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Abstract.—Short-term (5-d) mortality of chinook salmon *Oncorhynchus tshawytscha* caught and released in the Kenai River was assessed with radiotelemetry. From 1989 to 1991, 446 adult chinook salmon were tagged with radio transmitters in four experiments. Overall hooking mortality averaged 7.6% and ranged from 10.6% in 1989 to 4.1% in 1991. Mortality was highest for small males (<750 mm mid-eye length) compared with large males and all females. Wound location and bleeding were the factors principally associated with mortality. Survival of chinook salmon that were hooked in the gills or were bleeding was significantly reduced; however, the frequency of these injuries was small in all experiments. Most mortalities occurred within 72 h of release. These results support the use of hook-and-release regulations in similar freshwater chinook salmon fisheries to reduce sportfishing mortality effectively and achieve spawning escapement goals.

A widespread and successful strategy for managing commercial fisheries for Pacific salmon *Oncorhynchus* spp. is to achieve a desired spawning escapement by manipulating fishing mortality (Minard and Meacham 1987). Implicit in this management strategy is an ability to estimate the in-river abundance of fish. This strategy was recently adopted for the Kenai River, which sustains the largest recreational fishery for chinook salmon *Oncorhynchus tshawytscha* in Alaska. The Kenai River supports two runs of chinook salmon (Burger et al. 1985). Separate escapement goals have been developed for the early run (May–June) and the late run (July–August). Hydroacoustic assessment (sonar) is used to estimate the in-river abundance of chinook salmon, and fishing mortality is estimated from a creel survey. The difference between these two estimates equals the spawning escapement. Management options for the recreational fishery, such as mandatory catch-and-release fishing, restrictions on the use of bait, and total fishery closures, are used to regulate the harvest of chinook salmon to achieve escapement goals for each run.

The Kenai River enjoys a wide reputation for abundant catches of large chinook salmon. As the fishery expanded during the 1980s and bag limits were reduced, voluntary catch-and-release fishing emerged as a popular method to selectively harvest trophy-sized fish. By 1988, the Alaska Department of Fish and Game estimated that the released component of the early-run catch was equivalent to 73% of the spawning escapement. The rapid growth of catch-and-release fishing and the likelihood of using it to achieve spawning escapement goals raised concerns among anglers and fishery managers over the mortality of released fish. Few studies are available on hooking mortality of salmon in freshwater (Wydoski 1980; Mongillo 1984). Estimates of hooking mortality for chinook salmon in marine fisheries vary widely, ranging from 20.5% (Wertheimer 1988) to 71% (Parker and Black 1959). If hooking mortality were high in the Kenai River, the spawning escapement could be seriously underestimated.

The objective of our study was to estimate the short-term (5-d) mortality rate for chinook salmon that were hooked and released in the Kenai River recreational fishery. In this study, we used radiotelemetry to monitor the daily locations of chinook salmon and a matrix of criteria based on telemetry signals and movement behavior to estimate the fates of tagged fish. Associations between mortality and biological and fishery variables were also examined. Based on our results, we discuss the appropriateness of catch-and-release angling as a management option for Kenai River chinook salmon.

Study Site

The Kenai River (Figure 1) is a glacial stream that flows west 136 km across the Kenai Peninsula lowlands before reaching Cook Inlet in south-central Alaska. The river drains an area of approxi-

