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Migratory Patterns of Different Spawning Aggregates of Dolly Varden in the Kenai River Watershed

Douglas E. Palmer and Bruce E. King

Abstract

Radiotelemetry was used to monitor the seasonal movements of adult Dolly Varden *Salvelinus malma* in the Kenai River watershed. Dolly Varden from spawning aggregates in Cooper Creek (*N*=20), Quartz Creek (*N*=60), South Fork of the Snow River (*N*=60) and the upper Kenai River (*N*=79) were implanted with radio transmitters and tracked for varying periods from September 1998 through December 2001. Nearly half (*N*=109) of the radio-tagged Dolly Varden provided movement information for one year or longer. All radio-tagged Dolly Varden migrated seasonally between lake and riverine habitats to fulfill critical habitat needs. Lacustrine habitats were selected for winter refuge with Kenai and Skilak lakes providing the majority of overwinter habitat. Movement to overwintering lakes began in October and was complete by December. Movement from overwintering lakes to summer feeding areas began in May. Patterns of movement during the summer months were different for each spawning aggregate, but were generally associated with the timing and location of smolting or spawning salmon. Most radio-tagged fish were found in riverine habitats from June through September except for fish from the Snow River spawning aggregate which remained in Kenai Lake through mid-summer. The Killey River was an important early summer feeding area for many fish, but by August most fish were found in the Kenai River above and below Skilak Lake. Fish were located at spawning areas from late September through October. Although a few fish spawned during consecutive years, it appears that most Dolly Varden from these spawning aggregates will skip a year or two between spawning.

Introduction

The Kenai River provides a variety of recreational fishing opportunities and receives more angler effort than any other river in Alaska (Howe et al. 2001d). Although most anglers participate in popular sport fisheries targeting Chinook salmon *Oncorhynchus tshawytscha*, sockeye salmon *O. nerka*, coho salmon *O. kisutch*, and rainbow trout *O. mykiss*, the Kenai River also supports a major fishery for Dolly Varden *Salvelinus malma*. Catches of Dolly Varden in the Kenai River have ranged from 34,577 to 107,785 fish annually since 1990 (Appendix 1; Mills 1991–1994; Howe et al. 1995, 1996, 2001a–d, Walker et al. 2003, Jennings et al. 2004). Dolly Varden are caught throughout the Kenai River, however, anglers targeting this species generally concentrate their efforts above Skilak Lake and in the middle Kenai River above the Moose River. Catches of Dolly Varden in these sections have comprised about 74% of the total catch in the Kenai River since 1990.

Angler effort directed at Dolly Varden in the upper and middle Kenai River has increased substantially in recent years. An increase in angler effort, coupled with a perception by the

Authors: Douglas E. Palmer is a senior fishery biologist with the U.S. Fish and Wildlife Service. He is the corresponding author and can be contacted at the Kenai Fish and Wildlife Field Office, P.O. Box 1670, Kenai, Alaska; or douglas_palmer@fws.gov. Bruce E. King is currently retired but was formerly a fisheries research biologist with the Alaska Department of Fish and Game in Soldotna, Alaska.

public that harvest was increasing and that numbers of Dolly Varden were declining, generated concern about negative impacts to the population. Because no data were available regarding stock status, the Alaska Board of Fisheries responded to this concern beginning in 1990 with a series of more restrictive regulations for Dolly Varden in the Kenai River watershed (Gamblin et al. 2004). Regulation changes included a reduction in bag/possession limit, size restrictions, and spawning season closures in three tributary streams.

Concern over potential negative impacts to Dolly Varden populations in the Kenai River and the lack of base population data prompted the development of a cooperative study between the U.S. Fish and Wildlife Service and the Alaska Department of Fish and Game. The primary focus of the study was to use radiotelemetry to describe the extent and patterns of movement of Dolly Varden in the Kenai River watershed. Preliminary investigations in 1996 and 1997 focused on identification of spawning aggregates of Dolly Varden in the upper Kenai River watershed. Spawning aggregates were identified in Cooper Creek, Quartz Creek, South Fork of the Snow River, and the upper mainstem Kenai River. This report describes the seasonal distribution and migratory patterns of Dolly Varden from these spawning aggregates. Radio transmitters used during the study provided up to two years of location data that also allowed us to examine frequency of spawning and fidelity to overwintering habitats.

Study Area

The Kenai River drainage encompasses approximately 5,500 km^2 on the Kenai Peninsula in South-central Alaska (Figure 1). The Kenai River is glacially fed and originates at the outlet of Kenai Lake. The upper reach of the Kenai River is about 27 km long and extends from Kenai Lake to the inlet of Skilak Lake. The river traverses Skilak Lake for about 24 km, and then flows another 17 km to Naptowne Rapids. Below Naptowne Rapids, the river flows another 63 km to Cook Inlet.

Discharge in the Kenai River depends on the outflow of Kenai and Skilak lakes and lacks the flow extremes characteristic of streams without headwater lakes. The mean annual discharge in the Kenai River at Soldotna is approximately 167 m^3/s with summer flows ranging from 142 to 850 m^3/s (Bigelow et al. 1985). Glacial melt produces turbid conditions throughout the year, but water clarity improves during winter months when flows range from 23 to 142 m^3/s.

Major tributaries that enter the Kenai River above Naptowne Rapids include the Killey River which empties into the Kenai River at river kilometer (rkm) 70.8, Skilak River which contributes melt water from Skilak Glacier at the east end of Skilak Lake, Russian River (rkm 118.7), Cooper Creek (rkm 127.4), and Juneau Creek (rkm.127.8). Major tributaries to Kenai Lake include Quartz Creek, Trail River, Ptarmigan Creek, and the Snow River.

Methods

Dolly Varden in spawning condition were surgically implanted with radio transmitters during 1998 and 1999 (Appendix 2). During 1998, transmitters were implanted in Dolly Varden that were spawning in Cooper and Quartz creeks and the South Fork of the Snow River. Radio-tagging efforts during 1999 focused on Dolly Varden spawning in the upper Kenai River above Jim's Landing. The majority of fish were captured with hook-and-line, however drift gill nets (7.6 mm stretch mesh) were also fished in the upper Kenai River to capture fish for radio transmitter implants.

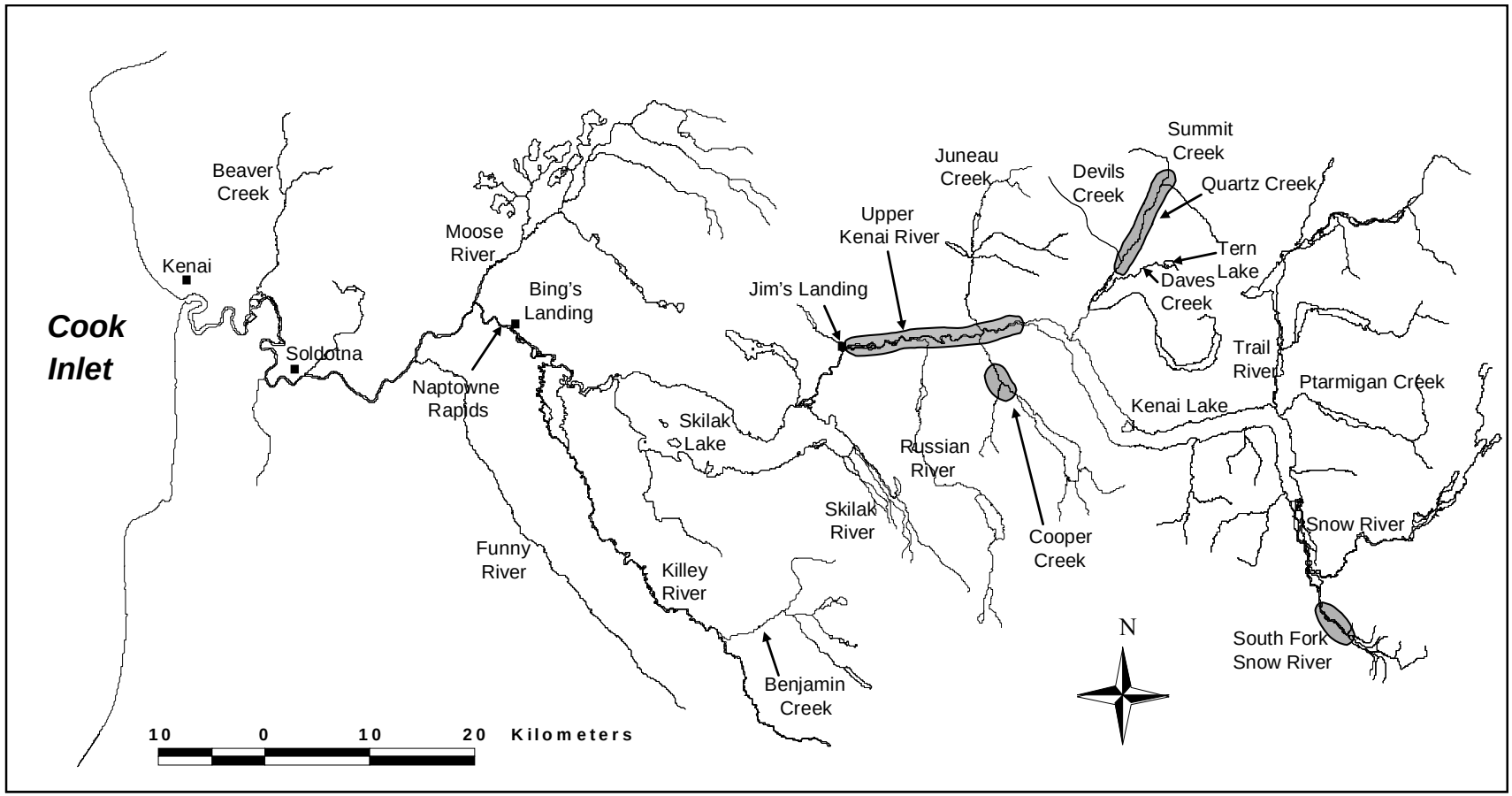

FIGURE 1.—Map of the Kenai River watershed. Shaded areas indicate locations where Dolly Varden were captured and implanted with radio transmitters during 1998 and 1999.

Implanting Transmitters

Dolly Varden were anesthetized with a 30-mg/L solution of clove oil. Unconscious fish were placed ventral side up in a neoprene-lined cradle, and their gills were irrigated with a combination of anesthesia and oxygenated water during the procedure. A 2–3-cm incision large enough to accommodate the transmitter was made anterior to the pelvic girdle approximately 1 cm from the midventral axis. The transmitter antenna was routed under the pelvic girdle and through the body wall slightly off the midventral axis and anterior to the vent using a hypodermic needle and grooved director. Oxytetracycline was administered intraperitoneally at a dosage of 0.5 mg/kg body weight to help prevent infection. The incision was closed with three or four individual stitches of absorbable suture and Vetbond® adhesive. Surgical instruments and transmitters were soaked in a cold sterilant and rinsed in saline solution before use. Each surgery averaged 6 min, and fish were swimming upright and respiring normally within 3–5 min of being returned to a freshwater holding tank. Fish were released near the capture site once they gained equilibrium and were actively swimming. Surgical implant procedures were similar to those described by Summerfelt and Smith (1990).

Radio transmitters (Lotek® model CFRT–3EM) were 48 mm in length and 10 mm in diameter and equipped with a 30-cm plastic coated wire antenna. Each transmitter weighed 8.1 g in air and never exceeded 2% of fish weight (Winter 1983). All transmitters had a 5 second burst rate for 8 hours each day. This duty cycle provided an estimated transmitter life of 635 days. Each transmitter emitted a unique digital signal on one of ten frequencies between 149 and 151 MHZ.

Radio-Tracking Procedures

Movements of radio-tagged Dolly Varden were documented using a combination of aerial and ground-based surveys. Receivers used for tracking were the SRX 400 receiver/datalogger (Lotek Engineering Incorporated®). A portable global positioning system (GPS) was used to determine the latitude and longitude of each located fish.

Ground-based tracking was conducted from boats, highway vehicles, all-terrain vehicles (ATV), and on foot. Boat tracking surveys were conducted on the Kenai River and Kenai and Skilak lakes during ice-free periods. A four-element Yagi antenna attached to a 2.4-m mast was used to locate radio-tagged Dolly Varden. A hand-held H-antenna was used to locate fish during other ground surveys (highway vehicle, ATV, and foot) that occurred on several tributary streams including Quartz, Ptarmigan, and Cooper creeks and the Russian and Snow rivers. Aerial tracking generally was conducted once each month during ice-free periods and bimonthly during the winter. Surveys were conducted from a Cessna 185 fixed-wing aircraft equipped with two H-antennas, one mounted on each wing strut. Aerial surveys were conducted at approximately 300–400 m above ground along the Kenai River including Skilak and Kenai lakes and tributary watersheds. The number of tracking surveys conducted at each location during the study period is summarized in Appendix 3.

