FISHERY RESEARCH

LAKE TROUT SPAWNING LOCATIONS IN LAKE PEND OREILLE, 2007

LAKE PEND OREILLE FISHERY RECOVERY PROJECT

ANNUAL PROGRESS REPORT
March 1, 2007—February 28, 2008

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ABSTRACT

Kokanee *Oncorhynchus nerka* in Lake Pend Oreille are currently at a record low abundance. In an attempt to increase kokanee survival, an intensive predator removal program was initiated to reduce lake trout *Salvelinus namaycush* and rainbow trout *O. mykiss* abundance. A major component of this program involves targeting lake trout with gill nets and deepwater trap nets. To better direct netting efforts, we used telemetry to identify locations where lake trout congregate during spawning. During 2007, we tagged 31 adult lake trout (mean total length = 858 mm; mean mass = 6.2 kg) with combined acoustic and radio telemetry tags. Beginning in mid-July, we tracked tagged lake trout every two weeks. Starting in mid-August, tracking occurred at least once per week and increased in frequency through mid-October. Winter tracking occurred once per month. Tagged lake trout were relocated 618 times, with an average of 20 relocations per individual. From mid-September to mid-October, lake trout aggregated for spawning in two shoreline areas dominated by cobble and rubble substrates with prespawn aggregations first appearing in August. Spawning appeared to occur in greater depths than in other lakes, as lake trout were predominately located from 25–35 m depths during the spawning period. Although we were unable to capture lake trout eggs in egg traps, we did capture mature and ripe lake trout at the two potential spawning sites, and divers observed eggs at 29 m deep, providing evidence of deepwater spawning at these two locations. The information gathered in this study will help guide future lake trout removal efforts by targeting spawning aggregations more effectively.

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INTRODUCTION

Lake Pend Oreille once provided the largest kokanee *Oncorhynchus nerka* fishery in the state of Idaho. Kokanee entered the lake in the early 1930s by downstream dispersal from Flathead Lake, Montana and had established a self-sustaining population by the 1940s. Since then, kokanee have been the primary pelagic prey species consumed by bull trout *Salvelinus confluentus*, rainbow trout *O. mykiss*, and lake trout *S. namaycush*. The kokanee forage base provided exceptional growth for these predatory salmonids, with a former world-record rainbow trout (16.8 kg) and the current world-record bull trout (14.5 kg) caught from Lake Pend Oreille. Historically, kokanee harvests averaged 1 million kokanee/yr (Jeppson 1953), but by 1985, kokanee harvest declined dramatically to a low of 71,208 harvested (Bowles et al. 1987). Continued declines in kokanee abundance led to the fishery being closed to all angler harvest in 2000. Early kokanee declines were related largely to fall drawdowns of the lake for flood control and power production (Maiolie and Elam 1993), but continued declines were attributed to high predation by bull trout, rainbow trout, and the increasing lake trout population (Maiolie et al. 2002; Maiolie et al. 2006).

Lake trout were stocked in numerous lakes throughout western North America during the late 1800s and early 1900s (Crossman 1995), including Lake Pend Oreille in 1925. Lake trout present a threat to native salmonids, especially bull trout (Donald and Alger 1993; Fredenberg 2002), through competition for prey or predation. After introduced lake trout became well established, kokanee and bull trout declined to very low levels in Flathead Lake, Montana (Stafford et al. 2002) and Priest Lake, Idaho (Bowles et al. 1991). Other western United States lakes have experienced detrimental effects to native fish populations following lake trout introductions (Martinez et al. 2009). In Lake Pend Oreille, lake trout abundance remained low from initial introduction through the 1990s, but by 1999 the population began to increase exponentially (Hansen et al. 2006). The delay in lake trout population growth appeared to be related to a lack of forage for juveniles. *Mysis* shrimp *Mysis relicta*, introduced in 1966, became abundant (>1,200 *Mysis*/m^2) by the mid-1980s (Maiolie et al. 2006). This newly abundant forage base increased survival of juvenile lake trout in Lake Pend Oreille, similar to Flathead Lake (Stafford et al. 2002). Lake trout population modeling indicated that the lake trout population in Lake Pend Oreille was doubling every 1.6 years and would reach 131,000 adults by 2010 (Hansen et al. 2006). This prediction suggested that without management intervention, the Lake Pend Oreille fishery would become dominated by non-native lake trout as in Flathead and Priest lakes.

In an attempt to collapse lake trout and recover kokanee in Lake Pend Oreille, the Idaho Department of Fish and Game (IDFG) initiated an intense predator removal program with a goal of increasing lake trout total annual mortality to over 50% (see Healy 1978). Hansen (2007) estimated that, at 2006 exploitation rates, a combination of gill and trap netting as well as angling would reduce lake trout numbers 67% by 2015. Therefore, IDFG removed all creel limits for lake trout, allowed anglers to fish with up to four rods, and initiated an Angler Incentive Program that offered anglers $15 per lake trout harvested. To increase harvest of lake trout further, IDFG contracted with commercial fishermen (Hickey Brothers, LLC, Bailey’s Harbor, Wisconsin) to remove lake trout with gill nets and trap nets during the spring and fall. Maximizing the efficiency of both angling and netting for lake trout to meet the total annual mortality goal and to remove predation pressure from the depressed kokanee population is necessary to reduce the likelihood of complete kokanee extirpation.

Understanding lake trout distribution should contribute to higher lake trout catches and mortality. Spawning aggregation sites are potential areas to concentrate efforts to remove mature individuals and reduce potential recruitment. Lake trout, which exhibit slow adult replacement (Shuter et al. 1998), would not be able to sustain this level of exploitation. During fall, lake trout tend to aggregate in nearshore habitats for 5 to 20 days to spawn (DeRoche 1969; Gunn 1995). This period generally coincides with lake destratification and water temperatures in the range of 8-14°C (Gunn 1995). Mid-lake shoals, prominent points, and islands facing the prevailing wind are typically favored for spawning (Scott and Crossman 1973). Substrates consisting of broken rock or rubble, mostly 3.8 to 10.2 cm in diameter with intermixed large boulders and a lack of fine sediments, are also favored (Martin 1957; Scott and Crossman 1973). Spawning occurs in depths of 1.5 to over 30 m, but most commonly takes place in less than 10 m of water (Scott and Crossman 1973). In Ontario, lake trout commonly spawn in <2 m of water (MacLean et al. 1990, Gunn 1995). Unlike most other species of salmonids, lake trout prepare no nest (DeRoche 1969) as the eggs are broadcast over bottom substrates and settle into interstitial spaces where they are protected from predation, ice scour, and wave disturbance (DeRoche 1969; Edsall et al. 1992). Lake trout are almost exclusively nocturnal spawners (Gunn 1995).

PROJECT GOAL

The goal of this study was to identify spawning locations and timing for lake trout in Lake Pend Oreille. We intend to use this information to aid ongoing predator removal efforts. Ultimately, we anticipate this will aid kokanee population recovery and reduce the threat that lake trout pose to native salmonids in Lake Pend Oreille.

STUDY AREA

Lake Pend Oreille is located in the northern panhandle region of Idaho (Figure 1). It is the state's largest and deepest lake, with a surface area of 32,900 ha, a mean depth of 164 m, and a maximum depth of 357 m. The Clark Fork River is the largest tributary to the lake. Outflow from the lake forms the Pend Oreille River. Lake Pend Oreille is a temperate, oligotrophic lake in which thermal stratification typically occurs from late June to September (Maiolie et al. 2002) with epilimnetic temperatures averaging approximately 9°C (Rieman 1977). Operation of Albeni Falls Dam on the Pend Oreille River keeps the lake level high and stable at 628.7 m above mean sea level (MSL) during summer (June-September), followed by lower lake levels of 626.4 m to 625.1 m during fall and winter. Littoral areas are limited, as most shoreline areas have steep slopes.

A diverse assemblage of fish species is present in Lake Pend Oreille. Native game fish include bull trout**,** westslope cutthroat trout *O. clarkii lewisi*, and mountain whitefish *Prosopium williamsoni.* Native nongame fishes include pygmy whitefish *P. coulterii*, slimy sculpin *Cottus cognatus*, five cyprinid species, and two catostomid species. The most abundant nonnative game fish present are kokanee, Gerrard rainbow trout, lake whitefish *Coregonus clupeaformis*, and lake trout. Other introduced game fishes include northern pike *Esox lucius*, brown trout *Salmo trutta*, smallmouth bass *Micropterus dolomieu*, largemouth bass *M. salmoides*, and walleye *Sander vitreus* (Hoelscher 1992).

Historically, bull trout and northern pikeminnow *Ptychocheilus oregonensis* were the top native predatory fish in Lake Pend Oreille (Hoelscher 1992). The historical native prey population included mountain whitefish, pygmy whitefish, slimy sculpin, suckers, *Catostomus spp*., peamouth *Mylocheilus caurinus*, and redside shiner *Richardsonius balteatus*, as well as juvenile salmonids (bull trout and westslope cutthroat trout). Presently, the predominant predatory species are lake trout, rainbow trout, bull trout, and northern pikeminnow.

METHODS

Lake Trout Telemetry

We tracked lake trout movement using telemetry equipment to determine spawning locations of lake trout. Combined acoustic and radio transmitters equipped with depth and temperature sensors (Lotek Wireless Inc., Newmarket, Ontario) were implanted into 31 lake trout. We used combined acoustic and radio tags because acoustic transmission works best if fish are in deep (>20 m) water, while radio transmission works best if fish are in shallow water, which we expected during spawning. Tags measured 50 mm in length, 16 mm in diameter, and weighed 24 g in air, with an expected battery life approximately eight months. Tags alternated between acoustic and radio signals, every five seconds. The acoustic signal operated at a frequency of 76.8 kHz, while the radio signal operated at 151.890 MHz.

Hickey Brothers, LLC captured lake trout to be implanted with transmitters in trap and gill nets. Only lake trout greater than 680 mm were tagged to ensure sexual maturity (IDFG, unpublished data). Most fish were tagged from May 18-30, 2007, whereas additional fish were tagged in September 2007. Total length, wet mass, and sex were recorded for each fish. Sex was determined using external characteristics (i.e. head shape, vent size). Transmitters were implanted using a surgical procedure similar to that described by Ross and Kleiner (1982). After surgery, lake trout captured in the spring were held in nearby trap nets where they recovered for three to six days before release, while lake trout captured in the fall were released immediately after surgery.

Lake trout were tracked on a twice-monthly basis from July-August and November-December and weekly during September-October. Paired, boat-mounted, omnidirectional hydrophones were used for mobile tracking. This system used MAPHOST software (Lotek Wireless Inc., Newmarket, Ontario), which allows simultaneous decoding of multiple signals and uses stereo hydrophones to provide direction of arrival of the transmitters' acoustic signal. Once each tagged fish was located, we recorded transmitter code, date, time, latitude and longitude, fish depth, transmitter temperature, lake depth under fish, and lake surface temperature. Shoreline areas were searched during day and night, to locate tagged lake trout and to determine whether diel period influenced location and depth use. The route used for tracking consisted of a path 0.4 km off the shore around the lake where water depths were at least 20 m deep as well as a loop around the islands on the north end of the lake. A complete perimeter survey required three, 8-hour days with a boat speed of 10 km/hr.

Documentation of Spawning Activity

To document spawning at sites where lake trout aggregated, we used egg traps, underwater video, and diver surveys to search for egg deposition. Additionally, gill nets were used to document the presence of mature and ripe fish in shoreline areas where tagged lake trout aggregated. Combining these methods has proven effective in determining if spawning occurs at a particular site (Marsden et al. 1995). Egg traps were similar to those described by Schreiner et al. (1995). We deployed three sets of egg traps (five egg trays per set) at potential spawning areas on September 25, 2007, deployed an underwater video camera during tracking surveys, and conducted a diver survey on November 6, 2007 to document spawning activity at potential spawning areas. To capture lake trout at potential spawning sites, gill nets (91.4 m long by 6.1 m tall with 5.1 cm bar mesh) were set perpendicular to shore for one hour in the early afternoon on September 27, October 10, and October 16 in locations where tagged lake trout were concentrated. We enumerated, measured total length, sexed, and examined all lake trout captured in gill nets for sexual maturity.

RESULTS

Lake Trout Telemetry

We tagged 28 lake trout in the spring from the north end of the lake, and 3 additional lake trout in the fall from the south end of the lake (Table 1; Figure 2). We captured 25 of the 28 lake trout tagged during the spring in trap nets and three in gill nets (Table 2). We captured all fish tagged in the fall in trap nets (Table 2). Tagged lake trout averaged 858 mm total length (range = 720-1010 mm; Table 2; Figure 3) and 6.2 kg in mass (range = 3.6–9.5 kg; Table 2).

Lake trout were tracked for 40–266 days (median = 223 d), depending on the fate of individual fish. Two tagged lake trout (#11-29600 and #32-31700) either expelled their tags or died by late July, as we observed no movement or changes in temperature and depth readings throughout the summer and fall. An angler harvested fish #26-31100 in mid-July, and fish #12-29700 was only located on July 12 and October 25 before being caught by an angler on November 3, 2007. Through mobile tracking, the 31 tagged lake trout were relocated 618 times ($\bar{x}$ = 20 relocations/fish). In the fall of 2007, we tracked 26 of the remaining 28 at-large lake trout to potential spawning locations.

We successfully relocated an average of 74% of at-large lake trout per week (range = 46-93%). Tagged lake trout migrated away from spring capture and tagging locations and began aggregating along the east shore of Lake Pend Oreille by early August. By mid-August (17-23), 71% (n = 17) of all at-large tagged fish were observed between Windy Point and Deadman Point (Figure 4). One month later (September 17-20), 21 tagged lake trout (78% of all tagged fish) were observed at the Windy Point area (Figure 5) where most tagged fish remained until October 11. Also at this time, four tagged lake trout aggregated near Bernard Beach in the south end of the lake (Figure 5). Tracking surveys on October 15 and 16 showed movement away from Windy Point, with less than half (n = 13; 48%) of all tagged fish still present there. By October 25, only five tagged lake trout (19%) remained near Windy Point, while others dispersed throughout the north end of the lake (Figure 6). Only two tagged lake trout remained at Windy Point into mid-November, and none were observed at Windy Point after November 14. Only one fish (#12-29700) was never located at a potential spawning site. However, we were unable to locate this fish anywhere in the lake during the spawning period and therefore are unsure of its location. See Appendix B for all telemetry maps.