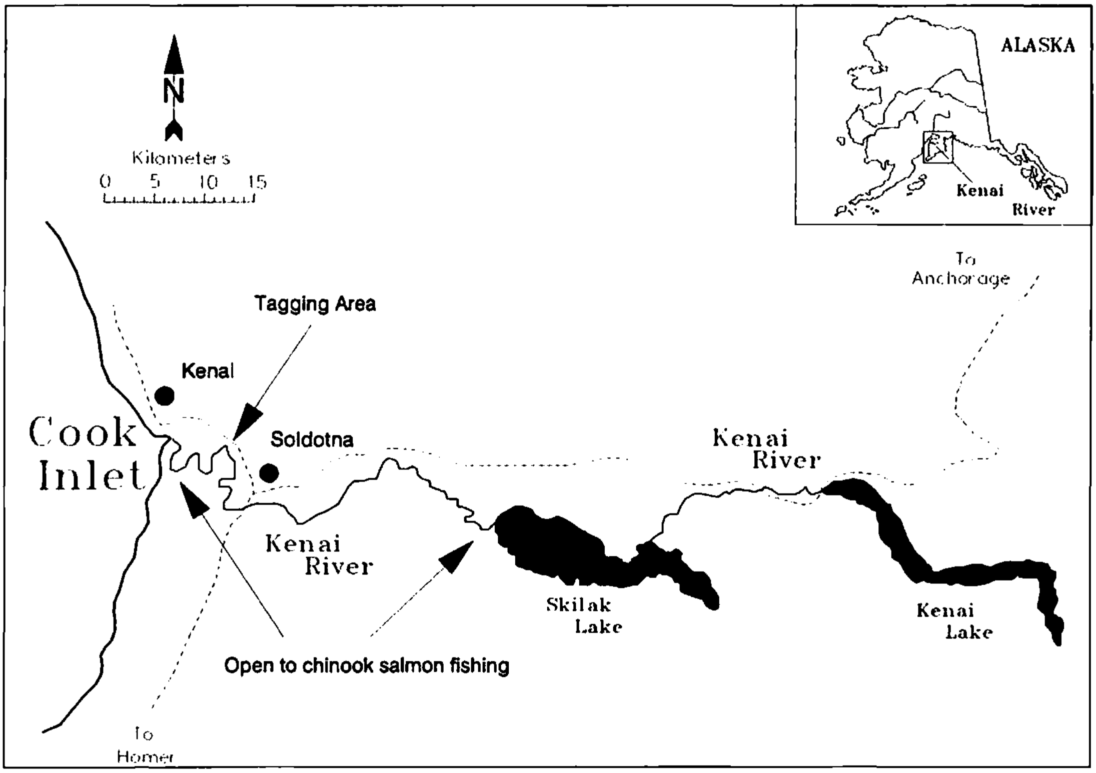

FIGURE 1.—Map of the Kenai River drainage in south-central Alaska.

mately 5,700 km^2 and has a mean annual flow of 160 m^3/s (Scott 1982). Flows are highest in summer due to glacial meltwater; however, peak discharges from glacier-dammed lakes may occur throughout the year. Changes in stream temperature and discharge are moderated by the presence of two large lakes that are intersected by the main-stem Kenai River.

In recent years, up to 26% of the total statewide fishing effort has occurred in the Kenai River drainage. Much of that effort (annual mean, 473,320 angler-hours) is directed at chinook salmon, resulting in a mean annual harvest of 17,223 fish since 1985. Most chinook salmon are caught by anglers fishing from small outboard-powered boats. Fishing takes place throughout the lower 80 km of the main stem; however, 82% of the chinook salmon fishing effort and 88% of the harvest occurs in a 19-km reach of the lower river where our study was conducted.

Methods

Experimental design and assumptions.—The turbidity of the Kenai River prevents direct observation of study animals. The absence of weirs or similar structures and the remoteness of many spawning areas makes the recovery of marked-and-released fish problematic. We used radiotelemetry to identify and locate individual fish, and determine their fates following release. Thus, the mortality we estimate includes effects of handling and tagging. Although radiotelemetry has been used to study chinook salmon spawning and migratory behavior (Liscom et al. 1978; Gray and Haynes 1979; Burger et al. 1985; Eiler 1990), we are not aware of other studies that have used radiotelemetry to estimate hook-and-release mortality.

Radiotelemetry provided a means of estimating the mortality of fish that were released back into the river after hooking, unlike most hooking mortality studies, in which the study population is confined. Daily records of fish locations and status allowed determination of survival of tagged fish, and methods of survival and analysis (Cox and Oates 1984) accounted for removal of animals from the study (tagged fish could be retaken in the fishery or removed from the population of tagged fish if tag failure or emigration occurred). We estimated mortality during the 5 d following hook and release because up to 95% of salmonid hooking mortality has occurred within 48 h of capture in previous studies (Warner 1979; Mongillo 1984).

Attenuation of radio signals is high in salt water (Stasko and Pincock 1977) and there is some evidence that hooking mortality of salmon is higher in salt water than in freshwater (Parker et al. 1959). Consequently, we limited our tagging to a 4.8-km reach of the lower Kenai River that corresponded to the upper limit of tidal influence but was 5–6 km above salt water. We assumed that all fish had a similar opportunity to acclimate to freshwater before entering the study.