Data Analysis

Information collected with various tracking methods was integrated into one database that archived the dates and locations of each radio-tagged Dolly Varden. Locations were recorded as latitude and longitude coordinates and displayed on a geographic coverage of the Kenai River watershed using ArcView® software. The study period for each Dolly Varden was defined as the number of days between transmitter implantation and the date of final radio contact or last observed movement. A fish was considered dead or to have expelled the transmitter when the

transmitter was retrieved during a ground survey, or the transmitter signal did not move from a specific location during a period when radio-tagged fish were seasonally migrating between habitat types.

Distances between consecutive locations were used to describe movement of radio-tagged Dolly Varden. Distances in Skilak and Kenai lakes were calculated as the shortest distance (nearest 0.1 km) between two consecutive locations. River distances were calculated to the nearest 0.1 rkm. The home range of individual Dolly Varden was defined as the number of river kilometers between the furthest upstream and downstream location. Only fish that provided one year or more of tracking information were used for home range calculations.

Dolly Varden from Cooper Creek and South Fork of the Snow River with tracking histories that included two or more consecutive spawning periods were used to describe spawning periodicity. Radio-tagged fish in the Quartz Creek and Kenai River spawning aggregates were excluded from this analysis because it was difficult to distinguish between spawning and non-spawning fish in these waters.

Dolly Varden with tracking histories that included two or more consecutive overwintering periods were used to describe fidelity to overwintering habitats.

Results

Fish Survival and Transmitter Performance

A total of 219 Dolly Varden were radio-tagged during 1998 and 1999 (Appendix 2). Twenty-three (11%) of these fish disappeared, died, or expelled their transmitters during the first 30 days of tracking. Of the remaining fish, 170 (74%) survived the winter and provided movement data going into the following summer (June 1). About half (N=109) of the Dolly Varden provided movement information for one year or longer. The study period for 45 fish (21%) exceeded two years. Twelve (5%) fish with active transmitters were harvested by anglers during the study period.

Cooper Creek Spawning Aggregate

Radio transmitters were implanted into 20 spawning Dolly Varden in Cooper Creek near the Stetson Creek confluence on September 24, 1998 (Appendix 2). Movement of Dolly Varden from spawning locations in Cooper Creek to overwintering locations began in early October (Figure 2). By November, the majority of fish had selected overwintering locations in Skilak (41%) or Kenai (41%) lakes. Three fish were found in the outlet area below Skilak Lake (rkm 78-80) during November, but moved into Skilak Lake by January. Dolly Varden remained in Skilak or Kenai lakes through April, then began moving downstream toward summer feeding areas in May. Most of the fish selected the Killey River as a feeding location during June (69%) and July (81%). Dolly Varden began moving out of the Killey River during late July and were found primarily in the mainstem Kenai River between Bing's Landing and Skilak Lake during August (54%) and September (58%).

Two (16.7%) Dolly Varden with active transmitters returned to Cooper Creek during September 1999 to spawn for a second consecutive year (Table 1). Movement patterns after September 1999 were similar to those observed the previous year except that most fish (92%) selected Skilak Lake as an overwintering location. Eight Dolly Varden had active transmitters by September 2000, and three (37.5%) of these fish returned to spawn in Cooper Creek after

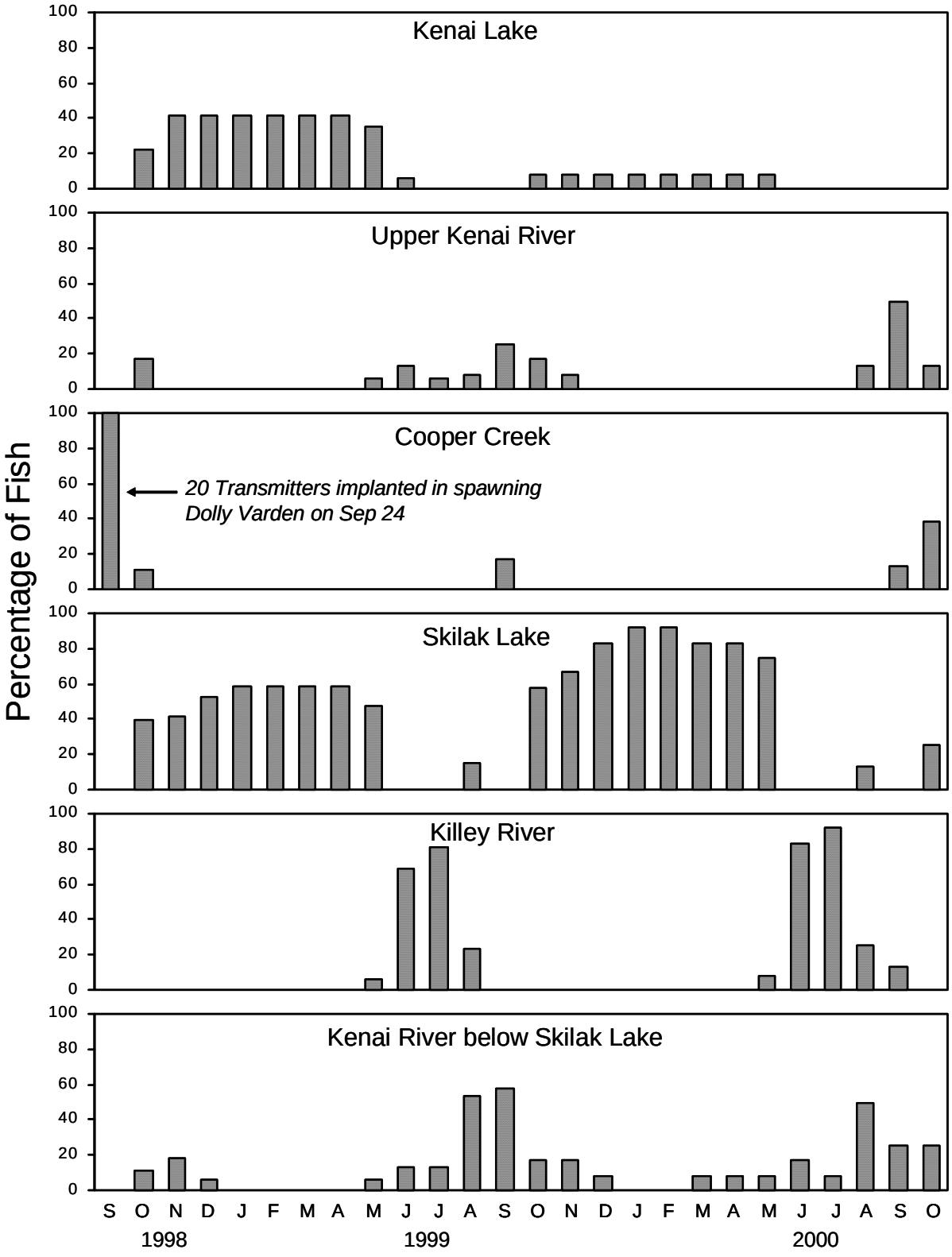

FIGURE 2.—Seasonal distribution of Dolly Varden that were radio-tagged in Cooper Creek during September 1998.

skipping the spawning season in 1999 (Table 1). The other five fish with active transmitters either skipped spawning in both 1999 and 2000 (*N*=3) or skipped a year after spawning in 1998 and 1999 (*N*=2).

Seasonal locations of Dolly Varden radio-tagged in Cooper Creek and other spawning locations are displayed in Appendices 4-8.

TABLE 1.—Frequency of spawning for Dolly Varden radio-tagged in Cooper Creek and the South Fork of the Snow River during 1998.

Spawning aggregate	Spawning year	Number of fish with active tags	Number of spawners	Percent of fish spawning
Consecutive Year Spawners				
Cooper Creek	1999	12	2	16.7
SF Snow River	1999	32	5	15.6
Total	1999	44	7	15.9
Skip Year Spawners				
Cooper Creek	2000	8[a]	3	37.5
SF Snow River	2000	12[b]	6	50.0
Total	2000	20	9	45.0

[a] Fish with active transmitters that did not spawn in 2000 either skipped spawning in both 1999 and 2000 (N=3) or skipped a year after spawning in 1998 and 1999 (N=2).

[b] Fish with active transmitters that did not spawn in 2000 either skipped spawning in both 1999 and 2000 (N=5) or skipped a year after spawning in 1998 and 1999 (N=1).

Quartz Creek Spawning Aggregate

Radio transmitters were implanted into 60 spawning Dolly Varden in the Quartz Creek watershed during September 1998 (Appendix 2). Twenty-nine fish were captured in the upper reaches of Quartz Creek above Devils Creek and the remainder were captured in Devils (*N*=11) and Summit (*N*=20) creeks (Figure 1). Movement of Dolly Varden from spawning areas to overwintering locations began in early October (Figure 3). By November, the majority of fish had selected overwintering locations in Kenai (67%) or Skilak (22%) lakes. Two fish selected Tern Lake in the Quartz Creek watershed as an overwintering location. Dolly Varden remained in these lakes through May, and then began moving toward summer feeding areas in June. During July, most Dolly Varden were found at feeding areas in the upper Kenai River (42%), Quartz Creek (25%), and the Killey River (22%). Later in the summer, the majority of fish were located in Quartz Creek or the Kenai River above and below Skilak Lake. Nearly half (46%) of the Dolly Varden selected feeding areas between Bing's Landing and Skilak Lake during September. About 20% of the fish with active transmitters were located in Quartz Creek watershed during September (*N*=5) and October (*N*=4), but it was not possible to determine if these fish were spawning or feeding.

Twenty-one Dolly Varden had active transmitters by October 1999. Unlike the previous winter where most of the Quartz Creek fish overwintered in Kenai Lake, the majority of fish (71%) selected Skilak Lake to spend the second winter. Feeding areas used during 2000 were similar to those observed during 1999 except that a larger percentage of fish used the Killey River during June (41%) and July (57%). About half of the fish with active transmitters were located near spawning and feeding areas in Quartz Creek during September and October 2000.

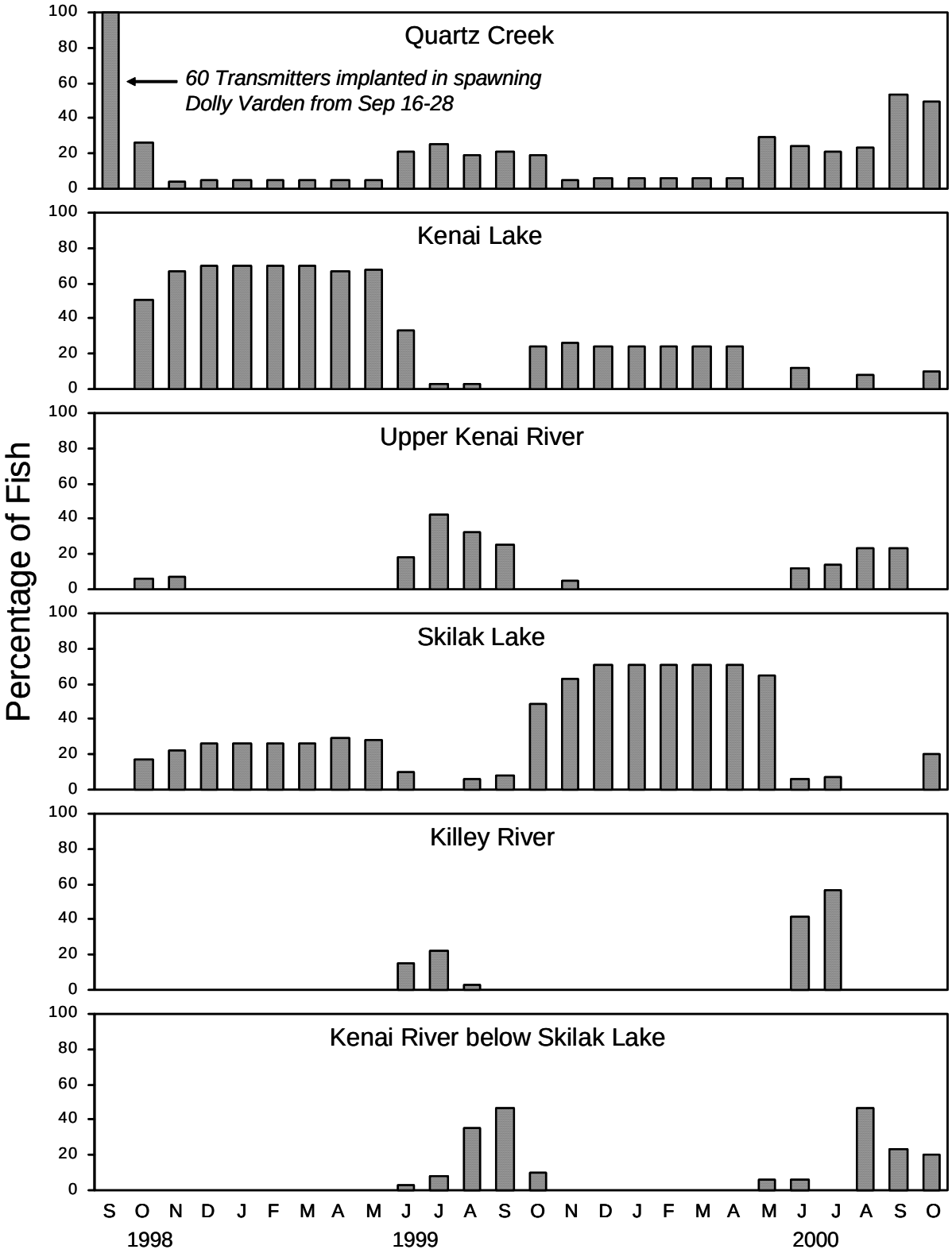

FIGURE 3.—Seasonal distribution of Dolly Varden that were radio-tagged in Quartz Creek during September 1998.