The duration of time tagged lake trout spent at potential spawning sites varied between the sexes. Tagged female lake trout were located at the spawning grounds an average of 37 consecutive days (±14 d 90% CI; range = 9-53), while males were on the spawning grounds an average of 56 consecutive days (±14 d 90% CI; range = 17-90; Table 3). The average date of arrival was August 30 for females compared to August 18 for males. The last day lake trout were located at a spawning site was, on average, October 10 and October 20 for females and males, respectively (Table 3). Of the 26 fish tracked to potential spawning sites, five did not remain for the entire spawning period. These fish were located elsewhere in the lake at least once between periods spent at the spawning grounds. These periods of absence lasted from 7-45 d ($\bar{x}$ = 19 d). No fish used both potential spawning sites during the spawning period.

Across all seasons, tagged lake trout used water depths between 0 and 100.0 meters ($\bar{x}$ = 33.1 m; Table 4) and water temperatures from 2.8 to 11.6°C ($\bar{x}$ = 6.4°C; Table 5). Prior to spawning (July 10 to September 5), depth use varied from 16.3 to 79.6 m ($\bar{x}$ = 30.9). During spawning (September 10 to October 18), depth of tagged lake trout at Windy Point and Bernard Beach averaged 35.2 m (mode = 30.6 m) and 33.7 m (mode = 30.6), respectively (Figure 7; Table 4). We detected no discernable diel differences in depth use by lake trout during the spawning period. Temperature use averaged 6.3°C during spawning (Table 5). Depth and temperature use varied greatly (Table 4; Table 5) after fish departed spawning sites.

Documentation of Spawning Activity

Surveys to document lake trout spawning activity and egg deposition were conducted at the locations and depths where tagged lake trout aggregated, primarily at Windy Point, with some additional underwater video and gill netting at Bernard Beach. Divers in the Windy Point area documented the presence of several eggs at 29 m on November 6. The eggs were discovered by removing cobble substrate and searching the interstitial spaces from 24 to 32 m. Egg traps placed near Windy Point (set October 1 to October 19) captured no eggs. We saw no evidence of spawning activity during underwater video surveys. Adult lake trout were observed on several occasions, but no spawning behavior or eggs were detected using underwater video. Both underwater video and divers confirmed that large cobble and boulders with a lack of fine sediments characterized the substrate at these locations.

Gill nets had limited success capturing lake trout at potential spawning sites. Two gill nets set at Windy Point on September 27 captured nine lake trout. Seven of the lake trout were mature males ($\bar{x}$ = 570 mm; range = 521–654 mm) and two were immature females ($\bar{x}$ = 516 mm; range = 458–573 mm; Figure 8). Nets placed in the same locations on October 10 captured 16 lake trout (15 mature males [$\bar{x}$ = 749 mm; range = 497–938 mm] and one immature female [587 mm]; Figure 8). Gill nets placed at Bernard Beach on October 16 yielded ten adult lake trout (8 mature males, 2 mature females), averaging 676 mm (range = 475–914 mm; Figure 8); one of these females was the only ripe female lake trout captured.

DISCUSSION

During 2007, we successfully located aggregations of tagged lake trout at potential spawning sites, obtained evidence of spawning activity, and learned about spawning behavior and timing in Lake Pend Oreille. From late August to mid-October, 93% of tagged lake trout visited one of two areas in the 32,900 ha lake, which combined, covered only about 10 km of the total 180 km of shoreline of Lake Pend Oreille. The presence of localized aggregations was not a novel event given behaviors documented in other systems (Flavelle et al. 2002; Dux 2005), but the low number of aggregations was somewhat unexpected given the large size of the lake. Two major spawning sites were documented in Lake McDonald, Montana, a 2,763 ha lake (Dux 2005), whereas 21 sites exist in 5,860 ha Lake Opeongo, Ontario (Flavelle et al. 2002). However, the distribution of captured lake trout may have presented a bias in our study. The majority of tagged lake trout in Lake Pend Oreille were captured from the north end of the lake and may have used the closest potential spawning site (Windy Point). We need to expand the distribution of capture locations for tagged fish to explore the possibility of spawning sites existing elsewhere in the lake and better assess the potential spawning site at Bernard Beach.

Nevertheless, the aggregations of adult lake trout in the two locations identified in 2007 should help guide gill net placement in the future.

Methods used to document spawning activity provided limited data to confirm spawning. Video and egg traps found no evidence of spawning, while divers had only minimal success finding eggs. Furthermore, gill nets placed at the spawning sites on three separate occasions captured only 35 lake trout. Of these, only five were females (two mature, three immature); highly skewed sex ratios are common at lake trout spawning sites (Martin and Olver 1980; Dux 2005). Additionally, the length distribution of fish captured at the potential spawning sites suggests that fish smaller than those tagged visited these areas. However, we tagged large lake trout to ensure sexual maturity (i.e. fish would visit spawning sites), and the sample size of fish captured in gill nets was small. In the future, it would be beneficial to place more emphasis on documenting spawning activity. Despite limited empirical data to confirm spawning took place, information from the combined methods, especially the aggregations of tagged lake trout, suggests lake trout used these sites for spawning from about September 10 to October 18, 2007.

Though lake trout may spawn for a period of 5-20 d (DeRoche 1969; Gunn 1995), congregations of fish may be located near spawning areas for a much longer period. We determined fish were located near the potential spawning sites for up to two months, but we did not find any ripe females until very close to the end of the spawning period. Despite our lack of evidence to confirm the exact timing of when spawning activity began, much of the time tagged lake trout spent at potential spawning sites was likely for staging rather than spawning. Based on our data, early concentrations of lake trout began prior to destratification in early August (possibly prespawning aggregations), while lake trout spawning in Lake Pend Oreille most likely occurs from mid-September to mid-October, (lake destratification typically happens during early October). After this time, <20% of at-large tagged lake trout were located at potential spawning sites. Similar patterns were reported in Lake McDonald (Dux 2005).

Tagged male lake trout in Lake Pend Oreille arrived earlier and remained later at potential spawning sites than the females. This phenomenon has been observed previously in lake trout populations (Martin and Olver 1980) and likely caused the skewed sex ratio of lake trout captured in gill nets at the spawning sites. However, our sexual identification technique for lake trout implanted with acoustic tags was not validated adequately. Therefore, we cannot be certain how accurate we were identifying females. In the future, we need to test our ability to differentiate accurately between male and female lake trout using external characteristics.

Based on depth data from acoustic transmitters and the depth of egg deposition observed during diver surveys, it appears lake trout in Lake Pend Oreille spawn deeper than commonly reported. Most studies have suggested lake trout spawn <10 m deep (e.g., DeRoche 1969; MacLean et al. 1990; Flavelle et al. 2002). Contrastingly, our data indicated lake trout spawned between 25 and 30 m deep. Fish remained at these depths throughout the duration they were at potential spawning sites, and we did not observe any vertical movement patterns that would suggest nocturnal spawning in shallower water. These results are similar to those documented in Seneca Lake, New York, where spawning was observed at up to 30 m (Storr 1962) and might take place at depths of up to 44 m (Sly and Widmer 1984). Similarly, lake trout in Lake McDonald, Montana spawn at a mean depth of 18 m (Dux 2005). Lake Pend Oreille, although much larger, has similar bathymetry to Seneca Lake and Lake McDonald (i.e. steeply sloping shorelines). Because lake trout appear to spawn at these depths in Lake Pend Oreille, controlling this population by manipulating lake levels to reduce egg survival is not an option since Albeni Falls Dam can only regulate the upper 3.6 m of the water column.

Lake trout in Lake Pend Oreille spawned in water temperatures slightly cooler than those reported elsewhere. The mean temperature recorded from the tags during the spawning period was 6.3°C, cooler than the 8-14°C commonly used by lake trout (Gunn 1995). Surface water temperatures during the much of the spawning period in Lake Pend Oreille (mid-September to mid-October) were warmer than the optimal range for lake trout spawning. Surface water temperatures in Lake Pend Oreille were above 14°C until October 4 and did not reach 8°C until late November (after lake trout had vacated the two potential spawning areas). However, since surface water temperatures reached the optimal range for lake trout spawning by early October, this should not have prevented lake trout from spawning in shallower water; thus, another mechanism may be driving the selection of deeper spawning habitat in Lake Pend Oreille.

Both of the potential spawning locations were at the bottom of steep, north-facing slopes that were >750 m high. With the prevailing winds on Lake Pend Oreille coming from the south or southwest during the fall, these potential spawning locations were protected from the wind. This situation is atypical as lake trout typically spawn along areas that face into prevailing winds (Scott and Crossman 1973). Subsurface water currents may occur in Lake Pend Oreille and may provide cool, well-oxygenated water at the depths where spawning occurs. Another possible explanation is that these slopes contain many slide areas (e.g., avalanche chutes) that provide an influx of cobble, rubble, and boulder substrates to the spawning sites. These large substrates are preferred by lake trout for spawning (Martin 1957; Scott and Crossman 1973). As such, it is possible that substrate availability plays a larger role than fetch distance or aspect in the selection of spawning sites by lake trout in Lake Pend Oreille. Seemingly, the spawning depths we observed would be less influenced by prevailing winds than in lakes where shallower spawning occurs and could explain why more protected sites were selected.

During this study, wind and fish movement patterns sometimes decreased tag detection distances and, in turn, limited our ability to relocate lake trout. Given the large size of Lake Pend Oreille, we had high success relocating tagged fish; however, exploring the availability of a more powerful acoustic telemetry receiver and tracking during calm weather could increase our relocation success of lake trout. Future telemetry studies on Lake Pend Oreille should use acoustic telemetry tags instead of combined radio and acoustic tags since lake trout were not generally found in water depths <20 m.

RECOMMENDATIONS

1. In 2008, use gill nets to remove spawning lake trout from the aggregation sites identified.

2. Tag additional lake trout from locations more widely distributed throughout the lake to better assess whether additional spawning sites exist.

3. Monitor lake trout distribution throughout the year to see if other patterns exist that would help guide removal efforts.

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LITERATURE CITED

Bowles, E. C., V. L. Ellis, D. Hatch, and D. Irving. 1987. Kokanee stock status and contribution of Cabinet Gorge Hatchery, Lake Pend Oreille, Idaho. Idaho Department of Fish and Game, Annual Report to Bonneville Power Administration, Contract DE-A179-85BP22493, Project 85-839. Portland, Oregon.

Bowles, E. C., B. E. Rieman, G. R. Mauser, and D. H. Bennett. 1991. Effects of introductions of *Mysis relicta* on fisheries in northern Idaho. American Fisheries Society Symposium 9:65-74.

Crossman, E. J. 1995. Introduction of the lake trout (*Salvelinus namaycush*) in areas outside its native distribution: a review. Journal of Great Lakes Research 21 (1):17-29.

DeRoche, S. E. 1969. Observation on the spawning habits and early life of lake trout. The Progressive Fish Culturist 31:109-113.

Donald, D. B., and D. J. Alger. 1993. Geographic distribution, species displacement, and niche overlap for lake trout and bull trout in mountain lakes. Canadian Journal of Zoology 71:238-247.

Dux, A. M. 2005. Distribution and population characteristics of lake trout in Lake McDonald, Glacier National Park: implications for suppression. Master's thesis. Montana State University, Bozeman, Montana.

Edsall, T. A., C. L. Brown, G. W. Kennedy, and T. P. Poe. 1992. Lake trout spawning habitat in the Six Fathom Bank-Yankee Reef Lake Trout Sanctuary, Lake Huron. Journal of Great Lakes Research 18(1):70-90.

Flavelle, L. S., M. S. Ridgway, T. A. Middel, and R. S. McKinley. 2002. Integration of acoustic telemetry and GIS to identify potential spawning areas for lake trout (*Salvelinus namaycush*). Hydrobiologia 438:137-146.

Fredenberg, W. 2002. Further evidence that lake trout displace bull trout in mountain lakes. Intermountain Journal of Sciences 8(3):143-152.

Gunn, J. M. 1995. Spawning behavior of lake trout: effects on colonization ability. Journal of Great Lakes Research 21 (Supplement 1):323-329.

Hansen, M. J., M. Liter, S. Cameron, and N. Horner. 2006. Mark-recapture study of lake trout using large trap nets in Lake Pend Oreille. Idaho Department of Fish and Game, Interim Progress Report to Avista Utilities, Agreement number R-30686, Report number 07-19, Boise, Idaho.

Hansen, M. J. 2007. Predator-prey dynamics in Lake Pend Oreille. Idaho Department of Fish and Game, Final Report to Avista Utilities, Agreement number R-30686, Report number 07-53, Boise, Idaho.

Healey, M. C. 1978. The dynamics of exploited lake trout populations and implications for management. Journal of Wildlife Management 42:307-328.

Hoelscher, B. 1992. Pend Oreille Lake fishery assessment 1951 to 1989. Idaho Department of Health and Welfare, Division of Environmental Quality Community Programs. Boise, Idaho.

Jeppson, P. 1953. Biological and economic survey of fishery resources in Lake Pend Oreille. Idaho Department of Fish and Game, Job Completion Report, Project F 3-R-3. Boise.

MacLean, N. G., J. M. Gunn, F. J. Hicks, P. E. Ihssen, M. Malhoit, T. E. Mosindy, and W. Wilson. 1990. Environmental and genetic factors affecting the physiology and ecology of lake trout. Ontario Ministry of Natural Resources, Lake Trout Synthesis, Physiology and Ecology Working Group.

Maiolie, M. A., and S. Elam. 1993. Influence of lake elevation on availability of kokanee spawning gravels in Lake Pend Oreille, Idaho, *in* Dworshak Dam impacts assessment and fisheries investigations. Idaho Department of Fish and Game, Annual Report to Bonneville Power Administration, Contract DE-AI79-87BP35167, Project 87-99. Portland, Oregon.

Maiolie, M. A., K. Harding, W. J. Ament, and B. Harryman. 2002. Lake Pend Oreille fishery recovery project. Idaho Department of Fish and Game, Completion Report to Bonneville Power Administration, Contract number 1994-047-00, Report number 02-56. Portland, Oregon.

Maiolie, M. A., T. P. Bassista, M. P. Peterson, W. Harryman, W. J. Ament, and M. A. Duclos. 2006. Lake Pend Oreille fishery recovery project. Idaho Department of Fish and Game, Completion Report to Bonneville Power Administration, Contract number 1994-047-00, Report number 06-25. Portland, Oregon.

