Williamson River and into Upper Klamath Lake before their tags stopped transmitting in late May. Travel times from Beatty Gap to the lower Williamson River were 307 and 576 hours for these two male KLS. Tags from the remaining fish stopped transmitting either while the fish were still in Beatty Gap or while they were in the Sprague River Valley during their return migration (Figure 5a and 5b).

We tracked three male and one female KLS to the Nine Mile area between rkm 18 and 38 on the Sprague River during the spring of 2006 (Figure 6). These fish took between three and six days to migrate upstream from Chiloquin Dam to the Nine Mile area. One female and one male lingered in this area for approximately four and six weeks, respectively. Of the remaining two KLS tracked into the Nine Mile area, one shed its tag and the other was not detected after the first week of reaching the Nine Mile area.

Two female KLS were located in the North Fork of the Sprague River (Figure 7). One was located at rkm 3.7 in the North Fork of the Sprague River at the confluence of Five Mile Creek and the other was located several times in the mainstem of the North Fork of the Sprague River, the furthest upstream of which was between Ivory Pine Road and Bailey Flat at rkm 10.4. Another male KLS was located in the Sycan River above the Sycan remote station at rkm 4.8 (Figure 8). It is unknown how far upstream these fish migrated or if they spawned but larval KLS were collected in the Sycan River during this study (USGS, unpublished data). Additionally, radio-tagged KLS released from the Chiloquin Dam fish ladder had also been located in the Sycan River and in the North Fork of the Sprague River in 2005 (Ellsworth et al. 2007). Upstream travel times from Chiloquin Dam to Beatty Gap were 324 and 385 hours for the two female KLS we located in the North Fork. The upstream travel time from Chiloquin Dam to the Sycan River remote station was 445 hours for the male KLS located in the Sycan River. Lingering times above Beatty Gap were 344 and 781 hours for the two females located in the North Fork. Lingering time above the Sycan River remote station for the male KLS located in the Sycan River was between 59 and 184 hours. All three of these fish were captured in the Chiloquin Dam fish ladder from April 14 to April 24 and were subsequently tracked downstream to the lower Williamson River or Upper Klamath Lake after their upstream migrations. Downstream travel times were 112 and 115 hours for the two KLS located in the North Fork and 378 hours for the KLS located in the Sycan River.

Three female KLS were tracked past the remote station at S'Ocholis Canyon into the Sprague River Valley, where they were not detected again until they passed S'Ocholis Canyon again on their downstream migration (Figure 9a). These three fish, which were tagged throughout the KLS spawning run, were above the S'Ocholis Canyon remote station between one and five weeks before returning downstream. Because these fish were not detected in the main channel of the Sprague River during our weekly aerial surveys or at upstream remote stations at Beatty Gap or the Sycan River, it is possible that they migrated into a tributary between S'Ocholis Canyon and Beatty Gap. Two of these fish were located entering Upper Klamath Lake on their return migration while the third lingered in the Nine Mile area until its tag expired.

The one male KLS fitted with a radio tag and released in the lower Williamson River on March 28 had a fork length of 359 mm. Upon release, this fish was tracked downstream into Upper Klamath Lake. It was detected again in the lower Williamson River on May 2 where it lingered for approximately 35 hours before returning to the lake.

Lost River Sucker

Lost River suckers were captured in the Chiloquin Dam fish ladder from March 20 to May 31 with the greatest number of fish caught from April 21 to May 5 (Janney et al. *In review*; Figure 3). We fitted 32 LRS (17 females and 15 males) with radio tags from March 27 to May 12. Five of these (three females and two males) were tagged on March 27 and March 31 during the first days that substantial numbers of LRS were observed entering the fish ladder. The remaining fish, except for one female tagged on May 12, were tagged between April 10 and May 3 during the period which encompasses the peak LRS catch at the fish ladder (Janney et al. *In review*; Figure 3). The mean (± SD) fork length of LRS fitted with radio transmitters at the Chiloquin Dam fish ladder was 589 ± 36 mm for males and 651 ± 43 mm for females. Lost River suckers captured in the Chiloquin Dam fish ladder and fitted with radio tags were observed migrating to four general areas in 2006. Most radio-tagged LRS were located migrating to the lower Williamson River from the weir to the confluence of the Sprague River and continuing up the Sprague River to Chiloquin Dam. Radio-tagged LRS released above the dam were generally located below Chiloquin Narrows, in the Nine Mile area, and in Beatty Gap. Individuals were also located migrating to the Sprague River Valley and the Sycan River (Figure 10). Radio-tagged LRS released above Chiloquin Dam earlier in the year generally migrated further upstream (i.e., Beatty Gap and the Nine Mile area) than LRS released later in the year.

We tracked four female and three male LRS to Beatty Gap in 2006 (Figure 11a and 11b). Three of these fish (one male and two females) were tagged from among the first individual LRS captured in the Chiloquin Dam fish ladder in late March. The other four were tagged between April 10 and April 21, which was prior to the peak catch of LRS in the fish ladder (Figure 3). The mean (± SD) upstream travel time from Chiloquin Dam to Beatty Gap was 279 ± 41 hours for male LRS and 305 ± 60 hours for female LRS. The mean (± SD) lingering time in Beatty Gap was 322 ± 150 hours for male LRS and 108 ± 46 hours for female LRS. Three of the LRS that were tracked to Beatty Gap (two males and one female) were subsequently tracked downstream to Upper Klamath Lake on their return migration. The mean (± SD) travel time from Beatty Gap to the lower Williamson River was 346 ± 75 hours for these male LRS. Two females returned to the Nine Mile area on their downstream migration where they remained until their tags stopped transmitting. One fish was tracked downstream into the Sprague River Valley where it appeared to linger at rkm 102 (approximately 5 rkm downstream of the confluence of the Sprague and Sycan rivers) for at least one week before its tag expired. The remaining fish was last located at the remote telemetry station in Beatty Gap. We did not locate any LRS upstream of Beatty Gap in 2006.

We tracked one male and four female LRS upstream into the Nine Mile area after their release above Chiloquin Dam (Figure 12). These fish were tagged on April 14 and April 17, which was prior to the peak catch of LRS in the fish ladder. Two of these fish (one male and one female) remained in the Nine Mile area until their tags stopped transmitting. One female remained in an off-channel habitat at rkm 28.1 for approximately four weeks before moving a short distance upstream after falling water levels dewatered the backwater she had been using. Two other females were tracked into the Nine Mile area but only stayed for a short period (one to three days) before migrating back down to the lower Williamson River and the lake. The remaining female was located in the Nine Mile area 25 days after it had been released above Chiloquin Dam. This was the only detection of this fish prior to its tag expiring.

One female LRS was tracked into the Sycan River (Figure 8). Upstream travel time from Chiloquin Dam to the remote station on the Sycan River was 236 hours. Lingering time in the Sycan River was 93 hours and downstream travel time to Upper Klamath Lake was 72 hours. How far upstream this fish migrated or if it spawned is not known, but larval LRS were collected in the Sycan River below where this fish was located in 2006 (USGS, unpublished data). Another LRS (a male) was tracked into the Sprague River Valley but was not located for approximately three weeks despite multiple aerial surveys of the area. After this fish was relocated in the Sprague River Valley on a subsequent aerial survey, it was tracked back down to Upper Klamath Lake (Figure 9b). We suspect this fish may have moved into a tributary of the Sprague River between S'Ocholis Canyon and Beatty Gap during the three weeks it went undetected.

We also tracked four male and three female LRS into the reach of the Sprague River between Chiloquin Dam and the bottom of Chiloquin Narrows. Their lingering times in this area ranged from approximately one to three days. Two other LRS shed their tags while migrating upstream through this section of river. Five male and four female LRS fell back over Chiloquin Dam shortly after release. These fish were tagged from March 31 to May 12 with most being released during the peak catch of LRS in the fish ladder. The amount of time these fish spent above the dam after release ranged from five minutes to 12 hours. The majority of fish that fell over the dam, however, lingered either immediately below the dam or further downstream in the Sprague or Williamson rivers for at least one week before returning to Upper Klamath Lake (Figure 13c and 13d). This behavior is similar to that exhibited by LRS falling over the dam in 2005 (Figure 13a and 13b).

An additional 30 male and 29 female LRS tagged in Upper Klamath Lake as part of a concurrent USGS study, as well as one female LRS tagged in Lake Ewauna prior to the opening of the new Link River Dam fish ladder, were detected in the Williamson and Sprague rivers in 2006 (Table 2). Not one of these LRS was located in the Chiloquin Dam fish ladder or above the dam. Most male LRS crossed above the Williamson River fish weir from April 21 to April 29, and most female LRS crossed above the weir from April 23 to May 6 (Figure 14). Male LRS also spent more time above the weir than females--a mean (± SD) of 326.9 ± 119.4 hours above the weir versus 183.5 ± 76.3 hours.

Shortnose Sucker

Shortnose suckers were captured in the Chiloquin Dam fish ladder from 14 April to 19 May. We tagged 28 SNS (14 females and 14 males) captured in the fish ladder from 24 April to 12 May, which was during the period with the highest number of SNS captures in the fish ladder (Janney et al. *In review*; Figure 3). Shortnose suckers captured in the Chiloquin Dam fish ladder and fitted with radio tags were mostly located in the lower Williamson River from the weir to the confluence of the Sprague River and continued up the Sprague River to below Chiloquin Narrows (Figure 15). The mean (± SD) fork length of SNS fitted with radio tags at the Chiloquin Dam fish ladder was 429 ± 29 mm for males and 445 ± 19 mm for females.

Similar to SNS behavior observed in 2005, some individuals fell back over the dam shortly after being released in 2006 and returned directly to Upper Klamath Lake, while others lingered above and below Chiloquin Dam before migrating back downstream (Figure 16). Lingering times above Chiloquin Dam after release ranged from 18 minutes to more than 22 days. Only one SNS (a male) passed above the remote telemetry station at Braymill, spending approximately seven days in the Nine Mile area. We tracked six male and five female SNS into the reach of the Sprague River between the impoundment and the bottom of Chiloquin Narrows (Figure 16c and 16d). Five males and two females spent more than one week above Chiloquin Dam after release. Eight male and nine female SNS fell back over the dam within 18 hours of release. Among the males that fell over the dam shortly after release in 2006, one remained in the vicinity of the dam and navigated back upstream through the fish ladder 14 days after falling over. This fish was later detected approximately 1.5 rkm upstream of the dam and was then tracked back downstream into the Williamson River before its tag expired.

An additional 30 male and 30 female SNS tagged in Upper Klamath Lake during a concurrent USGS study were tracked into the Williamson River in 2006 (Table 2). Not one of these SNS was located in the fish ladder or above Chiloquin Dam. Most male SNS crossed above the Williamson River fish weir from April 26 to May 8 and most female SNS crossed above the weir from April 24 to May 10 (Figure 14). These male

SNS spent more time above the weir than females--a mean (± SD) of 451.7 ± 255.1 hours above the weir versus 220.2 ± 163.7 hours.

Habitat Associations

Observations of habitat associations during radio telemetry tracking efforts in the Sprague River above Chiloquin Dam in 2006 show an increased occurrence of radio-tagged fish detected in off-channel habitats as compared to 2005. Most detections made in 2006 were still made in main-channel habitats including pools (27%), glides (16%), and runs (15%); but 20% of the detections were in off-channel backwaters and oxbows. In contrast, less than 1% of detections were made in off-channel habitats in 2005when water levels in the Sprague River were lower. The substrate at sites where fish were located was mainly silt, cobble, and clay; however, these observations were most likely inaccurate due to an inability to gauge substrate type in deep water. Approximately 22% of the habitat observations were at locations with water depths >2.5 m, the depth limit for our sampling gear. Of those that were measurable, the mean (± SD) depth at fish locations for all habitat types combined was 1.72 ± 0.49 m, and the mean (± SD) water velocity 10 cm above the substrate was 0.98 ± 1.11 m/s. Water temperatures at fish locations ranged from 9.5 to 22.0 ºC.

Habitat use was similar between KLS and LRS with the exception that LRS were observed more often in pools than other habitat types. The number of habitat observations for SNS was too limited for comparison. Despite repeated sampling with egg mats and plankton net tows, spawning was not confirmed during any of the tracking surveys in 2006. This was primarily because of deep water, high turbidity, and high water velocities resulting from above average flows in the Sprague River in 2006 and because we targeted areas where spawning was suspected but had not been previously documented. Fish were observed congregating in areas where spawning was confirmed in 2005 and the presence of catostomid larvae was documented in 2006 during a concurrent larval catostomid drift study (USGS, unpublished data).

Fish Behavior at Chiloquin Dam

Radio-tagged LRS and SNS were first detected at Chiloquin Dam in the third week of April, 2006. The arrival of radio-tagged fish corresponded to increased detections of PIT-tagged fish on the remote PIT tag detection antennas at the Chiloquin Dam fish ladder and fish captures in the ladder (Janney et al. *In review*; Figure 17). As expected, the remote telemetry station at the dam first started detecting radio-tagged fish approaching the dam which was then followed by an increase in PIT tag detections on the antenna at the bottom of the fish ladder and then an increase in fish captures in the fish ladder. A comparison of PIT tag detections for KLS with the capture of KLS in the ladder showed an early increase in PIT tag detections prior to fish being captured in the fish ladder (Janney et al. *In review*; Figure 17a). The first large catch of catostomids in the fish ladder occurred when the river temperatures reached approximately 11^{o}C and movement through the ladder generally occurred during increases in water temperature. This indicates there may have been some sort of temperature related delay for KLS attempting to pass through the Chiloquin Dam fish ladder early in the season in 2006. In contrast, a comparison of radio tag detections, PIT tag detections, and captures in the ladder for LRS and SNS did not suggest such a delay, although movement through the fish ladder also occurred during increases in water temperature (Figure 17b and 17c). The timing of these detections also showed that the spawning runs for the three catostomid species came through the fish ladder in short succession in 2006.

Travel times for radio-tagged fish between the telemetry stations located at the weir and the dam showed that SNS generally took longer to arrive at the dam than LRS. The mean time to cross this distance was 164.3 ± 149.7 hours for male SNS and 182.6 ± 82.8 hours for female SNS, as compared to 87.2 ± 21.6 hours for male LRS and 69.8 ± 28.8 hours for female LRS (Figure 18). For radio-tagged fish that were detected migrating upstream past the weir, only 51% of LRS and 39% of SNS were subsequently detected at the Chiloquin remote telemetry station in the lower Sprague River (Table 2).

The mean (± SD) number of approaches and amount of time spent by upstream-migrating LRS at the dam was greater for males than females (Figure 19 and Figure 20). The mean number of approaches on the dam was 5.6 ± 8.7 for male LRS and 3.5 ± 3.4

for female LRS. The mean time spent at the dam prior to migrating back downstream was 211.3 ± 137.5 hours for male LRS and 57.1 ± 43.0 hours for female LRS. Male SNS migrating upstream also averaged more approaches on the dam but generally spent less time at the dam than female SNS (Figure 19 and Figure 20). The mean number of approaches on the dam was 5.8 ± 8.1 for male SNS and 4.4 ± 5.8 for female SNS. The mean time spent at the dam prior to migrating back downstream was 24.5 ± 28.1 hours for male SNS and 73.0 ± 127.3 hours for female SNS.