South Fork of the Snow River Spawning Aggregate

Radio transmitters were implanted into 60 spawning Dolly Varden in the South Fork of the Snow River during October 1998 (Appendix 2). All fish were captured at a spawning area approximately 15 km upstream from Kenai Lake. Spawning occurred through late October and by mid-November most fish (89%) had moved to overwintering locations in Kenai Lake (Figure 4). Only two fish selected Skilak Lake as an overwintering area. Dolly Varden remained in Kenai and Skilak lakes through May 1999. Four fish moved into the Kenai River during June, however, the majority of fish (88%) remained in Kenai Lake. During July, about half of the fish moved to feeding areas in Quartz Creek (2%) and the Kenai River above (33%) and below (13%) Skilak Lake. The mainstem Kenai River above and below Skilak Lake continued to be the most important feeding areas for these fish during August and September.

Five (15.6%) Dolly Varden with active transmitters returned to the South Fork of the Snow River during October 1999 to spawn for a second consecutive year (Table 1). Movement patterns after October 1999 were similar to those observed the previous year except that a larger number of fish (27%) selected Skilak Lake as an overwintering location. Twelve Dolly Varden had active transmitters by October 2000, and six (50%) of these fish returned to spawn in the South Fork of the Snow River after skipping the spawning season in 1999 (Table 1). The other six fish with active transmitters either skipped spawning in both 1999 and 2000 (N=5) or skipped a year after spawning in 1998 and 1999 (N=1).

Upper Kenai River Spawning Aggregate

Radio transmitters were implanted into 79 spawning Dolly Varden in the upper Kenai River during October 1999 (Appendix 2). All fish were captured and released between the outlet at Kenai Lake and Jim's Landing (Figure 1). Most Dolly Varden moved from spawning locations in the upper Kenai River to overwintering locations during November (Figure 5). By December, all fish had selected overwintering locations in Skilak (83%) or Kenai (17%) lakes. Dolly Varden remained in these lakes through April, and then began moving toward summer feeding areas in May. The majority of fish were found at feeding areas in the Kenai River downstream of Skilak Lake during June (62%), July (68%), August (75%), and September (70%). Other feeding locations selected during the summer included the Killey River and upper Kenai River. Over half (54%) of the fish were located in the upper Kenai River during October 2000, while others had moved to overwintering locations in Skilak (32%) or Kenai (10%) lakes. Movement patterns observed from November 2000 through October 2001 were nearly identical to those observed the previous year.

Home Range

Home ranges of radio-tagged Dolly Varden ranged from 18 to 165 km (Figure 6). Most Dolly Varden (83%) had home ranges between 51 and 150 km. Three Dolly Varden radio-tagged in the South Fork of the Snow River had a home range greater than 150 km. Two fish from the Quartz Creek spawning aggregate had a home range less than 25 km. One of these fish was tracked for over two years and remained within the Quartz Creek watershed for the entire period.

Upper Kenai River Dolly Varden generally had home ranges which extended lower in the watershed than tributary spawning aggregates. The majority of upper Kenai River fish (62.8%) spent some time during the summer and fall months below Bing's Landing. Conversely, smaller numbers of Dolly Varden from Cooper (8.3%) and Quartz (9.1%) creeks and the South Fork of the Snow River (18.8%) utilized this section of river.

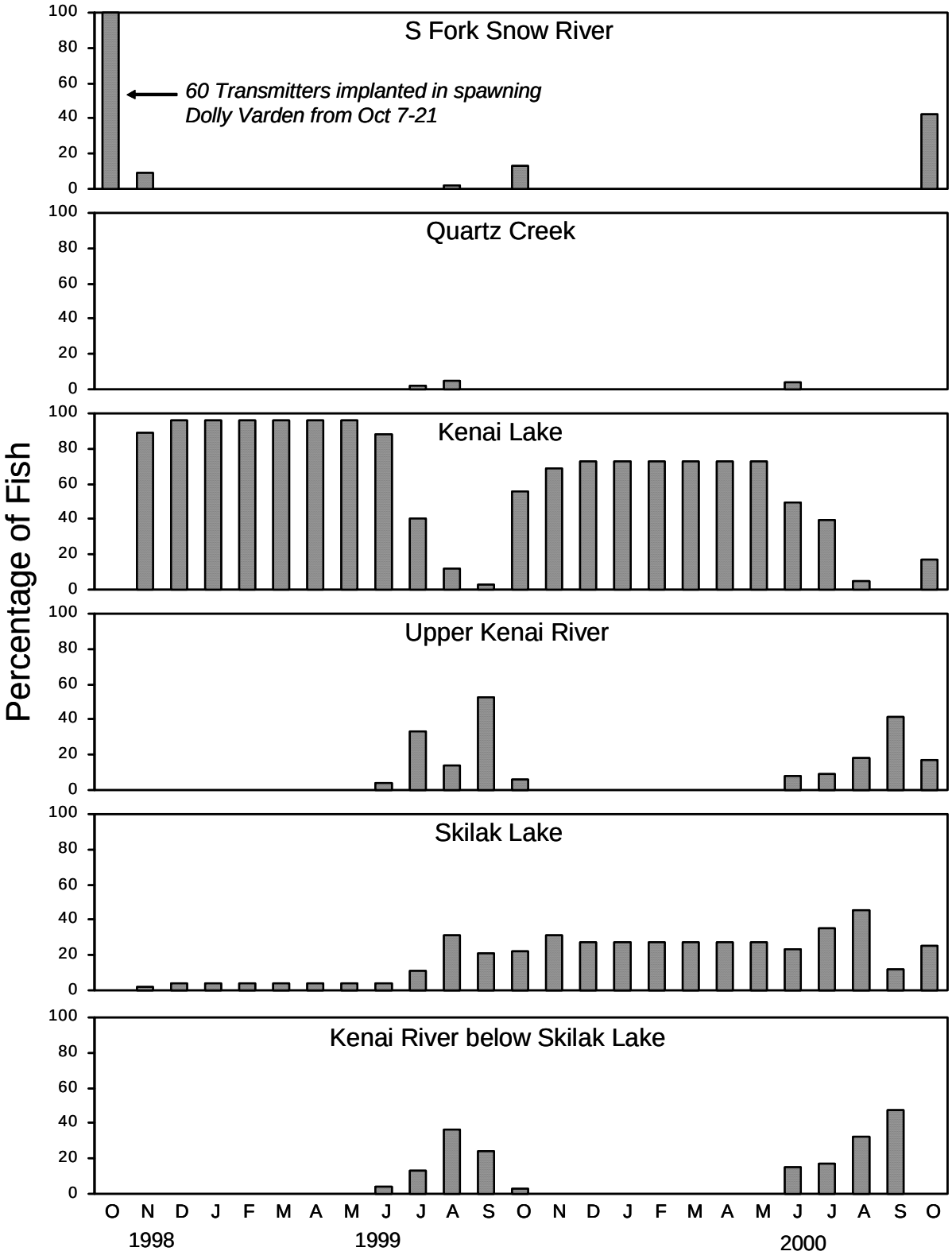

FIGURE 4.—Seasonal distribution of Dolly Varden that were radio-tagged in South Fork of the Snow River during October 1998.

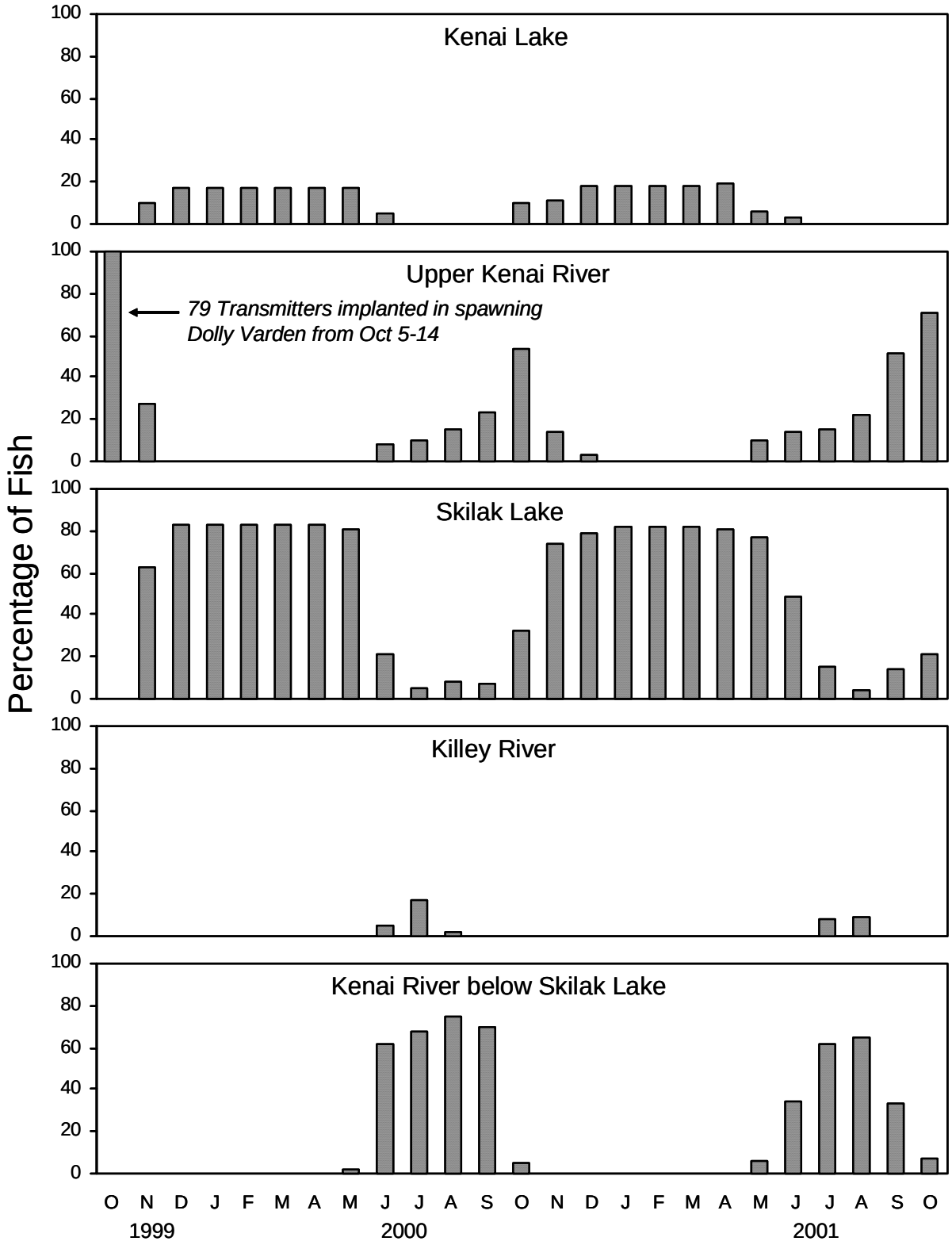

FIGURE 5.—Seasonal distribution of Dolly Varden that were radio-tagged in the upper Kenai River during October 1999.