Marsden, J. E., J. M. Casselman, T. A. Edsall, R. F. Elliot, J. D. Fitzsimmons, W.H. Horns, B. A. Manny, S. C. McAughey, P. G. Sly, and B. L. Swanson. 1995. Lake trout spawning habitat in the Great Lakes—a review of current knowledge. Journal of Great Lakes Research (Supplement 1):487-497.

Martin, N. V. 1957. Reproduction of lake trout in Algonquin Park, Ontario. Transactions of the American Fisheries Society 86(1):231-244.

Martin, N. V., and C. H. Olver. 1980. The lake charr. Pages 205-277 *in* E. K. Balon, editor. Charrs: salmonid fishes of the genus *Salvelinus*. Dr. W. Junk, The Hague, Netherlands.

Martinez, P. J., P. E. Bigelow, M. A. Deleray, W. A. Fredenberg, B. S. Hansen, N. J. Horner, S. K. Lehr, R. W. Schneidervin, S. A. Tolentino, and A. E. Viola. 2009. Western lake trout woes. Fisheries 34:424-442.

Rieman, B. E. 1977. Lake Pend Oreille limnological studies. Idaho Department of Fish and Game, Job Performance Report, Project F-53-R-12, Job IV-d. Boise, Idaho.

Ross, M. J., and C. F. Kleiner. 1982. Shielded-needle technique for surgically implanting radio-frequency transmitters in fish. Progressive Fish Culturist 44:41-43.

Schreiner, D. R., C. R. Bronte, N. R. Payne, J. D. Fitzsimons, and J. M. Casselman. 1995. Use of egg traps to investigate lake trout spawning in the Great Lakes. Journal of Great Lakes Research 21 (1):433-444.

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184.

Shuter, B. J., M. L. Jones, R. M. Korver, and N. P. Lester. 1998. A general, life history based model for regional management of fish stocks: the inland lake trout (*Salvelinus namaycush*) fisheries of Ontario. Canadian Journal of Fisheries and Aquatic Sciences 55:2161-2177.

Sly, P. G. and C. C. Widmer. 1984. Lake trout (*Salvelinus namaycush*) spawning habitat in Seneca Lake, New York. Journal of Great Lakes Research 10(2):168-189.

Stafford, C. P., J. A. Stanford, F. R. Hauer, and E. B. Brothers. 2002. Changes in lake trout growth associated with Mysis relicta establishment: a retrospective analysis using otoliths. Transactions of the American Fisheries Society 131:994-1003.

Storr, J. F. 1962. Delta structures in the New York Finger Lakes and their relation to the effects of currents on sediment distribution and aquatic organisms. Pages 129-138 *in* Proceedings of the 5th Conference of Great Lakes Research. International Association of Great Lakes Research, Ann Arbor, Michigan.

Table 1. Trap net capture location for lake trout tagged with combined acoustic and radio transmitters in Lake Pend Oreille, 2007.

	Number Tagged	
Net Location	**Spring**	**Fall**
Bottle Bay	2	0
Idlewilde Bay	0	1
Lee's Point [a]	5	0
Pearl Island	5	0
Sheepherder Point	6	0
Thompson Point	8	0
Warren Island	2	0
Whiskey Rock Bay	0	2
Total	28	3

[a] Includes three lake trout captured and tagged from gill nets at Lee's Pt.

Table 2. Mean size and number of lake trout captured and tagged with combined acoustic and radio transmitters by season in Lake Pend Oreille, 2007.

Season	**N**	**Gill net**	**Trap net**	**Mean total length (mm)**	**Mean weight (kg)**
Spring	28	3	25	866	6.37
Fall	3	0	3	779	4.07
Total	31	3	28	858	6.20

Table 3. Duration of time spent at potential spawning sites by male and female acoustic tagged lake trout in Lake Pend Oreille, 2007.

	Average first day at spawning sites	**Average final day at spawning sites**	**Mean number of days at spawning sites**	**Range of days at spawning sites**
Males	August 18	October 20	56	17-90
Females	August 30	October 10	37	9-53

Table 4. Summary of seasonal depth use by acoustic tagged lake trout in Lake Pend Oreille, 2007.

	Depth (m)					
Season	**Mean**	**SE**	**Mode**	**Min**	**Max**	**# of records**
All tracking seasons (7/10 - 2/14)	33.1	0.42	30.6	0.0	100.0	606
Summer/Prespawn (7/10 - 9/5)	30.9	0.63	30.6	16.3	79.6	125
Spawning (9/10 - 10/18)						
Windy Pt	35.2	0.49	30.6	22.4	75.5	293
Bernard Beach	33.7	1.21	30.6	24.5	44.9	23
Winter/Post-Spawn (10/22 - 2/14)	30.9	1.01	26.5	0.0	100.0	165

Table 5. Summary of seasonal temperature use by acoustic tagged lake trout in Lake Pend Oreille, 2007.

	Temperature (°C)					
Season	**Mean**	**SE**	**Mode**	**Min**	**Max**	**# of records**
All tracking seasons (7/10 - 2/14)	6.4	0.07	6.0	2.8	11.6	604
Summer/Prespawn (7/10 - 9/5)	7.2	0.13	6.8	3.6	11.6	125
Spawning (9/10 - 10/18)						
Windy Pt	6.3	0.09	4.4	3.6	10.8	288
Bernard Beach	6.3	0.27	6.0	4.4	8.4	23
Winter/Post-Spawn (10/22 - 2/14)	6.1	0.18	6.0	2.8	10.8	168

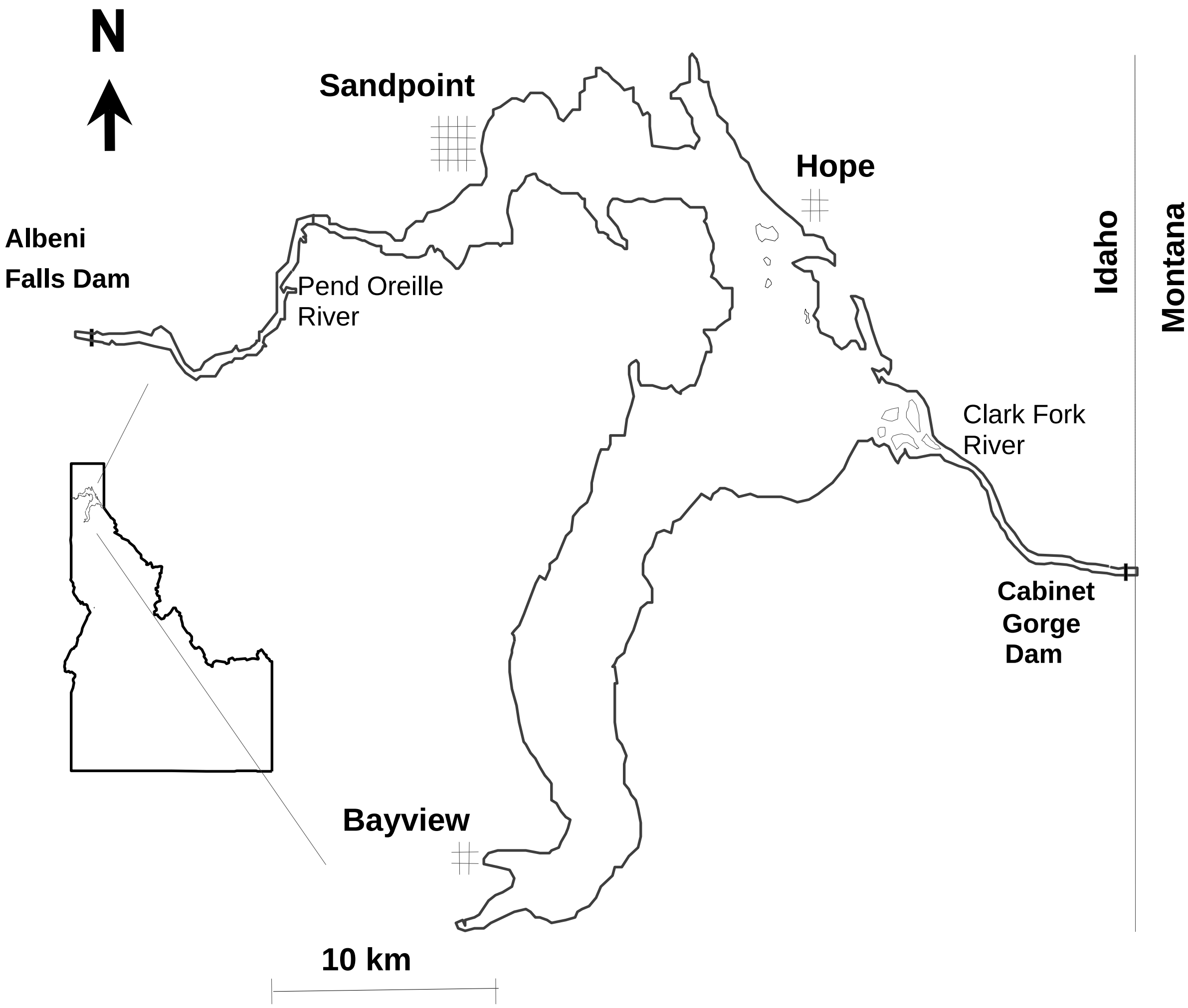


Figure 1. Map of Lake Pend Oreille, Idaho.

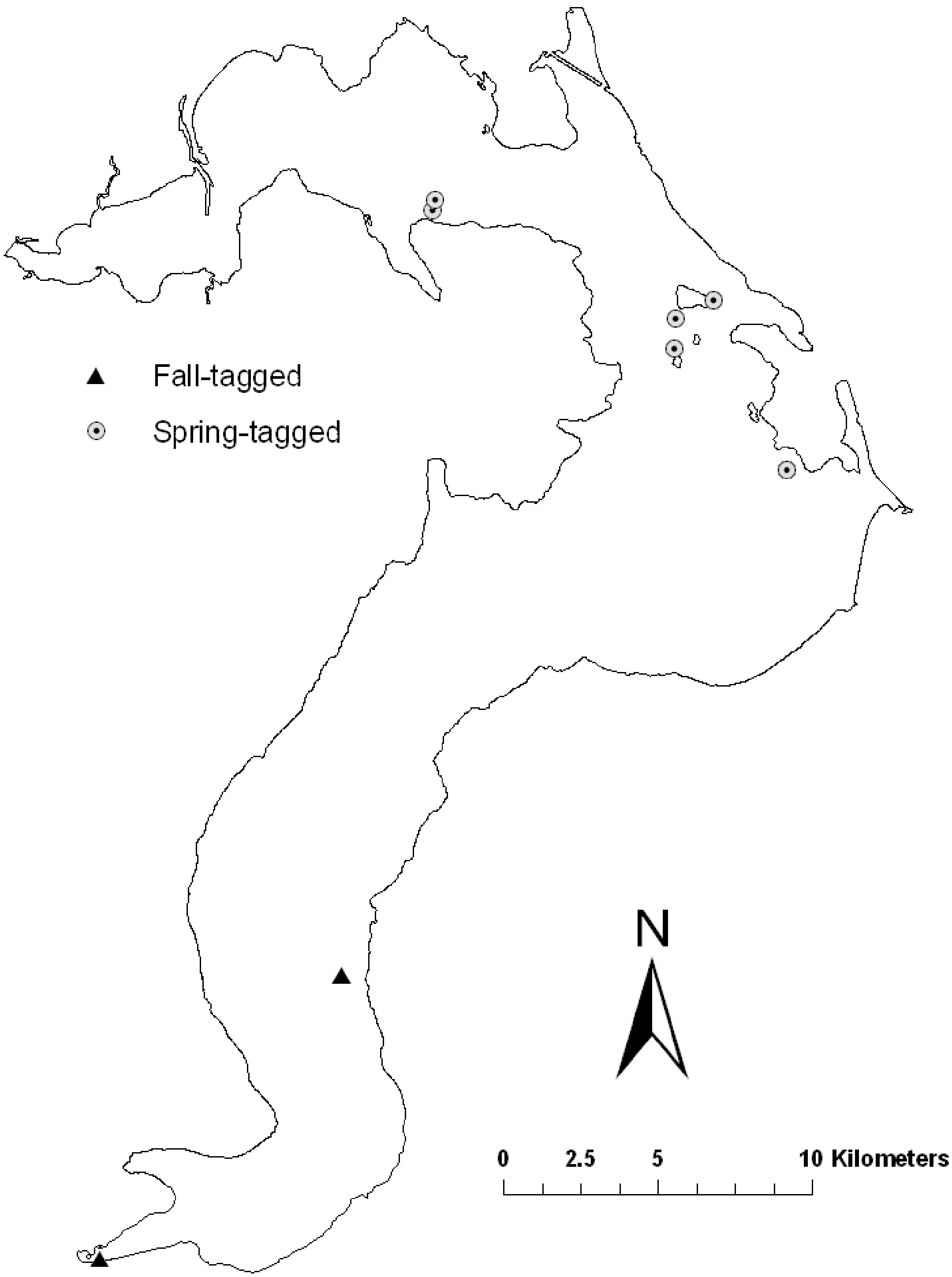


Figure 2. Location of capture for 31 adult lake trout implanted with transmitters in Lake Pend Oreille during 2007. Each point represents a capture location not individual fish; multiple fish were captured at each site. Gray circles represent spring capture sites, and black triangles represent fall capture sites.