More time elapsed between the first and last detection at the dam for males migrating upstream than for females for both LRS and SNS (Figure 21). After reaching the dam, 22% of LRS and 50% of SNS made multiple movements downstream past the Chiloquin remote station and then returned to the dam. Those individuals that left the reach below the dam and returned generally did so only one or two times. No male LRS were detected leaving the reach below the dam and subsequently returning to the dam.

Radio-tagged Fish That Did Not Cross the Williamson River Fish Weir

Most of the LRS and SNS that had been fitted with radio transmitters and released in Upper Klamath Lake entered the Williamson River and continued upstream across the fish weir in 2006. There was, however, a large percentage of radio-tagged fish (27% of LRS and 14% of SNS) that did not enter the Williamson River during the 2006 spawning season (Table 2). There was also a number of radio-tagged fish (7% of LRS and 9% of SNS) that were located in the Williamson River but did not cross the weir. Of these fish, only two (both LRS) were detected by the remote telemetry station located at the weir. Of the radio-tagged fish detected only in Upper Klamath Lake in 2006, a greater number were LRS (n = 16) than SNS (n = 10). We also observed a steady decrease in the amount of time spent in the river between Upper Klamath Lake and the weir prior to crossing upstream of the weir as the spawning season progressed (Figure 22). The initial detection of fish entering the river appeared to coincide with decreases in water temperature as measured at the Williamson River fish weir (Figure 22).

Radio Tag Retention and Gear Performance

We made additional improvements in our ability to successfully track fish fitted with external radio tags in 2006 when compared to our efforts in 2004 and 2005. These improvements were due to increased use of remote telemetry stations, better tag attachment material and technique, and longer lived radio transmitters than had been used in previous years. We successfully tracked 86% of fish fitted with external radio tags until either the tag expired after the expected 8 to 10 weeks or the fish returned to the lower Williamson River or Upper Klamath Lake. We determined that of the remaining fish tagged and released in 2006, 6% prematurely shed their tags and 8% experienced some sort of tag malfunction in which the tag stopped transmitting correctly or the fish was otherwise removed from the survey area.

We recorded 1978 approaches or crossings of radio-tagged fish at our six remote telemetry stations in 2006. An analysis of fish movements indicated that at least 43 fish crossings were not detected. The majority of these missed crossings occurred at two of our remote stations during a period of time when each receiver had stopped logging data. At the mouth of the Williamson River, 24 fish crossings were missed while the station was not operating from April 20 to 25, and at the weir, eight fish crossings were missed while the station was not operating from May 3 to 4. Of the remaining 11 missed crossings, seven occurred at the Braymill station from approximately April 17 to 23. We believe these misses were due to peak flows in the river at this time causing increased water depths at the station. This made it harder to detect signals from the fish or possibly guided fish to use an alternative channel in the river where detection was more difficult. Detection at this site improved after flows in the river dropped. We could not identify a cause for the remaining four missed crossings.

Discussion

Telemetry data collected in 2006 corroborates much of what was known about the spawning migrations of these fish prior to this study. However, this study has provided more detailed information on these spawning runs with respect to run timing, migration rates, extent of upstream migration, and use of tributaries of the Sprague River than what was observed during previous studies. We continue to observe multiple groups of catostomids passing through the Chiloquin Dam fish ladder during monitoring activities and tagging efforts. In general, KLS were observed in the fish ladder first, followed by LRS, and then SNS. Remote PIT tag detection and ladder catch data collected at the Chiloquin Dam fish ladder in 2006 suggest there was some degree of delay for migrating KLS trying to pass through the fish ladder early in the season. The same PIT-tag detection and ladder catch data, and the additional radio-tag data, collected for LRS and SNS approaching Chiloquin Dam did not show similar delays of fish approaching and entering the fish ladder. The high number of KLS, LRS, and SNS detected and captured in the fish ladder and the lack of a delay for LRS and SNS suggests that passage at the fish ladder was better in 2006 than what it is believed to have been in past years. This could be the result of above average flows in the Sprague River during these spawning runs making the fish ladder more accessible to fish on their upstream migration. Radio-tagged fish that had been released below the dam were not located in the fish ladder or upstream of Chiloquin Dam in 2006. This suggests that fish passage at the dam was still restricted to only a portion of each of the runs.

Monitoring movements of radio-tagged fish in the lower Williamson River continues to show a relatively high proportion of tagged fish moving into the river, but not subsequently being detected at the fish weir. It is still undetermined why some portion of the LRS and SNS population enters the lower Williamson River during the spawning season but does not continue upstream to spawn. Radio-tagged fish were also first detected in the Williamson River following decreases in water temperature (Figure 22) and then crossed the weir following increases in water temperature providing further evidence that water temperature may be acting as a cue for these fish on their spawning migrations (Barry et al. 2007; Ellsworth et al. 2007).

Results from radio tracking of catostomids migrating through the Chiloquin Dam fish ladder in 2006 continue to suggest that certain discrete reaches of the Williamson and Sprague rivers are important spawning or holding areas for KLS, LRS, and SNS (Figure 23). We did observe some spatial and temporal overlap in spawning areas used by KLS and early LRS migrants and by later LRS migrants and SNS. Klamath largescale sucker and SNS spawning appeared to be separated temporally and may have been separated spatially as well. Radio-tagged KLS migrated to areas primarily in the Nine Mile area (rkm 13 to 46) and Beatty Gap (rkm 112 to 120). Individual KLS were also located in the Sycan River and the North Fork of the Sprague River. Radio-tagged LRS migrated to areas in the lower Williamson River (rkm 10 to 17.5), the Sprague River up to Chiloquin Narrows (rkm 0 to 10), and Beatty Gap. Individual LRS were also located in the Nine Mile area, the Sprague River Valley (rkm 60 to 107), and the Sycan River. Radio-tagged SNS migrated to areas in the lower Williamson River and the Sprague River up to Chiloquin Narrows although one individual was tracked into the Nine Mile area. Within these reaches, catostomids were located in a variety of mesohabitat types but were primarily found in the main river channel. We observed in 2006, however, an increased presence of radio-tagged fish in backwaters, oxbows, and other off-channel habitats. This may be due to higher water levels and increased availability and connectivity of these habitats compared to 2005. Measurements of physical habitat suggest that fish occupy a range of depth, flow, and temperature regimes. Despite repeated sampling efforts, we were unable to directly confirm spawning activity in any of the areas surveyed in 2006 due to high instream flows and due to our focus on documenting the presence of catostomid eggs in areas where they had previously not been documented. However, catostomid larvae were collected emigrating from areas where radio-tagged fish were tracked to in 2006 with the exception of the North Fork of the Sprague River where no larval sampling took place (USGS, unpublished data).

We also had three KLS and one LRS cross the remote telemetry station at S'Ocholis Canyon that were not detected by the remote telemetry stations upstream in Beatty Gap or on the Sycan River, nor were they detected during weekly aerial surveys of the main stem of the Sprague River in the Sprague River Valley between these sites. This indicates there may be additional spawning areas for KLS and LRS in the tributaries to the Sprague River between S'Ocholis Canyon and Beatty Gap that have yet to be identified.

High river flows and associated changes in water temperature appear to have affected the timing and duration of spawning runs in 2006. We observed an apparent delay of the earlier of KLS migrants approaching the Chiloquin Dam fish ladder. In contrast to data collected in 2005, we did not see a strong trend between run timing of KLS through the fish ladder and destination in 2006. We again saw that LRS passing through the ladder earlier in the season were more likely to migrate to areas further upstream than later LRS migrants. These early migrants were located in the Nine Mile area, Beatty Gap, and the Sycan River whereas the later LRS migrants were mostly located in the lower Williamson River and the Sprague River up to Chiloquin Narrows. Other migrational trends seen in 2006 were also similar to those seen in 2005. For example, movement continued to appear to be triggered by water temperature and most fish, especially those moving furthest upstream, exhibited rapid upstream and downstream movement to and from relatively discrete reaches of the Sprague River basin. As in 2005, we saw several KLS and LRS slow or stop their downstream migration in the Nine Mile area suggesting there may be resident individuals inhabiting this reach.

The two additional telemetry stations installed on the Sprague River at Chiloquin and at Chiloquin Dam in 2006 also revealed valuable information on spawning migration behavior in this reach of the river. Combined data from radio tag detections, PIT tag detections, and fish ladder catches provided a means to quantify delay associated with passage at the Chiloquin Dam fish ladder. The number of approaches to the dam, hours spent at the dam, and the time between the first and last detections at the dam were also quantified to assess fish movements below the dam. We also determined that individuals that enter the Sprague River rarely make more than two returns to the Sprague River after migrating back downstream to the Williamson River during the spawning season. This information, in conjunction with data to be collected after the dam is removed, will be used for assessing the effects of dam removal on catostomid spawning migrations.

The placement of additional telemetry stations in 2006 also allowed for a rough assessment of the distribution of spawning activity in the Williamson and lower Sprague rivers. The observation that only half of the radio-tagged LRS and just over a third of radio-tagged SNS recorded crossing the weir were detected at a remote telemetry station in the lower Sprague River suggests there is a significant amount of spawning activity in the 8 rkm between the weir and the confluence of the Williamson and Sprague rivers. At the same time, however, this also indicates there is a relatively high concentration of fish in the 0.8 rkm below Chiloquin Dam during the spawning run. The question of whether fish entering the Sprague River to spawn naturally concentrate in this reach or whether these concentrations are a function of restricted passage at Chiloquin Dam remains undetermined and necessitates the continuation of monitoring fish passage in this reach using these or similar methods before and after the dam is removed.

Summary and Conclusions

Locations of radio-tagged catostomids in 2006 continue to suggest that catostomids repeatedly migrate to and presumably spawn in several relatively discrete reaches of the Williamson and Sprague rivers. These reaches are located both above and below Chiloquin Dam. Although some fish passage through the Chiloquin Dam fish ladder is believed to occur under certain flow and temperature conditions, no passage of radio-tagged fish released downstream of the dam was observed in 2006. The restriction of fish passage at Chiloquin Dam likely reduces the ability of migrating individuals from reaching upstream spawning areas and concentrates a high number of spawning fish in a relatively small area below the dam. Concentrating spawning fish below Chiloquin Dam increases the risk of predation and harassment, incidental hybridization, and the damage to eggs and larvae by fish spawning over existing redds. The scheduled removal of Chiloquin Dam in 2008 is expected to allow better access to spawning habitat further upstream in the Sprague River and may alleviate the problem of crowding in the reach below the dam. This study is establishing a baseline for the existing distribution, timing, and behavior of spawning catostomids in the lower Williamson and Sprague rivers prior to the removal of Chiloquin Dam. Continuation of this work after dam removal will provide a means to quantify changes in spawning distribution and help natural resource managers evaluate the effects of this action.

Acknowledgements

We thank Jonathan Baldwin, James Hoang, William Lehman, Rob Scheuermann, and other staff members at the Klamath Falls Field Station for their hard work and dedication in collecting and processing data and reviewing this manuscript. This project was funded by the U.S. Bureau of Reclamation (Interagency Agreement 01AA200026), the U.S. Fish and Wildlife Service (Agreement 81450-6-H515), and the U.S. Geological Survey. The use of trade, firm, or corporation names in this publication is for informational use and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Interior or the U.S. Geological Survey of any product or service to the exclusion of others that may be suitable.

Table 1. Number of radio-tagged Klamath largescale suckers (KLS), Lost River suckers (LRS), and shortnose suckers (SNS) detected in Upper Klamath Lake, Williamson River, and above Chiloquin Dam on the Sprague River in 2006.

		Release Location				
		Upper Klamath Lake	Williamson River	Chiloquin Dam	Total	
KLS	Male	0	1	12	13	31
	Female	0	0	18	18	
LRS	Male	32	0	15	47	91
	Female	27	0	17	44	
SNS	Male	37	0	14	51	98
	Female	33	0	14	47	
Total		129	1	90	220	

Table 2. The number of radio-tagged male and female Lost River suckers (LRS) and shortnose suckers (SNS) that were released in Upper Klamath Lake and detected at the four remote telemetry stations in the lower Williamson and Sprague rivers in 2006. The difference in the number of fish detected at each remote telemetry station indicates the number of fish that ceased their upstream migration in the reach between each station. River kilometers (rkm) are given from Upper Klamath Lake.

		Did not enter the Williamson River	Detected at the mouth of the Williamson River (rkm 0)	Detected at the Williamson River fish weir* (rkm 9.5)	Detected at the Chiloquin Remote Station (rkm 18)	Detected at Chiloquin Dam** (rkm 18.8)
LRS	Male	10	22	21	8	7
	Female	6	21	20	13	11
SNS	Male	7	30	26	10	9
	Female	3	30	28	11	9
Total		26	103	95	42	36

*All but two LRS (one male and one female) detected at the Williamson River fish weir crossed upstream in 2006.
**None of the radio tagged fish released in Upper Klamath Lake were detected upstream of Chiloquin Dam in 2006.

Table 3. Number of radio telemetry surveys where habitat association data were collected for radio-tagged fish in 2005. The number of fish detections and checks for catostomid eggs using egg mats or net tows by reach on the Sprague River are also given.

Reach	Survey area (rkm)	Number of surveys	Number of fish detections	Number of egg mat/net tow samples
Chiloquin Dam	rkm 0-13	10	79	6
Nine Mile	rkm 10-48	10	54	23
Beatty Gap	rkm 111-120	2	11	0

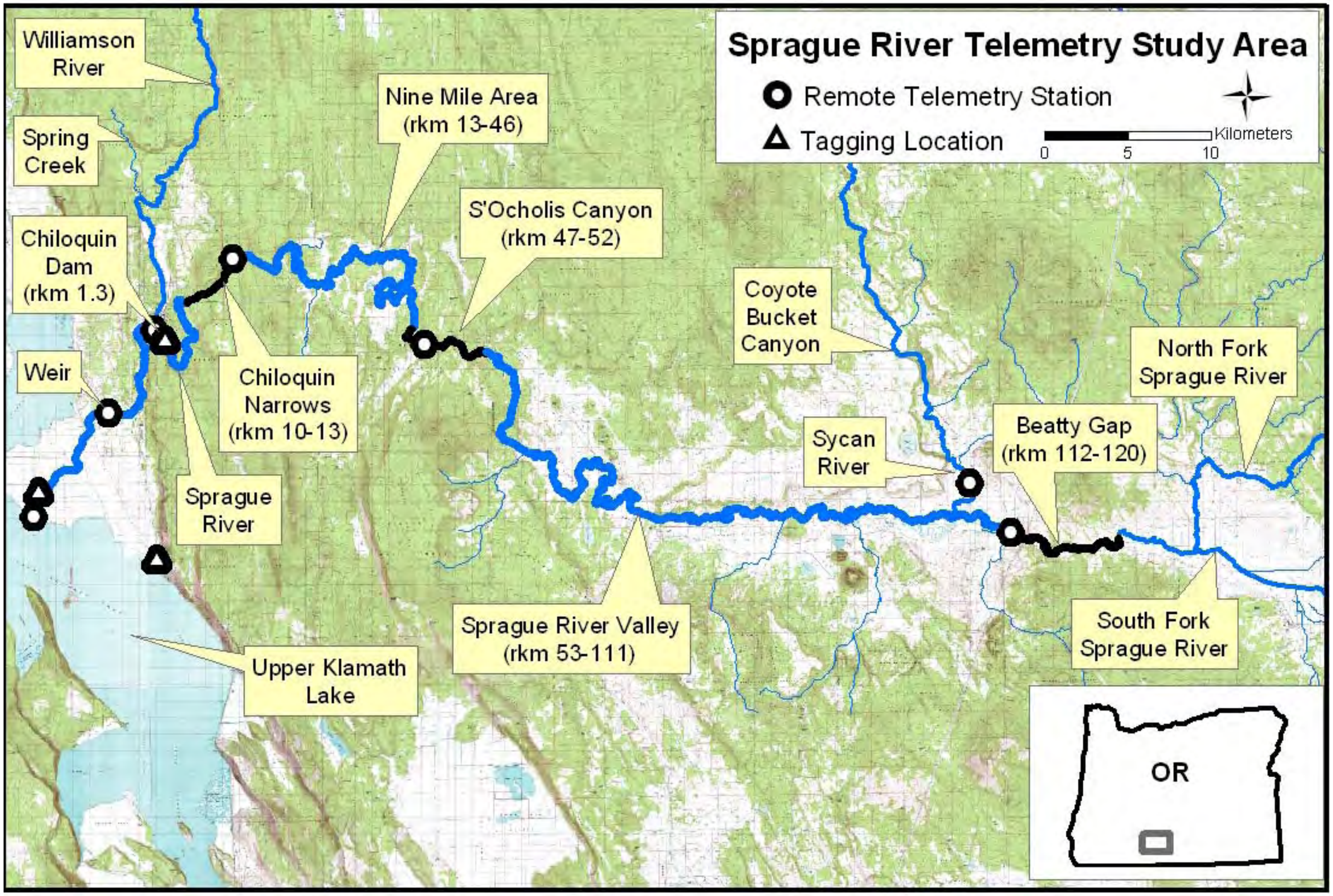

Figure 1. Map of the study area identifying river reaches, tagging locations, and remote telemetry station locations used to determine the spawning movements of Klamath largescale, Lost River, and shortnose suckers in the Williamson and Sprague rivers, Oregon, in 2006.

