STUDY 1.

SPAWNING OF ANADROMOUS FISH IN THE SITUK RIVER

Rationale

Adult anadromous fish migrate and spawn in areas of the Situk River that will be flooded when Russell Fiord overflows. To determine how flooding may affect anadromous fish, the extent of habitat use by adult fish in areas that would be flooded must be assessed.

Objectives

Objectives of this study were to determine migration timing, residence time in the main-stem flood zone, spawning distribution, and abundance of adults of all species of anadromous fish species in the Situk River; describe migration and spawning habitats of adult sockeye, chinook, and pink salmon; and describe egg incubation of all anadromous fish.

Summary of Results

All anadromous fish that return to the Situk River must enter the predicted flood zone to migrate to spawning areas. The maximum proportion of each species' escapement that is in the flood zone at one time varies greatly, ranging from about 90% of chinook to less than 10% of fall steelhead. About one-half of the total anadromous fish escapement to the Situk River spawn in the flood zone; however, the most economically important species (sockeye, coho, chinook, and steelhead) spawn mainly outside the flood zone. Ocean-type sockeye and eulachon are most vulnerable to flooding because their spawning habitat is almost entirely inside the flood zone.

METHODS

Results of this study are from NMFS field studies, published and unpublished records, and consultation with fisheries personnel from other agencies.

Adult Migrations

Time of adult entry into the Situk River was determined for each anadromous species. Entry timing of sockeye, chinook, pink, and coho salmon was obtained from Riffe (1987). Entry timing of chum salmon, steelhead, Dolly Varden, and eulachon was estimated from published and unpublished data, personal communications, and personal observations.

Residence time in the flood zone of the main-stem Situk River (between Forest Highway 10 and the boat landing at the end of Lost River Road; Fig. H.4) was estimated for each anadromous species. Residence time of sockeye and chinook was estimated by tagging and tracking adult fish. Residence time of pinks, chum, steelhead, Dolly Varden, and eulachon was inferred from published data, personal communications, and personal observations.

Adult sockeye and chinook were tagged at the adult salmon weir in the main-stem Situk River (Fig. H.4) between 14 June and 21 August 1988. Sockeye were tagged with spaghetti tags, and chinook were tagged with Petersen disc tags. The total run was divided into three periods: early, 7 June–7 July; middle, 8–25 July; and late, 26 July–22 August. A different tag color was used in each period. About 10% of all sockeye and chinook salmon were tagged, but the escapement and the percentage of the escapement tagged differed between periods (Table 1.1). Because of the small number of tagged chinook, radio transmitters were orally inserted into stomachs of 30 disc-tagged chinook to improve tracking (Fig. 1.1).

Surveys of the flood zone in the main-stem Situk River were conducted by boat every other week between 14 June and 8 August to observe fish and determine habitat use. During each survey, tagged fish were counted and numbers of pink salmon were visually estimated. Where groups of sockeye (>10 fish), pink salmon (>20 fish), or any chinook were found, we recorded habitat type (pool, riffle, or glide), water depth (mean of three or more measurements), and amount (absent, common, or abundant) of cover (i.e., overhanging or submerged riparian vegetation and large woody debris [LWD]). Habitat of other species was inferred from the literature, personal communications, and personal observations.

Because only some of the tagged fish were observed during each survey, the number of tagged fish actually in the survey area was estimated. We expanded the observed number of tags by our observation efficiency ($\hat{a}$), which we estimated from the proportion of tagged fish observed during the first survey when all tagged fish were assumed to be within the survey area. Observation efficiency was calculated from the equation

$$\hat{a} = \frac{n_1}{x_1} , \qquad (1)$$

where $\hat{a}$ is observation efficiency, n_1 is the number of tagged fish observed in the first survey of the tagging period, and x_1 is the cumulative number of fish tagged up to that first survey. Observation efficiency was estimated separately for each species each tagging period. We assumed that observation efficiency was constant during the tagging period. The number of tagged fish in the survey area was estimated for each species and tagging period by the equation

$$\hat{n}_i = \frac{n_i}{\hat{a}} , \qquad (2)$$

where $\hat{n}_i$ is the estimated number of tagged fish in the survey area at survey i, and n_i is the number of tagged fish observed during survey i.

The proportion of tagged fish from each tag group remaining in the survey area was calculated by the equation

$$\hat{P}_i = \frac{\hat{n}_i}{x_i} , \qquad (3)$$

where $\hat{P}_i$ is the proportion of tagged fish remaining in the survey area at survey i, and x_i is the cumulative number of fish tagged up to survey i.

To estimate $\hat{P}$ for any given date between surveys, we regressed $\hat{P}$ on day of the year (day 1 = 1 January), using arcsin transformation (Sokal and Rohlf 1969) of $\hat{P}$ to linearize the regressions (Table 1.2). To estimate the total number of fish (tagged and untagged) remaining in the survey area on a given day, $\hat{P}$ from the regressions was multiplied by the cumulative number of fish counted at the Situk River weir up to that date:

$$\hat{N}_d = \hat{P}_d I_d , \qquad (4)$$

where $\hat{N}_d$ is the estimated total number of fish in the main-stem flood zone on day *d*, $\hat{P}_d$ is the estimated proportion of tagged fish in the survey area on day *d*, and I_d is the cumulative number of fish counted at the Situk River weir up to that date. From $\hat{N}_d$, we estimated the median residence time as the number of days for 50% of the total escapement during a tagging period to emigrate from the main-stem flood zone.

Spawning Distribution and Habitat

Spawning distribution of sockeye, chinook, and pink salmon was estimated from surveys of the Situk River, West Fork, Old Situk River, and Mountain Stream (Fig. H.4) between 14 June and 30 September 1988. Surveys were by boat, foot, and fixed-wing aircraft until 14 September and by aircraft thereafter. During surveys, habitat characteristics at fish concentrations, counts of tagged fish, approximate numbers of pink salmon, and observations of other anadromous fish were recorded on maps. Spawning distributions of other species were estimated from published and unpublished data, personal communications, and personal observations.

Spawning habitat of sockeye and chinook was observed in 19 stream reaches containing isolated groups of redds. Within these reaches, 45 individual redds (26 sockeye and 19 chinook) and 18 multiple (overlapping) redds (5 sockeye and 13 chinook) were identified, and habitat characteristics (intragravel temperature, water temperature, water depth, and water velocity) were measured at each redd (Fig. 1.2). At the individual redds, we also measured maximum length and width of the redd and visually estimated percentage of three substrate size classes (fine, <2 mm; gravel, 2-100 mm; and coarse, >100 mm) in the bowl and tailspill of the redd.

Incubation

Incubation period was estimated for each anadromous species, based on approximate dates of peak spawning and peak emergence. Peak spawning dates were derived from surveys of tagged adults and ADF&G spawning surveys. Peak emergence dates were estimated from observations of emergent fry in the Situk River from 1988 through 1990 (Studies 3, 5, 7, and 9). Thermograph data from five sites in the Situk River (Fig. H.6) were used to determine the cumulative number of temperature units (T) recorded at those sites during incubation; one temperature unit equals one degree-day above 0°C. The mean number of temperature units ($\bar{T}$) needed for emergence of each species was estimated as the sum of the weighted T from each thermograph:

$$\bar{T} = \sum_{k=1}^{5} S_k T_k , \qquad (5)$$

where (S_k) is the proportion of spawners nearest to or best represented by thermograph *k*.

RESULTS AND DISCUSSION

Most adult anadromous fish enter the Situk River to spawn between early March and mid-September; an exception is fall steelhead, which enter the river primarily in October and November[9] (Fig. 1.3). Entry timing and habitat use overlap among several species. Tagging in 1988 showed that some adults moved steadily upstream through the main-stem Situk River, whereas others held in the same area for several weeks. The maximum percentage of adult escapement in the flood zone at any given time differs among species, ranging from nearly 90% for chinook (Fig. 1.4) to less than 10% for fall steelhead. In the flood zone, most migrating fish held in pools or deep (>1 m) glides along banks with overhanging or submerged vegetation.

Anadromous fish spawn throughout the Situk River watershed. The percentage of fish spawning in the flood zone ranges from 0% of fall steelhead to 100% of eulachon (Fig. 1.5). In 1988, about one-half of the entire escapement spawned within the flood zone, and eggs incubated there every month of the year (Fig. 1.6). Most (85%) fish that spawned within the flood zone were pink salmon or eulachon; many coho, steelhead, and Dolly Varden, however, also spawned there. Species usually spawned in different areas, and each species used different spawning habitat (Appendix 1).

Sockeye Salmon

Most adult sockeye entering the Situk River in 1988 migrated rapidly from salt water to lakes, or stream sections near lakes, and remained there until they spawned, the usual migration pattern for most lake-type sockeye (Bevan 1962; Ricker 1966; Foerster 1968). Most stream-spawning sockeye used spawning habitat similar to that of sockeye in other streams (Foerster 1968; Leman 1988): shallow, low-velocity water, variable substrate, and close proximity to lakes. Ocean-type sockeye in the Situk River, however, used habitat similar to ocean-type sockeye in the Taku River where they use holding areas in the main stem during upstream migration and spawn in areas with upwelling groundwater (Lorenz and Eiler 1989).

Migration of adult sockeye into the Situk River begins in mid-June, peaks in early July, and declines steadily through late August (Riffe 1987; Fig. 1.3). Based on 1988 tagging, sockeye were most numerous in the main-stem flood zone in July (Fig. 1.4), when about 40% of the escapement was present.

Based on models of the 1988 sockeye migration (Fig. 1.7; Table 1.2), median residence time of sockeye in the main-stem flood zone was 17.3 days, but differed between periods. Sockeye tagged in the early period of the run remained in the flood zone significantly ($P < 0.02$; Scheffé's test) longer (median, 34.2 days) than sockeye tagged in the late period (median, 10.6 days). Most (95%) sockeye tagged in the early period migrated out of the flood zone by 1 August, whereas most tagged in the middle and late periods left the flood zone by 10 August. Migrating sockeye primarily were in deep (>1 m) glides near pools formed by LWD or glides with overhanging or submerged vegetation.