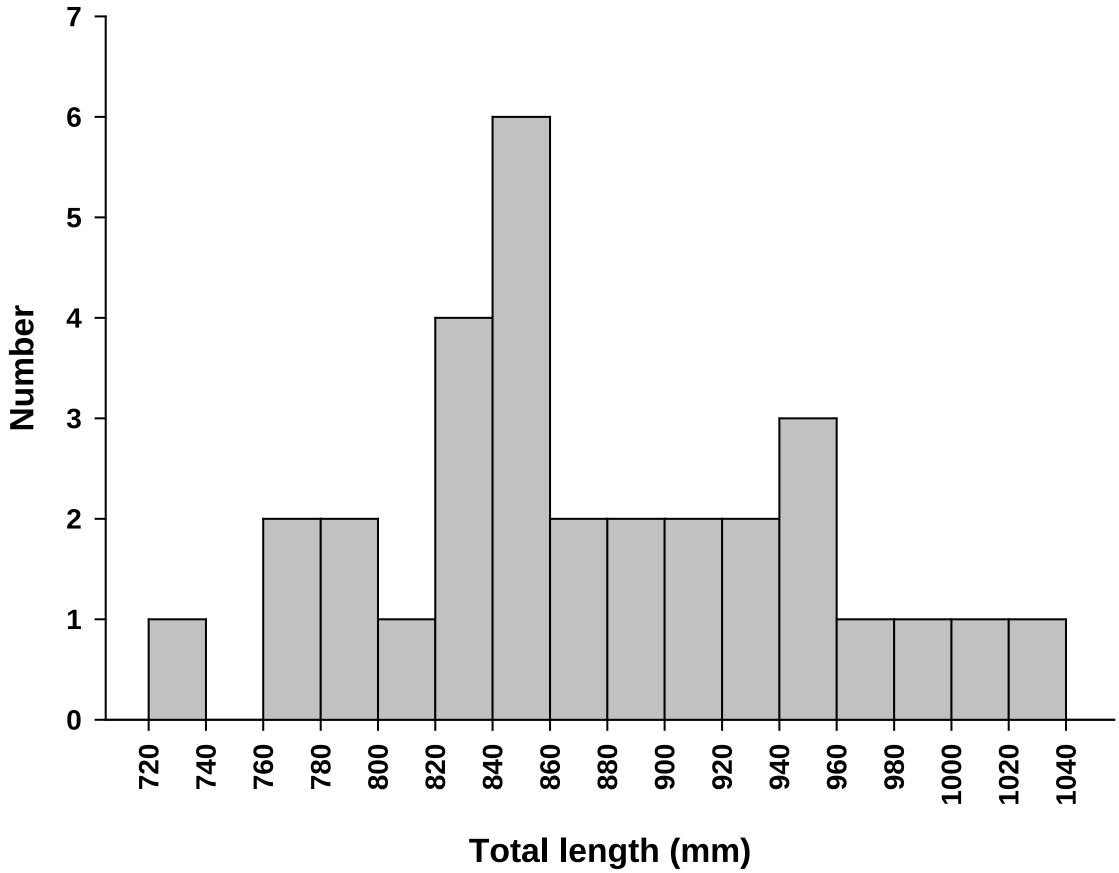


Figure 3. Length-frequency histogram for lake trout captured and implanted with transmitters in Lake Pend Oreille during 2007.

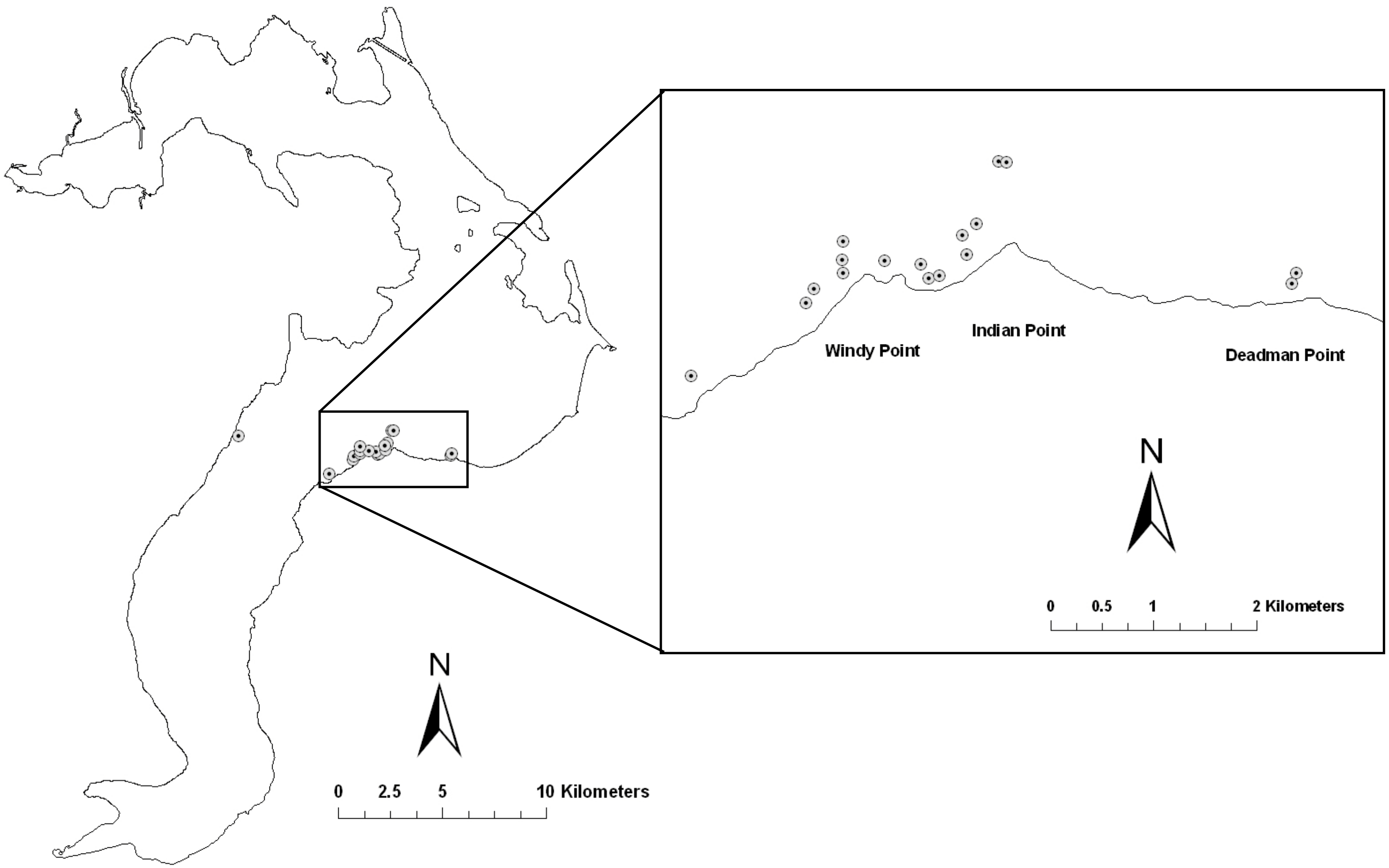


Figure 4. Telemetry locations for 18 lake trout from August 17 -23, 2007 in Lake Pend Oreille. Inset represents 17 lake trout at a potential spawning location.

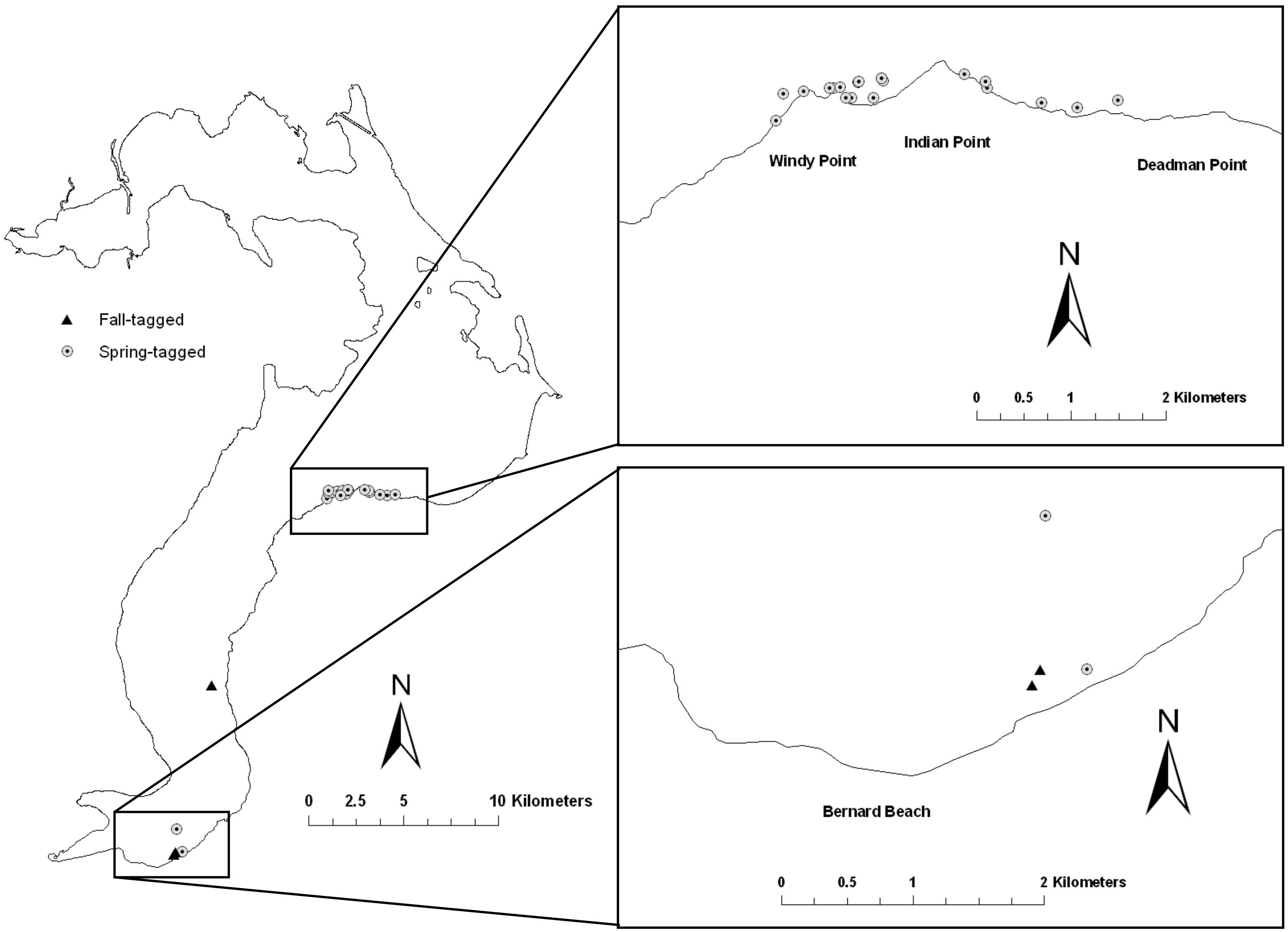


Figure 5. Telemetry locations for 22 lake trout from September 17-20, 2007 in Lake Pend Oreille. Insets represent 21 lake trout at potential spawning locations.

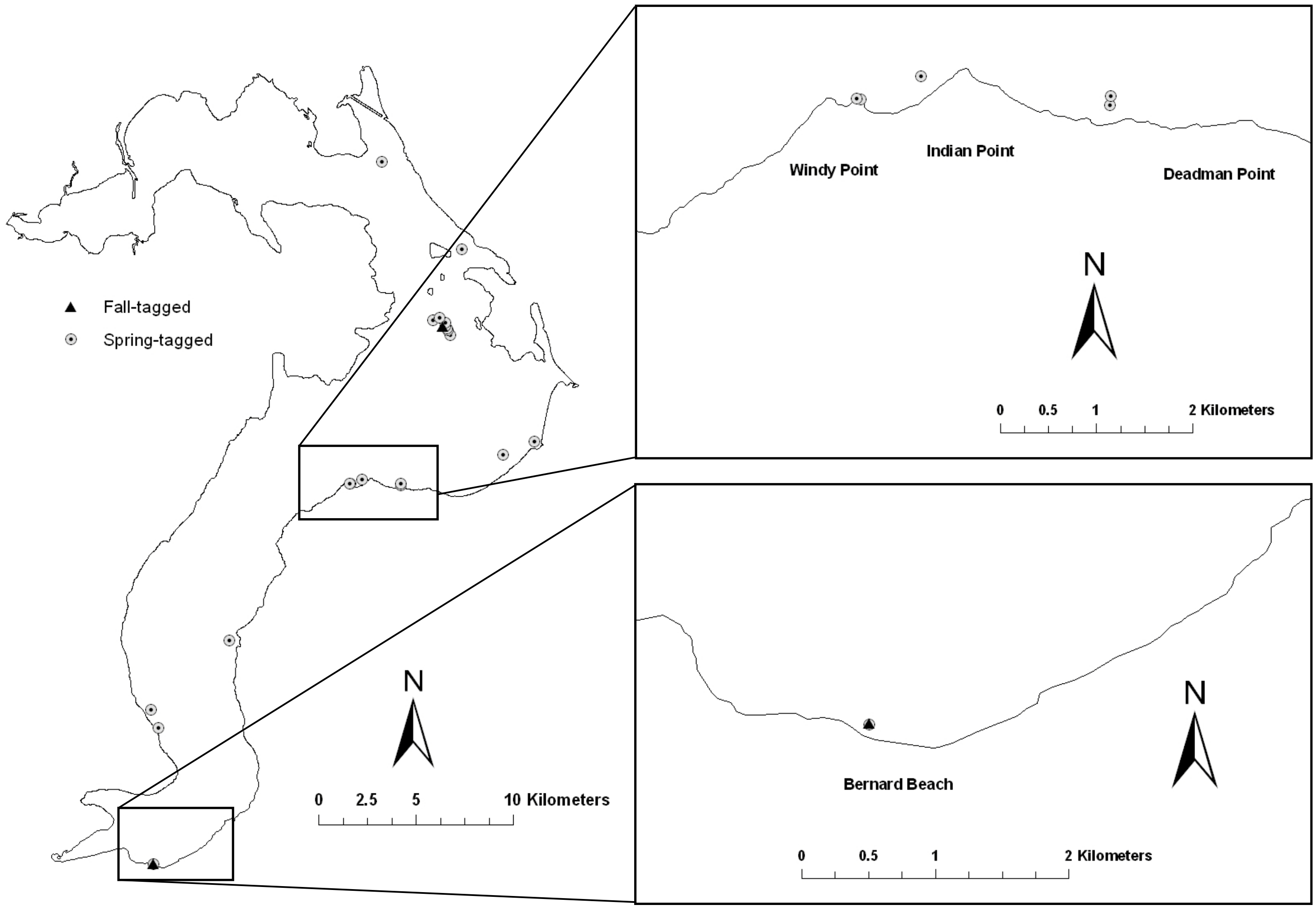


Figure 6. Telemetry location for 20 lake trout from October 22-26, 2007 in Lake Pend Oreille. Insets represent seven lake trout at potential spawning locations.