Tagging was carried out in four experiments; two replicates for each run of Kenai River chinook salmon provided four separate estimates of survival and an estimate of annual variability. Separate mortality experiments were conducted during the early runs in 1990 and 1991, and the late runs in 1989 and 1990. We attempted to tag 100 fish in each experiment and to deploy the tags in equal weekly proportions throughout each run.

Major assumptions of this study were (1) there was no tagging or natural mortality, (2) fish did not loose their tags, and (3) tags that were detached for reasons other than hook-and-release mortality or that we failed to locate were a random subset of the total sample.

Radiotelemetry.—We used low-frequency transmitters (48–50 MHz; Advanced Telemetry Systems, Inc., Isanti, Minnesota) that had unique radio frequencies separated by 10 kHz. Transmitters measured approximately 20 × 70 mm and had a 350-mm external wire antenna and a battery life of 85 d. Transmitters operated in one of three modes based on pulse rates: (1) normal, indicated by 1 pulse/s and maintained by intermittent movement of the tag; (2) mortality, indicated by 2 pulses/s and triggered when the tag was motionless for 6 h; or (3) active, indicated by the addition of pulses in the normal mode that resulted from exaggerated or rapid movement of the tag (Eiler 1990).

Transmitters were mounted on the right side of each fish beneath the anterior half of the dorsal fin. Nickle pins (7.6 mm), epoxied to each end of the tags, were inserted through the fish's musculature and securely tied against 2.5-cm plastic Petersen discs.

We located tagged fish daily from a Piper Super Cub (PA-18) aircraft that had a directional loop antenna mounted to the left wing jury strut. Aerial tracking was conducted at approximately 105 km/h and 300 m above the water surface. A programmable receiver scanned for frequencies at 2-s intervals, and the location of each fish was estimated to be under the point of maximum acoustic signal strength. Fish activity was recorded as either normal, active, or nil, depending upon transmitter pulse rates. We continued to locate tagged fish for up to 60 d or until a final fate for each fish could be estimated.

Fish acquisition and processing.—Fish used in our study were caught by recreational anglers. We did not attempt to influence the methods or terminal gears used to capture fish; however, a single-hook artificial lure requirement was in place during the 1990 and 1991 early-run fisheries. Our tagging crew, working from a small boat, started a stopwatch when a fish strike was observed. We subsequently inquired if the angler intended to release the fish and, if so, whether we could equip the fish with a radio transmitter. Fish that were obtained in this manner were played to the angler's boat and placed in a landing net. The leader was cut, and the fish and net were passed to the tagging boat without being removed from the water. Our crew started a second stopwatch to record the handling time, removed the fishing tackle, noted the location(s) of hook wound(s), and transferred the fish to a tagging cradle. Fish were not anesthetized, nor were they removed from the water during capture, transfer, or handling. All fish obtained in this manner were tagged and released regardless of the apparent severity of hooking injuries. Biological and fishery variables were recorded for each angling event (Table 1). When tagging and processing were concluded, the cradle was opened and fish were allowed to swim away.

Determining fates of tagged fish.—Each fish was assigned a 5-d and a final fate (Table 2). Tag recoveries from sport, commercial, and subsistence fisheries, interpretations of daily movements, and radio transmission modes were used to estimate fates. Five-day fates could not be established in some cases until later in the experiment due to the tendency of some fish to mill for extended periods in the lower river. The following three classifications defined fates at the end of 5 d.

(1) Survived—fish that sustained upstream movement, transmitted radio signals in either active or normal modes, or were harvested after the 5-d period.

(2) Died—fish that failed to move upstream from the intertidal area at river kilometer (rkm) 19.3, transmitted radio signals in the mortality mode, or were recovered dead (still tagged) within 5 d of release.

(3) Censored—fish removed from the study due

TABLE 1.—Summary of values for biological and fishery variables recorded during each hook-and-release event in the Kenai River, Alaska, 1989–1991.