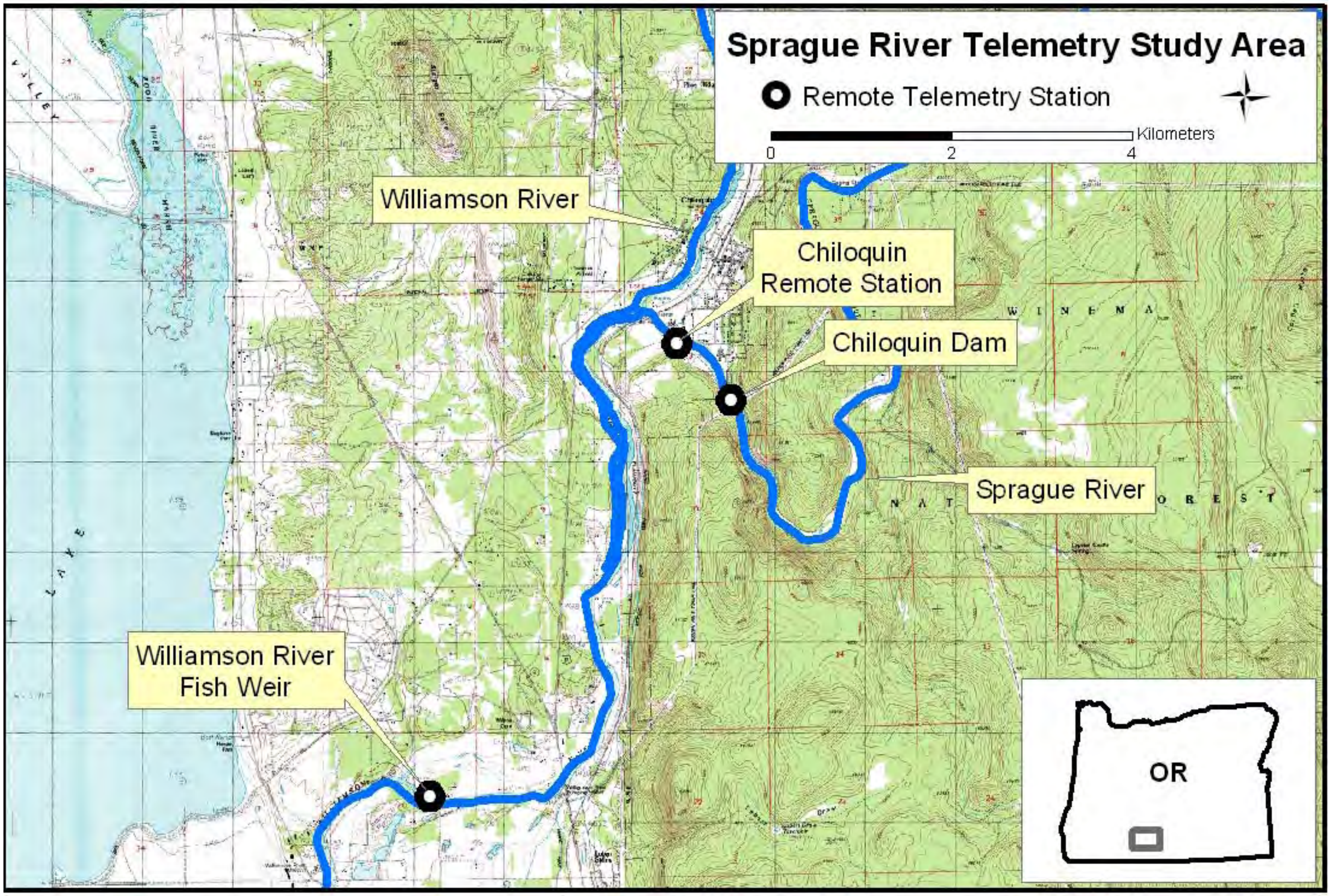

Figure 2. Map of remote telemetry station locations used to determine the spawning movements of Klamath largescale, Lost River, and shortnose suckers in the lower Sprague and Williamson rivers, Oregon, in 2006.

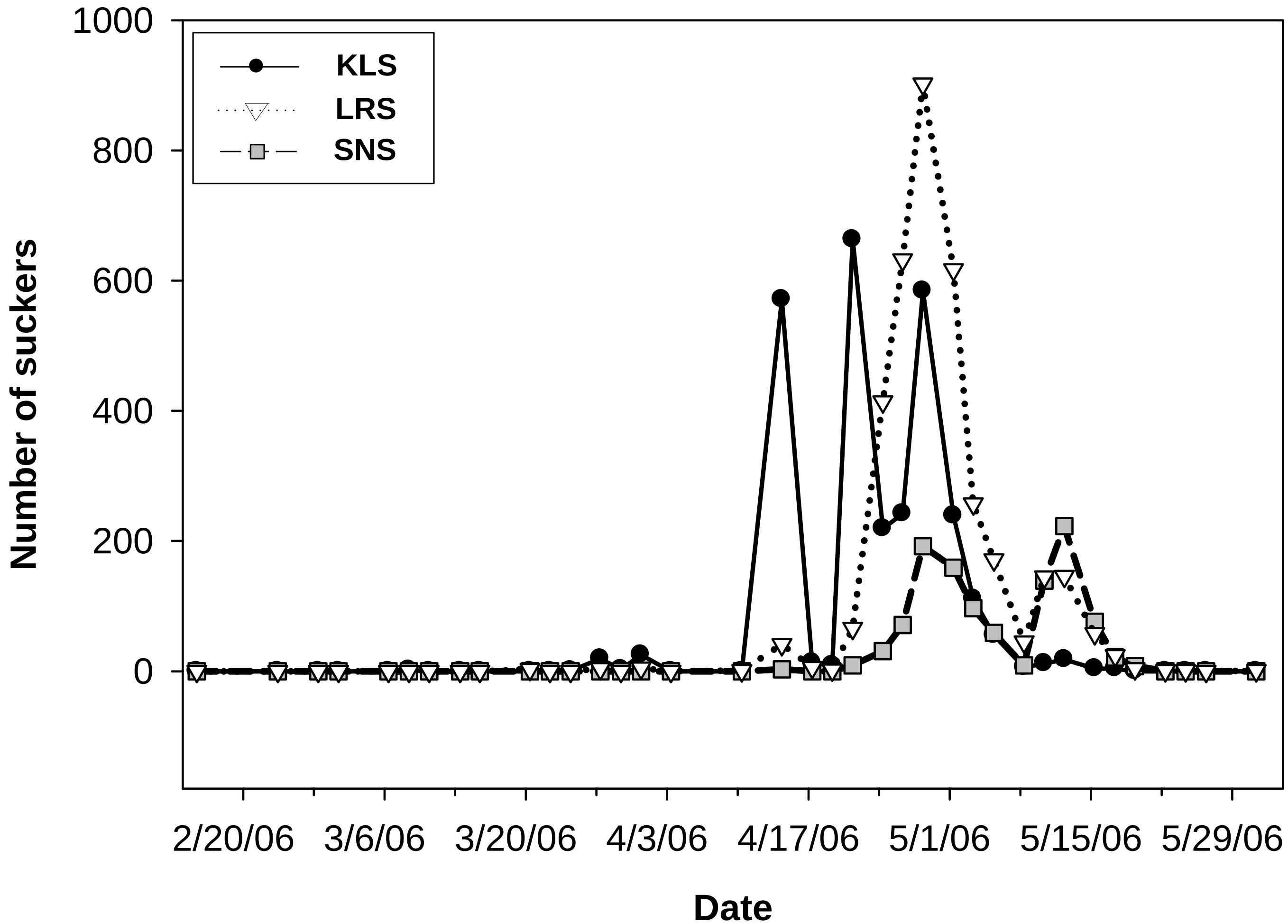

Figure 3. Number of Klamath largescale suckers (KLS), Lost River suckers (LRS), and shortnose suckers (SNS) captured in the Chiloquin Dam fish ladder by date in 2006 (from Janney et al. *In review*).

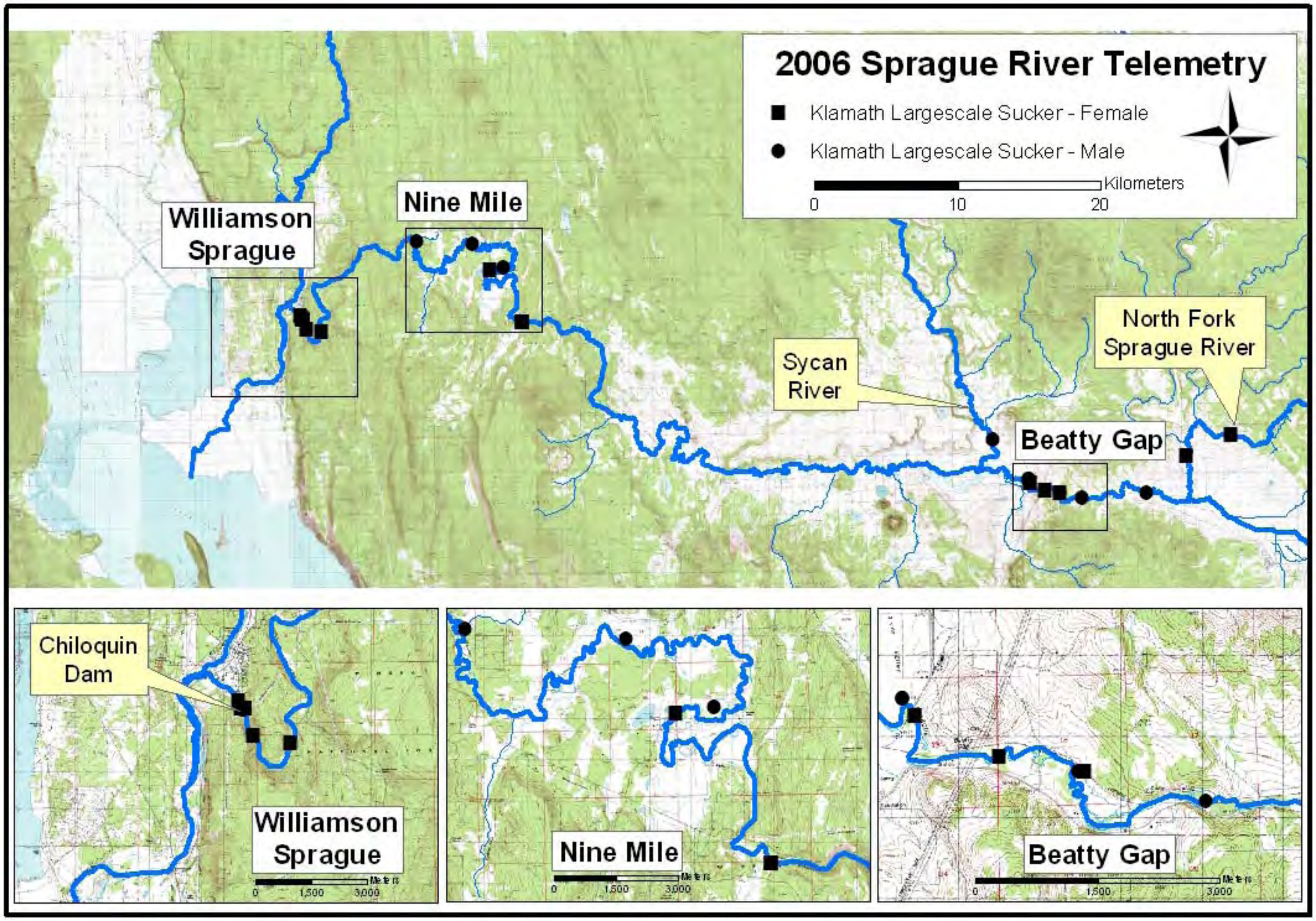

Figure 4. Furthest upstream detections of individual radio-tagged Klamath largescale suckers released in the lower Williamson River and above Chiloquin Dam in 2006.