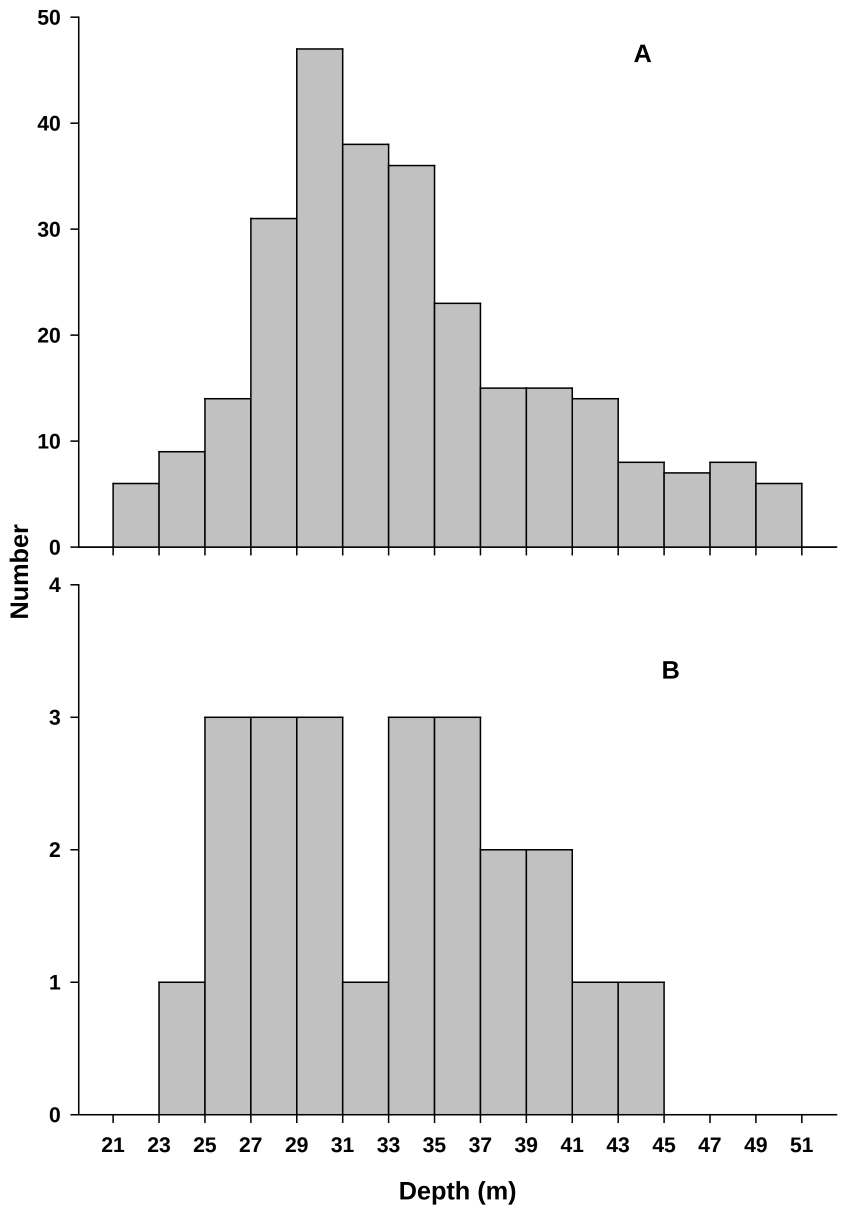


Figure 7. Depth-frequency histogram for 22 lake trout located at Windy Point (A) and four lake trout at Bernard Beach (B) from September 10-October 18, 2007.

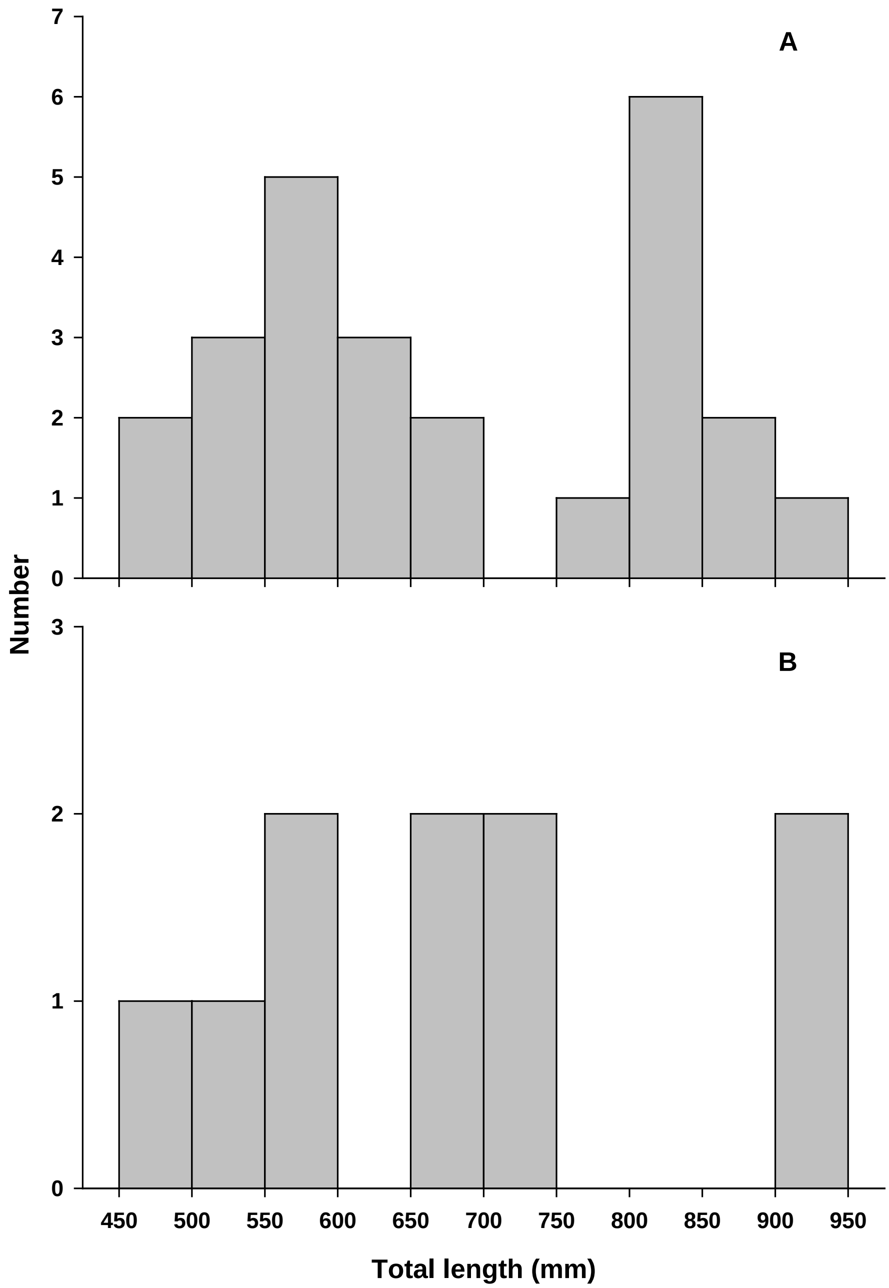


Figure 8. Length-frequency histogram for lake trout captured in gill nets at Windy Point (A) and Bernard Beach (B) during spawning in Lake Pend Oreille, 2007.

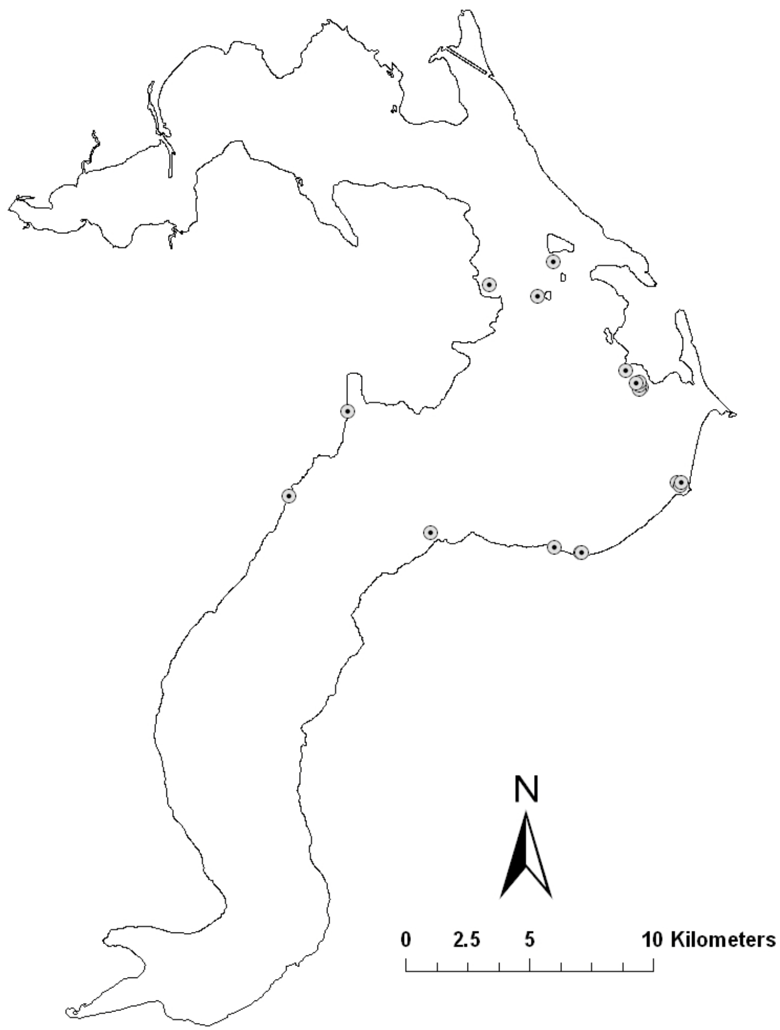
APPENDICES

Appendix A. Lake trout captured and tagged with combined acoustic and radio transmitters in Lake Pend Oreille, Idaho in 2007. Sex was defined as male (M), female (F), or unknown (U).

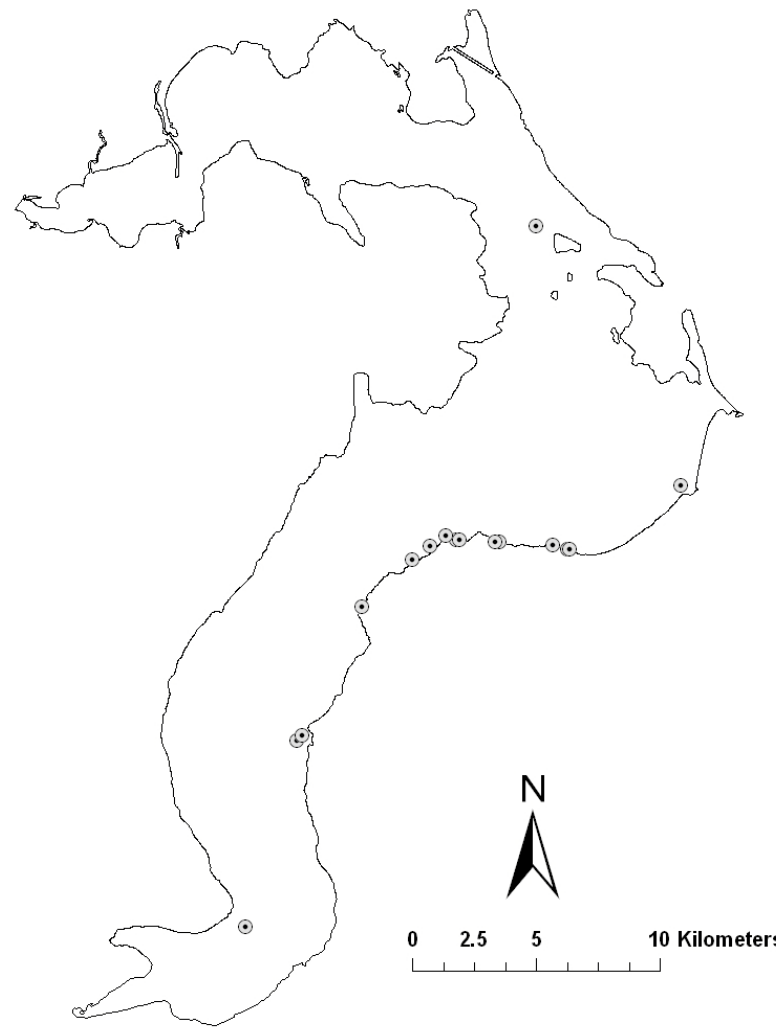
Tag ID	Date tagged	Capture method	Capture location	Holding/Release location	Total length (mm)	Weight (kg)	Sex	Number of relocations
10-29500	5/18/07	Trap net	Warren Island	Bottle Bay	792	5.40	F	18
11-29600	5/18/07	Trap net	Bottle Bay	Sourdough Pt	893	5.76	F	1
12-29700	5/18/07	Trap net	Bottle Bay	Sourdough Pt	810	4.90	M	2
13-29800	5/25/07	Trap net	Pearl Island	Warren Island - W	925	9.02	M	10
14-29900	5/25/07	Trap net	Sheepherder Pt	Warren Island - W	840	8.50	U	28
15-30000	5/25/07	Trap net	Sheepherder Pt	Warren Island - W	760	4.40	F	21
16-30100	5/25/07	Trap net	Warren Island - NE	Warren Island - NE	880	6.65	F	11
17-30200	5/25/07	Gill net	Lee's Pt	Warren Island - NE	775	3.94	M	27
18-30300	5/25/07	Gill net	Lee's Pt	Warren Island - NE	935	8.64	U	20
19-30400	5/25/07	Gill net	Lee's Pt	Warren Island - NE	895	6.90	U	29
20-30500	5/25/07	Trap net	Warren Island - NE	Warren Island - NE	850	4.22	M	26
21-30600	5/30/07	Trap net	Thompson Pt	Sheepherder Pt	1010	9.52	M	33
22-30700	5/30/07	Trap net	Thompson Pt	Sheepherder Pt	990	8.90	M	20
23-30800	5/30/07	Trap net	Thompson Pt	Sheepherder Pt	915	6.20	M	13
24-30900	5/30/07	Trap net	Thompson Pt	Sheepherder Pt	950	7.82	M	33
25-31000	5/30/07	Trap net	Thompson Pt	Sheepherder Pt	840	6.25	F	19
26-31100	5/30/07	Trap net	Thompson Pt	Sheepherder Pt	825	4.80	M	1
27-31200	5/30/07	Trap net	Thompson Pt	Sheepherder Pt	825	5.42	M	29
28-31300	5/30/07	Trap net	Thompson Pt	Sheepherder Pt	825	5.60	F	20
29-31400	5/30/07	Trap net	Sheepherder Pt	Sheepherder Pt	935	7.08	M	30
30-31500	5/30/07	Trap net	Sheepherder Pt	Sheepherder Pt	855	5.99	M	32
31-31600	5/30/07	Trap net	Sheepherder Pt	Sheepherder Pt	810	4.68	F	18
32-31700	5/30/07	Trap net	Sheepherder Pt	Sheepherder Pt	910	5.84	M	1
33-31800	5/30/07	Trap net	Lee's Pt	Pearl Island	980	9.24	M	32
34-31900	5/30/07	Trap net	Lee's Pt	Pearl Island	720	3.63	M	18
35-32000	5/30/07	Trap net	Pearl Island	Pearl Island	830	--	F	25
36-32100	5/30/07	Trap net	Pearl Island	Pearl Island	810	--	M	28
37-32200	5/30/07	Trap net	Pearl Island	Pearl Island	865	--	F	29
38-32300	9/11/07	Trap net	Idlewilde Bay	none	818	--	F	18
39-32400	9/18/07	Trap net	Whiskey Rock bay	none	768	4.44	F	7
40-32500	9/18/07	Trap net	Whiskey Rock bay	none	750	3.70	M	19

Appendix B. Telemetry locations of lake trout from July 10 to February 14, 2008 in Lake Pend Oreille. Only one location is shown for each fish during a tracking event.