In 1988, most sockeye spawned between late July and late September; many sockeye that spawned in lakes, however, could not be observed. Sockeye were first seen spawning in the main-stem Situk River 5 km upstream of Forest Highway 10 on 27 July, and a few were still spawning near the Situk Lake outlet during the final survey on 30 September. Spawning in streams peaked the second and third weeks of August.

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[9]Unpubl. data. Alaska Dep. Fish and Game, P.O. Box 49, Yakutat, AK 99689.

Sockeye bound for Mountain Lake in 1988 entered the Situk River earlier and emigrated from the main-stem flood zone significantly ($P < 0.01$; t-test) faster than the overall escapement. Mountain Lake sockeye made up about 50% (8,200 fish) of the 1988 escapement in the early period, 30% (5,100 fish) in the middle period, and 23% (3,900 fish) in the late period (Rowse 1990[10]). In the early and middle periods, Mountain Lake sockeye spent 14 and 15 days, respectively, between the weirs on the Situk River and Mountain Lake (Fig. H.4), and most (95%) fish tagged in the early and middle periods passed the Mountain Lake weir by 24 July and 16 August, respectively[11]. In the late period, Mountain Lake sockeye spent 22 days between weirs, and most passed the Mountain Lake weir by 2 September[7, 8].

In 1988, over 95% of the sockeye in the Situk River spawned in or near lakes. About 36% of the 1988 escapement spawned in Mountain Lake (Rowse 1990) and a smaller percentage in Situk Lake. Density of spawning in river habitat was greatest within 3 km downstream of Situk Lake. Many spawning sockeye also were observed in Mountain Stream and in the West Fork near Redfield Lake. Scattered spawning was observed in three other locations: the main-stem Situk River from 1 km downstream of the highway to 3 km downstream of Situk Lake; Old Situk River from the highway upstream 2 km; and sloughs along Old Situk River downstream of the highway (Fig. 1.8). Only about 5,000 sockeye spawned within the flood zone (Fig. 1.5), and (based on scale samples from sockeye in the Old Situk River[12]) about two-thirds of these probably were ocean type. Thus, most (>95%) ocean-type sockeye remained in the flood zone from the time they entered the Situk River until they spawned.

Of the sockeye that spawned in stream reaches in 1988, 65% used glides, 30% used pools, and 5% used riffles. Sockeye used an average of 3.7 m^2 of streambed for redds, in water averaging 49.6 cm deep and 26.5 cm/s in velocity. Substrate in redds averaged 23% fine sediment, 72% gravel, and 5% coarse sediment. Differences between surface water temperature (mean, 9.1°C) and intragravel temperature (mean, 6.2°C) indicated the presence of upwelling groundwater in spawning areas.

Sockeye eggs and alevins from the 1988 brood year incubated in the Situk River for about 250 days (Fig. 1.6); spawning peaked in mid-August, and fry emergence peaked in late April (Table 1.3). Incubation time in Old Situk River was about 10 days less than in the main stem; spawning peaked in late August, and emergence peaked in mid-April. During incubation, sockeye spawning areas downstream of Situk Lake received 1,245 temperature units ($\bar{T}$) with a mean temperature of 4.9°C, while those in Old Situk River received 820 temperature units ($\bar{T}$) with a mean temperature of 3.5°C; typically, sockeye incubating under similar conditions would require 800-865 temperature units to reach peak (50%) emergence (Table 1.3). Obviously, there was a large difference between the observed versus the predicted number of temperature units needed for sockeye emergence below Situk Lake. Thus, either the estimated incubation period was off by as much as a month on either end, there was a large difference between the temperature recorded by the thermograph and actual incubation temperature below Situk Lake, or some combination of the two.

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[10]For unknown reasons, the proportion of tagged fish in weir counts declined by 51% overall between the sites. Therefore, the preceding percentages may be inaccurate.

[11]Ben Kirkpatrick, Alaska Dep. Fish and Game, Div. Commercial Fisheries, P.O. Box 49, Yakutat, AK 99689. Pers. commun., Sept. 1988.

[12]Adam Moles, National Marine Fisheries Service, Auke Bay Lab., 11305 Glacier Hwy., Juneau, AK 99801. Pers. commun., Oct. 1989.

Chinook Salmon

The migration of adult chinook into the Situk River begins in mid-May, peaks in mid-June, and declines through mid-August (Riffe 1987; Fig. 1.3). In 1988, about 90% of adult chinook were in the main-stem flood zone in late July (Fig. 1.3). Chinook spent more time migrating through the main-stem flood zone than did sockeye. Based on models of chinook migration in 1988 (Fig. 1.7; Table 1.2), the median residence time of chinook in the main-stem flood zone was 29.8 days. Residence time was similar ($P > 0.1$; F test) among tagging periods.

As in other rivers (Hamilton and Buell 1976; Burger et al. 1985), chinook often held in large pools or deep glides until mature. Migrating chinook primarily used deep (>2 m), open pools or deep (>1 m) glides along banks with overhanging or submerged vegetation. Chinook that used deep glides usually moved upstream more steadily than chinook that held in pools. Individual chinook often held in the same pool for most of the time they were monitored in the flood zone, and then moved quickly (within 1 or 2 days) to spawning areas.

Chinook spawning was observed between 30 July and 14 September. Spawning was first observed on 30 July in the main stem 1.5 km upstream of the highway. Chinook spawning peaked about the first week of September and was finished before 30 September. On the last aerial survey on 30 September, no spawning chinook were seen, and most radio-tagged fish were dead.

As in other rivers (Smith 1973; Bjornn and Reiser 1991), chinook in the Situk River spawned in relatively deep, fast water and used large substrate. All chinook spawned either in riffles or glides. Chinook used an average of 19.0 m^2 of streambed to construct a redd. Spawning sites had mean water depth of 79.6 cm and mean water velocity of 73.0 cm/s. Substrate at redds averaged 5% fine sediment, 76% gravel, and 19% coarse sediment. Mean water temperature was 12.2°C and mean intragravel temperature was 11.9°C. All habitat characteristics differed significantly ($P < 0.05$; t test) from habitat of stream-spawning sockeye; chinook spawned in deeper, faster water, larger substrate, and less groundwater than sockeye.

About 95% of tagged chinook survived to spawn, and 90% of survivors spawned in the main stem between the highway and Situk Lake (Fig. 1.9). Some tagged chinook also spawned in the main stem within 1 km downstream of the highway and in the lower 1 km of the West Fork. Chinook without tags were seen spawning in the main stem within 3 km downstream of the highway and in Mountain Stream (Fig. 1.9). Only about 5% of chinook spawned in the flood zone.

Brood-year 1988 chinook salmon eggs and alevins incubated for about 235 days in the Situk River (Fig. 1.6); spawning peaked in early September, and emergence peaked in late April (Table 1.3). During incubation, chinook spawning areas received 924 temperature units ($\bar{T}$) and had a mean temperature of 3.9°C (Table 1.3).

Pink Salmon

Migration of adult pink salmon into the Situk River begins in early July, peaks in early August, and declines steadily through early September (Riffe 1987; Fig. 1.3). In 1988, pinks were most numerous in the main-stem flood zone from mid-July to mid-August (Fig. 1.4), when 20-25% of the escapement (30,000-40,000 fish) was present there. Migrating pinks were primarily in glides with overhanging vegetation or in tails of pools. Pinks apparently migrated directly to spawning areas, which is similar to behavior in other coastal streams (Ishida 1966; McNeil 1966; Heard 1978).

In 1988, pinks spawned from mid-August to early September with peak spawning in late August. Spawning was first observed on 10 August about 10 km upstream of the boat landing, and last observed on 8 September near the boat landing. Pinks spawned in three main areas: the main stem, from about 7 km upstream of the boat landing to 4 km downstream of Situk Lake; the Old Situk River, from its mouth to 1 km downstream of the highway; and in the West Fork (Fig. 1.10). In most years, about 40% of pinks (60,000 fish) spawn within the flood zone (Fig. 1.5). Pinks in the Situk River used similar spawning habitat as in other streams (Neave 1966; Bjornn and Reiser 1991): shallow (<40 cm) open glides or tails of pools.

Brood-year 1988 pink salmon eggs and alevins incubated for about 245 days in the Situk River (Fig. 1.6); peak spawning was in late-August and peak emergence was in early-May (Table 1.3). During incubation, pink salmon spawning areas received 790 temperature units ($\bar{T}$) and had a mean temperature of 3.2°C (Table 1.3).

Coho Salmon

Coho salmon are one of the most numerous and economically important species in the Situk River, yet relatively little is known about their escapement and spawning distribution (Pahlke and Riffe 1988). Data on coho escapement is incomplete because the timing of fisheries, weir counts, and stream surveys does not include the entire escapement and spawning periods[13]. Generally, coho in the Situk River migrate to spawning areas during high stream flow in fall and spawn throughout the watershed.

Migration of coho salmon into the Situk River begins in early August and peaks in early September (Riffe 1987; Fig. 1.3). Coho are most numerous in the main-stem flood zone in early September (Fig. 1.4), when about 25% of the total escapement (about 8,000 fish) are present there. Stream surveys indicate that coho escapement declines slowly from mid-September through mid-October[2,4,5].

Coho spawning in the Situk River begins in mid-September and continues through December[2,4,5]. Spawning coho have been observed in the main stem from 3 km downstream of Situk Lake, Old Situk River, West Fork, Mountain Stream[2], and many tributaries[14] (Fig. 1.11). Stream surveys indicate that 20-30% of coho spawn within the flood zone[2] (Fig. 1.5). Spawning habitat was not measured, but general habitat characteristics are summarized in Appendix 1.

Coho eggs and alevins incubate for about 210 days in the Situk River (Fig. 1.6), based on peak spawning in early to mid-October and peak emergence in early to mid-May (Table 1.3). During incubation, coho spawning areas received 437 temperature units ($\bar{T}$) and had a mean temperature of 1.9°C (Table 1.3). Coho fry that emerge in early July may incubate in cooler conditions or may be the offspring of fish that spawn in winter (Study 3); spawning as late as February has been observed in other areas of the Yakutat Forelands (e.g., Tawah Creek; Fig. H.4), and spawning also may occur very late in the Situk River watershed.