Variable	1989 Late run (N = 100)	1990 Early run (N = 125)	1990 Late run (N = 120)	1991 Early run (N = 101)	All runs (N = 446)
Sex					
Male	56	69	89	53	267
Female	44	56	31	48	179
Mean mid-eye length (mm)					
Males	854	904	704	836	819
Females	1,003	936	957	911	948
Guided angler					
Yes		96	66	72	234
No		29	54	29	112
Angling method					
Back-troll	8	125	26	101	260
Drift	92	0	91	0	183
Back-bounce	0	0	3	0	3
Terminal gear					
Bait	0	0	0	0	0
Artificial lure	15	125	23	101	264
Bait and lure	85	0	97	0	182
Hook type					
Single	94	122	106	87	409
Treble	6	3	14	14	37
Number of hooks					
One	1	119	9	81	210
Two	99	6	111	20	236
Hooking location					
Gill, eye, tongue	9	8	1	6	24
Jaw, snag	91	117	119	95	422
Hooks removed					
Yes	97	112	112	93	414
No	3	13	8	8	32
Bleeding					
Yes	11	26	15	18	70
No	89	99	105	83	376
Sea lice					
Yes	79	93	101	84	357
No	21	32	19	17	89
Condition					
Vigorous	91	120	116	100	427
Lethargic	9	5	4	1	19
Mean handling time (min)	17.0	14.8	14.8	14.7	15.3

to factors other than hook-and-release mortality, such as harvest in the recreational fishery, commercial fishery, or two in-river gill-net fisheries; fish that returned to salt water and were not subsequently located; and fish that were never located following release.

The most difficult determination of fate was estimating mortality. Because radio transmitters occasionally provided ambiguous evidence of fish death, we developed the following series of decision rules to help determine fate 2.

(2a) If a carcass was recovered within 5 d, the fish was allocated to hook-and-release mortality.

(2b) If a fish consistently moved upstream at any time during and after the first 5 d, it was considered a survivor (regardless of signal mode).

(2c) If a fish remained immobile, transmitted a mortality signal within 5 d, and continued to transmit in the mortality mode thereafter, the fish was considered a hook-and-release casualty regardless of river kilometer of location.

(2d) If a fish remained immobile in the intertidal area below rkm 19.3 within 5 d of release and remained immobile or moved slowly downstream, the fish was considered a hook-and-release casualty regardless of signal mode.

The first two rules (2a and 2b) are unambiguous; tracking a fish farther and farther upstream was

TABLE 2.—Fates of radio-tracked chinook salmon caught and released in the Kenai River, Alaska, 1989–1991. Small males were less than 750 mm (mid-eye length), and large males were 750 mm or longer.

	Late run 1989			Early run 1990			Late run 1990			Early run 1991			
Fate	Small males	Large males	Females	Small males	Large males	Females	Small males	Large males	Females	Small males	Large males	Females	Total
						First 5 d							
Died[a]	4	3	2	3	2	6	6		1	2		2	31
Survived	17	24	22	14	49	49	55	23	28	12	37	45	375
Gill-net harvest	4	2	8		1		2			1	1	1	20
Sport harvest		2	11			1	1	1	1				17
Dropout[b]							1	1					2
Unknown[c]			1										1
Total	25	31	44	17	52	56	65	25	30	15	38	48	446
						End of season							
Died[d]	4	3	2	4	2	9	6		1	3		3	37
Spawner	11	14	15	12	43	39	34	15	22	8	33	36	282
Gill-net harvest	4	4	10		2		7	4	1	2	1	1	36
Sport harvest	2	8	12		3	6	6	3	3	1	3	1	48
Tag failure							1				1	1	3
Dropout[b]	4	1	2	1	1	1	6	3	1			3	23
Upstream, lost[e]		1	2		1	1	5		2	1		3	16
Unknown			1										1
Total	25	31	44	17	52	56	65	25	30	15	38	48	446

[a] Fish that died within 5 d are classified as hook-and-release mortalities.
[b] Fish that returned to salt water and were not subsequently located.
[c] Tagged fish that we never relocated.
[d] Some fish were classified as dead that died after 5 d but prior to spawning.
[e] Fish that moved upstream and subsequently stopped transmitting a signal.

considered proof of survival. Rules 2c and 2d are necessary because transmitter mortality signals did not provide a clear indication of death. We observed mortality signals even in instances when fish were consistently located farther and farther upstream. Transmitters could also transmit several days of mortality signals while the fish remained immobile, then suddenly resume a normal signal while the fish moved upstream. Transmitters on stationary fish could transmit a mixture of mortality and normal signals. Assumptions that we made in rules 2c and 2d were (1) fish that disappeared from the Kenai River were alive, because a dead fish could not float out to sea; (2) because no spawning occurs in the intertidal area below rkm 19.3, fish observed to be stationary or slowly moving downstream in this area were dead regardless of signal; and (3) fish above rkm 19.3 that were immobile but transmitted normal signals were survivors.

Thus, location became crucial in our decision process. The most important assumption was that there was no spawning below rkm 19.3 (Burger et al. 1985), and a fish that did not migrate upstream of this point was dead.

