Fishery Data Series No. 13-16

Stock Assessment of Rainbow Trout in the Upper Kenai River, Alaska, 2009

by

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and

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April 2013

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$log_{2,}$ etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY DATA SERIES NO. 13-16

STOCK ASSESSMENT OF RAINBOW TROUT IN THE UPPER KENAI RIVER, ALASKA, 2009

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ABSTRACT

A multiple event mark–recapture study was conducted on rainbow trout (*Oncorhynchus mykiss*) in the upper Kenai River in 2009. The objectives of this study were to estimate the abundance and fork length (FL) composition of rainbow trout in the most heavily fished section of the upper Kenai River (river miles 69.6–73.2), and to compare these estimates to those from previous surveys conducted in 1986, 1987, 1995, and 2001 on the same stretch of river. Estimated abundance of rainbow trout at least 200 mm FL in the study area was 5,916 (SE 481) fish. The estimate included 5,106 (SE 354) rainbow trout at least 300 mm FL. The abundance estimate of fish at least 200 mm FL was 30% lower in 2009 than in 2001. The number of fish less than 450 mm FL was 45% less than that observed in 2001. Abundance of fish at least 300 mm FL was significantly larger than estimates from 1986 and 1987, but not significantly different from estimates in 1995 and 2001.

Key words: rainbow trout, *Oncorhynchus mykiss*, abundance, MARK, RMark, Huggins models, fork length, Kenai River, mark–recapture

INTRODUCTION

The Kenai River drainage (Figure 1) is the most heavily utilized system for freshwater sport fishing in Alaska. Although many anglers participate in Kenai River salmon fisheries, the drainage also supports a major rainbow trout (*Oncorhynchus mykiss*) fishery. Annual catch of rainbow trout has increased steadily since 1986 (Table 1). The Alaska Department of Fish and Game (ADF&G) statewide harvest survey estimated the average annual rainbow trout catch (2004–2008) to exceed 150,000 fish with the most recent estimate (2008) exceeding 200,000 fish (Jennings et al. 2010b; Table 1).

Participation and catch in the rainbow trout fishery is highest in the river section between Kenai Lake and Skilak Lake (henceforth referred to as the upper Kenai River). Fishing regulations governing the upper Kenai River have a long history and have become more conservative, allowing no harvest (catch-and-release only) from 1997 to 2004 (Table 2). However, in 2005 the Alaska Board of Fisheries liberalized the upper Kenai River rainbow trout sport fishery, allowing harvest of one rainbow trout less than 16 inches daily with no annual limit for individual anglers (Alaska Administrative Code 5AAC 57.120 [6] [c]). Annual catch and harvest estimates of rainbow trout in the upper Kenai River have steadily increased since then; harvest increased from 267 fish in 2005 to 941 fish in 2008 and catch increased from 57,936 to 103,095 fish during the same period (Table 1).

The area of the upper Kenai River between the Sportsman's Landing boat launch at river mile (RM) 73.7 and Jim's Landing (RM 69.6) (Figure 2) is highly popular with anglers due to ease of access and fishing success. Midsummer abundance of rainbow trout in this area (hereafter referred to as the "index area") was estimated in 1986, 1987, 1995, and 2001 as an index of abundance for the entire upper Kenai River rainbow trout population.

The rainbow trout population in the index area was evaluated for the first time in 1986 and 1987 (Lafferty 1989) as one element of a larger assessment of Kenai River rainbow trout population dynamics for a Master's thesis. Hook-and-line techniques and a mark–recapture estimator were used in 1986, whereas boat electrofishing techniques were employed in 1987. Abundance of rainbow trout at least 200 mm fork length (FL) in the index area was estimated to be 3,640 fish (SE 456) in 1986 and 4,950 fish (SE 376) in 1987 (Lafferty 1989). A companion creel survey estimated the exploitation rate to be low and found that catch-and-release angling for rainbow trout was a common practice in that area. The 1986–1987 fishing season was considerably shorter than in previous years (1977–1983), but the harvest of fish 20 inches or greater was still allowed (Table 2). Following increasingly restrictive regulations at intervals of every 2–3 years, Hayes and Hasbrouck (1996) estimated the 1995 abundance of rainbow trout at least 300 mm FL in the index area to be 5,598 fish (SE 735) using hook-and-line techniques for fish capture. The authors also reanalyzed the data from 1986 and 1987 (Lafferty 1989) to generate estimates of abundance of rainbow trout at least 300 mm FL during those years. The estimates of rainbow trout at least 300 mm FL were 2,520 fish (SE 363) in 1986 and 3,472 fish (SE 482) in 1987. Estimated population abundance in 1995 had increased since 1987 and had a more uniform distribution of fish among size classes, with a greater proportion of fish in the 450–550 mm size class than in 1987.

Using hook-and-line techniques as well, King and Breakfield (2007) estimated the 2001 abundance of rainbow trout at least 300 mm FL in the index area was 6,167 fish (SE 625). This estimate represented a 10% increase in this size class from 1995 and a 144% and 77% increase from 1986 and 1987, respectively ($P \approx 0$ for both comparisons). King and Breakfield (2007) also estimated the 2001 abundance of rainbow trout at least 200 mm FL in the index area was 8,553 fish (SE 806). This estimate was 73% larger for this size class than that of 1987, and statistically significant ($P \approx 0$). Abundance of rainbow trout between 200 mm and 299 mm FL was not assessed in 1995.