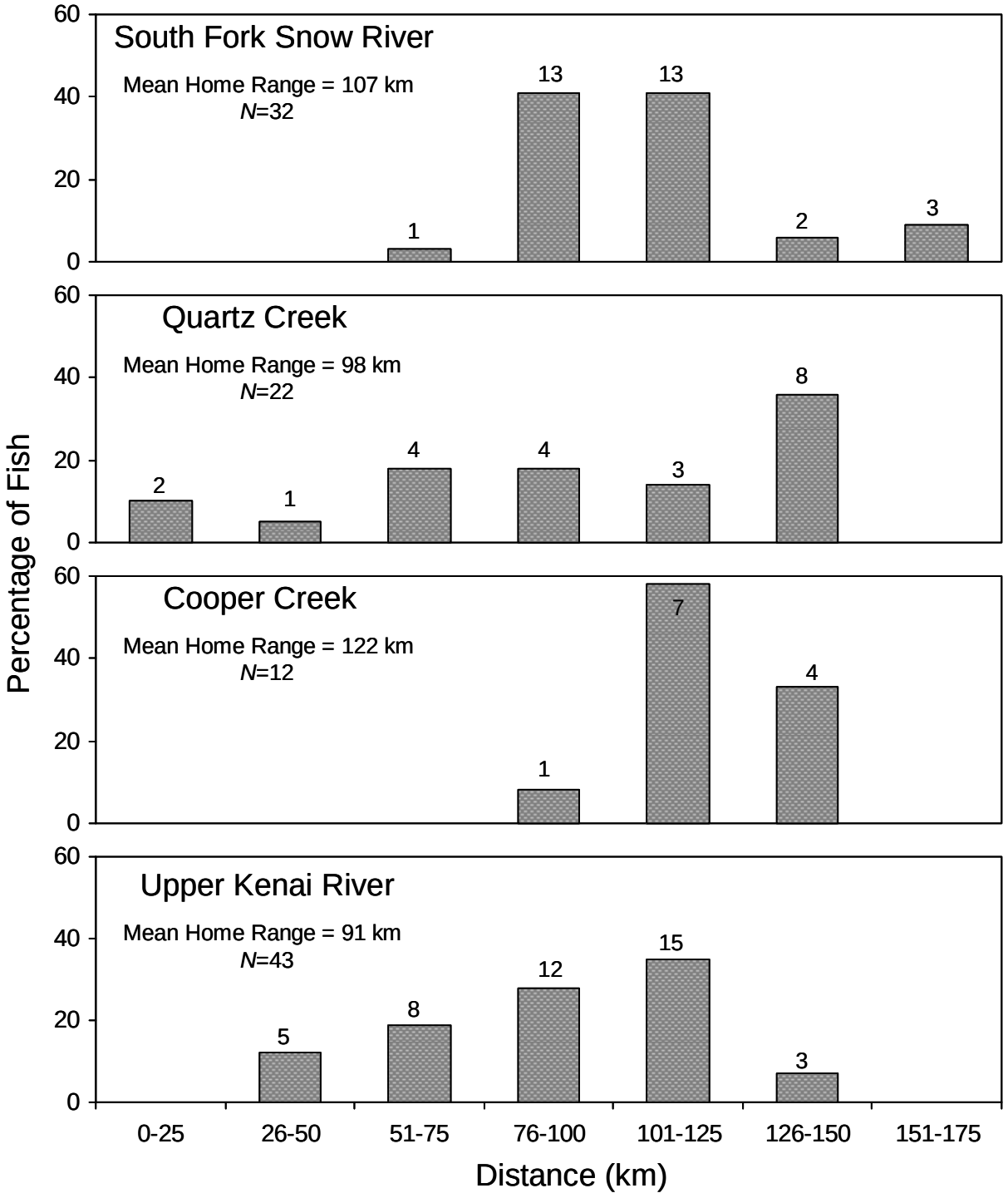

FIGURE 6.— Home range of radio-tagged Dolly Varden from each spawning aggregate expressed as the distance between the farthest upstream and downstream locations of individual fish in the Kenai River watershed. Only fish that were tracked for one year or longer are included. Sample size is indicated above each bar.

Fidelity to Overwintering Habitats

Dolly Varden from each of the spawning aggregates displayed a similar level of fidelity to lakes they selected for overwintering (Table 2). The number of Dolly Varden returning to the same overwintering lake ranged from 67% for Cooper Creek fish to 80% for upper Kenai River fish. Overall, about 76% of the Dolly Varden selected the same lake each year for overwintering.

TABLE 2.—Fidelity to overwintering lakes for Dolly Varden radio-tagged in Cooper and Quartz creeks, South Fork of the Snow River, and the upper Kenai River during 1998 and 1999.

Spawning aggregate	Number of observations	Number of fish returning to same overwintering lake	Number of fish selecting a different overwintering lake
Cooper Creek	12	8 (67 %)	4 (33 %)
Quartz Creek	17	13 (76 %)	4 (24 %)
SF Snow River	28	21 (75 %)	7 (25 %)
Upper Kenai River	35	28 (80 %)	7 (20 %)
Total	92	70 (76 %)	22 (24 %)

Discussion

When interpreting the results of this radiotelemetry study, we assumed that the behavior of radio-tagged Dolly Varden was similar to that of untagged Dolly Varden. Anglers that caught or harvested Dolly Varden with transmitters reported that these fish appeared in good condition. In most cases, the incision was completely healed and little or no abrasion resulted from the external antenna. Dolly Varden radio-tagged during this study were all adult spawners ranging from 375-611 mm fork length, therefore, results can only be applied to Dolly Varden in this size range.

Dolly Varden radio-tagged during this study were captured at spawning areas in Cooper and Quartz creeks, South Fork of the Snow River, and the upper Kenai River. Dolly Varden arrived at spawning locations in Cooper and Quartz creeks by mid to late September, but were not present in good numbers in the South Fork of the Snow River until mid-October. Glacial turbidity precluded observation of spawning Dolly Varden in the upper Kenai River, however fish captured during the first two weeks of October were in spawning condition. After spawning, all radio-tagged Dolly Varden migrated to a lake for overwintering. Movement to overwintering lakes occurred primarily during October and November. Kenai and Skilak lakes were selected as overwintering areas by all Dolly Varden except for two Quartz Creek fish which overwintered in Tern Lake. Migration to a lake for overwintering is characteristic behavior for the southern form of Dolly Varden which occur in lacustrine watersheds (Armstrong and Morrow 1980). The habit of overwintering in lakes may be advantageous because energy costs associated with activity would typically be less in habitats with little or no flow (Adams and Breck 1990). Lakes also provide the best refuge from severe conditions that can occur during winter months in northern systems (Northcote 1997).

Many Dolly Varden returned to the same lake for overwintering each year, however nearly a quarter of the fish used more than one lake for overwintering. Fidelity to overwintering lakes was lowest for Cooper Creek fish (33%) and highest for upper Kenai River fish (20%). The

choice of an overwintering lake appears to be influenced by the proximity of the lake to spawning and feeding areas. Large numbers of fish from the tributary spawning aggregates overwintered in Kenai Lake immediately after leaving the spawning grounds in 1998. Most of these fish were not repeat spawners in 1999 and some were found at feeding areas below Skilak Lake in late summer and early fall. The proximity of Skilak Lake to these feeding areas likely caused some fish to overwinter in Skilak Lake during the second winter.

Movement from overwintering lakes to summer feeding areas began in May, however, patterns of movement differed among the spawning aggregates. Most of the Cooper Creek Dolly Varden and some fish from the Quartz Creek and Kenai River spawning aggregates were located in the Killey River during June and July (Appendix 6). These Dolly Varden were likely attracted to the Killey River during the early summer because of abundant food supplies. Large numbers of chinook and coho salmon smolt emigrate from the Killey River during May and June (King and Breakfield 2002). The Killey River also provides spawning habitat for the majority of early-run Chinook salmon returning to the Kenai River watershed (Burger et al 1983). Early-run Chinook salmon enter the Killey River during late June and early July and spawn from mid to late July. Radio-tagged Dolly Varden were located throughout the Killey River during the early summer but tended to concentrate near the Benjamin Creek confluence in July. Lower Benjamin Creek is considered the most important spawning area for Chinook salmon in the Killey River watershed.

The migratory behavior of fish from the South Fork of the Snow River during early summer was quite different than that observed in other spawning aggregates. Rather than migrate to feeding areas in riverine habitats, most Snow River fish remained in Kenai Lake through June. This early summer behavior is more characteristic of the stream-lake resident form of Dolly Varden described by Armstrong and Morrow (1980). Although this form of Dolly Varden has received little study, these fish typically utilize lake habitats for feeding during the summer months. Food eaten by lake dwelling fish varies with habitat and availability but can include invertebrates, insects and fish. The food habits of Dolly Varden residing in Kenai Lake have not been studied, but their diet during early summer may include juvenile sockeye salmon which are abundant in the lake.

Most radio-tagged Dolly Varden were found in close proximity to spawning salmon during August and September. Spawn from thousands of salmon provide an important food resource to Dolly Varden during this time period. Although spawning salmon are found throughout the Kenai River and tributary watersheds, most Dolly Varden confined their movements to the Kenai River above the Moose River confluence. Exceptions to this distribution pattern were some Quartz Creek fish which favored Quartz Creek, and several fish from the upper Kenai River spawning aggregate that utilized feeding areas below the Moose River between June and September (Appendices 6 and 7). We are uncertain why lower reaches of the Kenai River attract so many of the upper Kenai River Dolly Varden during the summer months, but by October these fish return upstream to Skilak Lake or upper Kenai River locations.

Several radio-tagged Dolly Varden provided a year or more of location data which allowed us to examine frequency of spawning. We found that about 16% of the Dolly Varden in Cooper Creek and the South Fork of the Snow River spawned during consecutive years and about 45% of the fish spawned after skipping one year. Eight Dolly Varden did not spawn during 1999 or 2000 indicating that some fish from these spawning aggregates will skip at least two years between spawning. Consecutive and skip-year spawning has been documented for Dolly Varden stocks in southeast Alaska (Blackett 1968, Armstrong 1974), but this study may represent the only

documented occurrence where Dolly Varden have skipped more than one year between spawning.

Dolly Varden which occur in the upper Kenai River watershed should be considered southern form stocks (Armstrong and Morrow 1980). The southern form occurs as anadromous and nonanadromous stocks from the Aleutian Islands across the northwest coast of North America south to Puget Sound. Dolly Varden in the Kenai River clearly have an opportunity to migrate to sea, however, radio-tagged fish in this study confined their movements to the Kenai River watershed. This "potamodromous" strategy (Gresswell 1997) works well for Dolly Varden stocks in the Kenai River because critical habitats are readily accessible, food supplies are abundant, and there are few predators compared to a saltwater environment.

Management Considerations

Knowledge of the migrations and specific habitat requirements (spawning, feeding, and overwintering areas) of Dolly Varden in the Kenai River watershed is essential for formulating and improving management strategies. Findings from this study indicate that Dolly Varden from spawning aggregates in the upper Kenai River watershed have complex movement patterns. They occupy several river and stream habitats in the drainage during the summer and fall months, but appear to overwinter almost exclusively in Kenai and Skilak lakes. Dolly Varden from all spawning aggregates are exposed to some extent to sport fisheries that occur at various locations throughout the Kenai River watershed. A separate report (King and Palmer *In Preparation*) describes the exposure of each spawning aggregate to sport fisheries in the Kenai River watershed and evaluates the adequacy of the existing strategies for managing these stocks.

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References

Adams, S.M. and J.E. Breck. 1990. Bioenergetics. Pages 389-415 *in* C.B. Schreck and P.B. Moyle, editors. Methods for Fish Biology. American Fisheries Society, Bethesda, Maryland.

Armstrong, R.H. 1974. Migration of anadromous Dolly Varden (*Salvelinus malma*) in southeastern Alaska. Journal of the Fisheries Research Board of Canada 31:435-444.

Armstrong, R.H. and J.E. Morrow. 1980. The Dolly Varden charr. Pages 99-140 *in* E.K. Balon, editor. Charrs: salmonids fishes of the genus *Salvelinus*. Dr. W. Junk, The Hague, The Netherlands.

Blackett, R.F. 1968. Spawning behavior, fecundity and early life history of anadromous Dolly Varden *Salvelinus malma* (Walbaum) in southeastern Alaska. Alaska Department of Fish and Game, Research Report Number 6, Juneau, Alaska.