Survival estimation.—Chinook salmon survival was estimated with the nonparametric Kaplan–Meier procedure (Cox and Oates 1984; Pollock et al. 1989). This procedure computed the percentage of fish dying on each day of the experiment from all fish at risk at the beginning of that day, and it allowed for fish that were lost (censored) due to transmitter failure, harvest, or emigration (Pollock et al. 1989). The variance for the survivor function was estimated with Greenwood's formula (Cox and Oates 1984). The Kaplan–Meier estimator was stratified and a chi-square statistic was computed by the log-rank method (Kalbfleisch and Prentice 1980) to test the hypothesis that the survivor functions did not differ among strata. The influence of biological and fishing variables on hook-and-release mortality was estimated with Cox's proportional hazards regression model (Cox and Oates 1984); the Kaplan–Meier estimator was used as a base hazard.

An assumption of survival analysis is that censorship is a random process. We compared the size distributions of tagged fish that were censored with the distribution of the total released sample by using the Kolmogorov–Smirnov statistic (Conover 1980). The hypothesis of no association between the distribution of explanatory variables and censorship was tested with chi-square statistics (Snedecor and Cochran 1967). A chi-square test of independence was also used to compare the distributions of fates by 2-week periods. All statistical tests were conducted at the 95% significance level.

Results

Retention of chinook salmon in the recreational fishery was prohibited during most of the 1990 and 1991 early runs. In order to achieve optimum early-run escapement goals during these runs, the use of bait was prohibited and terminal gear was limited to single-hook artificial lures only. Consequently, a catch-and-release fishery was in place during these periods of the study. Fishery variables recorded during the study (Table 1) reflect these regulatory changes and account for the disparity in fishing methods and gears between the early- and late-run fisheries.

In total, 446 chinook salmon were caught, tagged, and released during 1989–1991 (Table 2). Tagging each fish required from 2 to 10 min and averaged 4.3 min (SD, 1.5 min). Angling times ranged from 20 s to 1 h and averaged 6.5 min (SD, 6.5 min). We tagged 100 fish during the late run in 1989, 125 fish during the early run in 1990, 120 fish during the late run in 1990, and 101 fish during the early run in 1991. Most (375) of these fish survived for 5 d after release, 31 fish died, and 40 were censored (Table 2).

Only 3 chinook salmon defined as hook-and-release casualties were recovered dead within 5 d of release. The remaining 28 casualties were fish that did not move above the intertidal area (rkm 19.3). About half of the tags on these fish transmitted consistently in the mortality mode; the remainder transmitted intermittent mortality signals.

The majority (282 fish; 63%) of our tagged fish were assigned final fates as spawners, and 84 fish (19%) were ultimately harvested. Thirty-nine fish (9%) either returned to salt water or were lost at some point upstream. One fish's (0.2%) final fate was unknown, three fish (0.7%) had tag failures, and an additional six fish (1.3%) died following the 5-d period but before spawning (Table 2).

Mortality of hooked-and-released fish during our four sampling events ranged from 10.6% during the 1989 late run to 4.1% during the 1991 early run. The average mortality for all experiments was 7.6%. The stratified Kaplan–Meier estimates of survival for these four experiments were not significantly different ($\chi^2 = 4.8$, df = 3, $P = 0.19$). However, the size and sex distributions of fish and censoring patterns differed significantly among the four experiments.

The size distribution of tagged chinook salmon varied among experiments. Females ranged from 590 mm to 1,155 mm (mid-eye length) and averaged 948 mm. Males ranged from 405 mm to 1,210 mm and averaged 819 mm. Few (2%) tagged females were under 750 mm in length because most females mature after spending at least 3 years in the ocean, by which time they are larger than 750 mm. However, the age composition of mature males encompasses younger fish, and 125 (47%) of our tagged males were under 750 mm. The relative proportion of small males varied, constituting up to 54% of the late-run experimental population in 1990.

The rate of censoring was different for the late run in 1989 compared with the other experiments. In 1989, 28 fish (28%) were censored within 5 d of release. Thirteen fish were harvested in the sport fishery and 14 fish were harvested in gill-net fisheries. Most (20) of the censored fish were females, and 11 of these were taken in the sport fishery. This high rate of censoring was not repeated in the 1990 or 1991 experiments, in which only 12 fish were censored (Table 2). To meet the assumption that censoring was random, we stratified our results for the survival analysis by experiment (1989 versus 1990–1991) and by size–sex groups: small males (<750 mm), large males (≥750 mm), and females.