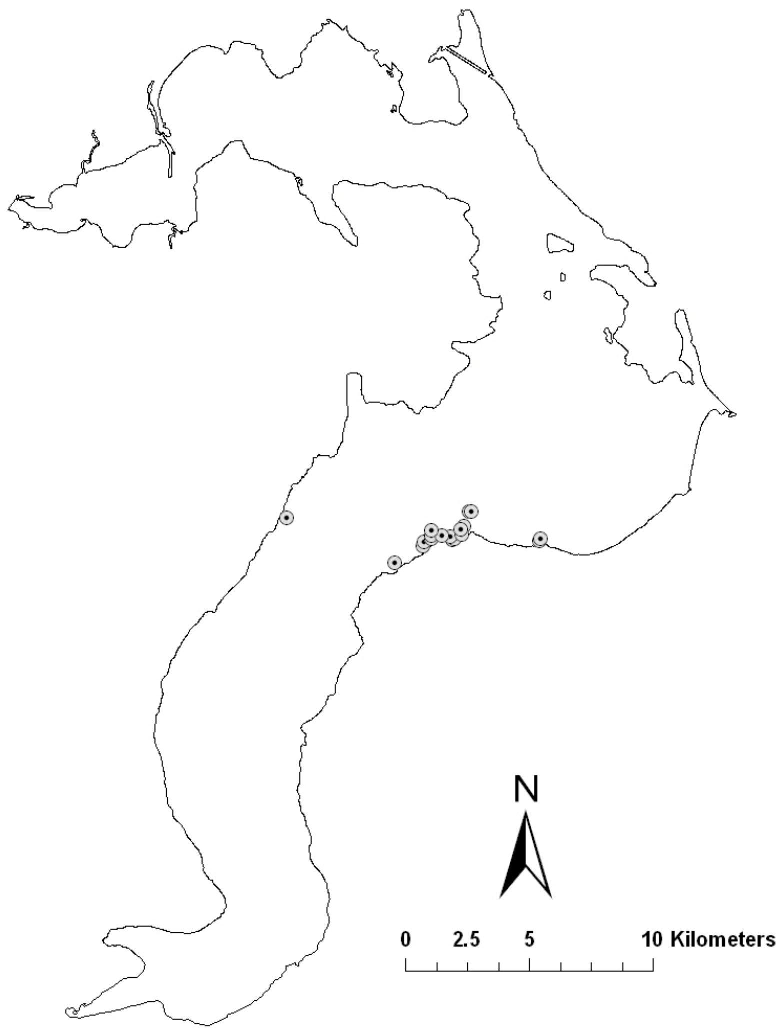
A) July 10-13, 2007



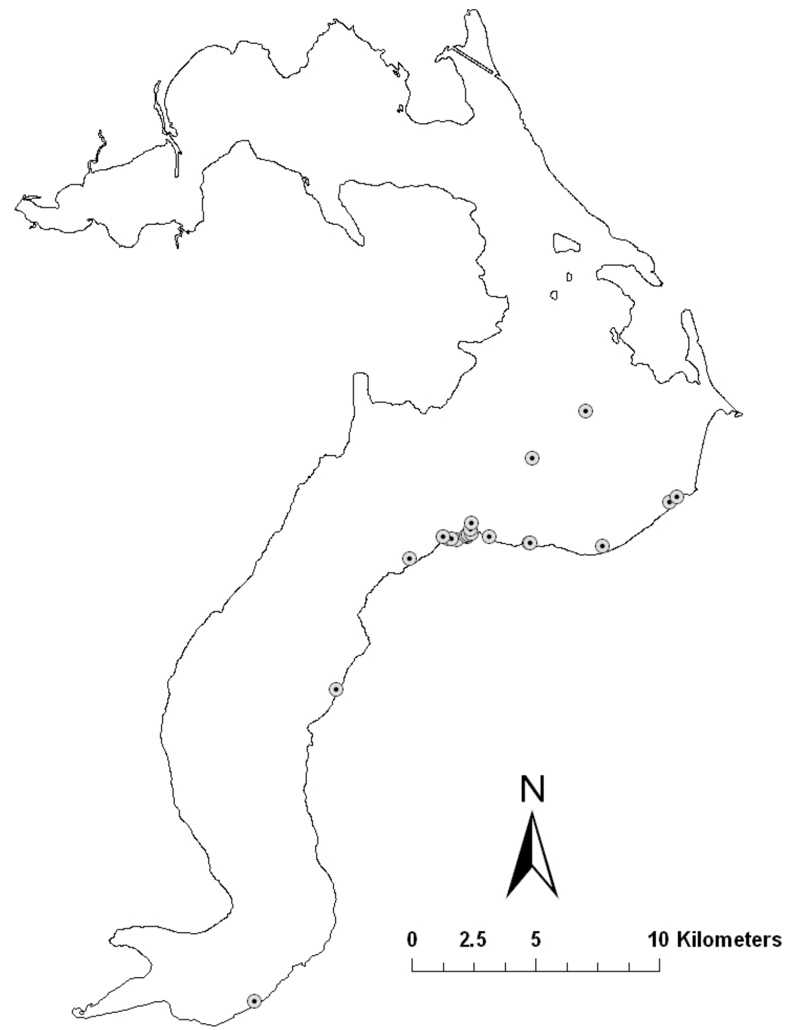
B) July 27-August 9, 2007



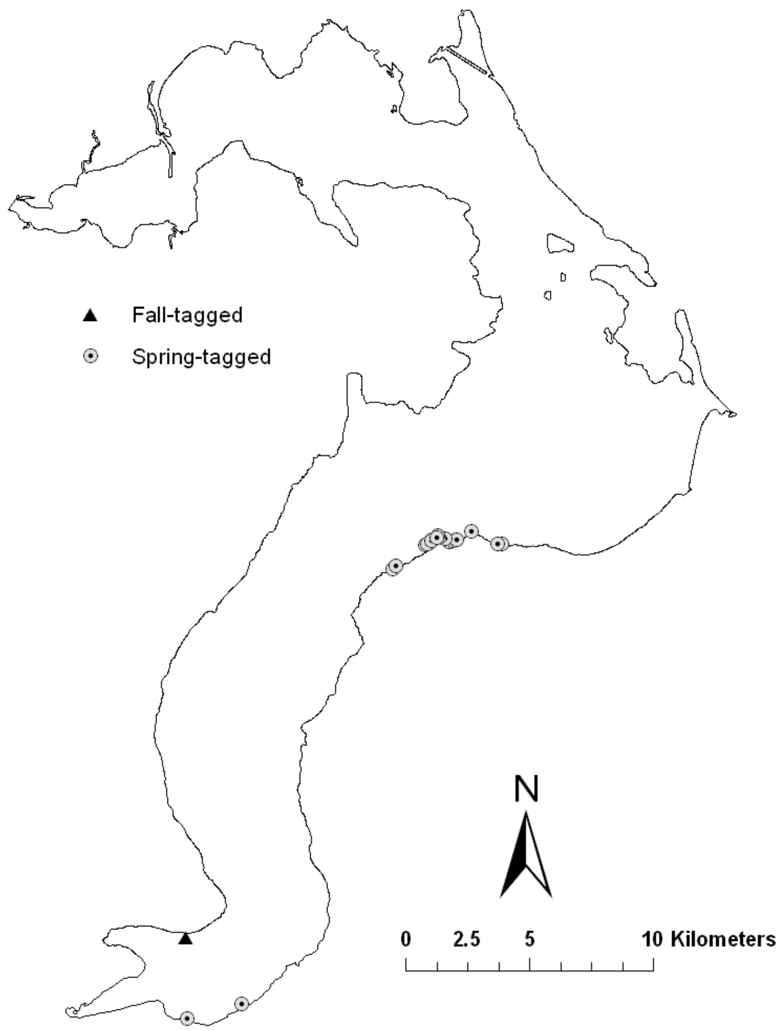
C) August 17-23, 2007



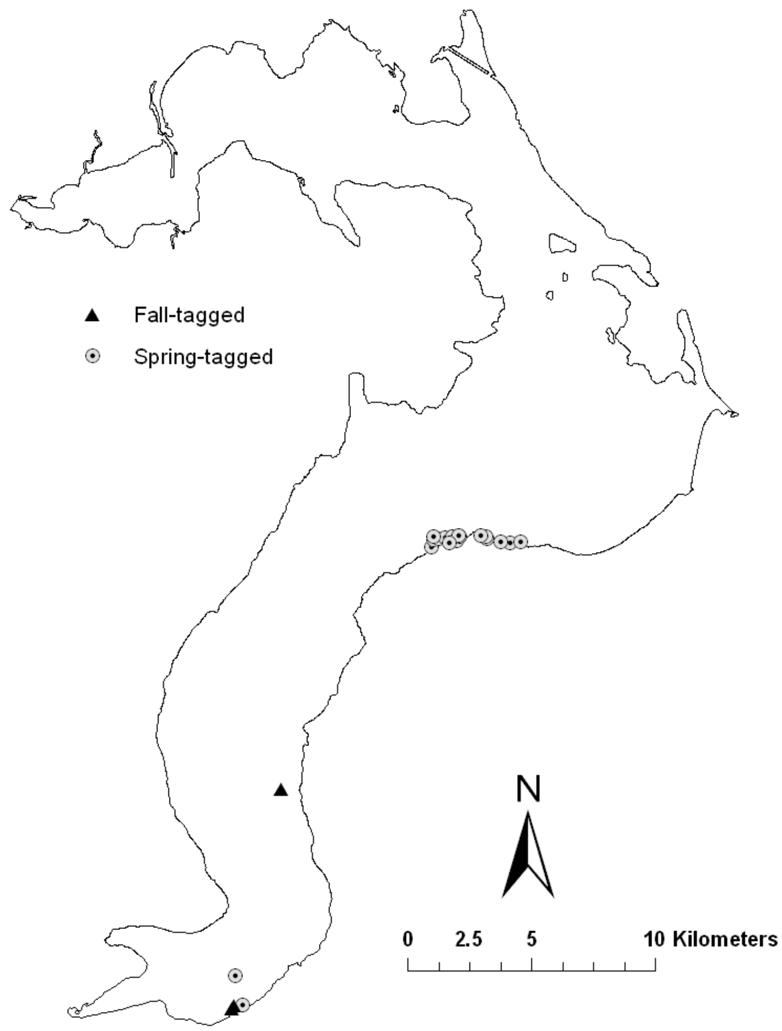
D) August 28-September 5, 2007



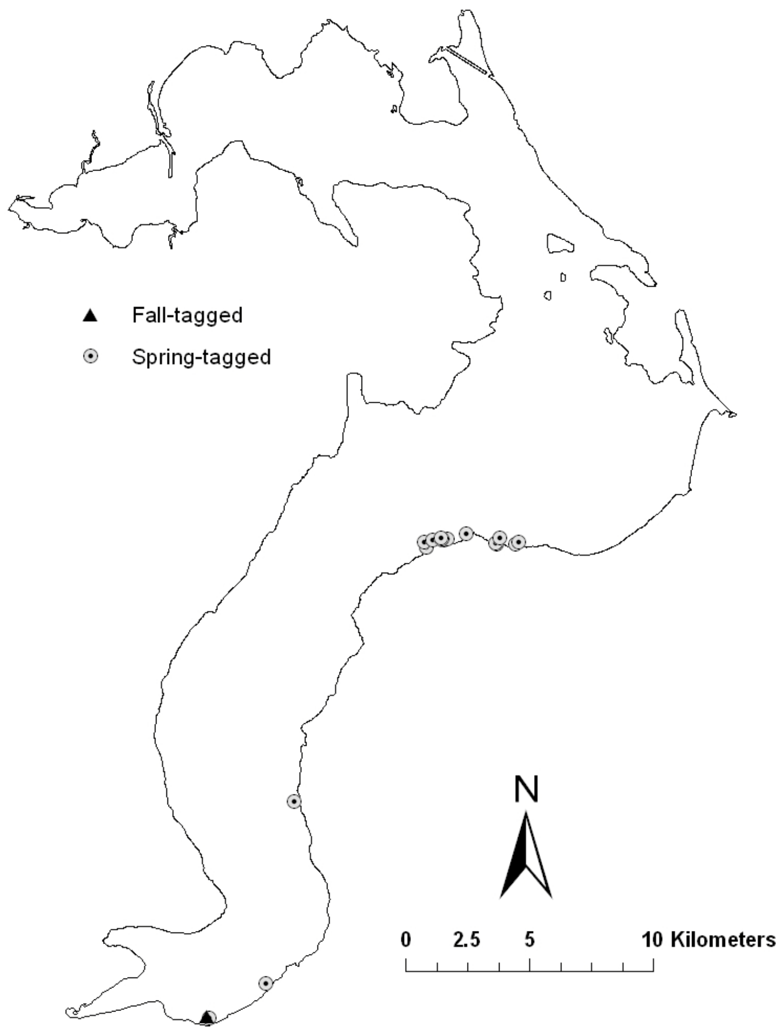
E) September 10-12, 2007



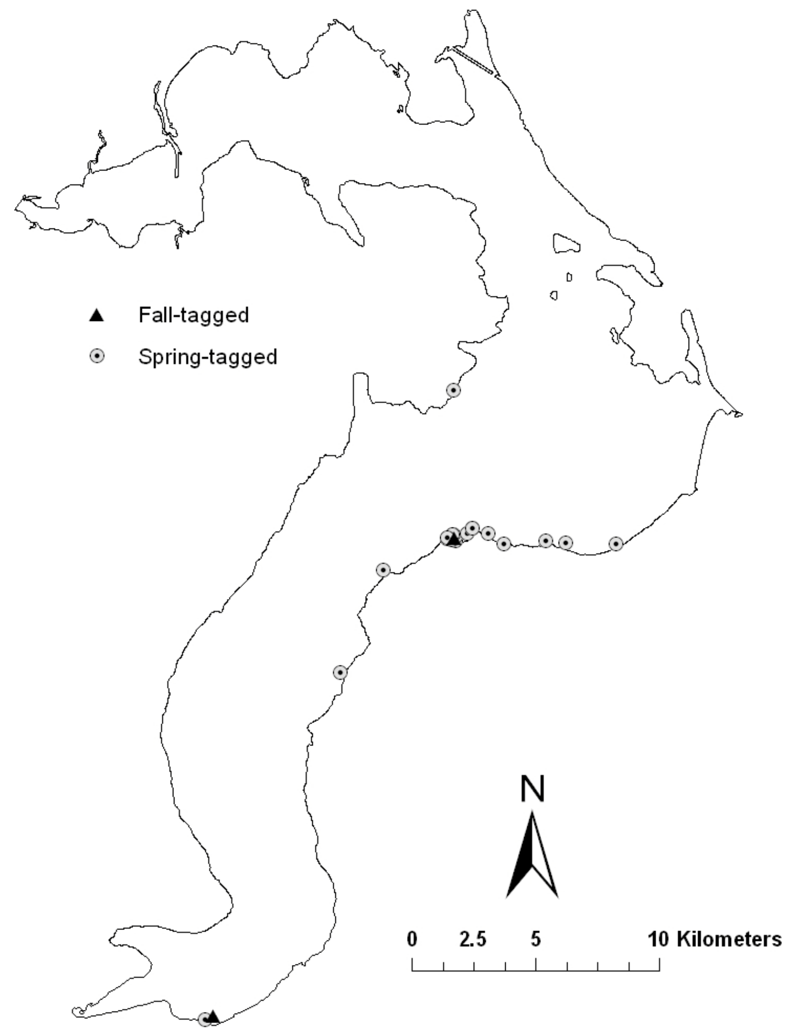