Bigelow, B.B., R.D. Lamke, P.J. Still, J.L. Van Maanen, and J.E. Vaill. 1985. Water resources data, Alaska, water year 1984. U.S. Geological Survey, Water Data Report AK-84-1, Anchorage.

Burger, C.V., D.B. Wangaard, R.L. Wilmot, and A.N. Palmisano. 1983. Salmon investigations in the Kenai River, Alaska 1979-1981. U.S. Fish & Wildlife Service, National Fishery Research Center-Seattle, Alaska Field Station, Anchorage.

Gamblin, M., L.E. Marsh, P. Berkhahn, and S. Sonnichsen. 2004. Area management report for the recreational fisheries of the Northern Kenai Peninsula, 2000–2001. Alaska Department of Fish and Game, Fishery Management Report Number 04-04, Anchorage.

Gresswell, R.E. 1997. Introduction to Ecology and Management of Potamodromous Salmonids. North American Journal of Fisheries Management 17:1027-1028.

Howe, A.L., G. Fidler, and M.J. Mills. 1995. Harvest, catch, and participation in Alaska sport fisheries during 1994. Alaska Department of Fish and Game, Fishery Data Series Number 95-24, Anchorage.

Howe, A.L., G. Fidler, A.E. Bingham, and M.J. Mills. 1996. Harvest, catch, and participation in Alaska sport fisheries during 1995. Alaska Department of Fish and Game, Fishery Data Series Number 96-32, Anchorage.

Howe, A.L., R.J. Walker, C. Olnes, K. Sundet, and A.E. Bingham. 2001a. Revised Edition: Harvest, catch, and participation in Alaska sport fisheries during 1996. Alaska Department of Fish and Game, Fishery Data Series Number 97-29 (revised), Anchorage.

Howe, A.L., R.J. Walker, C. Olnes, K. Sundet, and A.E. Bingham. 2001b. Revised Edition: Harvest, catch, and participation in Alaska sport fisheries during 1997. Alaska Department of Fish and Game, Fishery Data Series Number 98-25 (revised), Anchorage.

Howe, A.L., R.J. Walker, C. Olnes, K. Sundet, and A.E. Bingham. 2001c. Revised Edition: Harvest, catch, and participation in Alaska sport fisheries during 1998. Alaska Department of Fish and Game, Fishery Data Series Number 99-41 (revised), Anchorage.

Howe, A.L., R.J. Walker, C. Olnes, K. Sundet, and A.E. Bingham. 2001d. Revised Edition: Harvest, catch, and participation in Alaska sport fisheries during 1999. Alaska Department of Fish and Game, Fishery Data Series Number 01-8, Anchorage.

Jennings, G. B., K. Sundet, A. E. Bingham, and D. Sigurdsson. 2004. Participation, catch, and harvest in Alaska sport fisheries during 2001. Alaska Department of Fish and Game, Fishery Data Series Number 04-11, Anchorage.

King, B.E. and J.A. Breakfield. 2002. Coded wire tagging studies in the Kenai River and Deep Creek, Alaska, 1998. Alaska Department of Fish and Game, Fishery Data Series Number 02-03, Anchorage.

King, B.E. and D.E. Palmer. *In Preparation*. Use of radio telemetry data to assess the adequacy of fisheries management strategies for several Kenai River Dolly Varden spawning aggregates. Alaska Department of Fish and Game, Fishery Data Series Number xx-xx, Anchorage.

Mills, M.J. 1991. Harvest, catch, and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game, Fishery Data Series Number 91-58, Anchorage.

Mills, M.J. 1992. Harvest, catch, and participation in Alaska sport fisheries during 1991. Alaska Department of Fish and Game, Fishery Data Series Number 92-40, Anchorage.

Mills, M.J. 1993. Harvest, catch, and participation in Alaska sport fisheries during 1992. Alaska Department of Fish and Game, Fishery Data Series Number 93-42, Anchorage.

Mills, M.J. 1994. Harvest, catch, and participation in Alaska sport fisheries during 1993. Alaska Department of Fish and Game, Fishery Data Series Number 94-28, Anchorage.

Northcote, T.G. 1997. Potamodromy in salmonidae─living and moving in the fast lane. North American Journal of Fisheries Management 17:1029-1045.

Summerfelt, R.C. and L.S. Smith. 1990. Anesthesia, surgery, and related techniques. Pages 213–272 *in* C.B. Schreck and P.B. Moyle, editors. Methods for Fish Biology. American Fisheries Society, Bethesda, Maryland.

Walker R. J., C. Olnes, K. Sundet, A. L. Howe, and A. E. Bingham. 2003. Participation, catch, and harvest in Alaska sport fisheries during 2000. Alaska Department of Fish and Game, Fishery Data Series No. 03-05, Anchorage.

Winter, J.D. 1983. Underwater biotelemetry. Pages 371–395 in L.A. Nielsen and D.L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.Agresti, A. 1990. Categorical Data Analysis. John Wiley & Sons. New York.

APPENDIX 1.—Harvest and catch of Dolly Varden by section of the Kenai River as determined by the Department's Statewide Harvest Survey, 1984-2001.

	Harvest									Catch								
	Cook Inlet to Soldotna Bridge		Soldotna Bridge to Moose River		Moose River to Skilak Outlet		Skilak Inlet to Kenai Lake		Total	Cook Inlet to Soldotna Bridge		Soldotna Bridge to Moose River		Moose River to Skilak Outlet		Skilak Inlet to Kenai Lake		Total
Year	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number
1984	7,506	23.9	1,966	6.3	11,211	35.7	10,724	34.1	31,407									
1985	7,560	28.8	3,277	12.5	8,930	34.0	6,468	24.7	26,235									
1986	1,249	21.6	771	13.4	1,928	33.4	1,827	31.6	5,775									
1987	2,429	31.8	1,671	21.9	2,139	28.0	1,391	18.2	7,630									
1988	3,531	32.2	1,266	11.5	3,527	32.1	2,653	24.2	10,977									
1989	3,414	33.9	1,371	13.6	3,649	36.3	1,630	16.2	10,064									
1990	2,738	22.9	2,424	20.2	2,741	22.9	4,079	34.0	11,982	7,795	22.5	5,094	14.7	7,537	21.8	14,151	40.9	34,577
1991	4,211	29.0	3,285	22.6	4,268	29.4	2,740	18.9	14,504	10,665	15.5	8,116	11.8	19,363	28.2	30,601	44.5	68,745
1992	3,777	26.1	2,516	17.4	4,900	33.9	3,269	22.6	14,462	11,822	15.0	5,899	7.5	26,348	33.4	34,754	44.1	78,823
1993	4,599	36.2	1,539	12.1	3,503	27.6	3,057	24.1	12,698	13,019	17.1	6,079	8.0	20,778	27.2	36,451	47.8	76,327
1994	3,276	38.6	1,107	13.0	2,051	24.2	2,052	24.2	8,486	8,752	14.2	5,185	8.4	14,584	23.6	33,168	53.8	61,689
1995	4,069	42.7	1,732	18.2	2,113	22.2	1,609	16.9	9,523	10,146	18.4	5,399	9.8	12,447	22.6	27,103	49.2	55,095
1996	2,411	32.2	1,797	24.0	1,995	26.7	1,281	17.1	7,484	9,787	17.3	5,973	10.6	14,506	25.7	26,245	46.4	56,511
1997	2,518	36.2	1,042	15.0	2,824	40.6	573	8.2	6,957	9,955	11.0	5,268	5.8	22,266	24.5	53,317	58.7	90,806
1998	1,977	32.5	1,787	29.4	1,847	30.4	468	7.7	6,079	7,560	12.4	5,961	9.8	11,732	19.3	35,659	58.5	60,912
1999	3,867	51.1	1,086	14.3	1,932	25.5	683	9.0	7,568	14,752	20.2	6,316	8.7	20,053	27.5	31,826	43.6	72,947
2000	3,916	52.7	1,759	23.7	1,403	18.9	349	4.7	7,427	18,261	17.4	9,122	8.7	21,291	20.3	56,375	53.7	105,049
2001	3,763	57.6	1,613	24.7	789	12.1	363	5.6	6,528	16,304	15.1	8,367	7.8	28,312	26.3	54,802	50.8	107,785
Mean	3,710	35.0	1,780	17.4	3,430	28.5	2,510	19.0	11,430	11,570	16.3	6,400	9.3	18,270	25.0	36,200	49.3	72,440

From : Mills 1985-1994; Howe et al. 1995, 1996, 2001 a-d; Walker et al. 2003; Jennings et al. 2004.

APPENDIX 2.—Tracking history summaries of Dolly Varden radio-tagged in the Kenai River watershed during 1998 and 1999.

Transmitter number	Fork length (mm)	Sex	Implant location[a] (river km)	Study dates[b]	Study period (days)	Number of observations during study period[c]
Cooper Creek Radio Transmitter Implants						
0836	483	F	5.1	24-Sep-98 – 13-Dec-00	812	21
2138	528	M	5.1	24-Sep-98 – 20-Sep-99	362[e]	14
2238	456	F	5.1	24-Sep-98 – 16-Jan-01	846	35
2538	493	F	5.1	24-Sep-98 – 23-Jan-01	853	28
2638	490	F	5.1	24-Sep-98 – 31-Jul-00	677[e]	31
2738	525	F	5.1	24-Sep-98 – 14-Nov-00	783	29
8148	537	F	5.1	24-Sep-98 – 15-Jun-00	631[e]	32
8220	514	M	5.1	24-Sep-98 – 14-Aug-99	325[f]	18
8348	493	F	5.1	24-Sep-98 – 24-Jul-00	670[e]	33
8448	491	F	5.1	24-Sep-98 – 18-Oct-00	756	33
8848	484	M	5.1	24-Sep-98	0[d]	0
10130	490	M	5.1	24-Sep-98	0[e]	0
10320	565	M	5.1	24-Sep-98 – 9-Jun-99	259[e]	11
10930	472	F	5.1	24-Sep-98 – 14-Aug-00	691	28
11030	549	M	5.1	24-Sep-98 – 2-Aug-99	313[f]	4
11130	505	F	5.1	24-Sep-98 – 31-Oct-00	769	33
11330	502	M	5.1	24-Sep-98 – 19-Apr-01	939	32
13332	545	M	5.1	24-Sep-98 – 9-Aug-99	320[e]	5
14234	459	F	5.1	24-Sep-98 – 6-Nov-00	775	24
14420	546	F	5.1	24-Sep-98 – 13-Nov-98	51[e]	1
Quartz Creek RadioTransmitter Implants						
0320	575	M	12.1	28-Sep-98	0[e]	0
0440	482	M	12.1	28-Sep-98 – 17-Oct-00	751	48
0540	457	F	12.1	28-Sep-98 – 17-Aug-99	324[e]	16
0740	429	F	20.9	16-Sep-98 – 2-Dec-99	443[e]	28
0840	480	F	12.1	28-Sep-98 – 11-Sep-00	715[e]	26
1136	442	M	12.1	28-Sep-98 – 6-Jul-00	648[e]	27
1240	538	M	20.9	16-Sep-98 – 23-Aug-99	342[e]	28
1720	378	M	20.4	22-Sep-98 – 4-Nov-98	44[e]	3
1736	414	F	20.9	16-Sep-98 – 19-Aug-99	338[d]	18
1840	466	F	20.9	16-Sep-98 – 5-Nov-98	51[d]	3
1936	590	M	12.1	28-Sep-98 – 17-Jun-99	263[e]	10
2142	510	F	12.1	28-Sep-98 – 29-Jul-99	305[d]	14
2242	431	M	12.1	28-Sep-98 – 17-Nov-98	51[e]	7
2338	526	M	20.4	22-Sep-98 – 1-Oct-98	10[d]	2
2342	492	F	12.1	28-Sep-98 – 23-Apr-99	208[e]	10

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APPENDIX 2.—(Page 2 of 6).