Survival Following Hook-and-Release

Small males had the lowest survival in all experiments. In 1989, females had the highest survival, followed by large males, whereas in 1990–1991, large males consistently had higher survival rates than females. Survival curves (Figure 2) were much steeper for small males, reflecting the higher mortality rates for this group.

The overall survival estimate for 1989 was 0.894 (SE = 0.033). Estimated survival was 0.825 (SE = 0.081) for small males, 0.901 (SE = 0.054) for large males, and 0.935 (SE = 0.044) for females. Survival estimates for the three size–sex groups during 1989 were not significantly different ($P = 0.48$), but the proportion censored was significantly different among the three groups.

The overall survival estimate for the combined 1990–1991 experiments was 0.936 (SE = 0.013). Estimated survival was 0.885 (SE = 0.033) for small males, 0.982 (SE = 0.013) for large males, and 0.932 (SE = 0.022) for females. These esti-

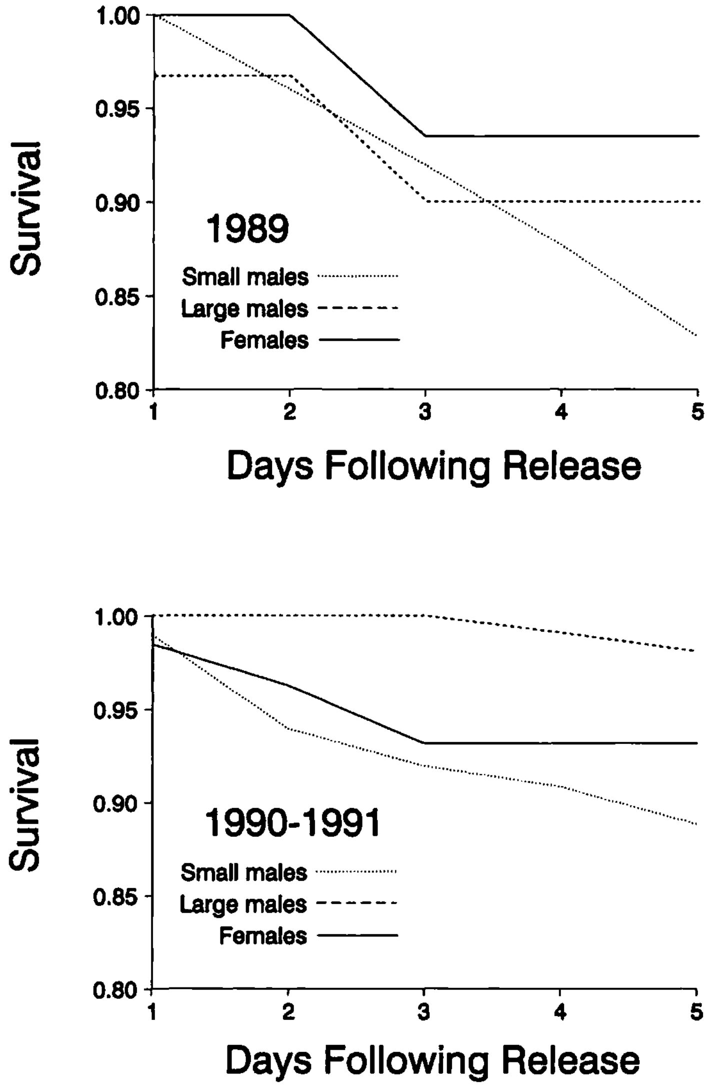

FIGURE 2.—The Kaplan–Meier survival function for chinook salmon by experiment and size–sex group, 1989–1991.

mates of survival by size–sex groups were significantly different. There was little censoring during 1990–1991 and no difference in censoring among size–sex groups.

Thirty-one hook-and-release casualties were detected during the four experiments. Of these, 24 (80%) died on or before the third day following release (Table 3). Hook-and-release mortality was independent of date of release for all of the experiments, and there was no significant association between the rate of censoring and fishery variables. Although two chinook salmon runs enter the Kenai River, and these are managed separately, there was no difference between these runs in their overall rate of hook-and-release mortality.