Chum Salmon

The migration and spawning characteristics of chum salmon in the Situk River are similar to other coastal Alaska streams (Helle 1960). Glacial moraine deposits adjacent to spawning areas probably are groundwater aquifers that supply those areas with upwelling water[15] where chums often prefer to spawn (Helle 1960; Bishop 1981).

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[13]Leon Shaul, Alaska Dep. Fish and Game, Div. Commercial Fisheries, Southeast Region (1), 802 Third St., Douglas, AK 99824. Pers. commun., Dec. 1991.

[14]Robert Johnson, Alaska Dep. Fish and Game, Div. Sport Fish, Southeast Region (1), 802 Third St., Douglas, AK 99824. Pers. commun., Nov. 1991.

[15]Steve Paustian, U.S. Forest Service, Tongass National Forest, Chatham Area, 204 Siginaka Way, Sitka, AK 99835. Pers. commun., April 1991.

Migration of adult chums into the Situk River begins in early August, peaks in late August, and ends in early September[2]. Distribution of spawning is poorly known; however, spawning in 1988 was observed in Old Situk River primarily upstream of the highway, and in the main stem from 3 km upstream of the highway to 7 km downstream of the highway (Fig. 1.12). At least one-half of the chums probably spawn within the flood zone (Fig. 1.5), and spawning probably peaks in late August. Spawning habitat in the Situk River was not measured, but general spawning habitat characteristics are summarized in Appendix 1.

Brood-year 1988 chum eggs and alevins probably incubated for about 240 days in the Situk River (Fig. 1.6); spawning peaked in late August and emergence peaked in late April (Table 1.3). During incubation, chum spawning areas received 840 temperature units ($\bar{T}$) and had a mean temperature of 3.5°C (Table 1.3).

Steelhead

The Situk River supports one of the largest runs of steelhead in Alaska (Van Hulle 1985); historical estimates exceed 20,000 fish (Knapp 1952). The river supports distinct runs of spring and fall steelhead, but most is known about the more numerous spring fish (Jones 1983; Johnson 1990, 1991; Fig. 1.3). From April through mid-June, with a peak in mid-April, spring steelhead migrate directly from the ocean to Situk River spawning areas. From August through December, with a peak in November, fall steelhead migrate from the ocean into the river, winter in the watershed, and spawn at approximately the same time as spring-run fish (Jones 1983; Johnson 1990, 1991). Spawning areas of spring and fall steelhead are moderately distinct[6], but the amount of mixing of spring and fall runs is unknown. Emigration from the river of spawned-out steelhead of both runs begins in early May, peaks in mid-June, and is complete by late July[2]. Steelhead are most numerous in the main-stem flood zone in early May (Fig. 1.4), when 60% of the escapement (3,000 fish, including emigrants) is present.

Spring steelhead spawn from late April through June (within 2-6 weeks of entering the river), and their spawning period overlaps that of fall steelhead (Johnson 1990). Many spring steelhead spawn within the flood zone (Figs. 1.5, 1.13). Surveys indicate that about 1,000 fish (one-quarter of the escapement) spawn downstream of the highway (Jones 1983). Spring steelhead also spawn in the main-stem Situk River upstream of the highway, in Old Situk River, and in the West Fork[6] (Fig. 1.13).

Most fall steelhead winter outside the flood zone. Eleven fall steelhead that were radio tagged in 1989 wintered in Situk Lake (Johnson 1991). Some fall steelhead, however, also winter in large riverine pools within the main-stem flood zone (Jones 1983), and a few may winter in Old Situk River[16]. Fall steelhead spawn mostly from late April through early June (Johnson 1990). Thus, some fall steelhead may spend 10 months in the watershed before spawning.

Nearly all fall steelhead probably spawn outside the flood zone[6] (Fig. 1.5). The most important spawning area is the first 8 km downstream of Situk Lake in the main stem (Johnson 1991). Some fall steelhead also spawn in the remainder of the main stem upstream of the highway, in Mountain Stream, in West Fork[6], and Old Situk River (Fig. 1.14). Steelhead spawning habitat in the Situk River was not measured, but general spawning habitat characteristics are summarized in Appendix 1.

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[16]Gordon Woods, Alaska Dep. Fish and Game, Div. Commercial Fisheries, P.O. Box 49, Yakutat, AK 99689. Pers. commun., Sept. 1991.

Steelhead eggs and alevins probably incubate for about 40 days in the Situk River (Fig. 1.6), based on peak spawning in late May and peak emergence in early July (Table 1.3). During incubation, steelhead spawning areas received 482 temperature units ($\bar{T}$) and had a mean temperature of 12.0°C (Table 1.3).

Dolly Varden

Seasonal distribution of Dolly Varden in the Situk River is poorly documented, but observations indicate that many adults spend much of the year in the watershed, consistent with behavior in other Alaska streams (Armstrong 1965a,b; Blackett 1968). Dolly Varden emigrate from lakes and other wintering areas (e.g., Old Situk River) in the Situk River watershed in early spring (March-April) and enter salt water; they immigrate into the watershed to feed on fish eggs and fry from April to mid-September (Fig. 1.3). Spawning probably occurs in the main stem and most tributaries (Fig. 1.15) and peaks about early October. The number of Dolly Varden in the Situk River is unknown, but, based on personal observations, at least 3,000 Dolly Varden spawn within the flood zone (Fig. 1.5). Dolly Varden spawning habitat in the Situk River was not measured, but general spawning habitat characteristics are summarized in Appendix 1.

Dolly Varden eggs and alevins probably incubate for about 235 days in the Situk River (Fig. 1.6); peak spawning probably occurs in early October, and peak emergence is in late May (Table 1.3). During incubation, Dolly Varden spawning areas received 784 temperature units ($\bar{T}$) and had a mean temperature of 2.1°C (Table 1.3).

Eulachon

Eulachon enter the Situk River in early March (Fig. 1.3), and spawning peaks in late March and is completed by mid-April. Eulachon are most numerous in the main-stem flood zone in early April (Fig. 1.4), when over 50% of the escapement is present. Nearly all eulachon spawn within the main-stem flood zone (Figs. 1.5, 1.16). Based on observations of larvae in late May, incubation is about 20 days (Fig. 1.6). During incubation, eulachon spawning areas received 49 temperature units ($\bar{T}$) and had a mean temperature of 2.6°C (Table 1.3). Spawning habitat of eulachon in the Situk River was not measured.

Table 1.1—Number of sockeye and chinook salmon tagged between 14 June and 21 August 1988, and escapement through the Situk River weir in three periods between 7 June and 22 August.

Species	Period	Number tagged	Escapement	% Tagged
Sockeye	Early	1,053	20,981	5.0
	Middle	1,642	17,907	9.2
	Late	1,850	8,118	22.8
	Total	4,545	47,006	9.7
Chinook	Early	43	280	15.4
	Middle	41	618	6.6
	Late	38	180	21.1
	Total	122	1,078	11.3

Table 1.2—Regression equations (with associated R^2 values) used in estimating the proportion ($\hat{P}$; where $\hat{P} = [\sin \hat{y}]^2$ and $\hat{y}$ is in radians) of the escapement of sockeye or chinook salmon in the main-stem flood corridor of the Situk River during each tagging period in 1988. Day (d) was 1 on 1 January and 366 on 31 December.

Species	Period	Regression equation	R^2
Sockeye	Early	$\hat{y} = 6.65 - 0.029d$	0.83
	Middle	$\hat{y} = 6.61 - 0.029d$	0.74
	Late	$\hat{y} = 10.11 - 0.043d$	0.83
Chinook	Early	$\hat{y} = 5.45 - 0.021d$	0.83
	Middle	$\hat{y} = 7.99 - 0.032d$	0.86
	Late	$\hat{y} = 13.78 - 0.053d$	0.68

Table 1.3—Incubation criteria of anadromous fish in the Situk River. *T* is temperature units or degree-days above 0°C. A dash indicates data are not available.

Species	Peak spawning observed	Peak emergence observed	Mean incubation temperature (°C)	$\bar{T}$ to 50% emergence estimated	*T* to 50% emergence typical
Sockeye	Aug 10-20	Apr 20-30	4.9	1,245	865[a]
Ocean-type[b] Sockeye	Aug 20-30	Apr 10-20	3.5	820	800[a]
Coho	Oct 5-15	May 5-15	1.9	437	460[a]
Pink	Aug 25-Sep 5	Apr 30-May 10	3.2	790	675[a]
Chinook	Aug 28-Sep 7	Apr 20-30	3.9	924	900[a]
Chum	Aug 23-Sep 2	Apr 20-30	3.5	840	645[a]
Steelhead	May 25-Jun 4	Jul 1-10	12.0	482	500[c]
Dolly Varden	Oct 2-12	May 20-Jun 10	2.1	784	—
Eulachon	Mar 20-30	Apr 10-20	2.6	49	—

[a] Murray and McPhail 1988.

[b] In the Old Situk River.

[c] Leitritz and Lewis 1980. Data for rainbow trout.

Figure 1.1—Inserting radio tag in a chinook salmon on the Situk River.

Figure 1.2—Measuring water velocity at a sockeye salmon redd in Old Situk River.