Transmitter number	Fork length (mm)	Sex	Implant location[a] (river km)	Study dates[b]	Study period (days)	Number of observations during study period[c]
2438	420	F	20.9	16-Sep-98 – 27-Jul-99	315[e]	7
2442	463	F	12.1	28-Sep-98 – 14-Aug-00	687	37
2820	395	M	20.9	22-Sep-98 – 14-Oct-98	23[e]	2
3038	527	F	20.9	16-Sep-98 – 20-Oct-98	35[d]	5
3538	462	F	13.8	25-Sep-98 – 7-Sep-99	348[d]	21
3542	420	M	20.9	16-Sep-98 – 10-Oct-00	756	33
3842	431	F	20.9	16-Sep-98 – 25-Sep-98	10[e]	1
3920	512	M	20.9	22-Sep-98 – 14-Oct-98	23[e]	4
3921	513	M	20.9	16-Sep-98 – 8-Oct-98	23[e]	1
4042	471	F	20.9	22-Sep-98 – 16-Aug-99	329[e]	8
4244	574	F	12.1	28-Sep-98 – 27-May-99	242[d]	9
4344	510	F	12.1	28-Sep-98 – 6-Oct-00	740	13
4444	404	F	12.1	28-Sep-98 – 25-Oct-00	759	37
4544	444	M	12.1	28-Sep-98 – 17-Oct-00	751	32
4644	480	F	12.1	28-Sep-98 – 14-Sep-99	352[d]	22
4744	438	M	12.1	28-Sep-98 – 4-Sep-99	352[e]	16
4820	405	F	12.1	28-Sep-98 – 24-Nov-98	58[e]	3
4920	505	M	12.1	28-Sep-98 – 30-Jun-99	276[e]	12
6146	496	M	12.1	28-Sep-98 – 28-Oct-99	31[e]	4
6246	560	F	12.1	28-Sep-98 – 25-Oct-99	393[e]	30
6346	542	F	12.1	28-Sep-98 – 22-Sep-99	360[e]	17
6446	486	F	12.1	28-Sep-98 – 15-Sep-99	353[d]	22
6546	425	F	12.1	28-Sep-98	0[d]	0
6646	455	F	12.1	28-Sep-98 – 22-Jan-01	848	38
6746	465	F	12.1	28-Sep-98 – 9-Nov-99	408[e]	29
6846	443	F	12.1	28-Sep-98 – 23-Apr-99	208[e]	8
8548	482	F	12.1	28-Sep-98 – 13-Jul-99	289[e]	8
8648	474	F	20.9	22-Sep-98 – 17-Aug-99	330[d]	13
9020	516	M	12.1	28-Sep-98 – 13-Oct-98	16[e]	4
9148	487	F	12.1	28-Sep-98 – 18-Sep-00	722	26
9248	517	F	13.8	25-Sep-98 – 26-Oct-98	32[d]	4
9348	481	F	12.1	28-Sep-98 – 27-Jun-00	639[e]	34
9448	450	F	12.1	28-Sep-98 – 16-Jan-01	842	48
10230	488	F	20.9	16-Sep-98 – 6-Nov-00	783	37
11530	415	F	13.8	25-Sep-98 – 23-Nov-99	425	17
11830	495	M	13.8	25-Sep-98 – 24-Aug-99	334[d]	21
11930	462	M	13.8	25-Sep-98 – 17-Oct-00	754	41
12020	550	M	13.8	25-Sep-98	0[e]	0

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Transmitter number	Fork length (mm)	Sex	Implant location[a] (river km)	Study dates[b]	Study period (days)	Number of observations during study period[c]
12232	465	M	20.9	16-Sep-98 – 28-Jun-00	652	24
13832	435	F	20.9	16-Sep-98 – 14-Oct-98	29[e]	4
14020	420	F	20.9	16-Sep-98 – 18-Jun-99	276[e]	9
14734	502	M	20.4	22-Sep-98 – 14-Nov-00	785	37
15534	475	F	20.9	16-Sep-98 – 6-Nov-00	783	37
15734	460	F	20.9	22-Sep-98 – 18-Oct-00	758	30
16034	518	M	20.9	16-Sep-98 – 12-Aug-99	331[e]	19
				Snow River RadioTransmitter Implants		
0136	550	F	15.1	21-Oct-98 – 31-Oct-00	742	38
0236	607	M	15.1	21-Oct-98 – 31-Aug-00	681[e]	41
0336	534	F	15.1	21-Oct-98 – 26-Jun-00	615	36
0436	500	F	15.1	21-Oct-98 – 24-Aug-99	308[d]	16
0536	533	M	15.1	21-Oct-98 – 8-Aug-00	658	31
0636	515	M	15.1	21-Oct-98 – 30-Oct-98	10[e]	1
0736	532	F	15.1	21-Oct-98 – 11-Oct-00	722	31
0920	457	M	15.1	21-Oct-98	0[e]	0
0940	555	M	15.1	21-Oct-98 – 28-Aug-00	678[e]	38
1040	475	M	15.1	21-Oct-98	0[d]	0
1140	520	M	15.1	21-Oct-98 – 18-Jul-99	279[e]	13
1340	519	F	15.1	21-Oct-98 – 2-Nov-00	744	42
1440	525	F	15.1	21-Oct-98 – 7-Nov-00	749	46
1540	530	M	15.1	21-Oct-98 – 2-Sep-99	317[d]	19
2542	595	M	15.1	21-Oct-98 – 5-Sep-00	686[e]	40
2642	555	F	15.1	21-Oct-98 – 26-Aug-99	310[d]	13
2742	588	M	15.1	21-Oct-98 – 28-Aug-00	678[e]	33
2842	542	F	15.1	21-Oct-98 – 28-Jul-99	281[e]	6
2938	537	M	15.1	21-Oct-98 – 10-Dec-99	416	26
2942	505	M	15.1	21-Oct-98 – 27-Apr-01	920	45
3042	551	M	15.1	21-Oct-98 – 23-Apr-99	185[e]	6
3138	538	M	15.1	21-Oct-98 – 2-Oct-99	347[d]	20
3238	530	M	15.1	7-Oct-98 – 9-Nov-98	34[e]	4
3338	555	F	15.1	21-Oct-98 – 26-Aug-99	310[d]	17
5044	535	M	15.1	21-Oct-98 – 9-Apr-01	902	38
5244	479	F	15.1	21-Oct-98 – 22-Dec-98	63[e]	3
5344	517	M	15.1	21-Oct-98 – 12-Jul-99	265[d]	7
5444	534	F	15.1	21-Oct-98 – 18-Jun-99	241[e]	9
5644	528	F	15.1	21-Oct-98 – 16-Jan-01	819	43
5744	455	F	15.1	21-Oct-98 – 11-Oct-00	722	40

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APPENDIX 2.—(Page 4 of 6).

Transmitter number	Fork length (mm)	Sex	Implant location[a] (river km)	Study dates[b]	Study period (days)	Number of observations during study period[c]
6946	520	M	15.1	21-Oct-98 – 13-Dec-00	785	45
7046	549	M	15.1	21-Oct-98 – 14-Sep-99	329[e]	19
7146	528	M	15.1	21-Oct-98 – 5-Nov-99	381	18
7246	512	M	15.1	21-Oct-98 – 9-Nov-99	385[e]	24
7320	500	F	15.1	21-Oct-98		0
7420	587	M	15.1	21-Oct-98 – 22-Jul-99	290[f]	15
9548	523	F	15.1	21-Oct-98 – 13-Dec-00	785	37
9720	520	F	15.1	21-Oct-98 – 4-Aug-99	288[f]	18
9848	504	F	15.1	21-Oct-98 – 13-Dec-00	785	44
9948	589	M	15.1	21-Oct-98 – 18-Oct-00	729[e]	42
10430	577	M	15.1	21-Oct-98 – 9-Nov-99	385[e]	19
10530	436	M	15.1	21-Oct-98 – 25-Aug-99	309[d]	16
10630	471	M	15.1	21-Oct-98 – 22-Dec-98	63[d]	5
10730	551	F	15.1	21-Oct-98 – 29-Nov-99	405[e]	21
10820	611	M	15.1	21-Oct-98 – 14-Aug-99	298[f]	19
12132	492	F	15.1	21-Oct-98 – 10-Oct-00	721	40
12332	609	M	15.1	21-Oct-98 – 22-Dec-98	63[d]	3
12432	473	F	15.1	7-Oct-98 – 6-Jun-00	609[e]	13
12532	538	M	15.1	21-Oct-98 – 6-Jul-00	625[e]	39
12632	447	F	15.1	21-Oct-98 – 6-Oct-00	717	34
12732	542	M	15.1	21-Oct-98 – 17-Oct-00	728[e]	43
12820	512	M	15.1	21-Oct-98	0[e]	0
12932	510	F	15.1	21-Oct-98 – 16-Nov-99	392[e]	22
14134	534	F	15.1	21-Oct-98 – 21-Sep-99	336[d]	19
14334	505	F	15.1	21-Oct-98 – 18-Sep-00	699	31
14534	460	F	15.1	21-Oct-98 – 10-Sep-99	325[d]	19
14634	508	F	15.1	21-Oct-98 – 14-Sep-99	329[d]	19
14834	559	F	15.1	21-Oct-98 – 31-Aug-00	681	35
14934	458	M	15.1	21-Oct-98 – 18-Sep-00	699	43
15034	520	F	15.1	21-Oct-98 – 24-Nov-98	35[d]	2
Mainstem Kenai River RadioTransmitter Implants						
0140	514	M	127.6	12-Oct-99 – 19-Sep-01	709	33
0240	530	F	127.6	14-Oct-99 – 19-Jul-00	280[f]	11
0340	445	F	115.8	5-Oct-99 – 26-Oct-01	753	17
0640	556	F	128.6	14-Oct-99 – 28-Aug-00	320[e]	18
0936	513	M	112.5	5-Oct-99 – 29-Nov-01	787	47
1036	596	M	124.2	12-Oct-99 – 23-Nov-99	43[d]	7
1236	565	F	118.4	5-Oct-99 – 5-Apr-01	549	30

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APPENDIX 2.—(Page 5 of 6).

Transmitter number	Fork length (mm)	Sex	Implant location[a] (river km)	Study dates[b]	Study period (days)	Number of observations during study period[c]
1336	538	F	118.4	8 Oct 99 – 26-Sep-00	355[e]	25
1436	601	M	130.2	14-Oct-99 – 19-Sep-01	707	39
1536	575	F	118.4	8 Oct 99 – 29-Nov-01	784	42
1636	559	F	128.6	14-Oct-99 – 31-Jul-00	292[d]	12
1640	524	F	118.4	8 Oct 99 – 5-Nov-01	760	32
1740	466	M	126.8	12-Oct-99 – 17-Oct-00	372	19
1836	565	F	130.2	14-Oct-99 – 21-Nov-01	770	45
1940	514	F	117.0	5 Oct 99 – 11-Oct-00	373[e]	19
2036	551	F	115.2	8 Oct 99 – 23-Oct-01	747	38
2040	543	F	115.2	6 Oct 99 – 24-Oct-01	750	48
2838	449	F	130.2	12-Oct-99 – 14-Aug-01	673	31
3142	498	F	127.6	14-Oct-99 – 9-Jul-01	635[e]	28
3242	475	F	123.2	12-Oct-99 – 28-Oct-99	17[e]	3
3342	530	F	118.4	8 Oct 99 – 9-Jul-00	276[f]	9
3438	472	F	126.8	12-Oct-99 – 31-Jul-00	294[d]	13
3442	484	F	118.4	8 Oct 99 – 17-Jul-01	649[f]	20
3638	475	F	115.8	5 Oct 99 – 31-Oct-00	393[e]	23
3642	529	F	130.2	12-Oct-99 – 16-Jan-01	463	27
3738	484	F	118.4	6 Oct 99 – 19-Jun-00	258[e]	2
3742	545	F	118.4	5 Oct 99 – 2-Oct-01	729	32
3838	466	M	127.6	14-Oct-99 – 28-Aug-00	328[d]	15
3938	480	M	126.8	12-Oct-99 – 14-Oct-99	3[e]	1
3942	535	F	115.8	5 Oct 99 – 11-Sep-01	708	33
4038	536	F	128.6	14-Oct-99 – 5-Oct-01	723	24
4144	464	F	130.2	14-Oct-99 – 6-Jul-01	632	13
4844	545	F	112.5	6 Oct 99 – 28-Aug-00	328[e]	15
4944	535	M	130.2	14-Oct-99 – 13-Dec-99	61[d]	6
5144	525	F	115.8	5 Oct 99 – 3-Sep-00	335[f]	22
5544	547	M	118.4	8 Oct 99 – 5-Sep-00	334[d]	5
5844	467	M	130.2	12-Oct-99 – 10-Dec-99	60[e]	3
5944	470	F	117.0	6 Oct 99 – 23-Oct-01	749[e]	32
6044	441	F	130.2	13-Oct-99 – 10-Aug-00	303[d]	11
7346	523	F	115.8	5 Oct 99 – 3-Nov-99	30[e]	3
7446	602	M	127.6	14-Oct-99 – 13-Dec-00	427	30
7546	556	M	130.2	12-Oct-99 – 10-Dec-99	60[e]	7
7646	565	F	118.4	5 Oct 99 – 2-Nov-99	29[e]	3
7746	570	M	118.4	6 Oct 99 – 6-Nov-01	763	29
7846	505	F	127.6	14-Oct-99 – 13-Nov-01	762	44
7946	467	M	127.6	12-Oct-99 – 5-Apr-01	542[e]	38

-continued-

APPENDIX 2.—(Page 6 of 6).