Variables Affecting Mortality

Hooking location was the most significant factor affecting the survival of released fish. Two proportional hazard models were fit to the data stratified by size–sex groups, one to the 1989 data and the second to the 1990–1991 data. Hooking location was the only explanatory variable that was identified as a significant covariate. Data were stratified by size–sex groups of released fish, and hooking locations were combinated into two

TABLE 3.—Daily numbers of hook-and-release fish at risk[a] and survival estimates for radio-tracked chinook salmon in the Kenai River, Alaska, 1989–1991. Small males were less than 750 mm (mid-eye length), and large males were 750 mm or longer.

Day[b]	Small males		Large males		Females	
	At risk	Survival	At risk	Survival	At risk	Survival
			1989			
1	25	1.000	31	0.968	44	1.000
2	24	0.958	30	0.968	37	1.000
3	23	0.917	29	0.901	31	0.935
4	21	0.873	24	0.901	27	0.935
5	18	0.825	24	0.901	23	0.935
			1990–1991			
1	97	0.990	115	1.000	134	0.985
2	96	0.938	115	1.000	131	0.963
3	90	0.917	112	1.000	128	0.932
4	86	0.907	112	0.991	122	0.932
5	84	0.885	109	0.982	122	0.932

[a] Numbers of fish at risk declined because of both death and data censorship (see Table 2). Fish censored during the first 5 d did not count against survival.

[b] Represents day after release. After day 5, all surviving salmon were censored from the experiment.

groups: vital areas including gills, tongue, or eye; and jaw or snag locations (Table 4). Over the entire 3 years, 24 fish were hooked in vital areas and 11 (46%) of these died (Table 4). The remaining 422 fish were hooked in the jaw or snagged, and of these only 20 (4.7%) died (Table 4). During 1990–1991, bleeding was also found to be significant. In total, 70 fish were bleeding when released and 15 (21.4%) of these died, whereas 16 of 376 fish not bleeding (4.3%) died (Table 4).

The effects of hooking location and bleeding were most pronounced on small males and females (Table 4). The predicted survival for each value of the covariate was estimated, all other covariates being held at their mean values. In the model fit to the 1990–1991 data, a small male hooked in a vital area was predicted to have only a 56.3% chance of survival and a female a 64.2% chance; a large male would still have a 91.6% chance of surviving upon release (Table 5). The predicted values for the model fit to 1989 data were more extreme, but

TABLE 4.—Distribution of explanatory variables by size–sex class and 5-d fates of radio-tracked chinook salmon during 1989–1991. Small males were less than 750 mm (mid-eye length), and large males were 750 mm or longer.

Size–sex group and variable	Numbers of fish (%) by 5-d fate		
	Censored	Died	Survived
	Hooking location		
Small males			
Vital area[a]	1 (11)	4 (44)	4 (44)
Jaw or snag	8 (7)	11 (10)	94 (83)
Large males			
Vital area[a]		1 (20)	4 (80)
Jaw or snag	8 (6)	4 (3)	129 (91)
Females			
Vital area[a]		6 (60)	4 (40)
Jaw or snag	23 (14)	5 (3)	140 (83)
	Bleeding		
Small males			
Not bleeding	9 (9)	8 (8)	83 (83)
Bleeding		7 (32)	15 (68)
Large males			
Not bleeding	7 (5)	3 (2)	119 (92)
Bleeding	1 (6)	2 (12)	14 (82)
Females			
Not bleeding	23 (16)	5 (3)	119 (81)
Bleeding		6 (19)	25 (81)

[a] Vital area includes gills, tongue, and eye.

TABLE 5.—Comparison of observed 5-d survival probabilities to those predicted with Cox's proportional hazard model (Cox and Oates 1984). Small males were less than 750 mm (mid-eye length), and large males were 750 mm or longer.

Year and fish status	Probability of survival		
	Small males	Large males	Females
	Observed		
1989	0.825	0.901	0.935
1990–1991	0.885	0.982	0.932
	Predicted		
1989			
Hooked in jaw or snagged	0.876	0.920	0.970
Hooked in gills, eye, or tongue	0.005	0.034	0.316
1990–1991			
Hooked in jaw or snagged	0.931	0.989	0.946
Hooked in gills, eye, or tongue	0.563	0.916	0.642
Not bleeding	0.942	0.991	0.955
Bleeding	0.794	0.966	0.837

sample sizes were much smaller ($N = 101$) compared with the 1990–1991 combined data set ($N = 346$).