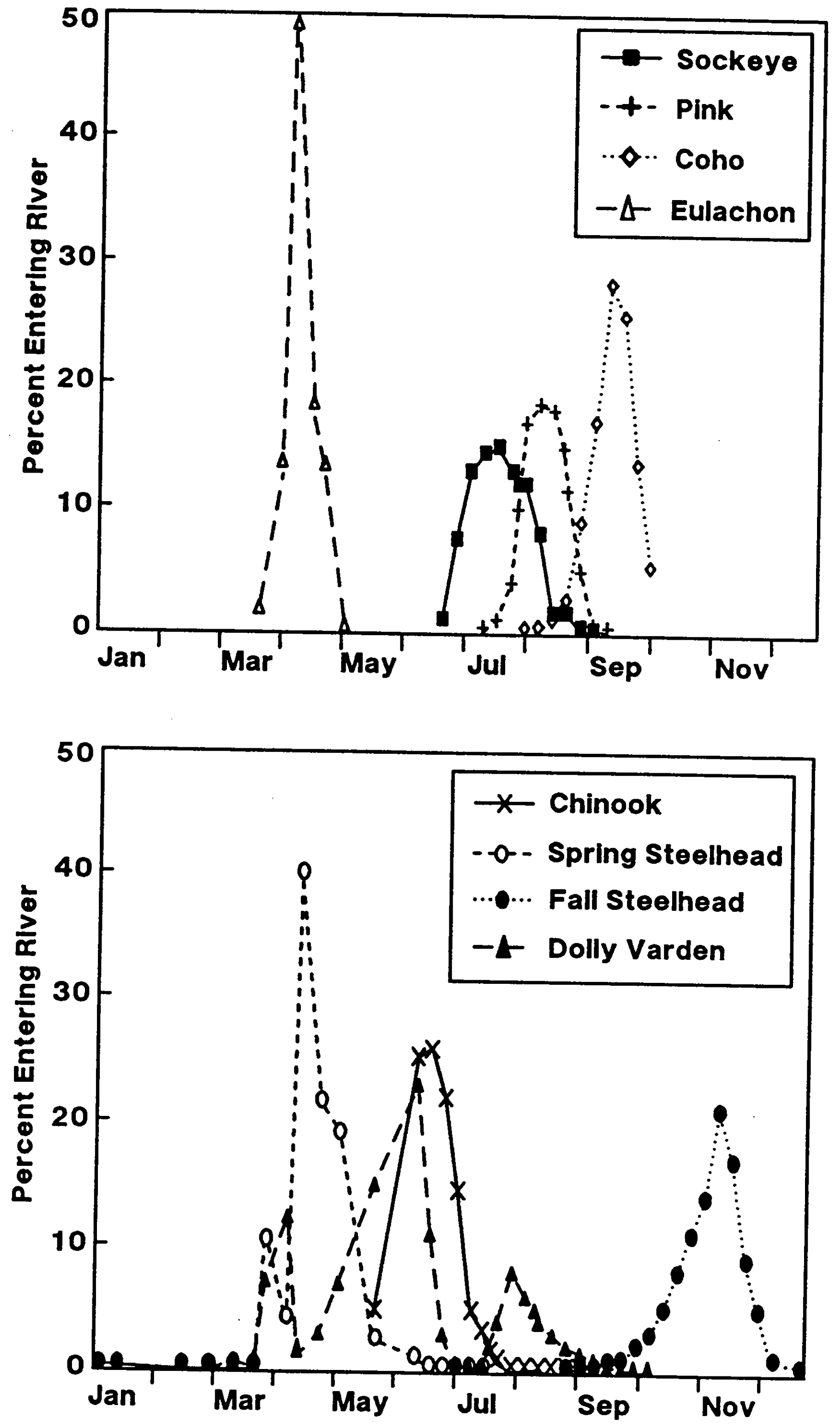

Figure 1.3—Approximate annual timing of river entry by adult anadromous fish returning to the Situk River.

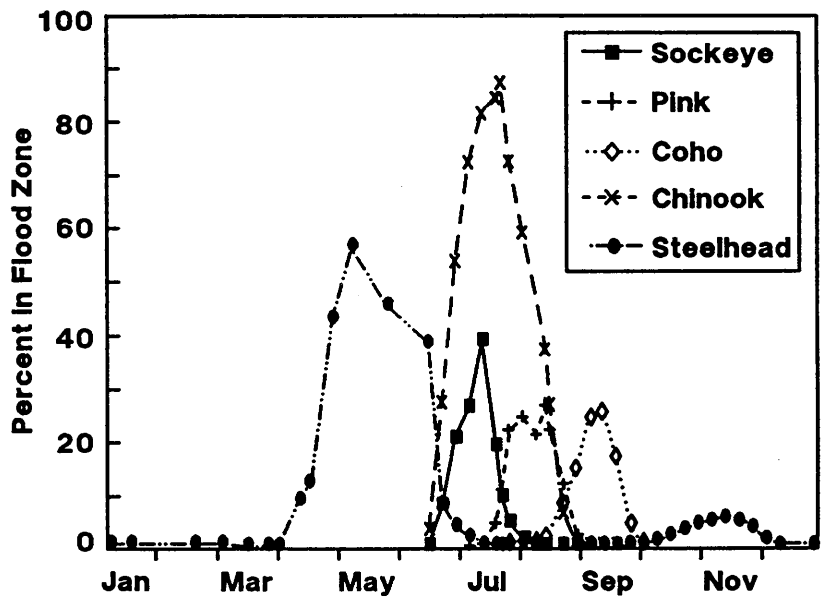

Figure 1.4—Estimates by date of the percentage of returning adult salmon and steelhead that are in the predicted flood zone.

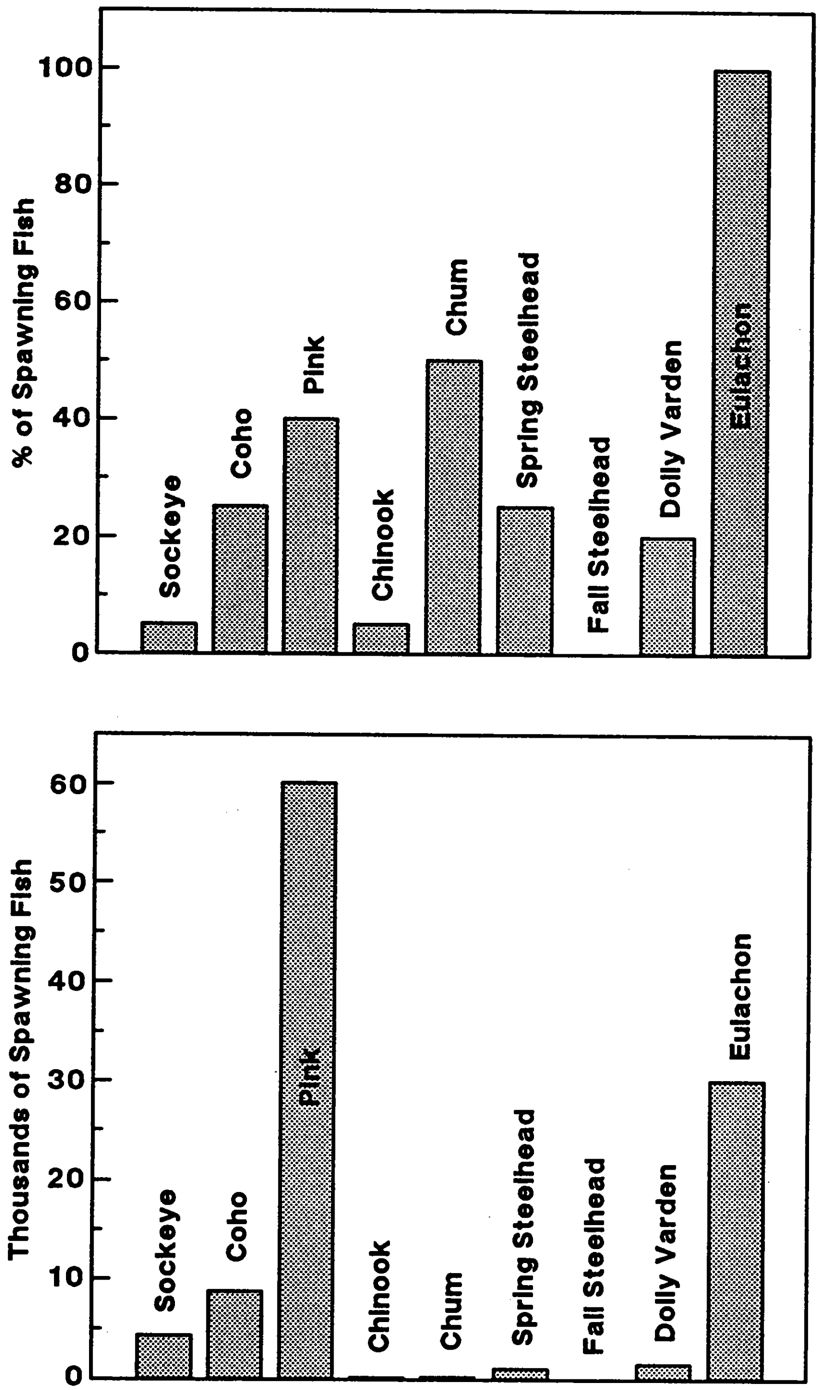

Figure 1.5—Estimates of average annual percentages and numbers of anadromous fish that spawn within the predicted flood zone of the Situk River.

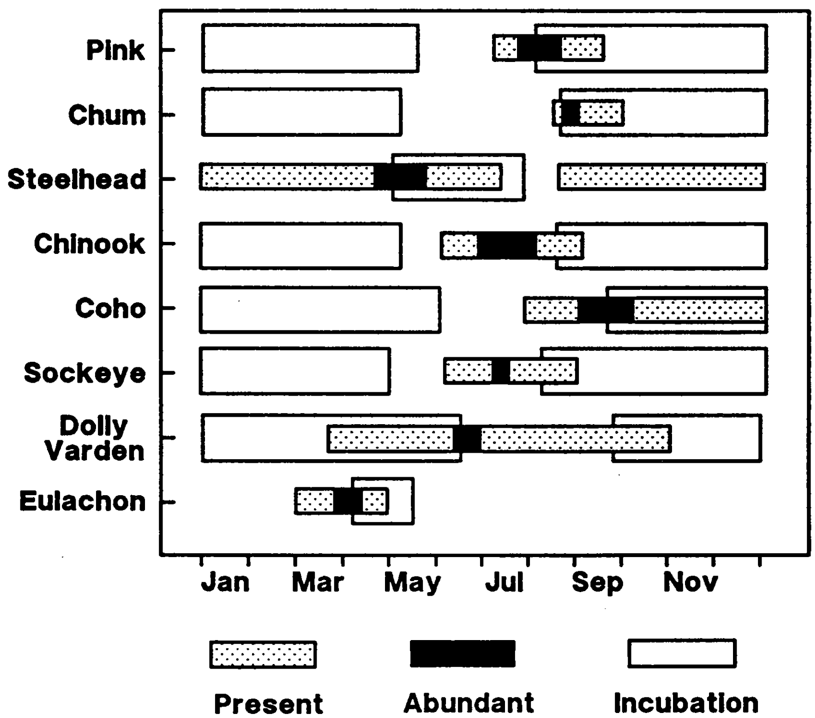

Figure 1.6—Timing and relative abundance of adult anadromous fish and egg incubation in the predicted flood zone of the Situk River.