F) September 17-20, 2007



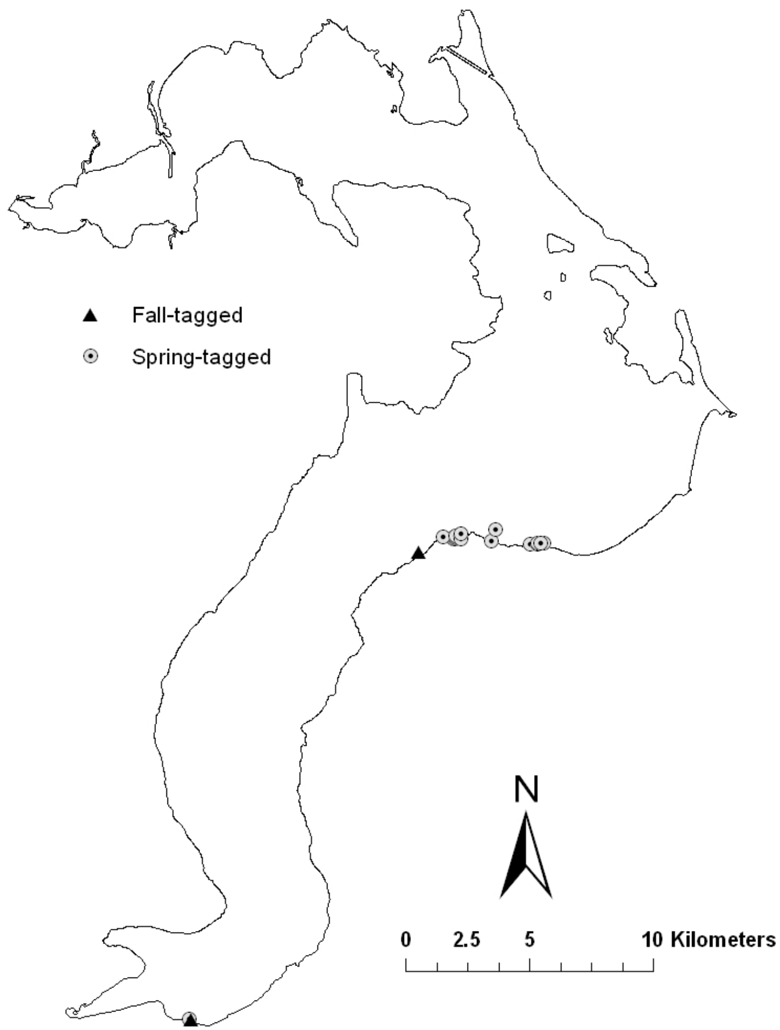
G) September 25-28, 2007



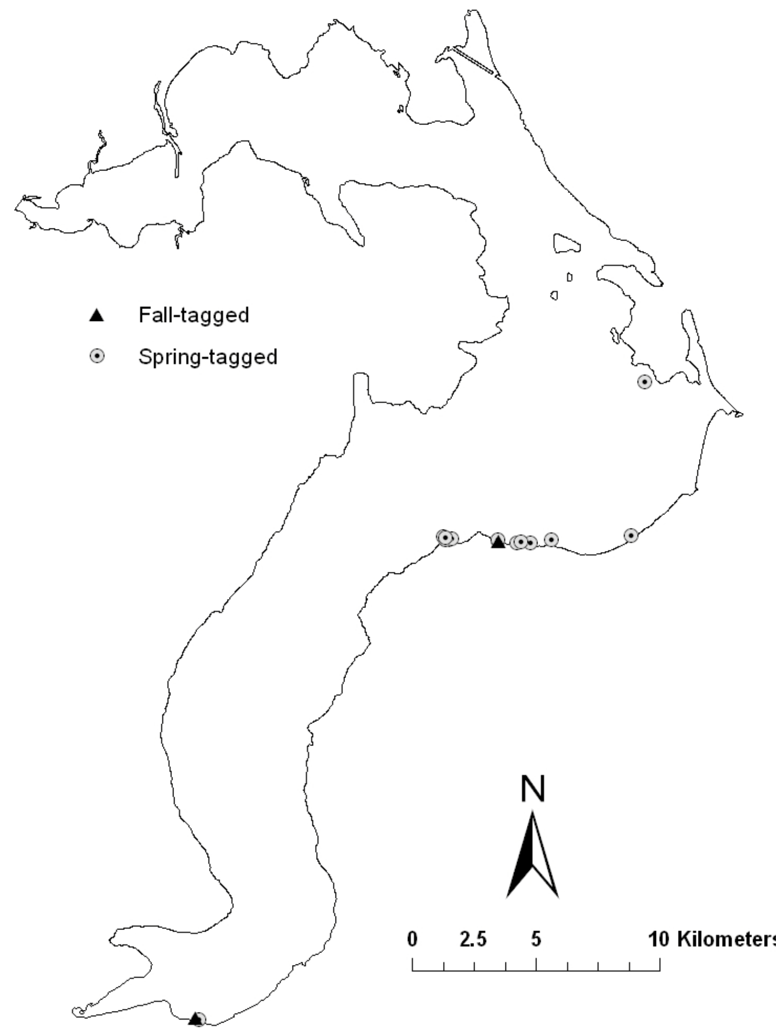
H) October 1-4, 2007



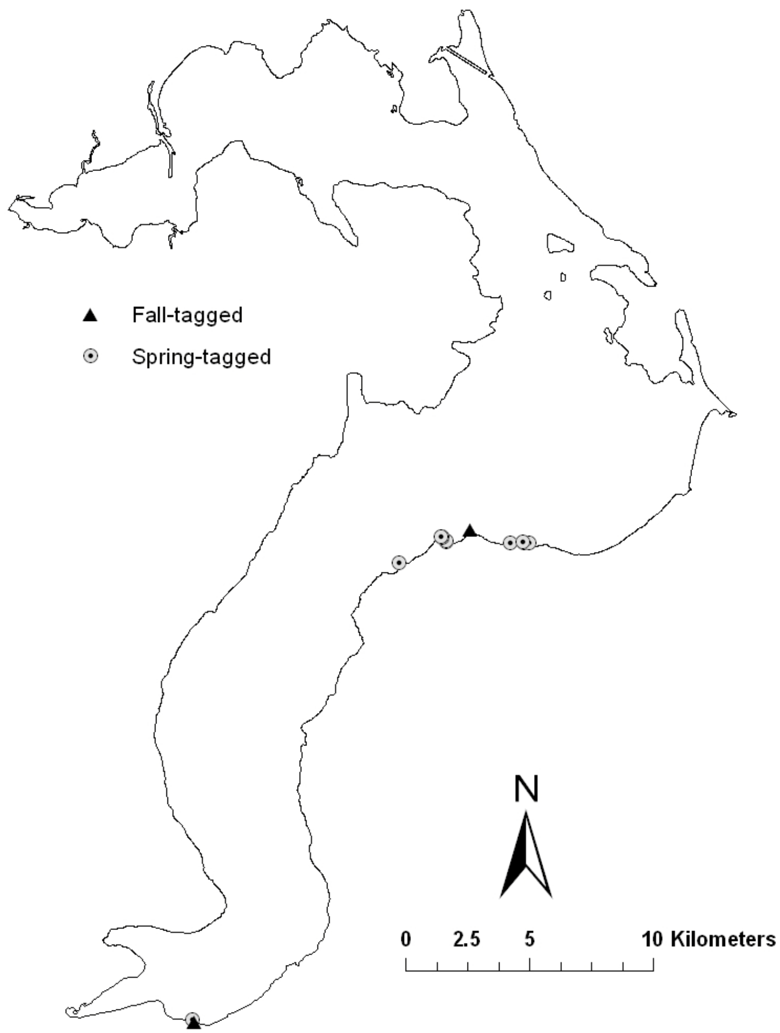
I) October 9-11, 2007



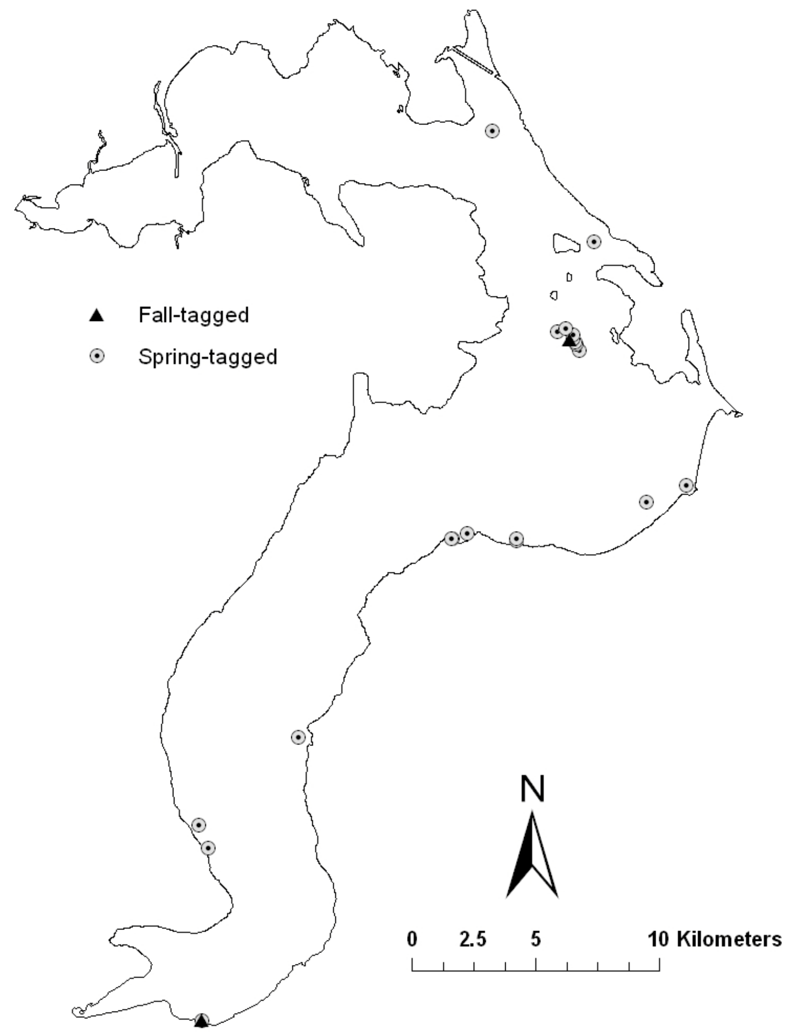
J) October 15-16, 2007



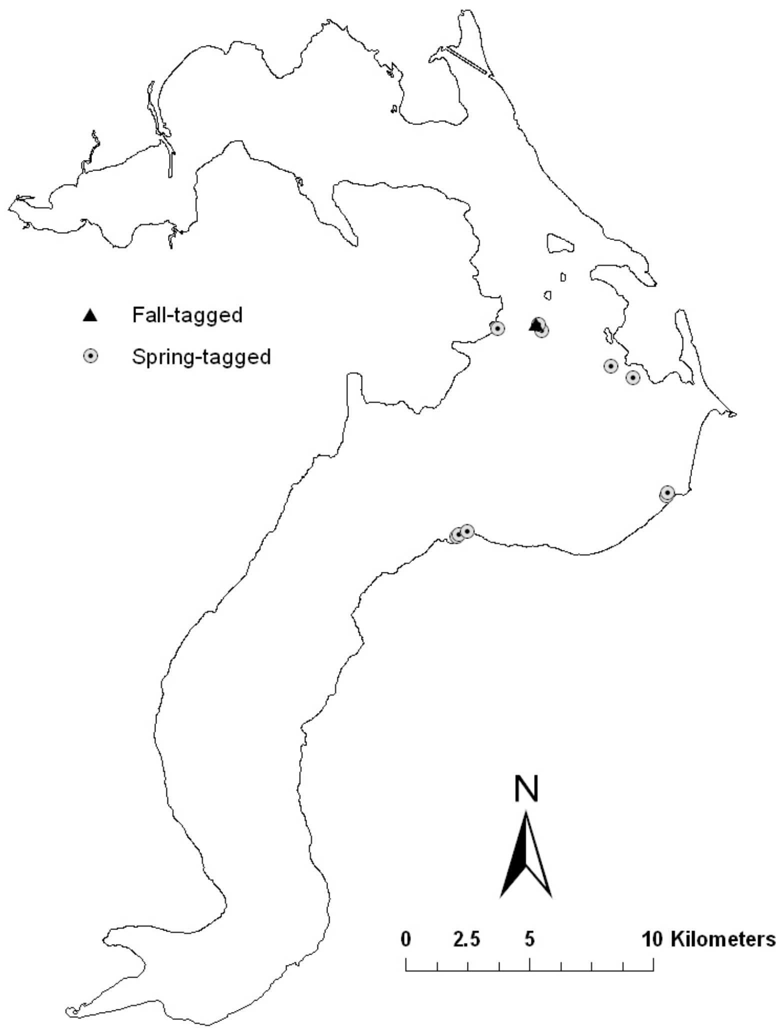
K) October 18, 2007



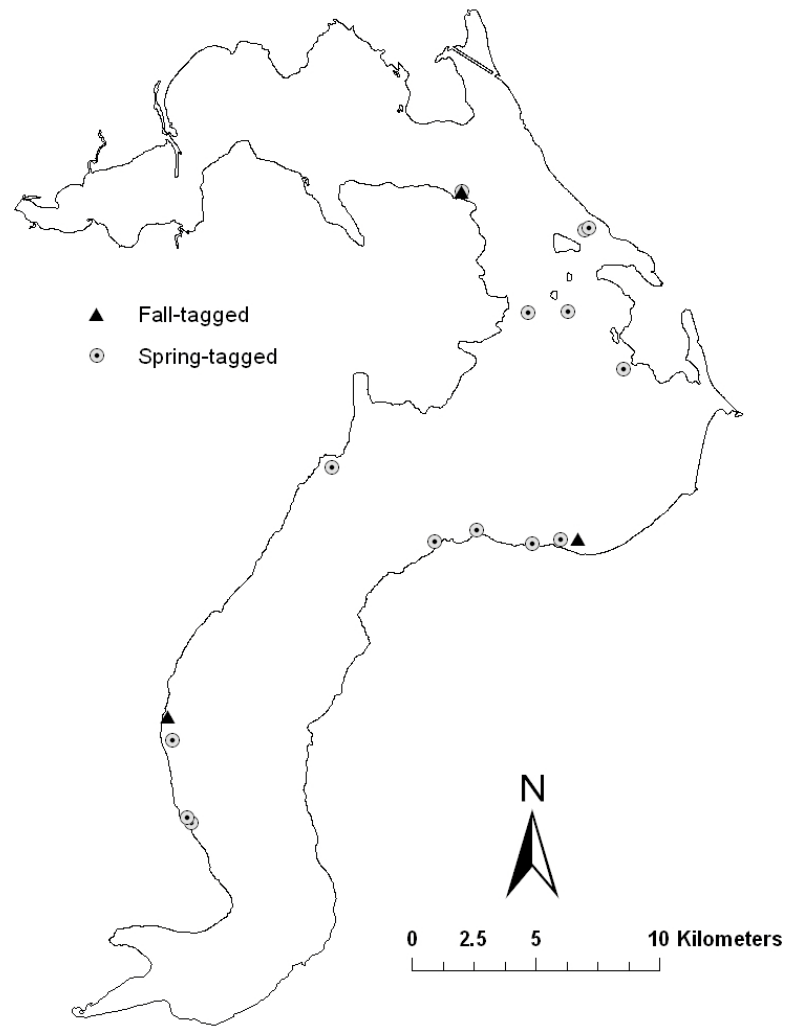