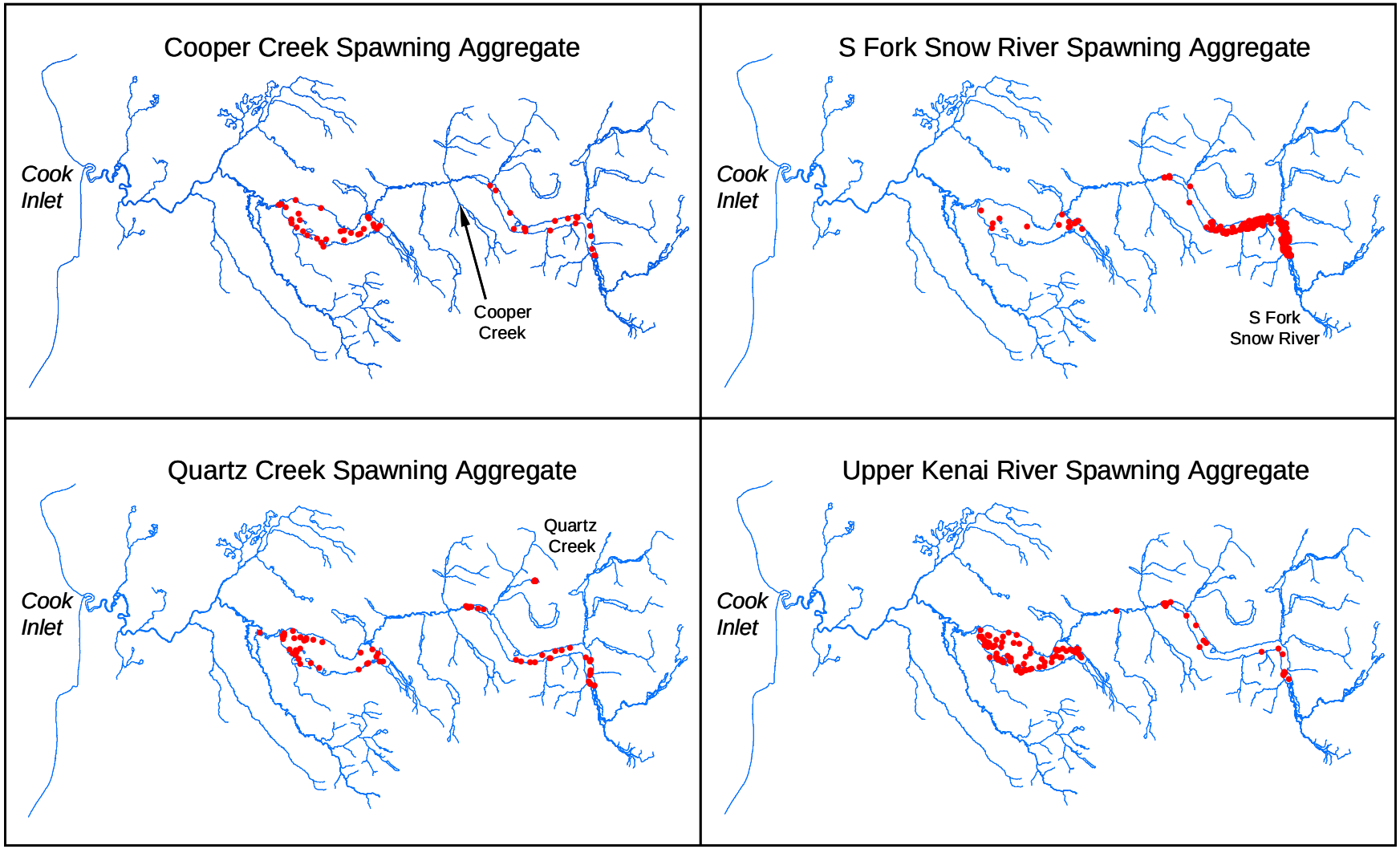
Transmitter number	Fork length (mm)	Sex	Implant location[a] (river km)	Study dates[b]	Study period (days)	Number of observations during study period[c]
8046	510	F	118.4	8 Oct 99 – 6-Nov-01	761	38
8248	375	M	128.6	13-Oct-99 – 7-Aug-00	300[d]	13
8748	565	M	127.6	14-Oct-99 – 15-Nov-99	33[e]	4
8948	504	F	117.0	6 Oct 99 – 30-May-01	603[e]	29
9048	470	M	130.2	13-Oct-99 – 25-Jul-01	652[f]	35
9648	505	F	127.6	14-Oct-99 – 14-Nov-00	398[e]	20
9748	402	F	118.4	8 Oct 99 – 3-May-00	209[e]	10
10048	518	F	115.8	5 Oct 99 – 21-Nov-01	779	43
10330	519	F	115.2	6 Oct 99 – 29-Nov-99	55[e]	5
10830	481	M	128.6	14-Oct-99 – 11-Sep-00	334[d]	15
11230	471	F	127.6	12-Oct-99 – 5-Sep-00	330[d]	18
11430	530	M	115.8	5 Oct 99 – 15-Jul-01	650[f]	40
11630	485	M	118.4	8 Oct 99 – 28-Aug-00	326[e]	21
11730	579	M	128.6	14-Oct-99 – 28-Oct-99	15[e]	2
12030	546	F	115.0	5 Oct 99 – 9-Nov-99	36[e]	5
12832	523	M	117.0	5 Oct 99 – 9-Oct-01	736[e]	32
13032	532	M	130.2	12-Oct-99 – 19-Oct-01	739	39
13132	496	M	118.4	5 Oct 99 – 10-Aug-00	311[e]	21
13232	522	M	127.6	14-Oct-99 – 13-Nov-01	762	36
13432	466	F	130.2	13-Oct-99 – 14-Nov-00	399[e]	27
13532	474	F	115.2	6 Oct 99 – 10-Oct-00	371	13
13632	549	F	117.0	8 Oct 99 – 15-May-01	586[e]	17
13732	490	M	128.6	14-Oct-99 – 18-Sep-01	706	40
13932	553	F	112.5	8 Oct 99 – 14-Oct-99	7[e]	1
14032	526	F	127.6	14-Oct-99 – 6-Nov-00	390	22
14434	485	F	112.5	5 Oct 99 – 7-Aug-00	308[d]	14
15134	560	M	128.6	12-Oct-99 – 25-Jul-00	288[f]	9
15234	405	M	117.0	6 Oct 99 – 23-Aug-01	688	24
15334	428	M	127.6	14-Oct-99 – 5-Jul-00	266[d]	15
15434	530	F	127.6	12-Oct-99 – 21-Nov-01	772	43
15634	475	F	117.0	5 Oct 99 – 14-Nov-00	407	30
15834	436	F	128.6	14-Oct-99 – 7-Aug-00	299[d]	16
15934	481	F	115.2	8 Oct 99 – 23-Nov-99	47[e]	5

[a] Distance from mouth of river or stream.
[b] From implantation of transmitter to final radio contact or last observed movement.
[c] Includes observations from ground and aerial tracking.
[d] Fish disappeared from the study area during first 365d of transmitter operation.
[e] Fish died or expelled transmitter.
[f] Fish harvested by angler.

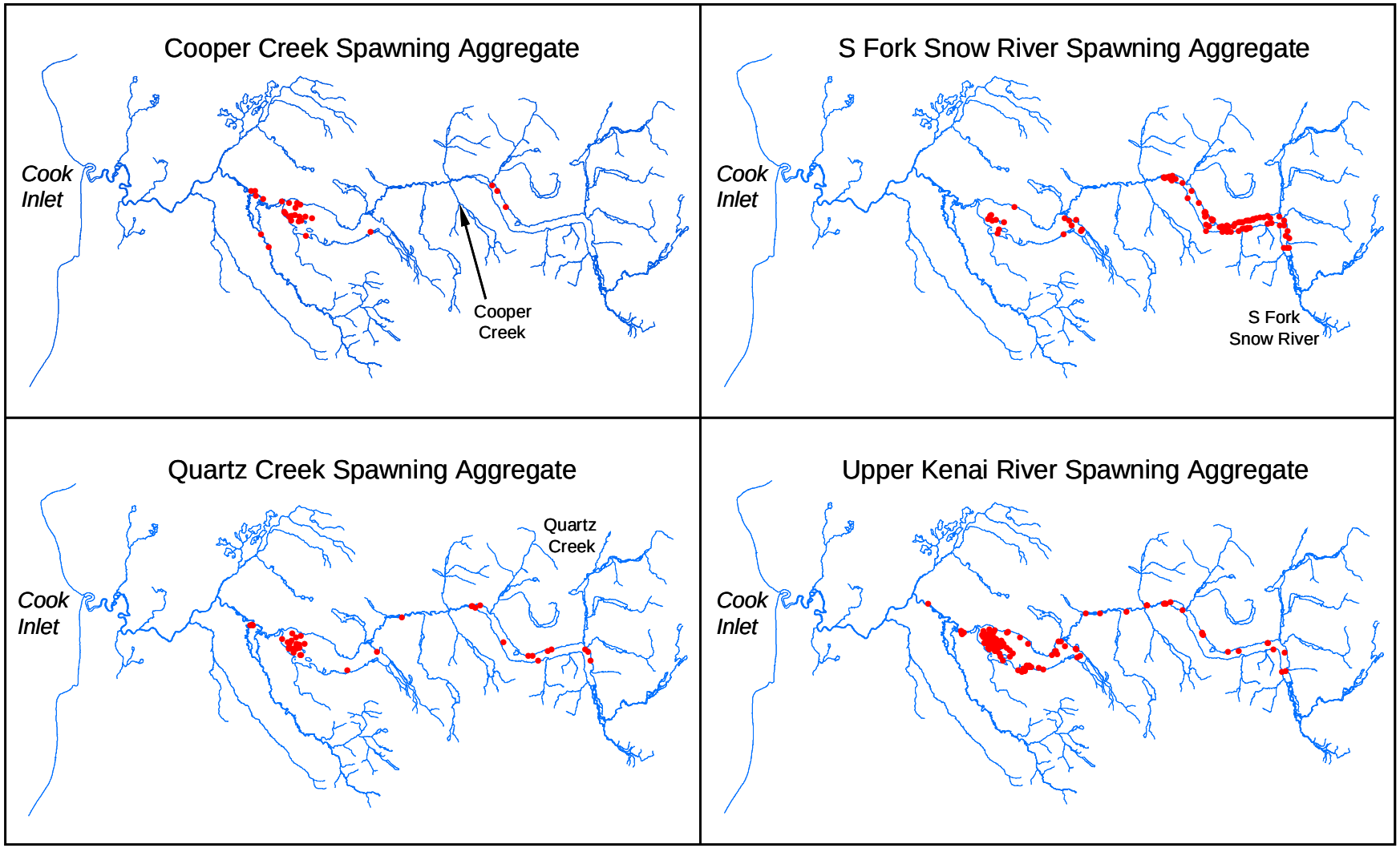
APPENDIX 3.—The number of telemetry tracking surveys conducted at various locations in the Kenai River watershed from October 1998 through December 2001.