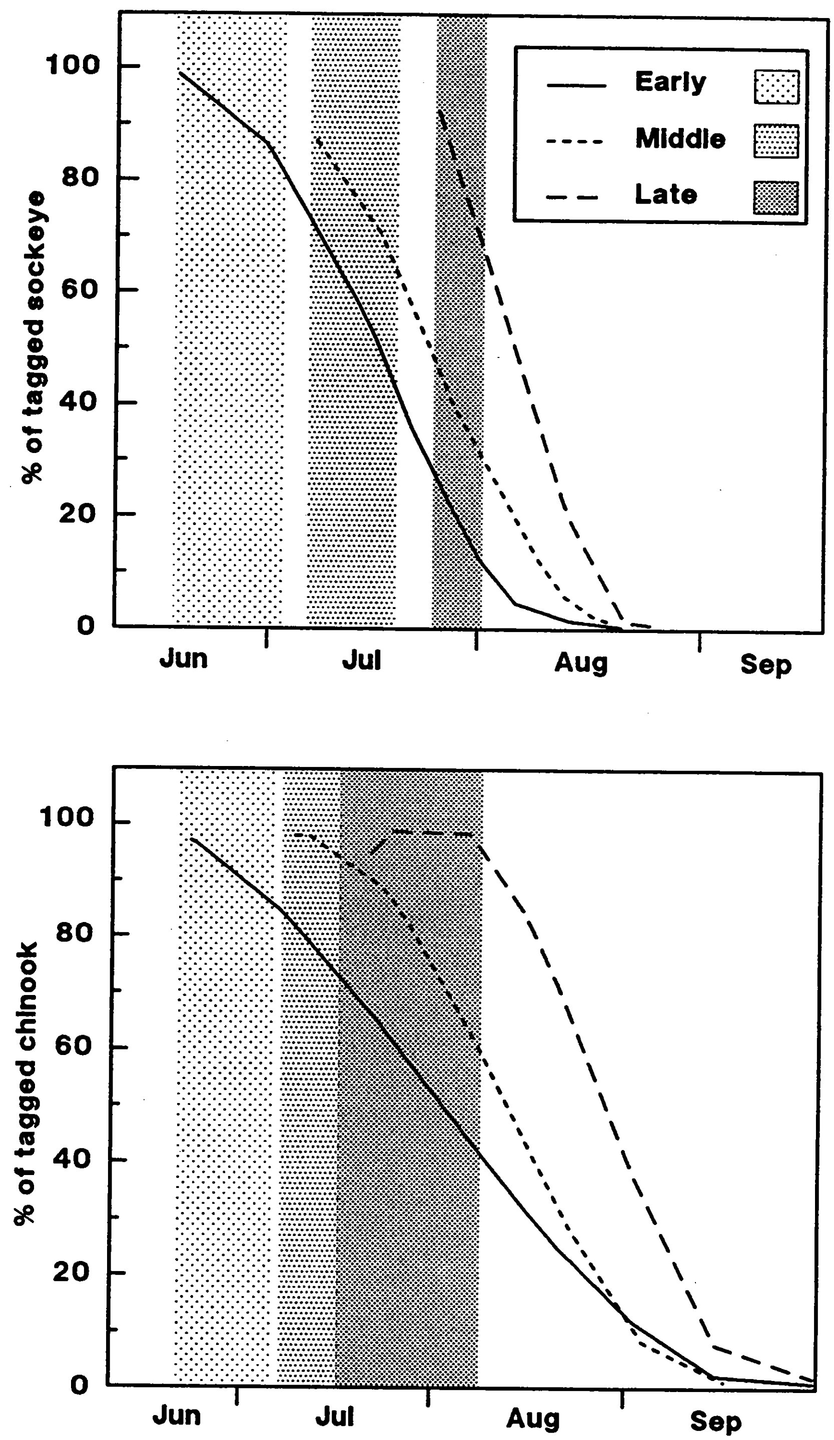

Figure 1.7—Estimated percentages of three respective groups of tagged sockeye and chinook salmon in the predicted main-stem flood zone of the Situk River, from 14 June through 14 September 1988. Shaded areas encompass tagging dates.

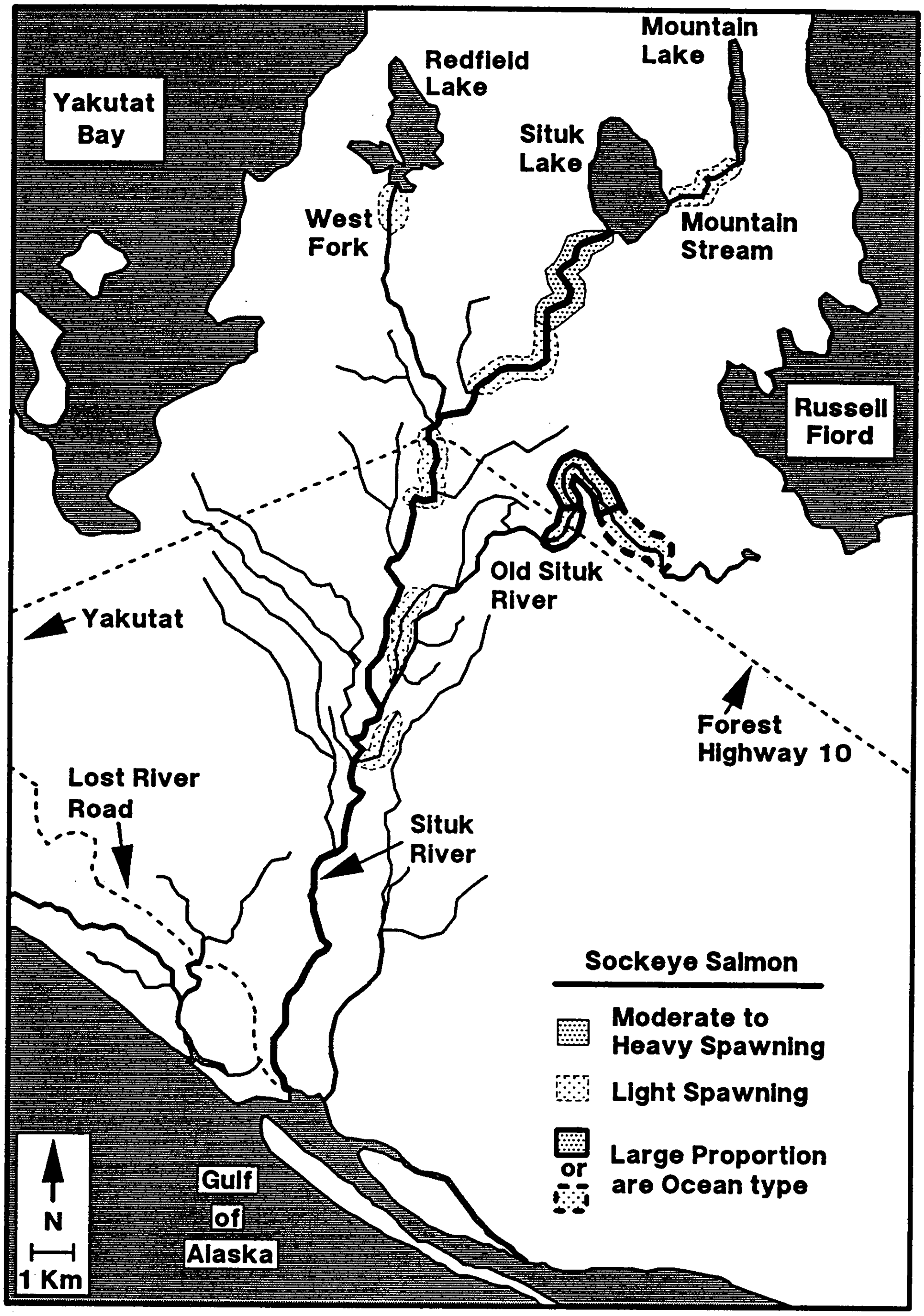

Figure 1.8—Distribution of stream spawning sockeye salmon in the Situk River watershed, 1988.