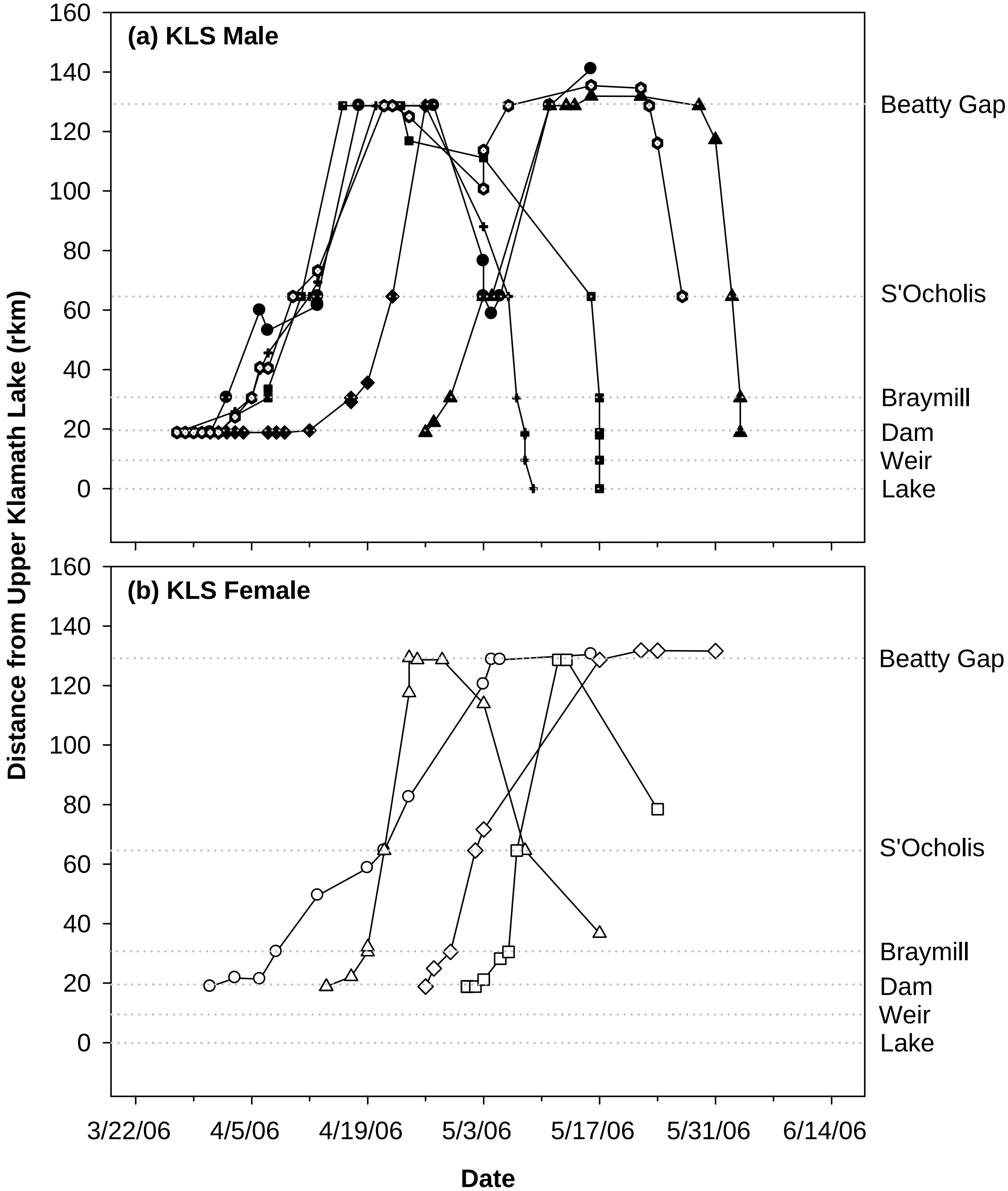

Figure 5. Seasonal migration of radio-tagged Klamath largescale suckers (KLS) to Beatty Gap displayed as river kilometers (rkm) of the lower Williamson and Sprague rivers from Upper Klamath Lake in 2006. Unique symbols represent individual fish while each symbol marker represents a detection of that fish. Locations of remote telemetry stations are listed on the right axis for reference.

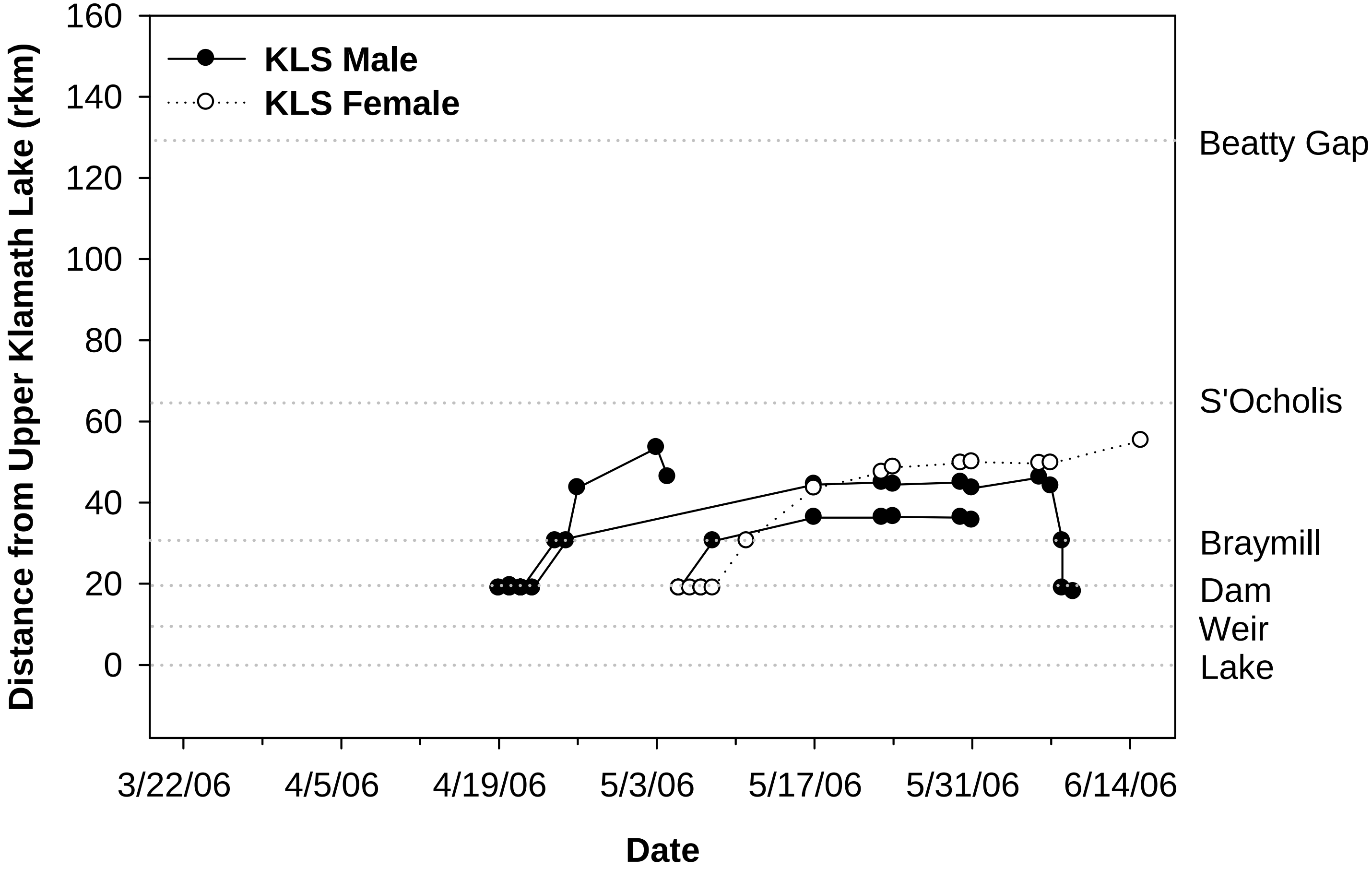

Figure 6. Seasonal migration of three male and one female radio-tagged Klamath largescale suckers (KLS) to the Nine Mile area displayed as river kilometers (rkm) of the lower Williamson and Sprague rivers from Upper Klamath Lake in 2006. Each symbol marker represents a detection of a fish while connected symbols represent migrations of individuals. Locations of remote telemetry stations are listed on the right axis for reference.

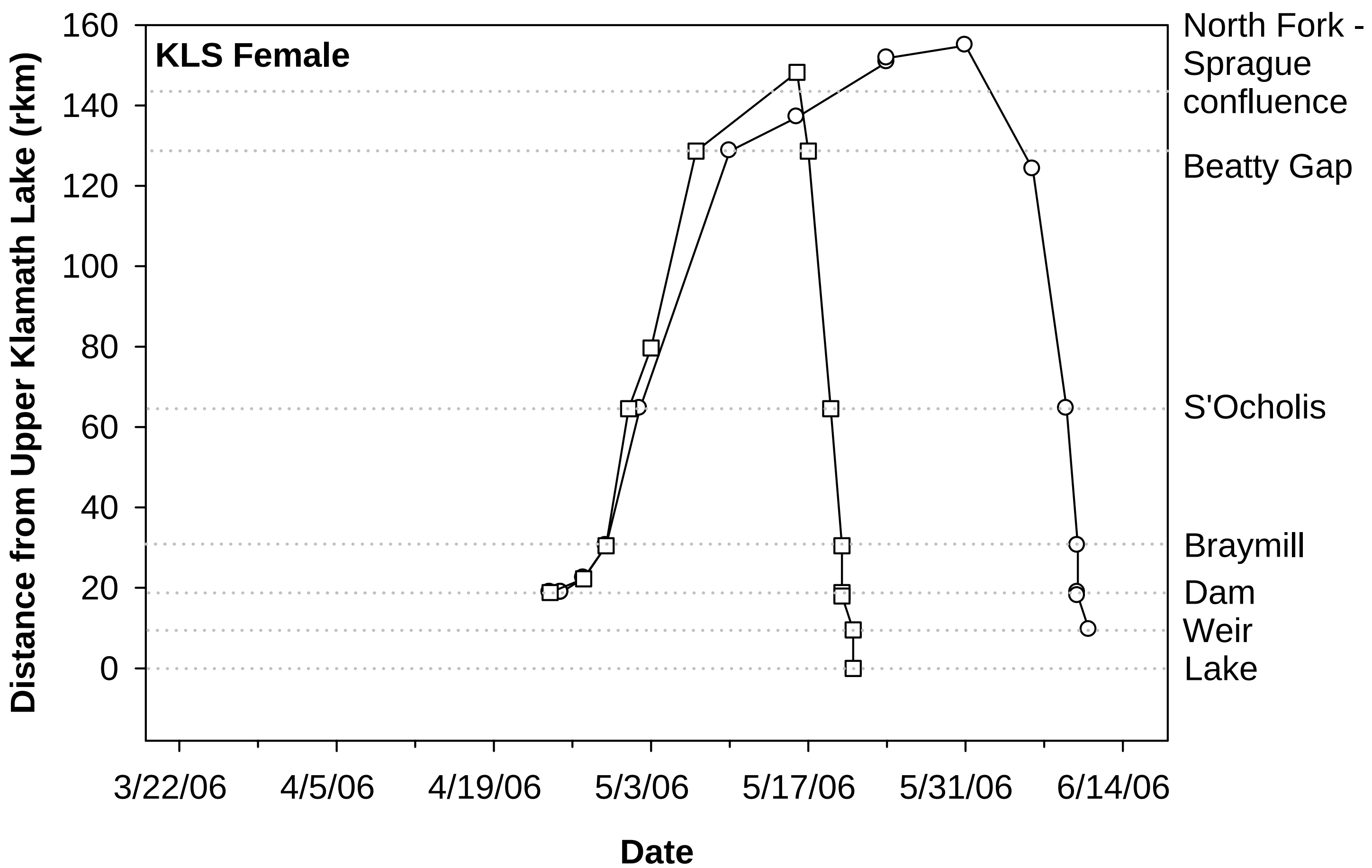

Figure 7. Seasonal migration of two female radio-tagged Klamath largescale suckers (KLS) to the North Fork of the Sprague River displayed as river kilometers (rkm) of the lower Williamson, Sprague, and North Fork of the Sprague rivers from Upper Klamath Lake in 2006. Unique symbols represent individual fish while each symbol marker represents a detection of that fish. Locations of remote telemetry stations and the confluence of the North and South Forks of the Sprague River are listed on the right axis for reference.

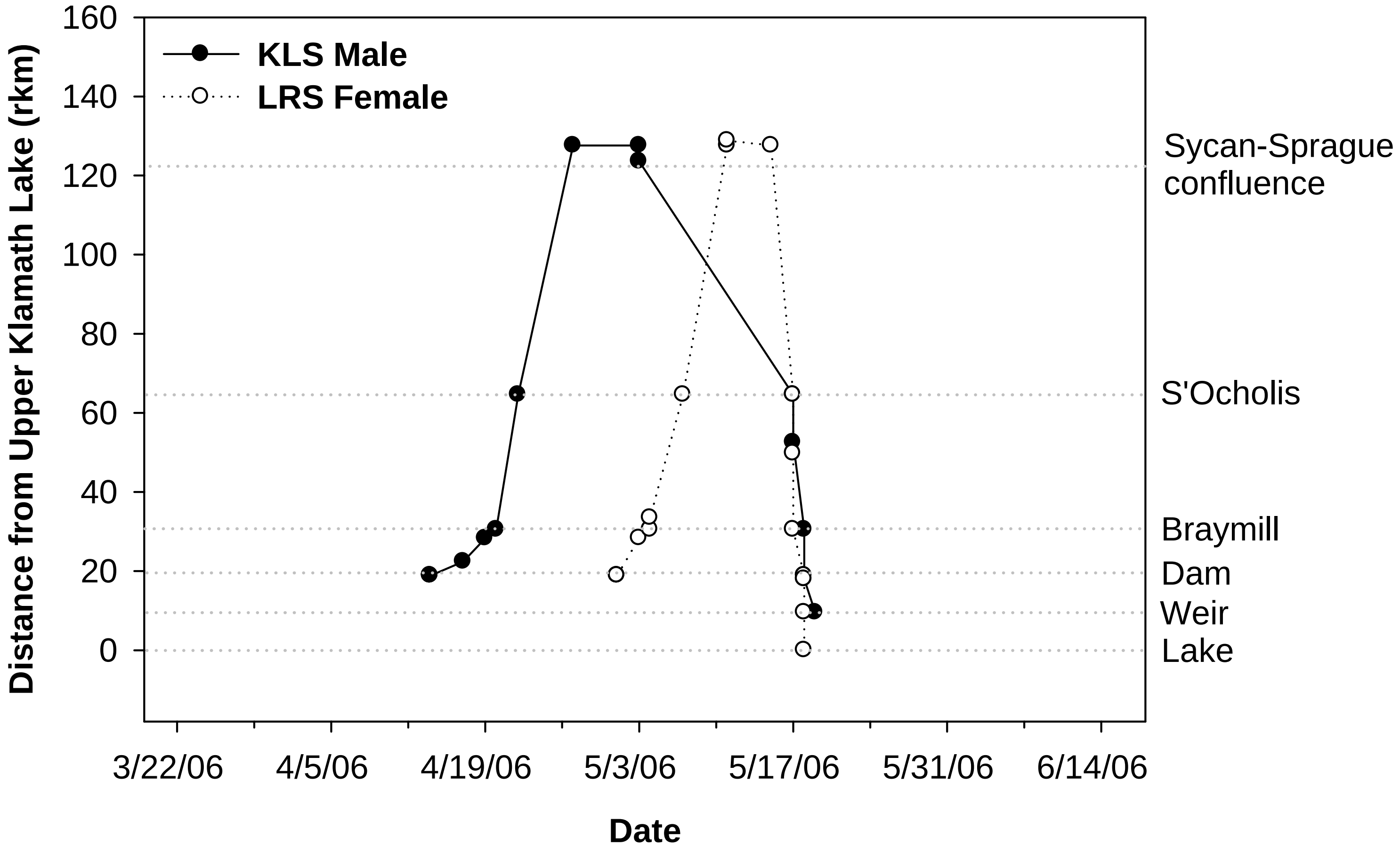

Figure 8. Seasonal migration of a male radio-tagged Klamath largescale sucker (KLS) and a female radio-tagged Lost River sucker (LRS) to the Sycan River displayed as river kilometers (rkm) of the lower Williamson, Sprague, and Sycan rivers from Upper Klamath Lake in 2006. Unique symbols represent individual fish while each symbol marker represents a detection of that fish. Locations of remote telemetry stations and the confluence of the Sycan River with the Sprague River are listed on the right axis for reference.