L) October 22-26, 2007



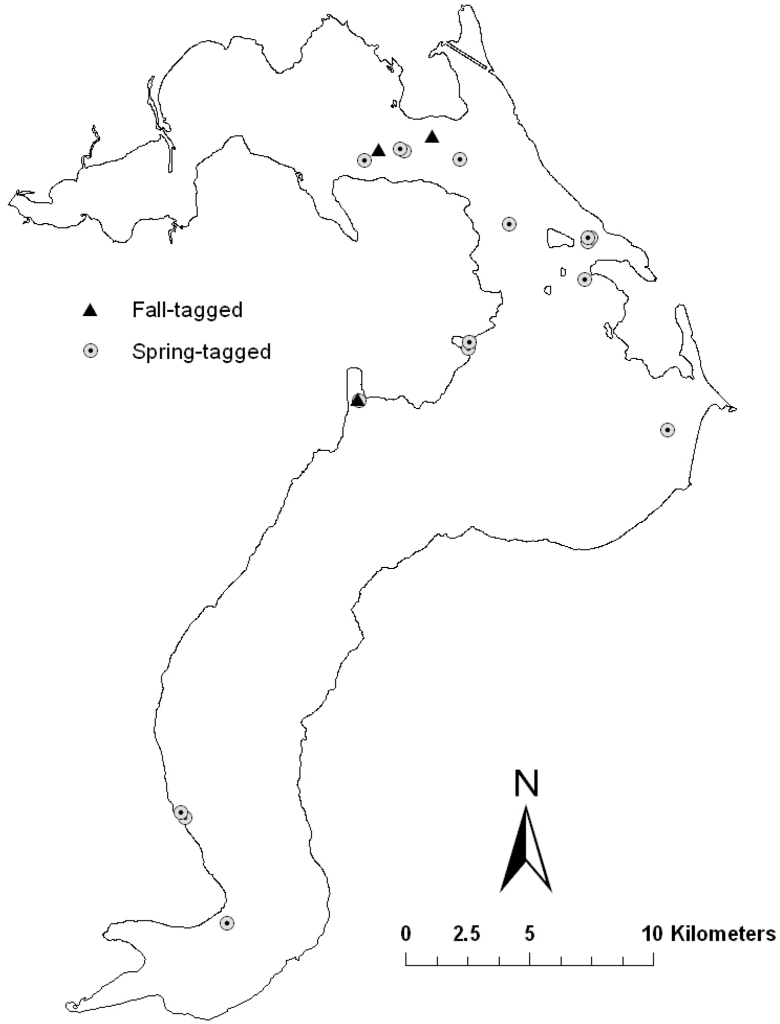
M) October 31-November 1, 2007



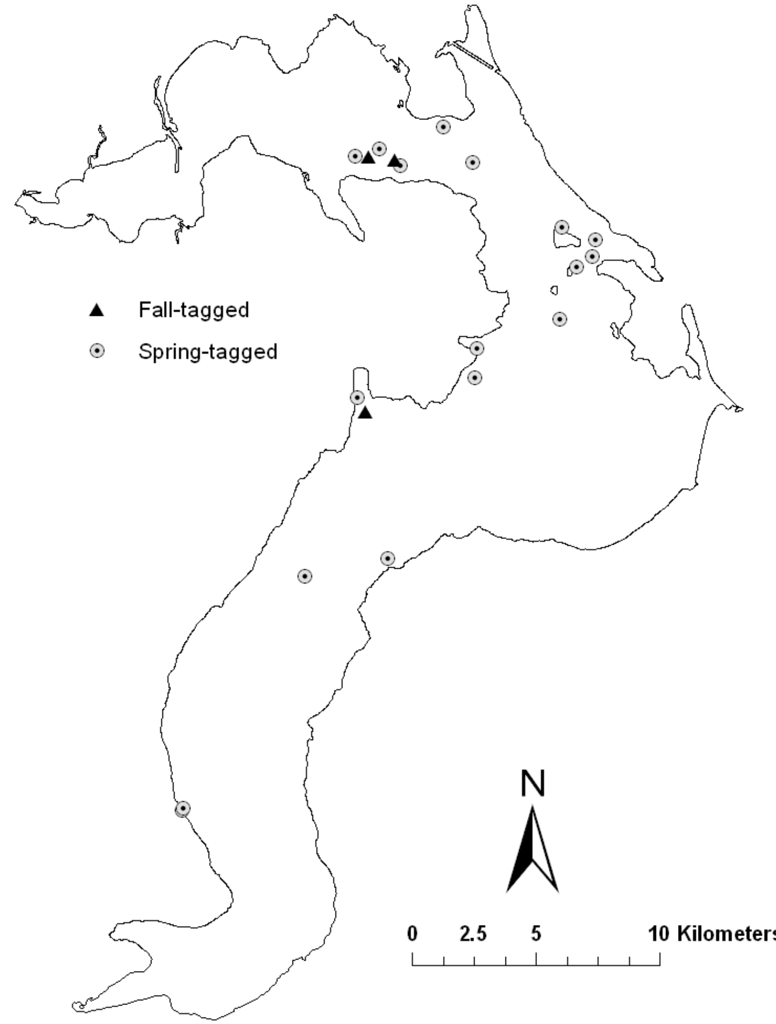
N) November 9-14, 2007



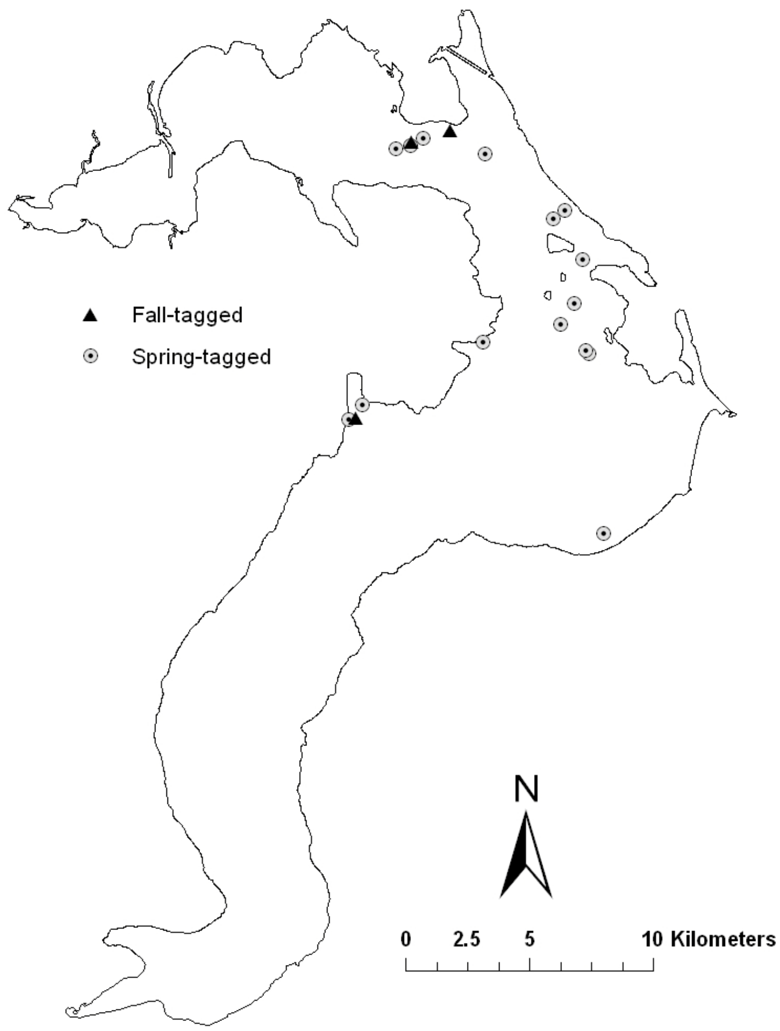
O) November 28-30, 2007



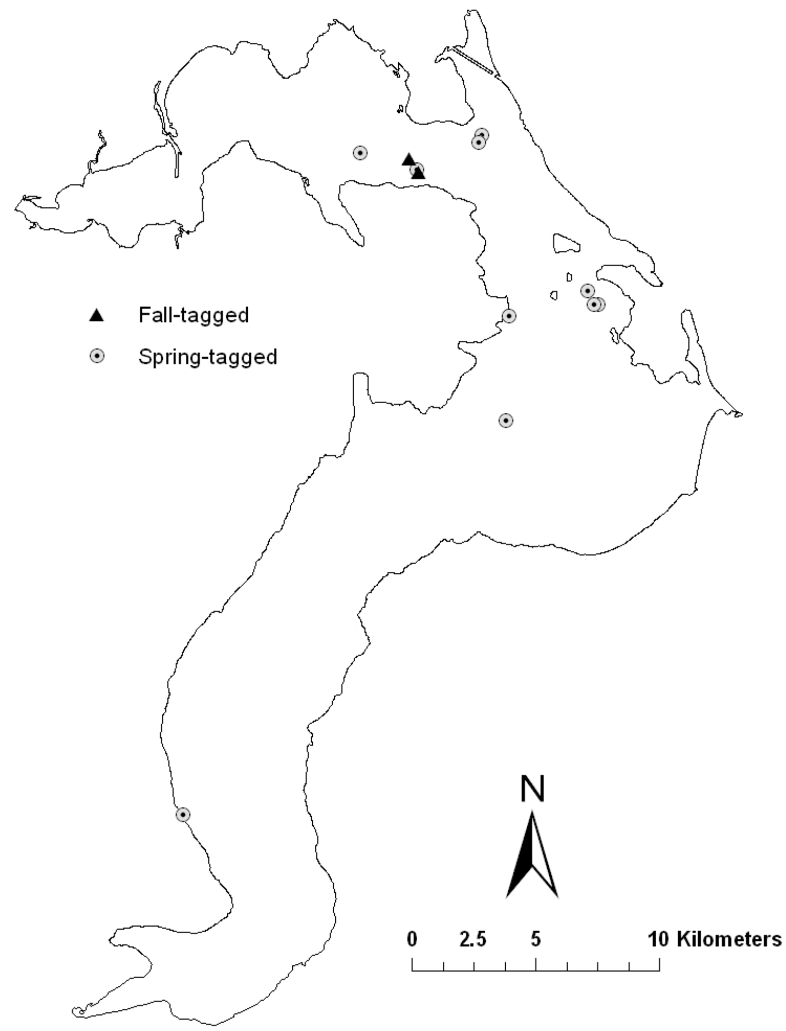
P) December 17-19, 2007



Q) January 3-10, 2008



R) February 12-14, 2008



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