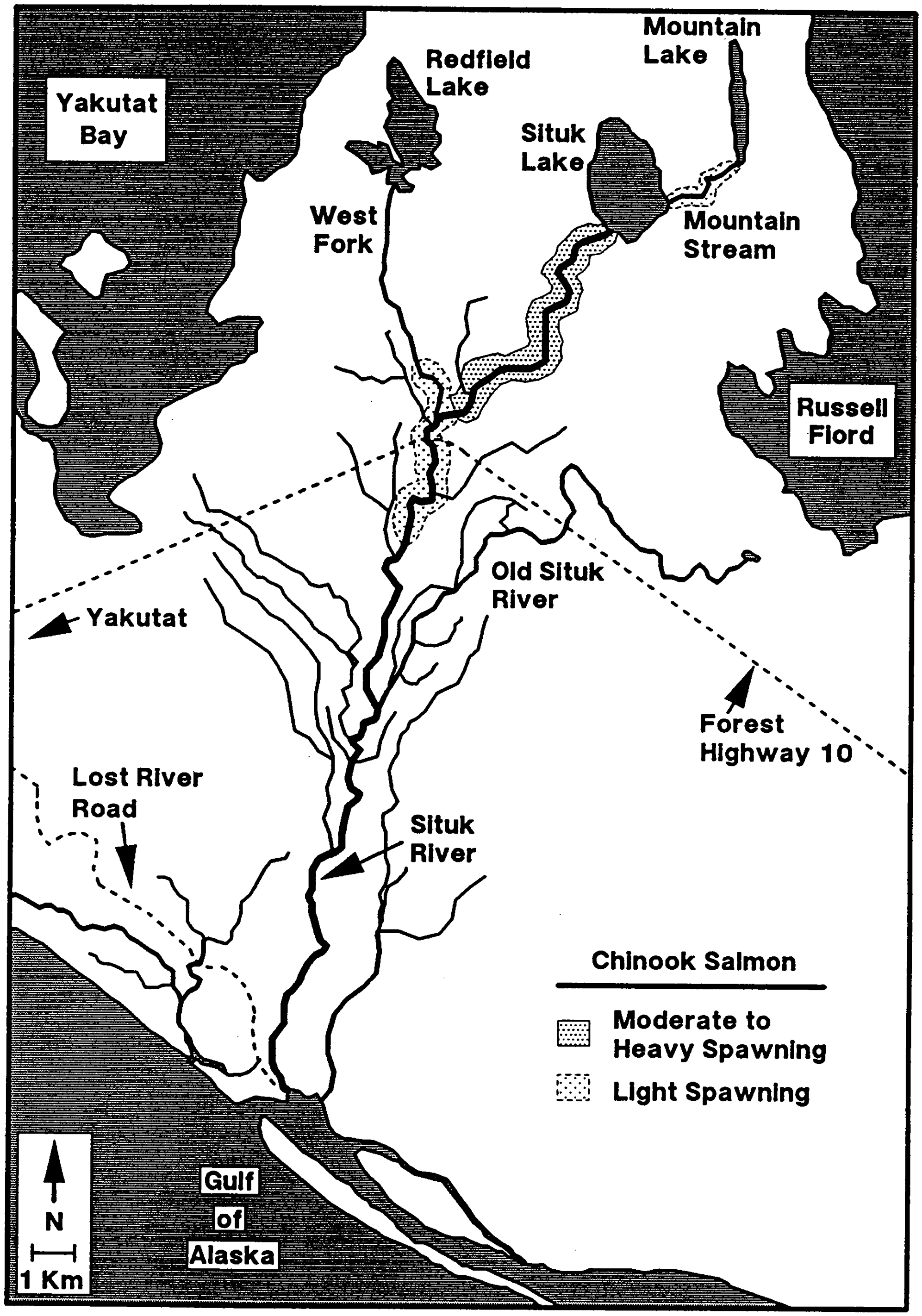

Figure 1.9—Distribution of spawning chinook salmon in the Situk River watershed, 1988.

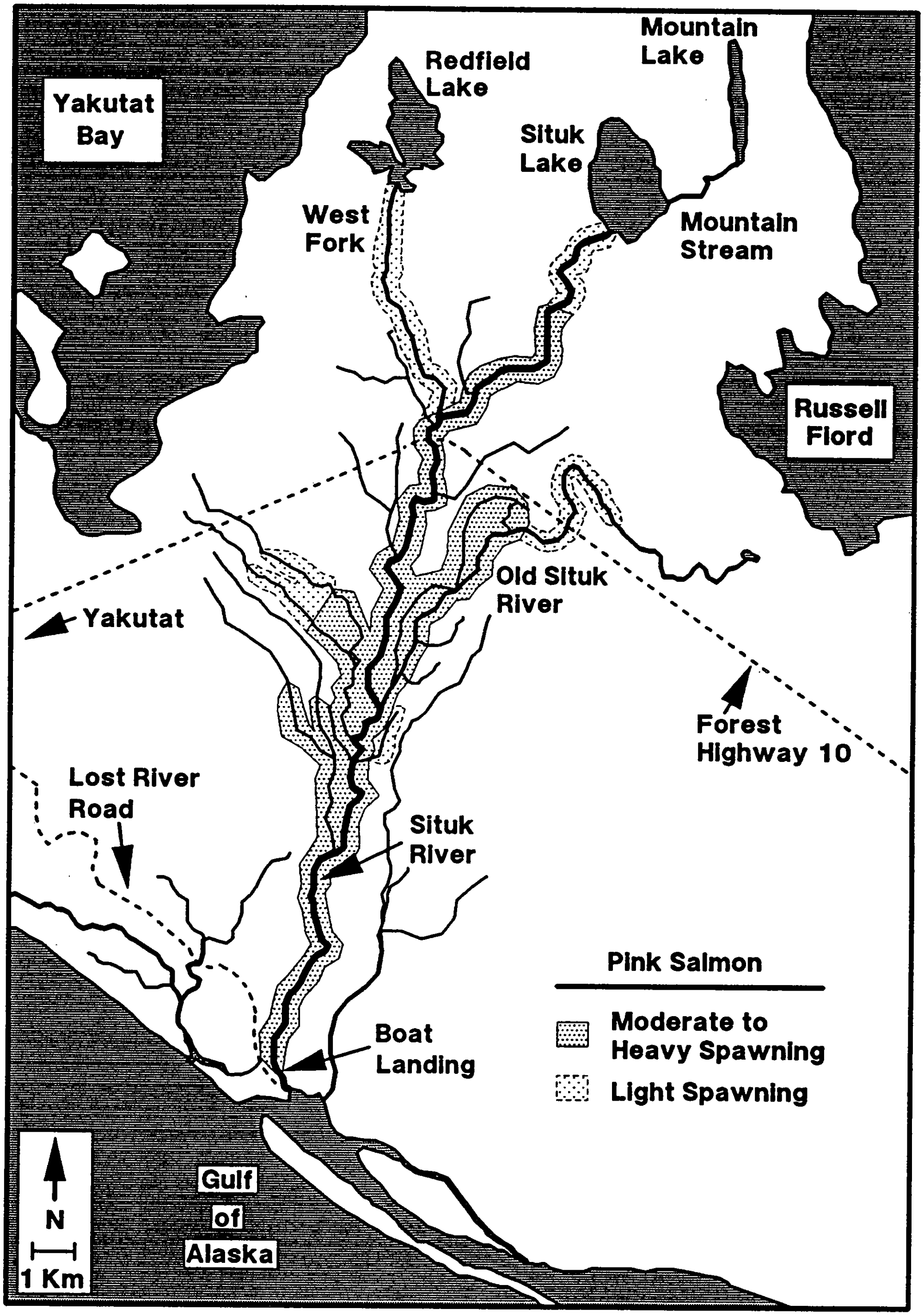

Figure 1.10—Estimated distribution of spawning pink salmon in the Situk River watershed, 1988.

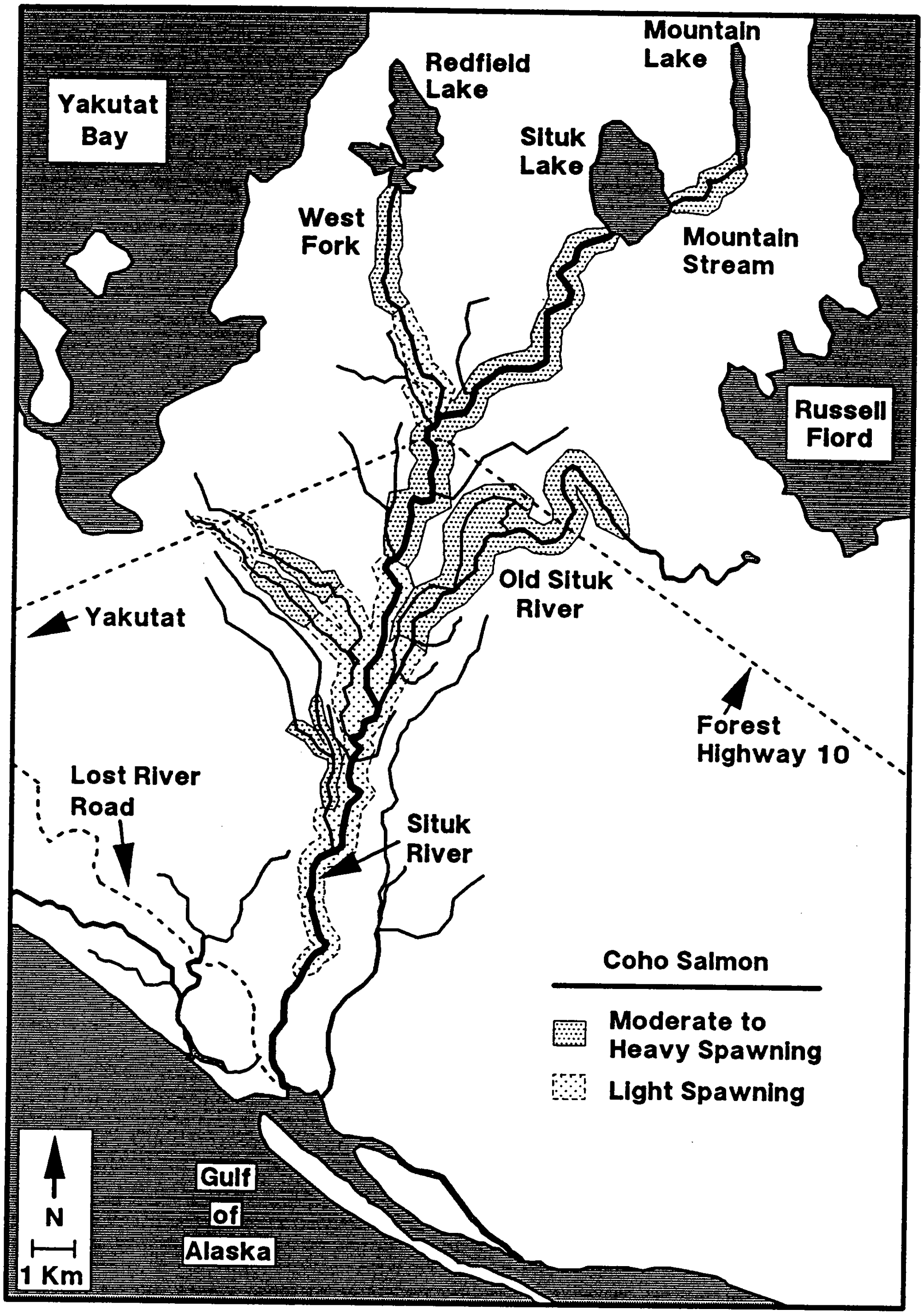

Figure 1.11—Estimated distribution of spawning coho salmon in the Situk River watershed.