Time Period	Aerial[a]	Kenai Lake	Skilak Lake	Upper Kenai River[b]	Middle Kenai River[c]	Lower Kenai River[d]	Tributary streams[e]
Oct - Dec 98	1	8	6	5	5	0	10
Jan - Mar 99	1	0	0	0	0	0	1
Apr - Jun 99	4	6	4	4	3	1	4
Jul - Sep 99	3	9	7	16	13	10	22
Oct - Dec 99	1	6	6	9	3	1	6
Jan - Mar 00	2	0	0	0	0	0	0
Apr - Jun 00	4	6	7	5	7	4	3
Jul - Sep 00	1	2	7	12	12	12	19
Oct - Dec 00	1	4	5	9	3	4	8
Jan - Mar 01	1	0	0	1	1	0	0
Apr - Jun 01	1	3	5	11	4	2	11
Jul - Sep 01	0	1	3	13	7	6	14
Oct - Dec 01	1	4	6	10	2	2	8
Total	46	77	80	150	109	75	136

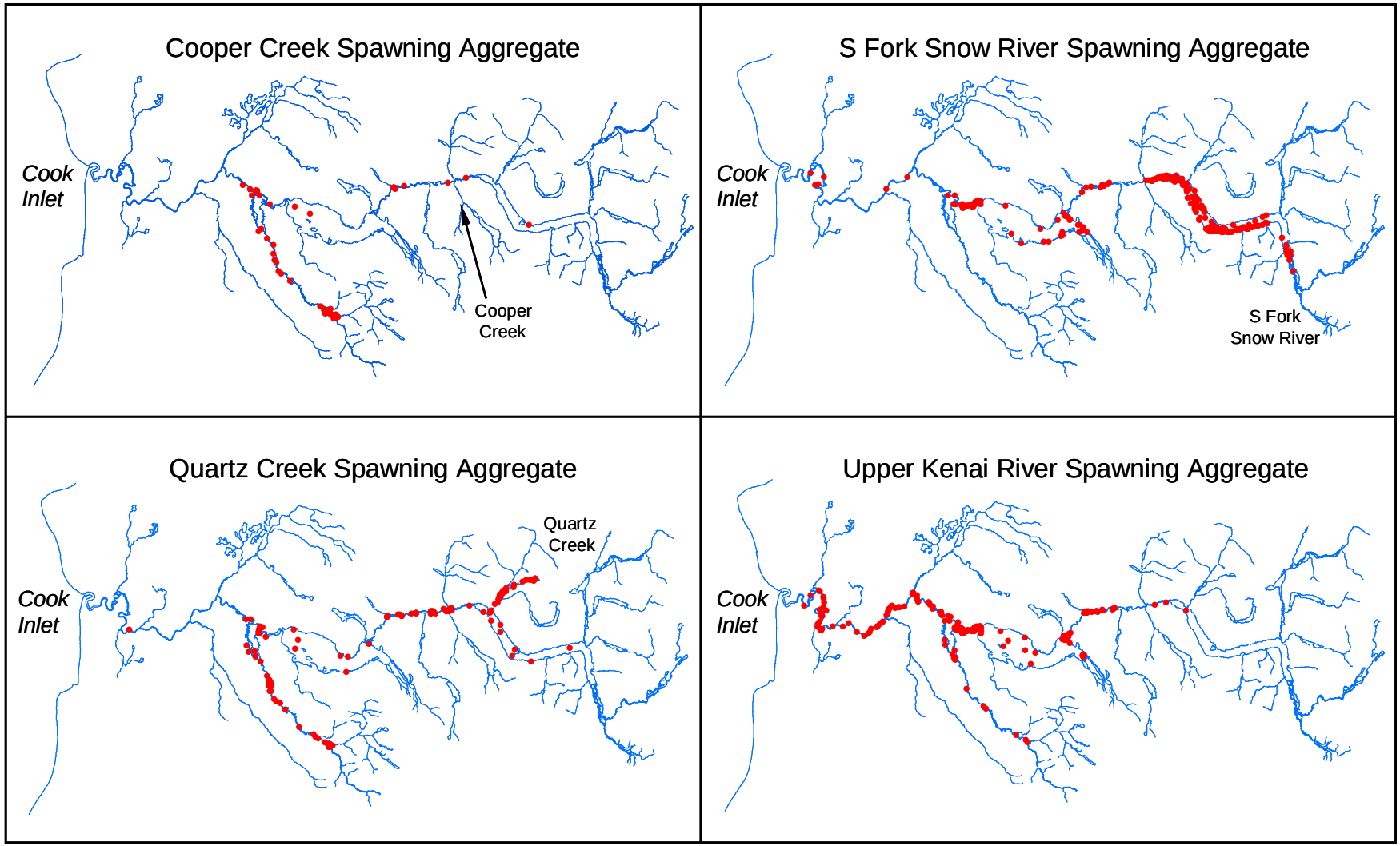
[a] Includes the Kenai River, Skilak, and Kenai lakes and tributary streams.
[b] Kenai River between Skilak and Kenai lakes.
[c] Kenai River between Naptowne Rapids and Skilak Lake.
[d] Kenai River below Naptowne Rapids
[e] Includes ground-based surveys on Quartz, Summit, Daves and Cooper creeks and the Russian, Killey and South Fork Snow rivers.



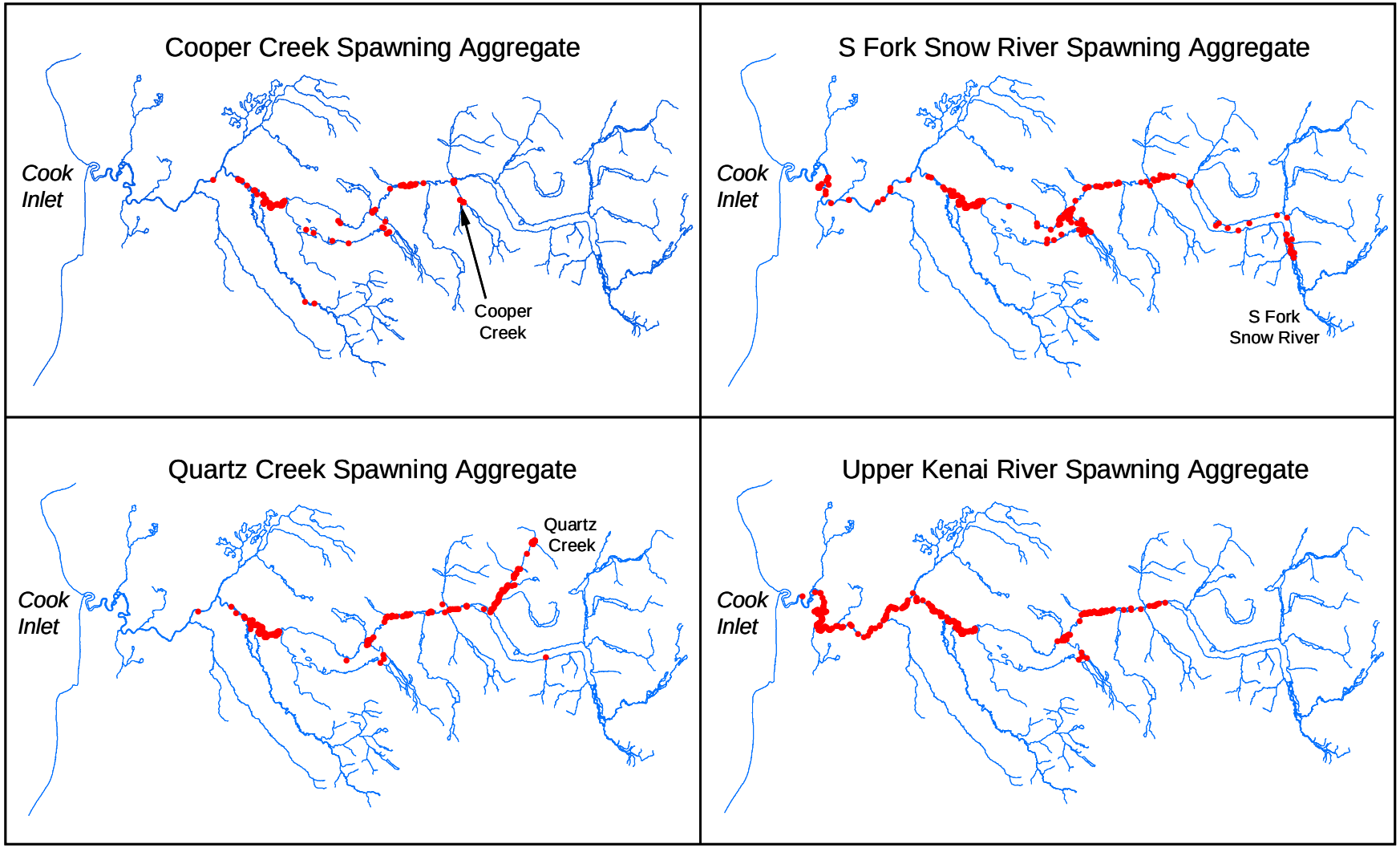
APPENDIX 4.—Distribution of radio-tagged Dolly Varden during the winter months (December through April). Locations displayed include observations recorded during all winter months from December 1998 through December 2001.



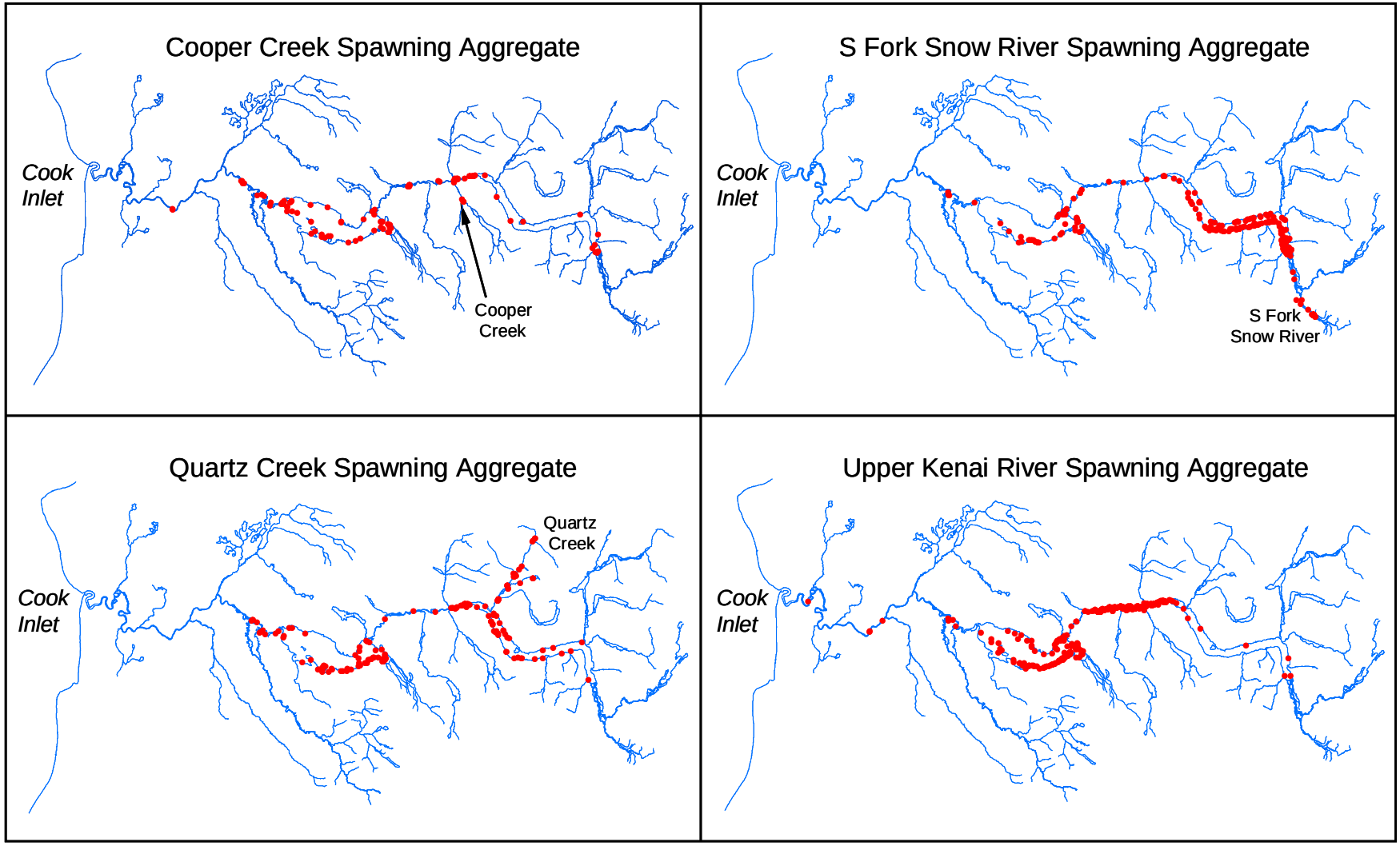
APPENDIX 5.— Distribution of radio-tagged Dolly Varden during May. Locations displayed include observations recorded in May during 1999, 2000, and 2001.



APPENDIX 6.— Distribution of radio-tagged Dolly Varden during June and July. Locations displayed include observations recorded in June and July during 1999, 2000, and 2001.



APPENDIX 7.— Distribution of radio-tagged Dolly Varden during August and September. Locations displayed include observations recorded in August and September during 1999, 2000, and 2001.



APPENDIX 8.— Distribution of radio-tagged Dolly Varden during October and November. Locations displayed include observations recorded in October and November during 1999, 2000, and 2001.