Discussion

Assumptions of the Study

We assumed that fish did not loose their tags in our study. Only three transmitters were not relocated daily during the first 5 d after release. No fish were found in any fishery with tagging scars, and there were no loose tags reported or turned in. We also assumed that there was no mortality resulting from the tagging procedure. We felt that tagging mortality was unlikely due to the brief handling time and low overall mortality estimates. Our data were stratified in order to satisfy the assumption that censorship was a random process. There were no indications that removal in any fishery or movement out of the river within the first 5 d was associated with any of the variables we measured or the time of tagging.

Estimates of Mortality

Our estimates of mortality for chinook salmon that were caught and released in the Kenai River are low, ranging from 4.1 to 10.6% and averaging 7.6% over four experiments. It is likely that these estimates are conservative, because they include effects from handling and radio-tagging. Also, 66 radio-tagged fish were caught again in the recreational fishery, and some of these fish were released again. Thus it is possible that tagged fish were subject to additional hook-and-release events not reported to us. Our estimates are lower than mortality rates in sport fisheries for many other species caught with bait (Wydoski 1980; Mongillo 1984), and they are considerably lower than estimates for troll-caught chinook salmon in marine fisheries. Parker and Black (1959) estimated a mortality rate of 71% (all sizes of chinook salmon) and Wertheimer (1988) estimated rates of 24.5% for small chinook salmon and 20.5% for large chinook salmon that were caught in marine troll fisheries.

Although our four experiments differed in several aspects, including the size and sex distributions of tagged fish, the rate and pattern of censoring, and the distribution of fishery variables, the final conclusion on the survival of fish that were hooked and released is the same for all experiments. Fish length, hooking locations, and bleeding were the only variables that affected mortality in our study. There were consistent differences in mortality among size–sex groups for all four experiments. Hooking mortality was highest for small males and ranged from 9.2 to 17.6%. For large males, estimates ranged from 0 to 9.7%; for females the range was 3.3–10.7%. The observed relationship between size and mortality was consistent with findings in previous studies of chinook salmon (Wertheimer 1988) and lake trout *Salvelinus namaycush* (Loftus et al. 1988).

Effects of Fishery Variables

Numerous studies have focused on the relationship between anatomical hook locations and subsequent mortality (Wydoski 1980; Mongillo 1984). Bleeding has also been associated with decreased survival of hooked fish (Warner and Johnson 1978; Nuhfer and Alexander 1992). A Kenai River chinook salmon that was hooked in a vital location (gills, eye, or tongue) had a significantly reduced chance of surviving compared with one that was snagged or hooked in the jaw. Fish that were bleeding also suffered increased mortality. However, the frequency of chinook salmon that were hooked in vital areas (5.4%) or bleeding (18.6%) was small in our study. Hence, the overall effect of these factors was minimal. We found no significant difference in mortality rate between fish caught with bait or with artificial lures, even though all of our early-run fish were caught on lures and most (83%) late-run fish were caught on baited hooks. Thus, chinook salmon caught in the Kenai River by backtrolling or drifting in small boats are apparently hooked superficially regardless of the terminal tackle that is used.

Most (80%) of the hooking-related deaths in our study occurred on or before the third day following release, suggesting that mortally wounded chinook salmon succumb quickly. We found no evidence for delayed mortality of our tagged fish. Most of our tagged fish could be accounted for in a fishery or on the spawning grounds up to 45 d following release.

Management Implications

Our findings suggest that fishing mortality for Kenai River chinook salmon can be reduced by over 90% by implementing catch-and-release regulations. However, the findings also suggest that these low mortality rates depend upon the characteristics of the fishery and to some extent on the large size of Kenai River chinook salmon. Nearly all chinook salmon fishing in the Kenai River is conducted from boats, and regulations prohibit an angler from removing a fish from the water if it is intended to be released. These factors must be considered before our results are applied to other stocks of salmon in freshwater fisheries.

Increased pressures on declining stocks have resulted in catch-and-release regulations for selected fisheries in most states and provinces across North America (Barnhart 1989). Catch-and-release regulations for the Kenai River have been successfully used to achieve escapement goals by reducing fishing mortality without restricting angling opportunity. Nevertheless, angler participation on the Kenai River declined precipitously in 1990 and 1991 following the implementation of catch-and-release regulations for the early-run fishery. Strong chinook salmon returns in adjacent Cook Inlet drainages contributed to the decline in Kenai River effort, but it is more likely that anglers who fish for food have been slow to embrace catch-and-release regulations for salmon fisheries.

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