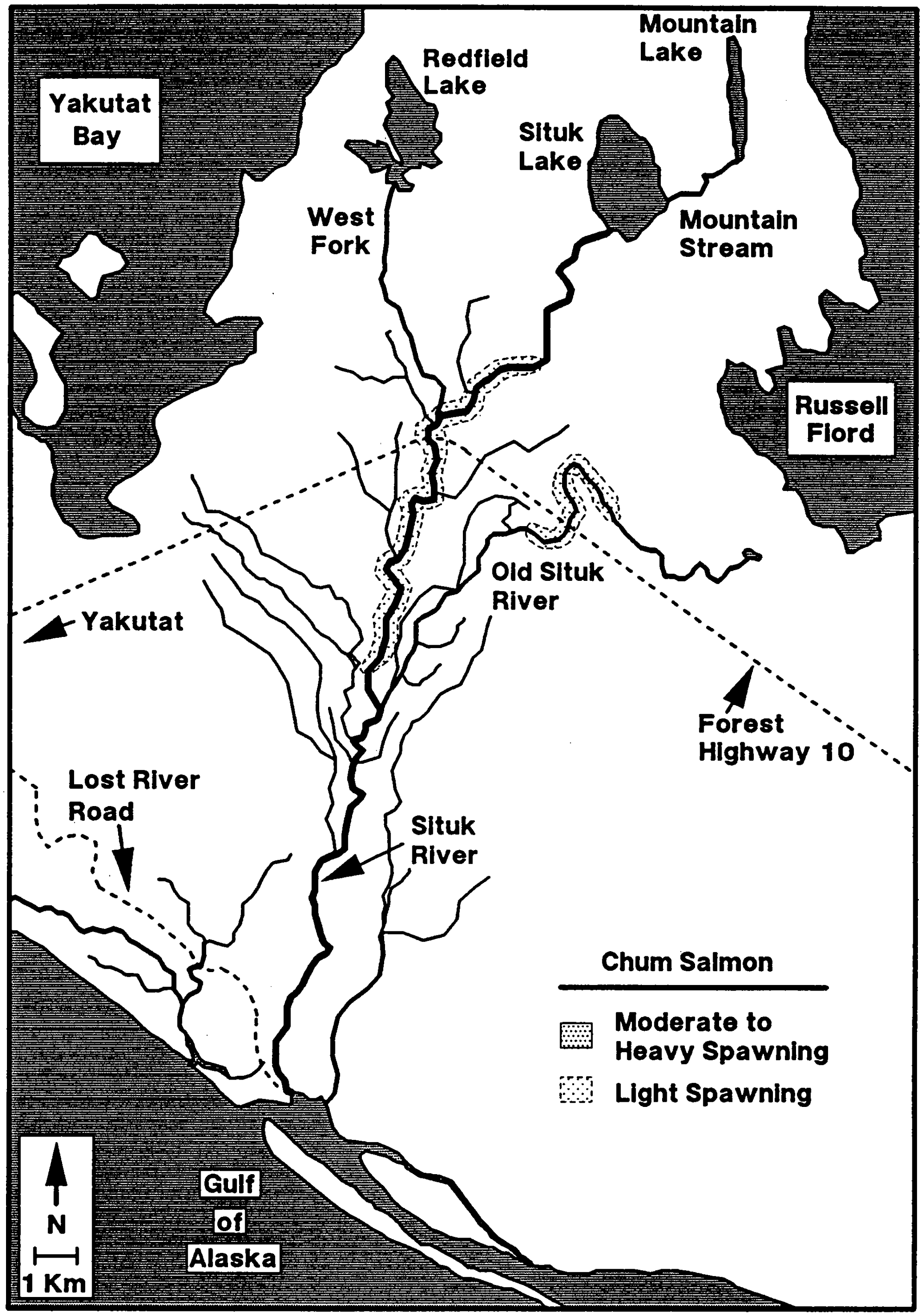

Figure 1.12—Estimated distribution of spawning chum salmon in the Situk River watershed.

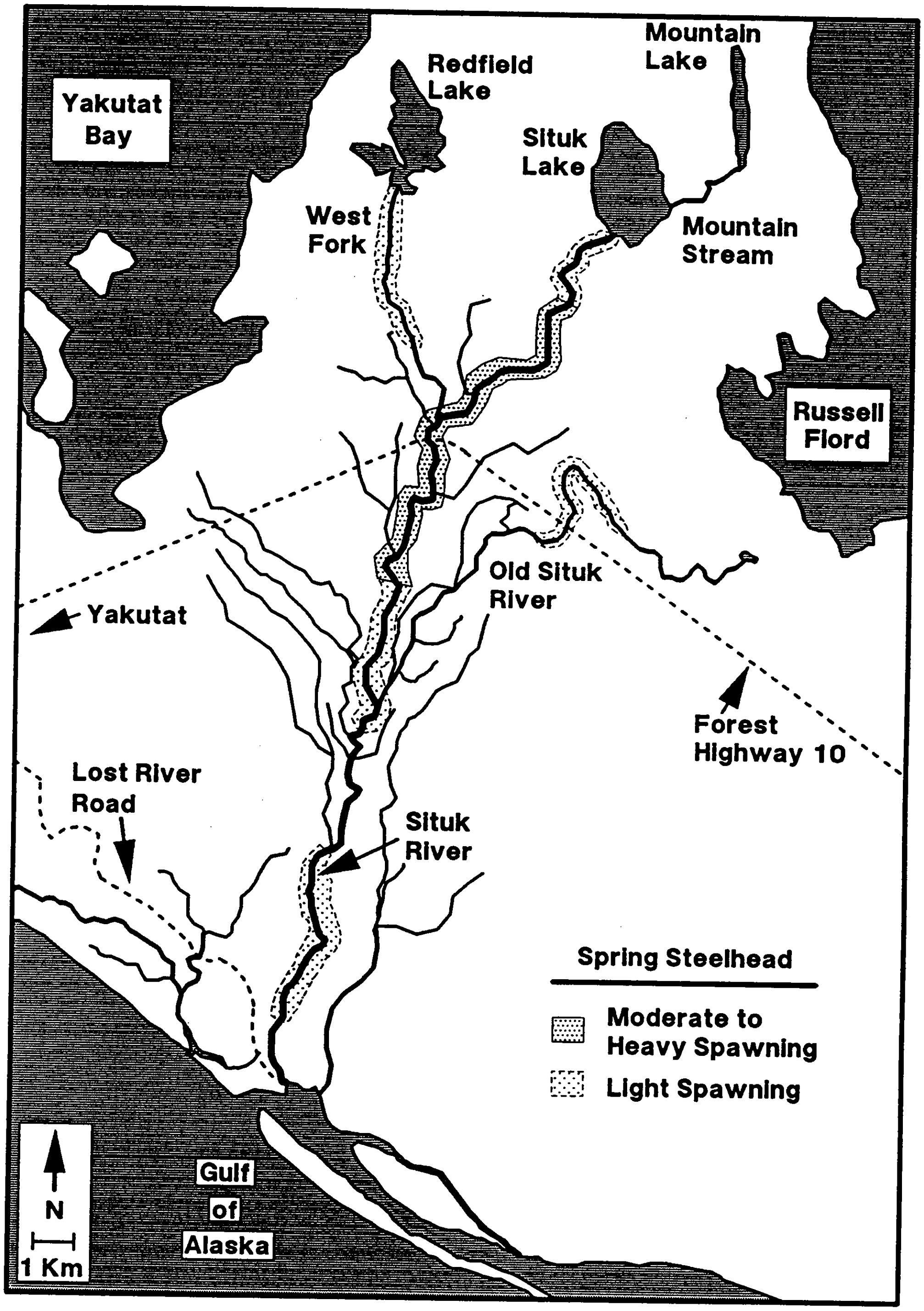

Figure 1.13—Estimated distribution of spawning spring steelhead in the Situk River watershed.