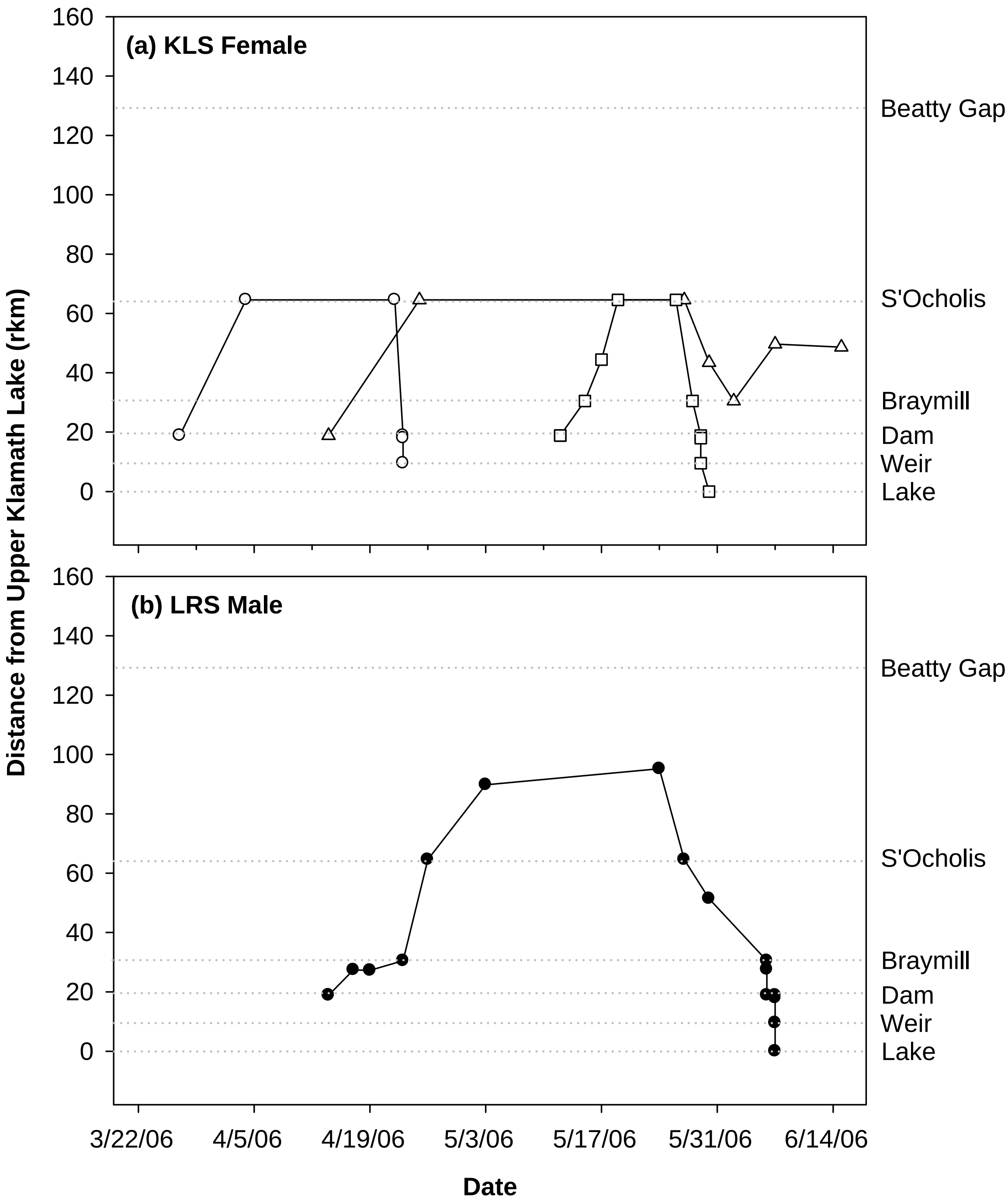

Figure 9. Seasonal migration of (a) three radio-tagged female Klamath largescale suckers (KLS) and (b) one male Lost River sucker (LRS) to the Sprague River Valley as displayed as river kilometers (rkm) of the lower Williamson and Sprague rivers from Upper Klamath Lake in 2006. Unique symbols represent individual fish while each symbol marker represents a detection of that fish. Locations of remote telemetry stations are listed on the right axis for reference.

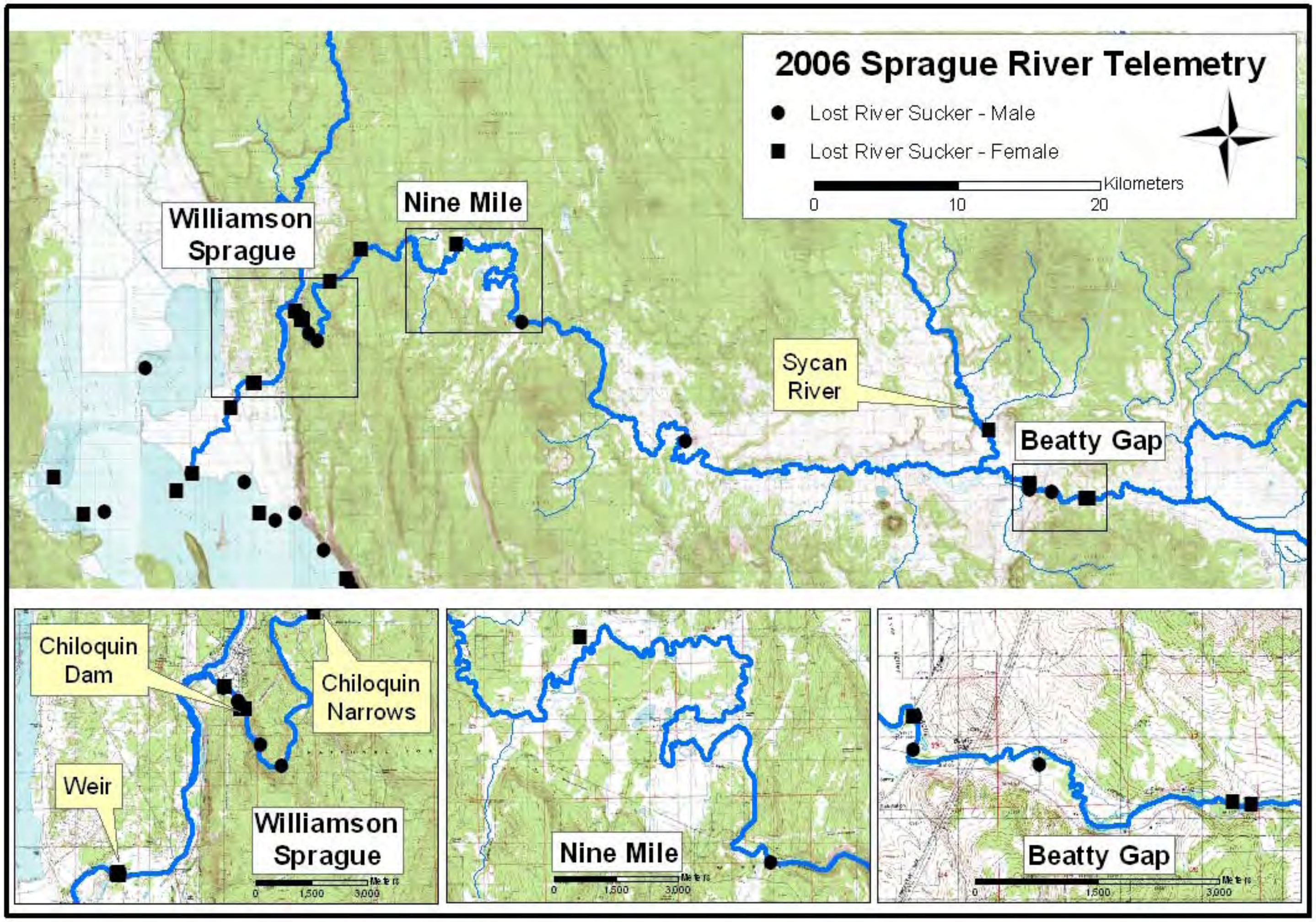

Figure 10. Furthest upstream detections of individual radio-tagged Lost River suckers released in Upper Klamath Lake and above Chiloquin Dam in 2006.

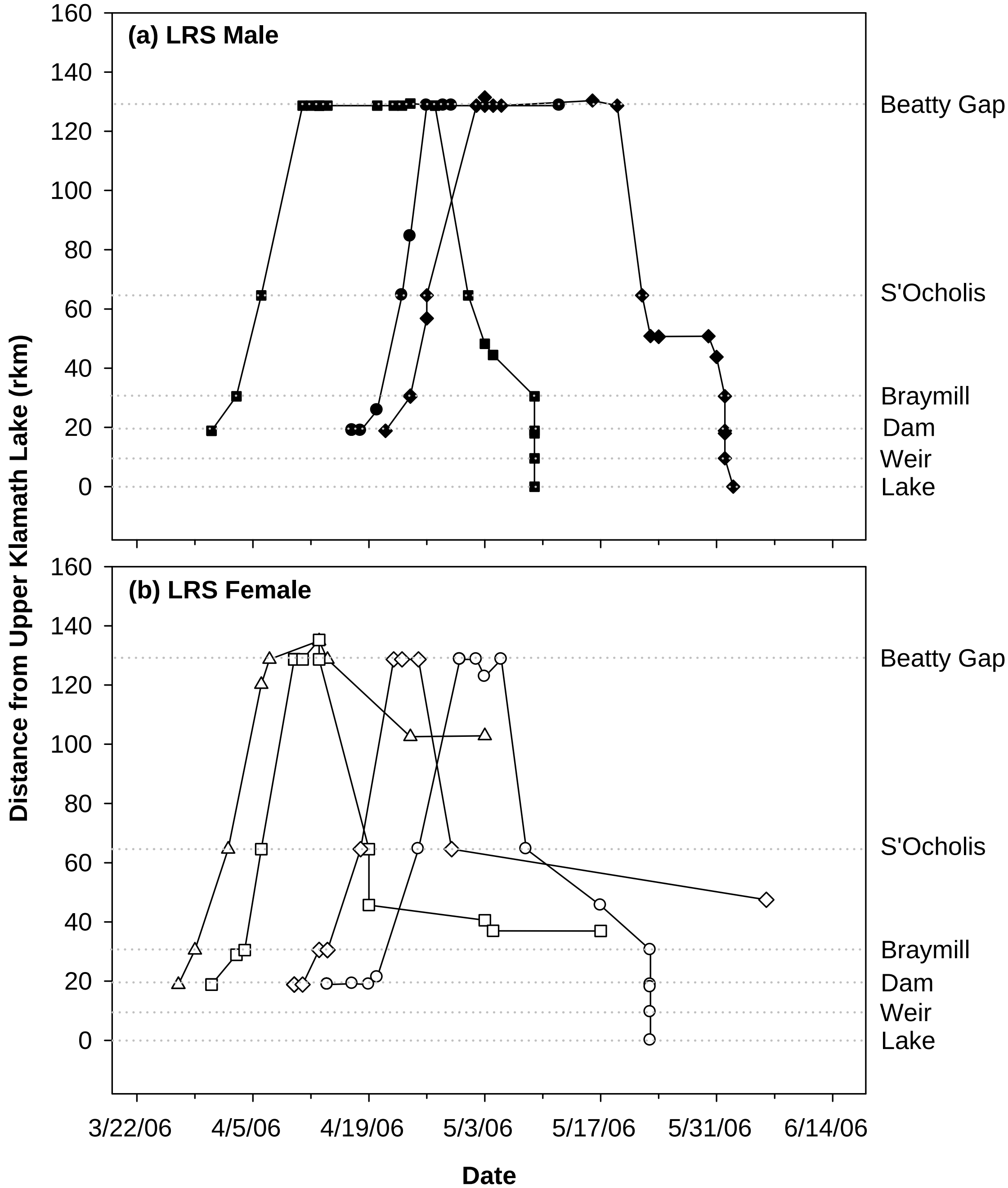

Figure 11. Seasonal migration of (a) male and (b) female radio-tagged Lost River suckers (LRS) to Beatty Gap displayed as river kilometers (rkm) of the lower Williamson and Sprague rivers from Upper Klamath Lake in 2006. Unique symbols represent individual fish while each symbol marker represents a detection of that fish. Locations of remote telemetry stations are listed on the right axis for reference.

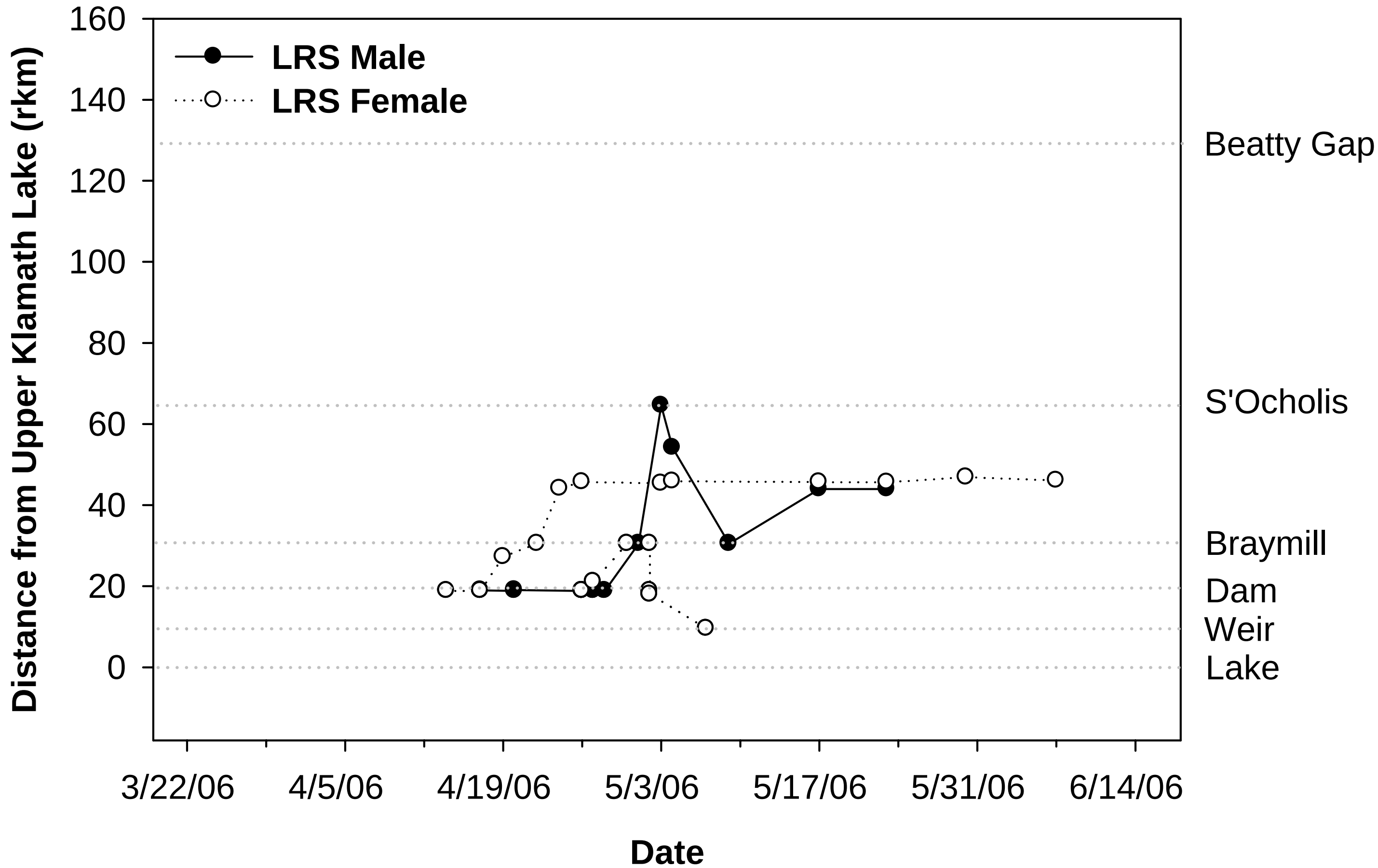

Figure 12. Seasonal migration of male and female radio-tagged Lost River suckers (LRS) to the Nine Mile area displayed as river kilometers (rkm) of the lower Williamson and Sprague rivers from Upper Klamath Lake in 2006. Unique symbols represent individual fish while each symbol marker represents a detection of that fish. Locations of remote telemetry stations are listed on the right axis for reference.