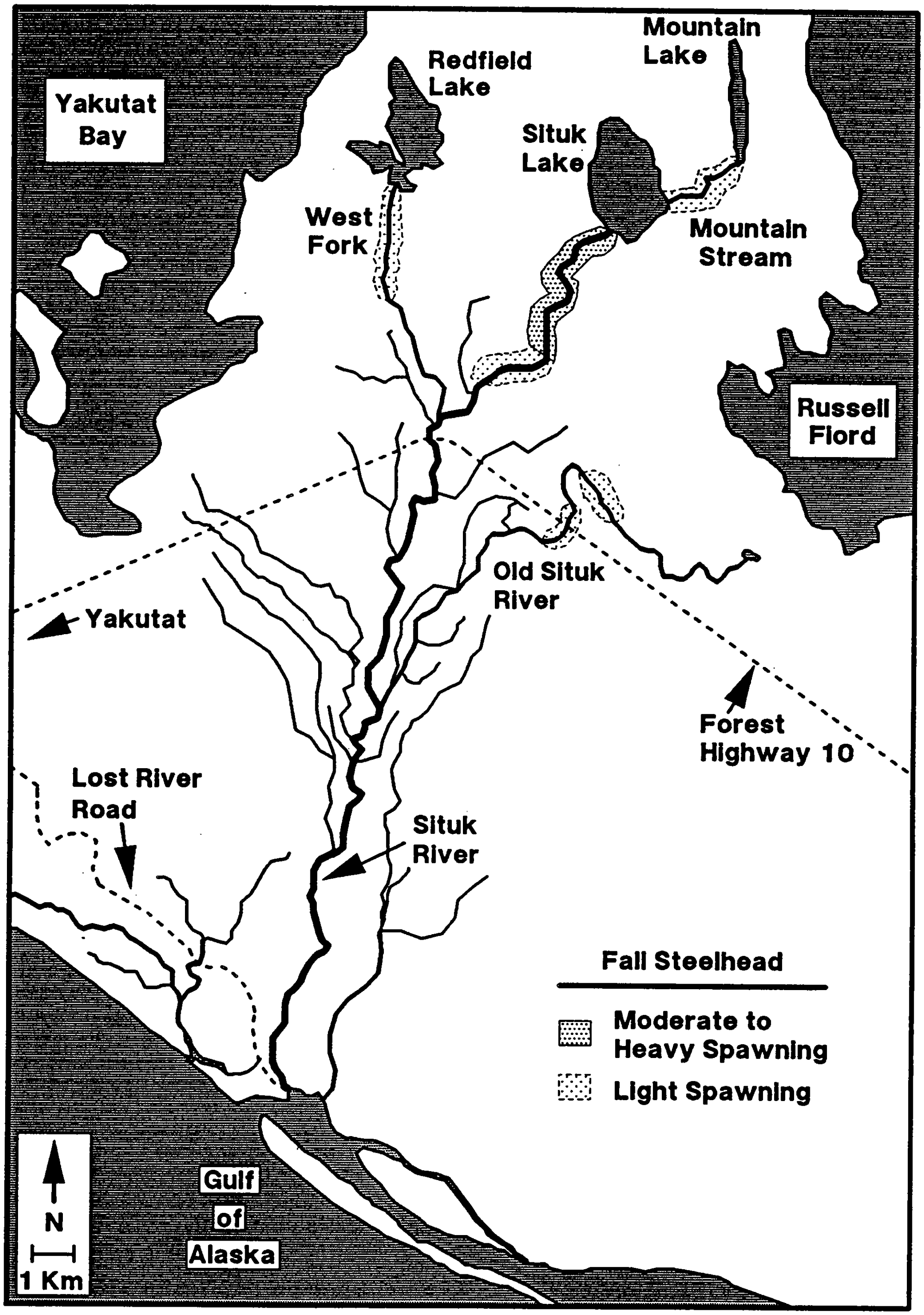

Figure 1.14—Estimated distribution of spawning fall steelhead in the Situk River watershed.

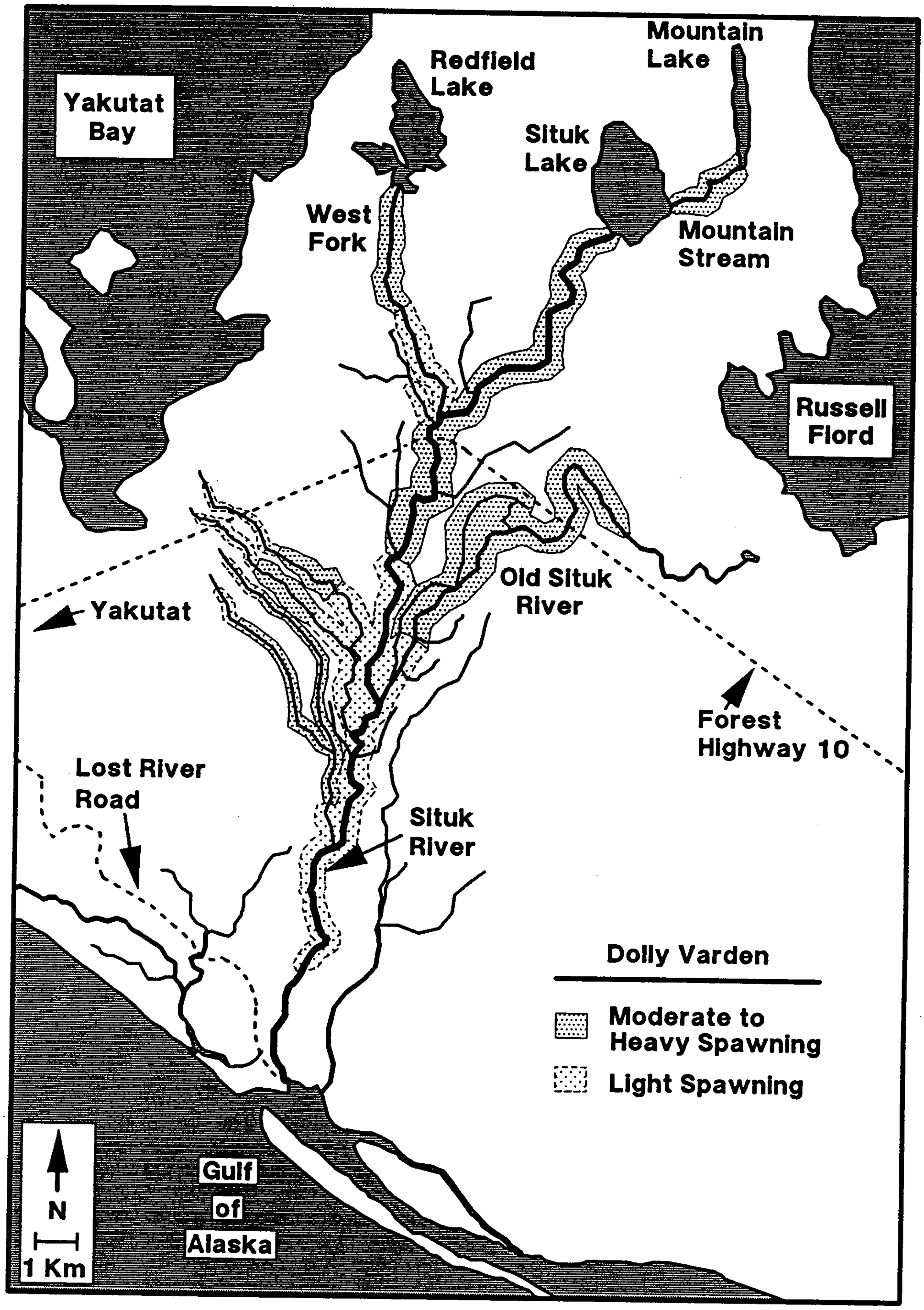

Figure 1.15—Estimated distribution of spawning Dolly Varden in the Situk River watershed.

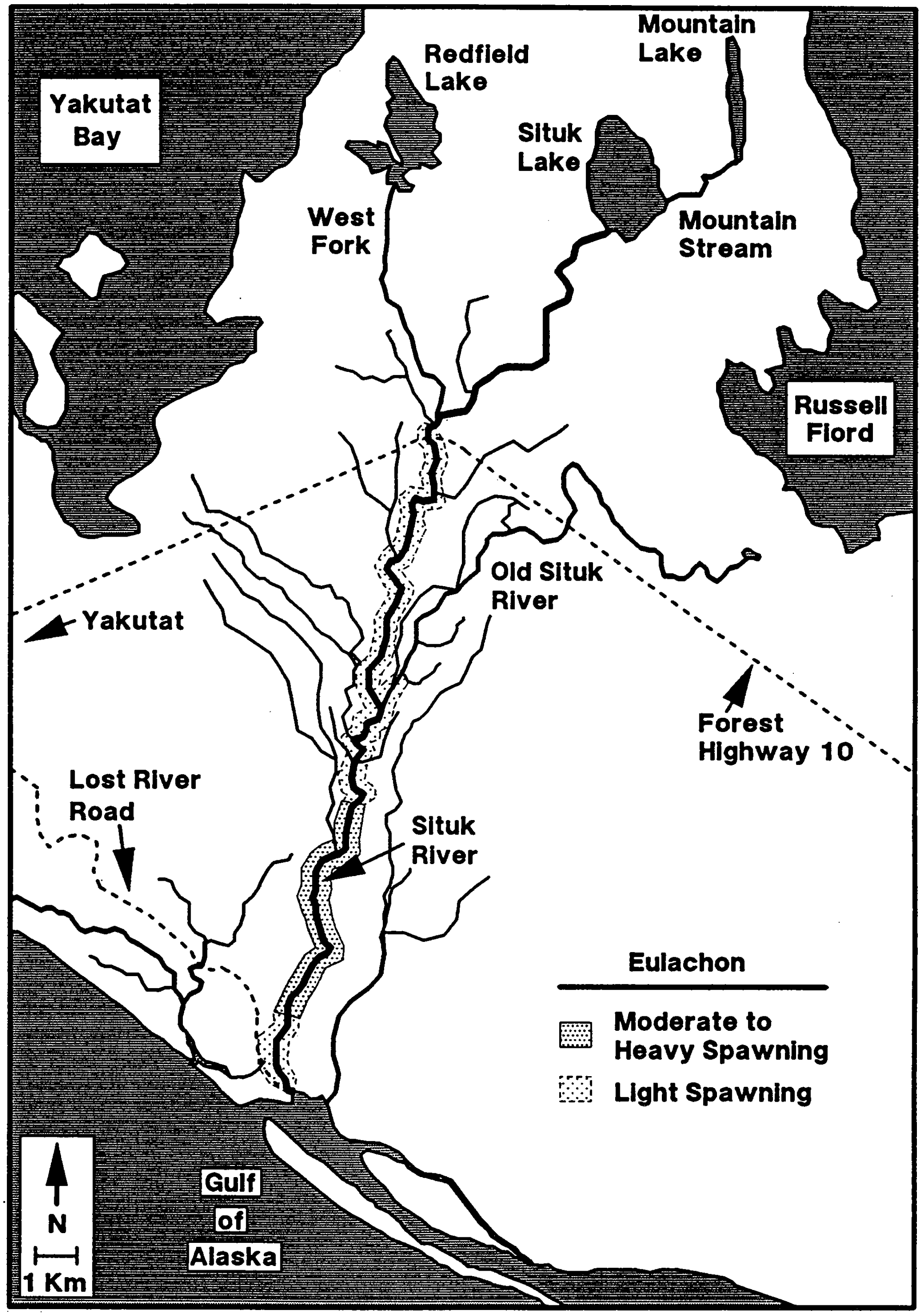

Figure 1.16—Estimated distribution of spawning eulachon in the Situk River watershed.