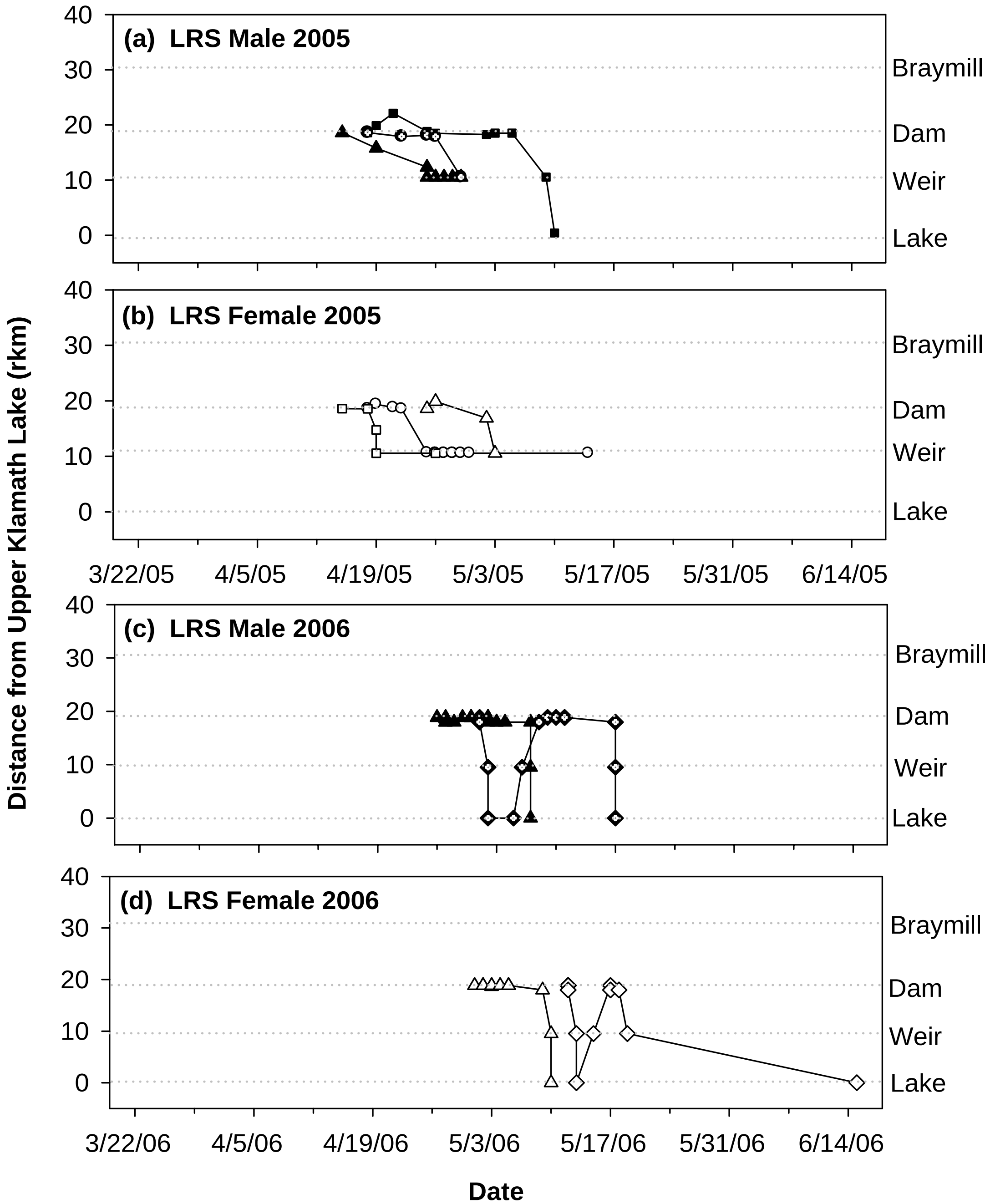

Figure 13. Selected seasonal migration of radio-tagged male and female Lost River suckers (LRS) released above Chiloquin Dam displayed as river kilometers (rkm) of the lower Williamson and Sprague rivers from Upper Klamath Lake in 2005 (a and b) and 2006 (c and d). Unique symbols represent individual fish while each symbol marker represents a detection of that fish. Locations of remote telemetry stations are listed on the right axis for reference. These migration routes are representative of several individual radio-tagged LRS released above Chiloquin Dam in 2005 and 2006 that remained in the Chiloquin Dam reach.

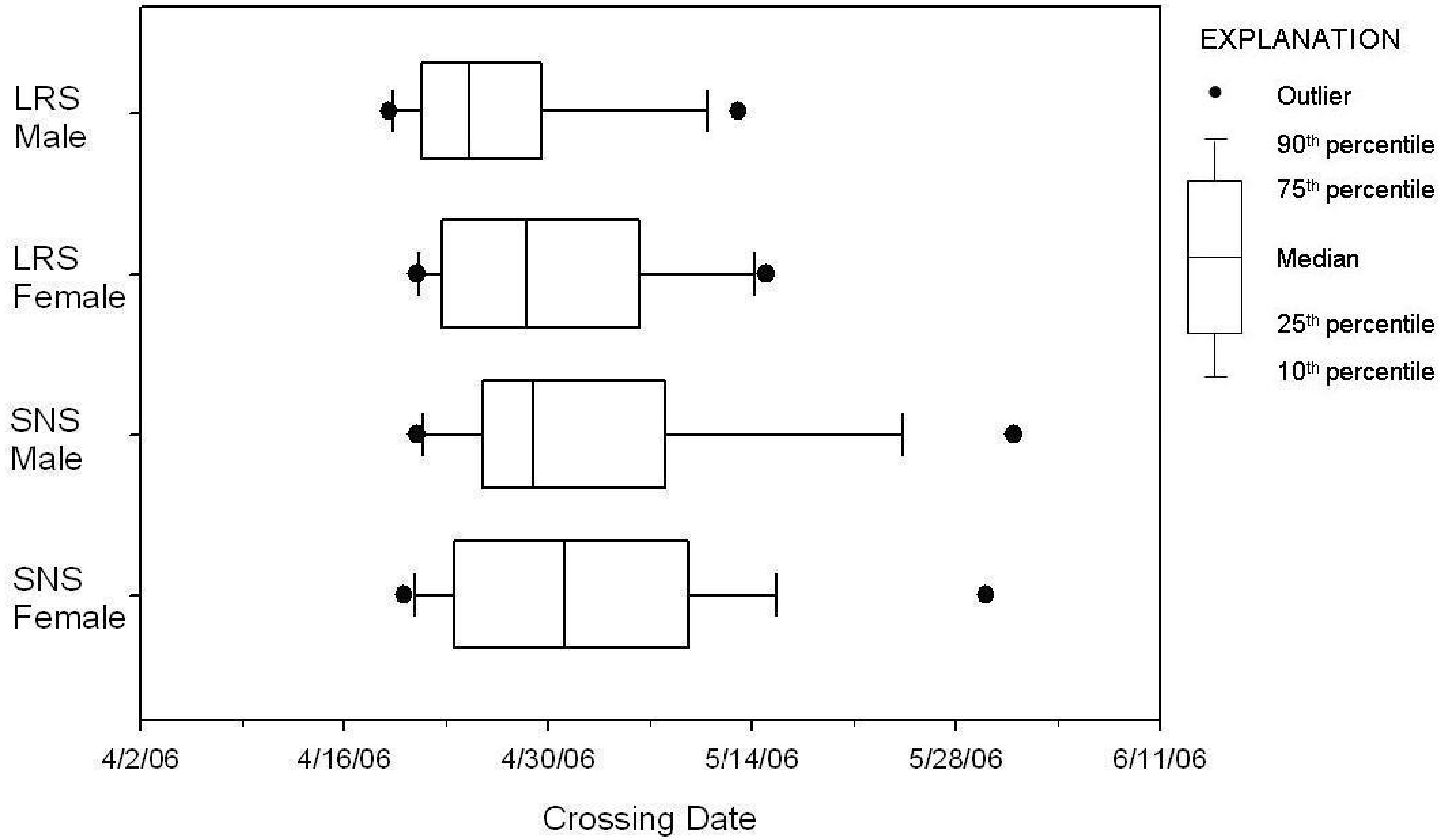

Figure 14. Number of radio-tagged Lost River suckers (LRS) and shortnose suckers (SNS) crossing the Williamson River fish weir moving upstream by date in 2006.

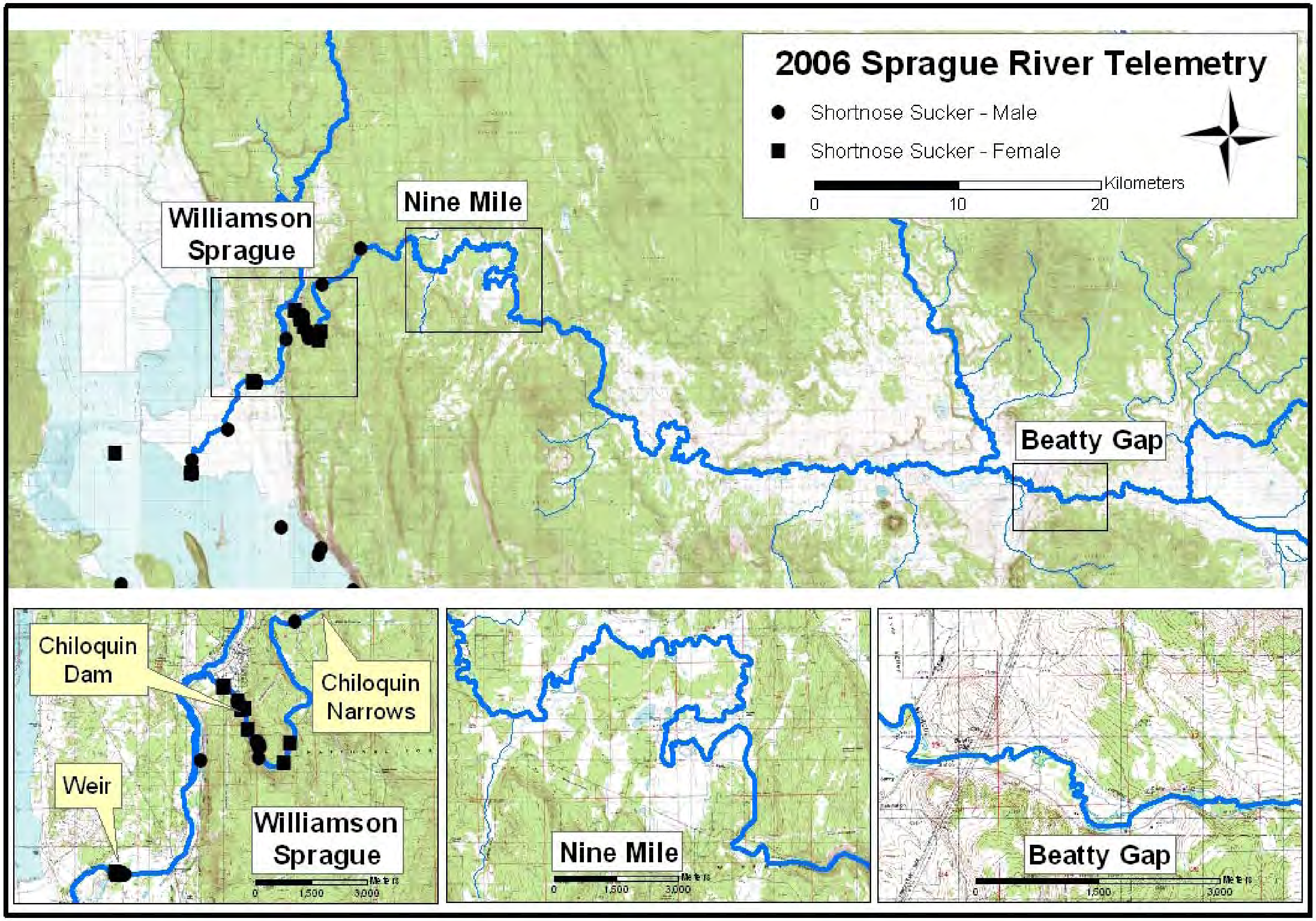

Figure 15. Furthest upstream detections of individual radio-tagged shortnose suckers released in Upper Klamath Lake and above Chiloquin Dam in 2006.

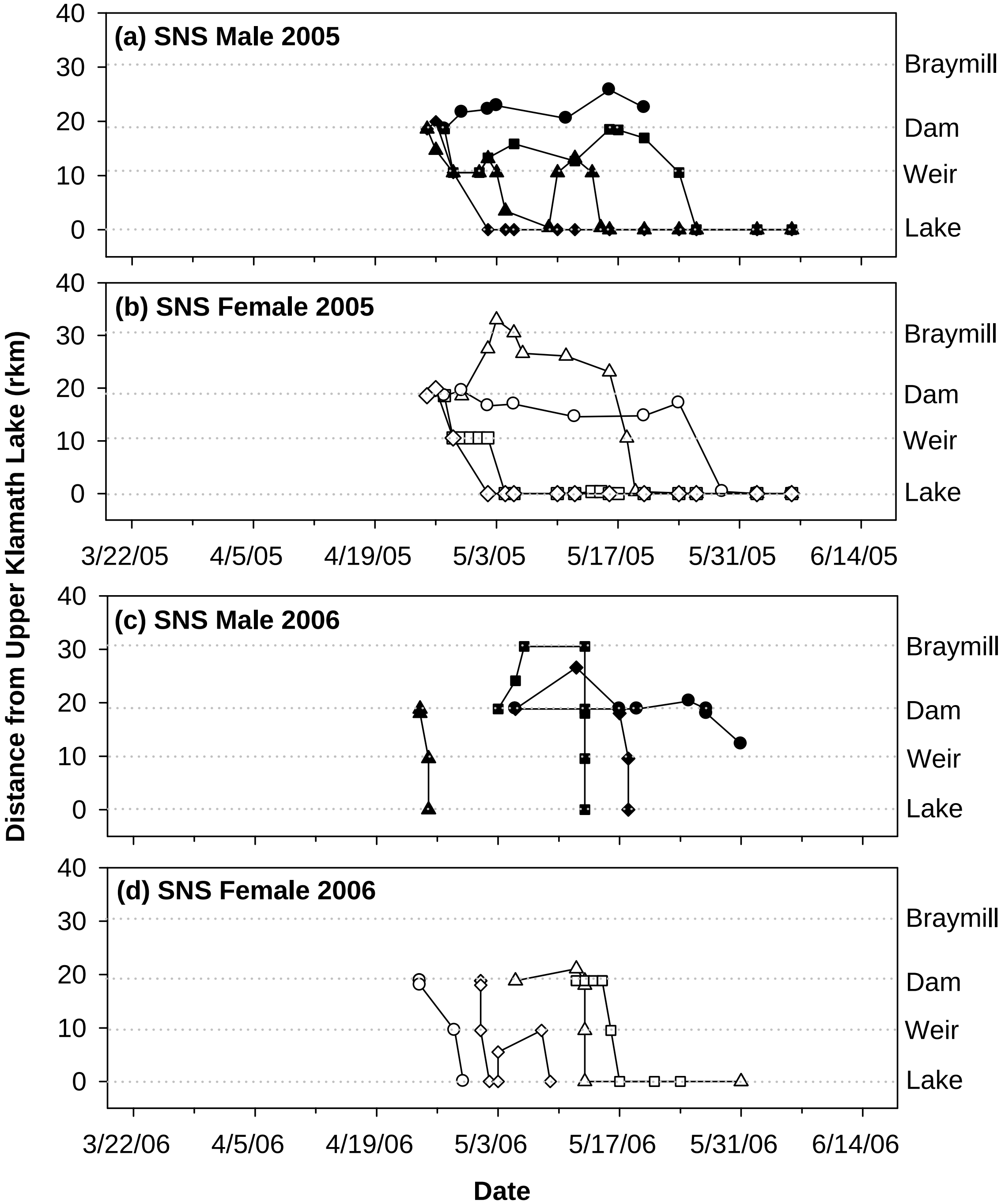

Figure 16. Seasonal migration of radio-tagged shortnose suckers (SNS) released above Chiloquin Dam as displayed as river kilometers (rkm) of the lower Williamson and Sprague rivers from Upper Klamath Lake in 2005 (a and b) and 2006 (c and d). Unique symbols represent individual fish while each symbol marker represents a detection of that fish. Locations of remote telemetry stations are listed on the right axis for reference. These migration routes are representative of several individual radio-tagged SNS released above Chiloquin Dam in 2005 and 2006 that remained in the Chiloquin Dam and Nine Mile reaches.

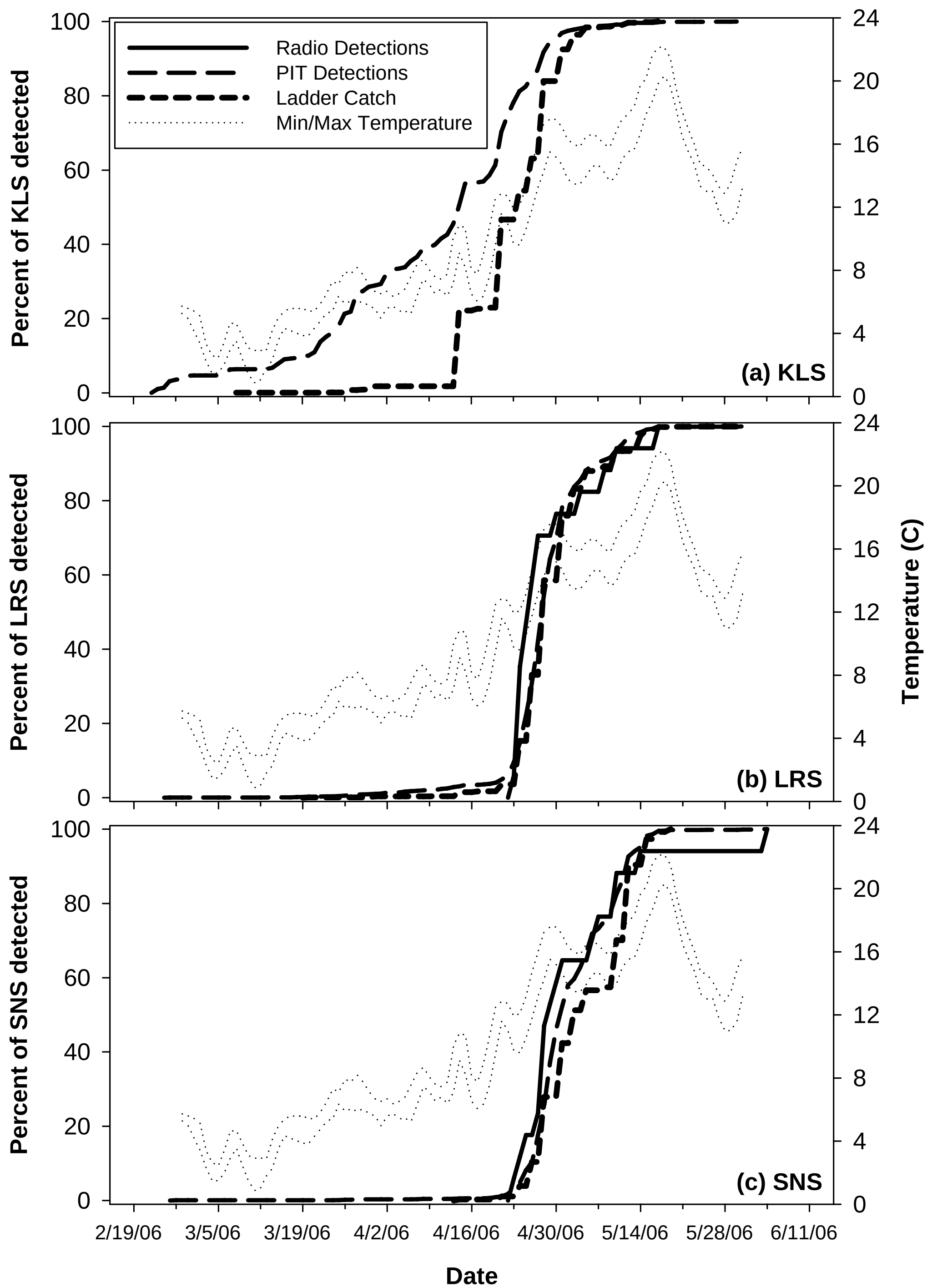

Figure 17. The cumulative percentages of radio tag detections, passive integrated transponder (PIT) tag detections, and ladder captures of (a) Klamath largescale suckers (KLS), (b) Lost River suckers (LRS), and (c) shortnose suckers (SNS) by date at Chiloquin Dam with minimum and maximum daily water temperatures as measured at Chiloquin Dam in 2006. Percentages of PIT tag detections and ladder captures are from Janney et al. (*In review*). Percentages are out of the total number of suckers detected or captured and are accumulated by an individual's date of first detection or capture.

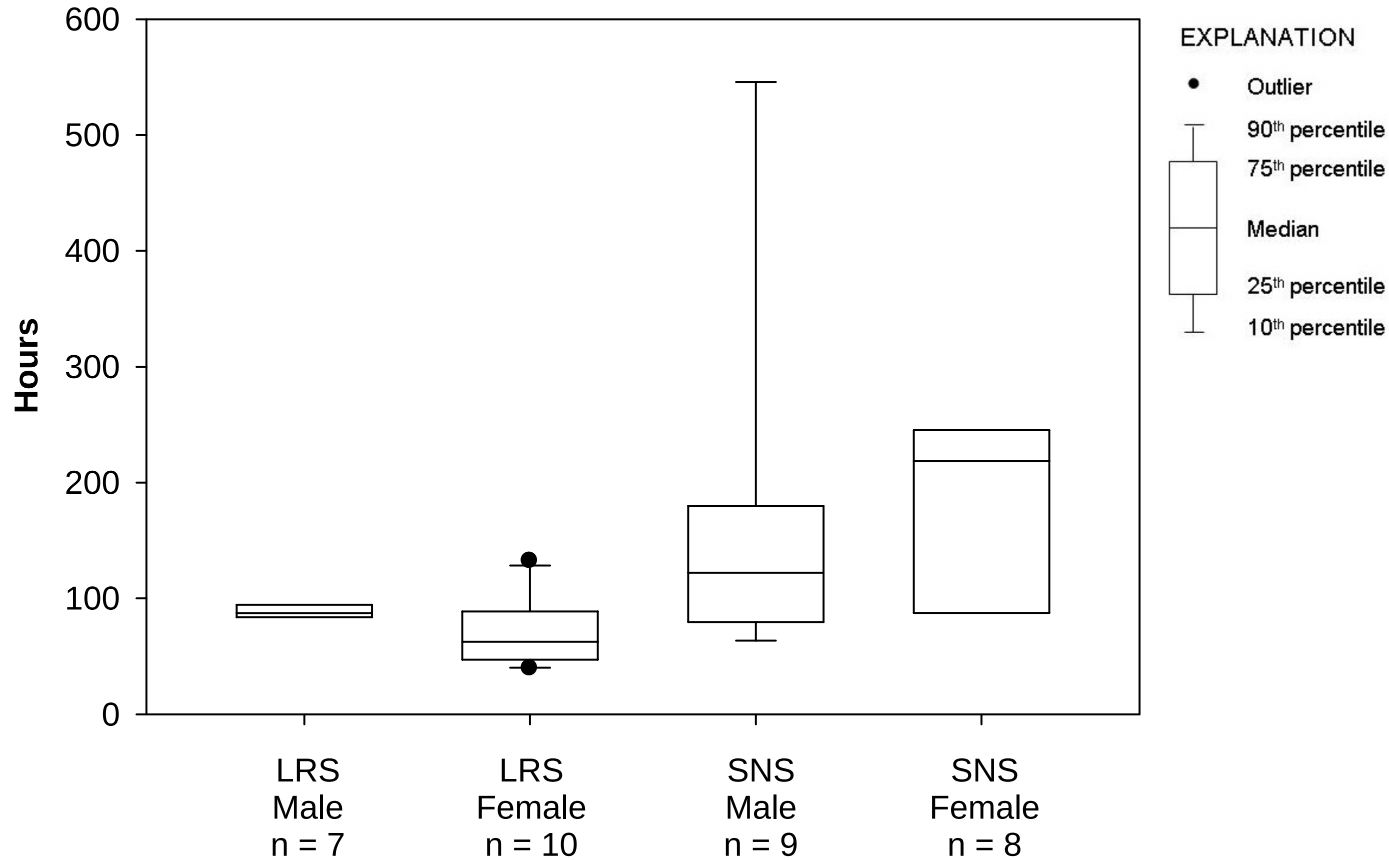

Figure 18. The number of hours between crossing the Williamson River fish weir and the first detection at Chiloquin Dam for radio-tagged male and female Lost River suckers (LRS) and shortnose suckers (SNS) moving upstream during the 2006 spawning migration.

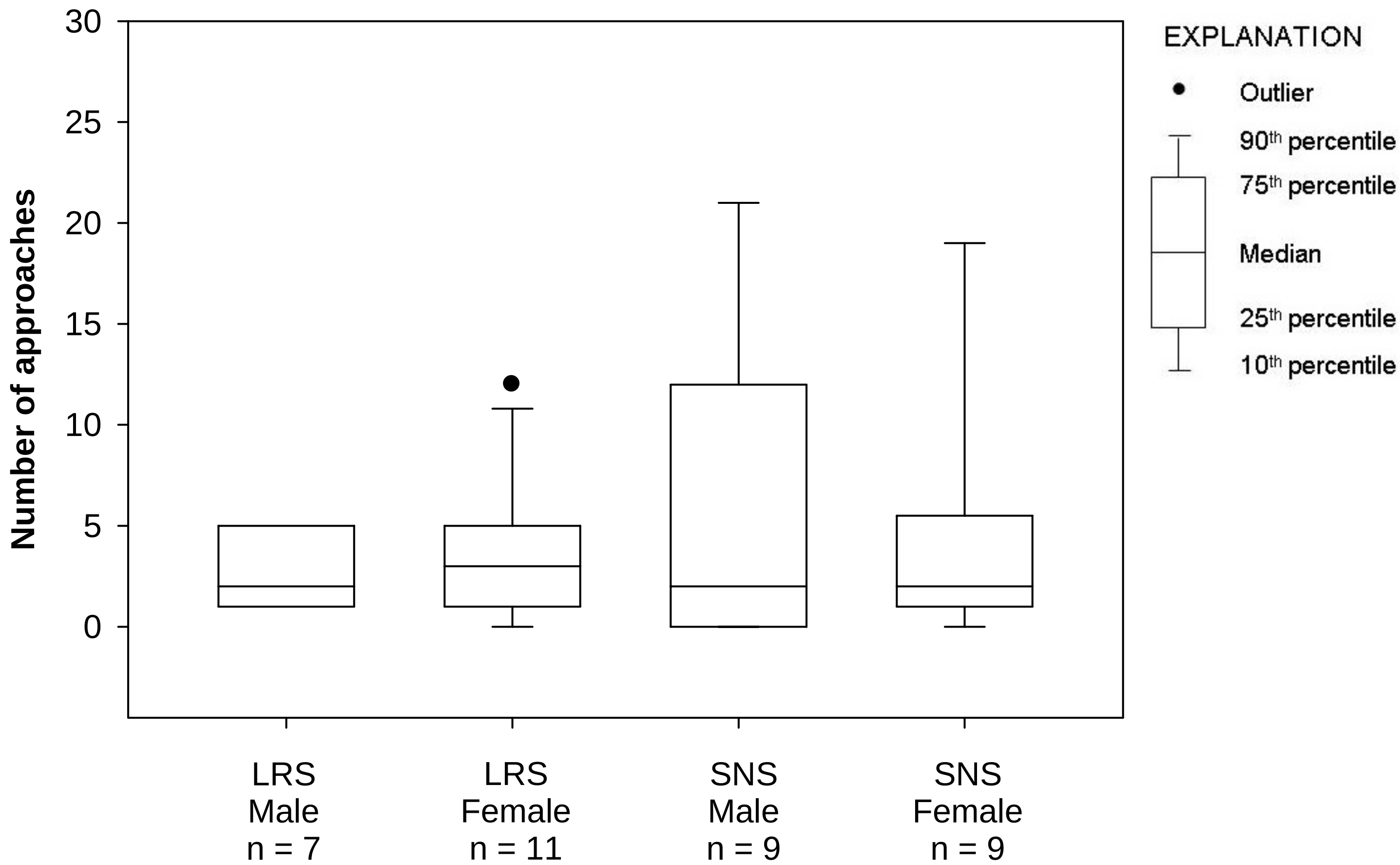

Figure 19. The number of approaches on the downstream side of Chiloquin Dam for radio-tagged Lost River suckers (LRS) and shortnose suckers (SNS) moving upstream during the 2006 spawning migration.

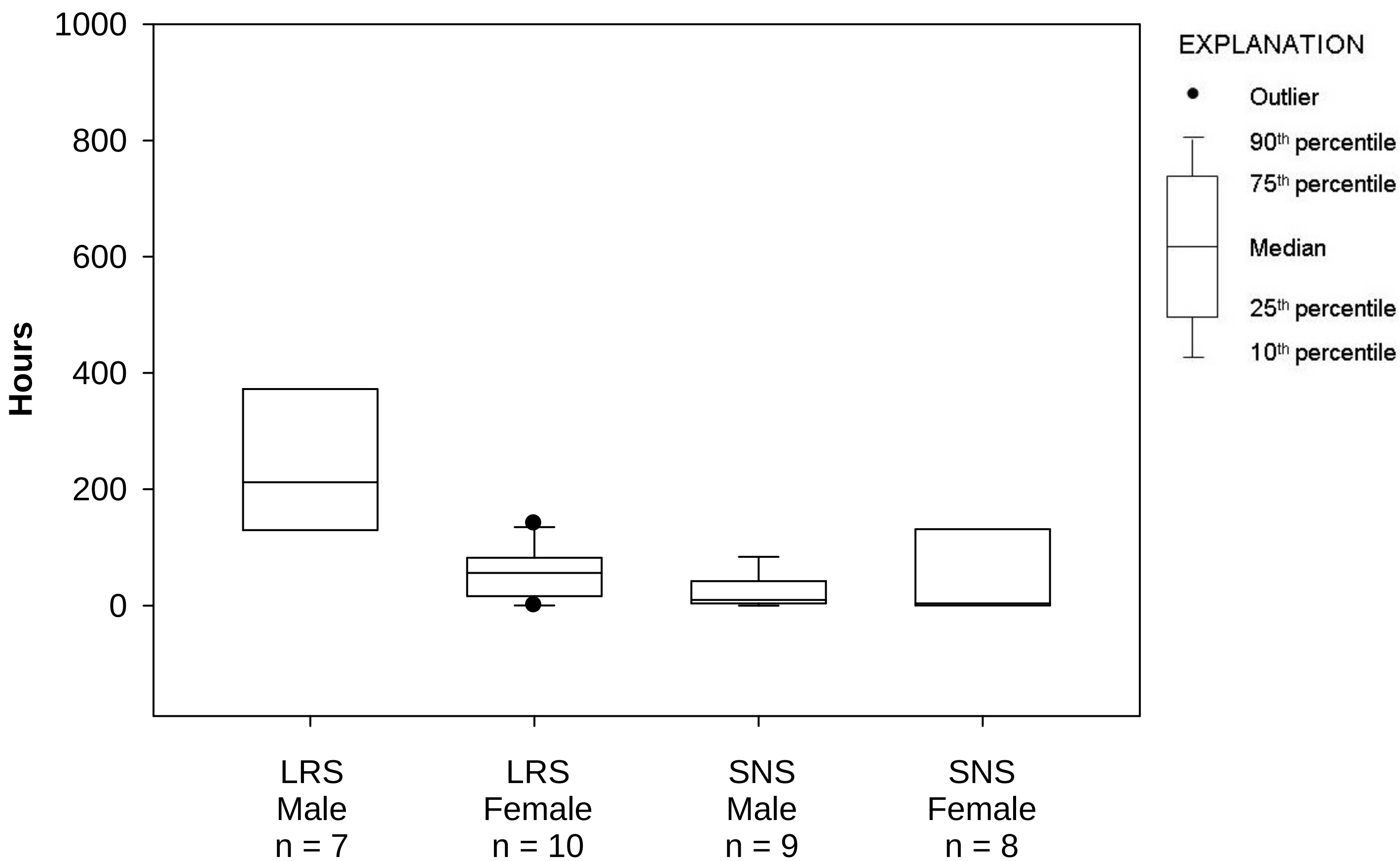

Figure 20. The number of hours spent at the base of Chiloquin Dam for radio-tagged Lost River suckers (LRS) and shortnose suckers (SNS) moving upstream during the 2006 spawning migration. The time spent is cumulative and excludes any absences.

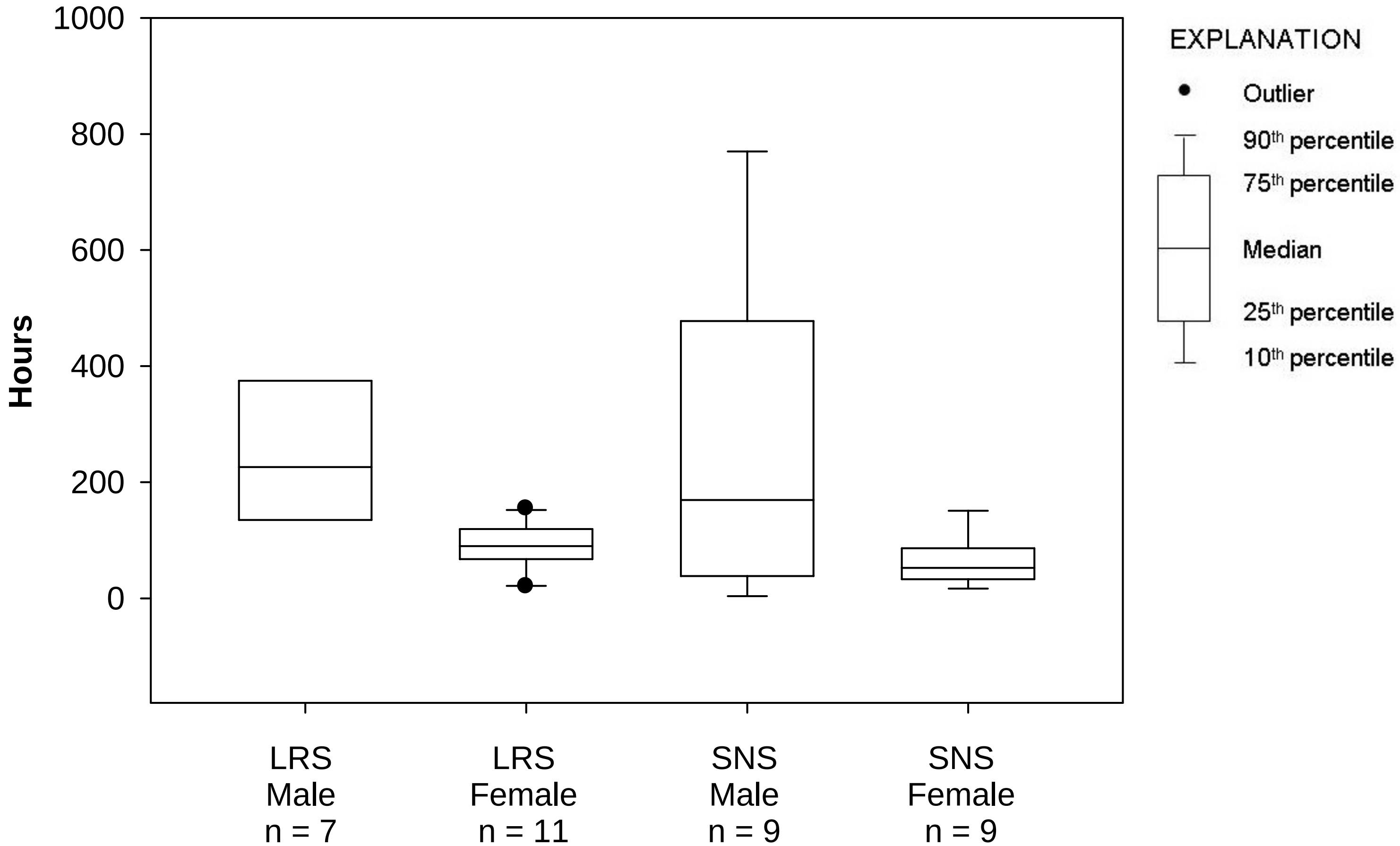

Figure 21. The number of hours between the first and last detections at the base of Chiloquin Dam for radio-tagged Lost River suckers (LRS) and shortnose suckers (SNS) moving upstream during the 2006 spawning migration.

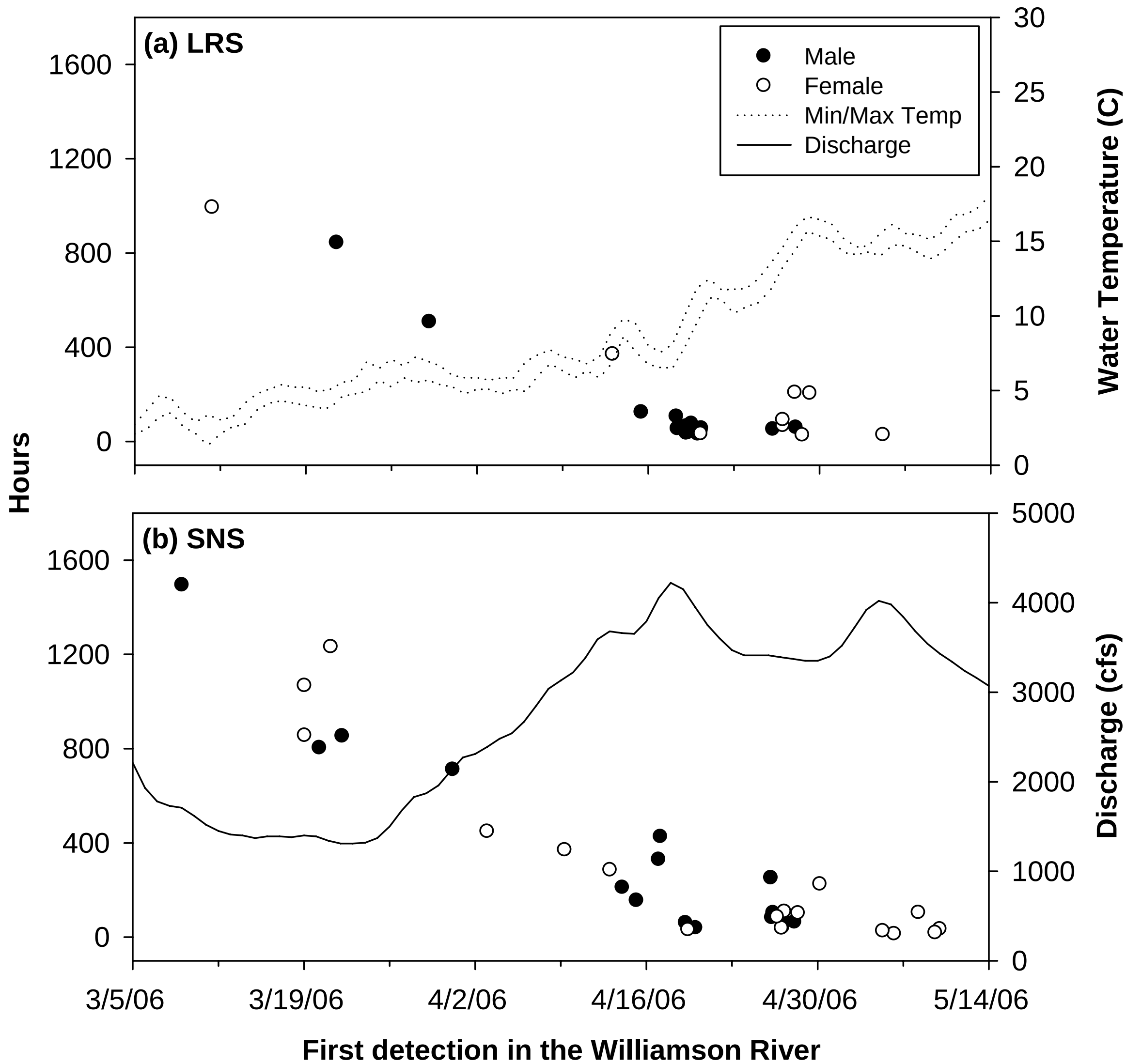

Figure 22. Time elapsed (h) between first detection of an individual radio-tagged (a) Lost River sucker (LRS) and (b) shortnose sucker (SNS) at the Lake Remote Station (rkm 0) near the mouth of the Williamson River and when it crossed the Williamson River fish weir moving upstream in 2006. Daily minimum and maximum water temperature for the Williamson River taken at the weir (a) and discharge as measured for the Williamson River at USGS gage 11502500 (b) are also shown.

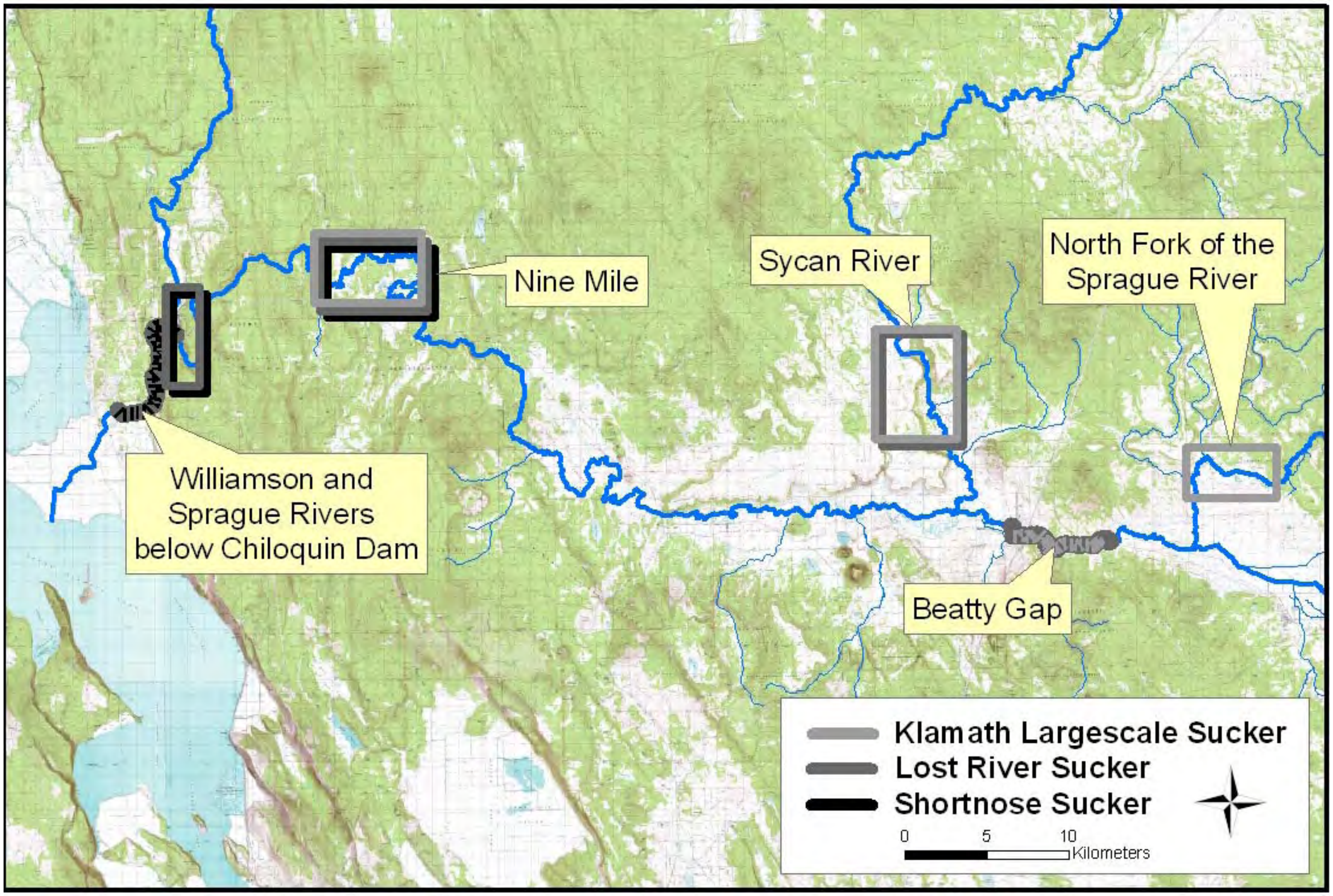

Figure 23. River reaches in the Sprague River drainage where catostomid spawning activity has been either confirmed (highlighted river reaches) or suspected (boxed river reaches) based on radio-tagged fish locations in 2006.

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