Despite the consistent increase in population estimates from 1986 to 2001, several indicators warranted another assessment of upper Kenai River rainbow trout. First, assuming catch-and-release mortality rates remained constant, rainbow trout mortality resulting from catch-and-release fishing has almost certainly increased to an all-time high. Second, regulation changes instituted in 2002 shortened the spawning closure period from 15 April through 14 June in 1998 to the current closure period from 2 May through 10 June (5AAC 57.120 [6] [c]). Third, in recent years, counts of spawning rainbow trout have decreased during ADF&G stream surveys on the Russian River, where there is an important spawning aggregate for rainbow trout in the Kenai River watershed (Palmer 1998). Lastly, harvest of rainbow trout has steadily increased to nearly 1,000 fish since the regulation allowing harvest of upper Kenai River rainbow trout less than 16 inches total length (TL) was implemented in 2005 (5AAC 57.120 [6] [c]).

Previous studies on upper Kenai River rainbow trout showed that rainbow trout migration from overwintering locations to summer feeding areas was essentially complete by the end of June; this provides a window of time where emigration and immigration in the study area is small, ideal for mark–recapture experiments (Hayes and Hasbrouck 1996; Lafferty 1989; Palmer 1998). ADF&G also determined by examination of the spawning population in the years 1999–2001 (unpublished data) that spawning was essentially over by the end of June.

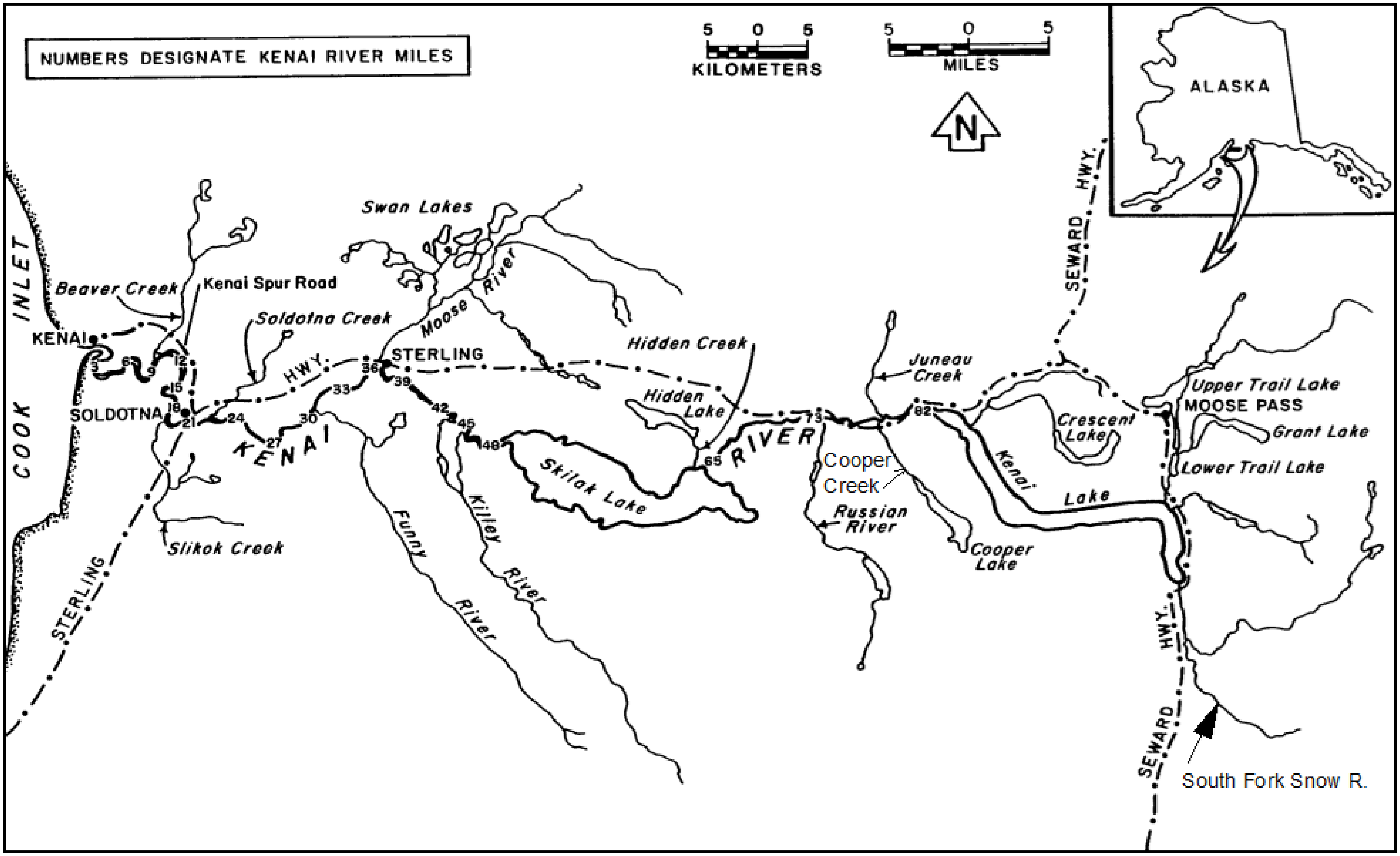

Figure 1.–Map of the Kenai River drainage.

Table 1.–Number of Kenai River rainbow trout caught and harvested by river section as estimated by Statewide Harvest Survey, 1984–2008.

	Cook Inlet to Soldotna Bridge			Soldotna Bridge to Moose River			Moose River to Skilak Outlet			Skilak Inlet to Kenai Lake			Kenai River total[a]		
		Harvested			Harvested			Harvested			Harvested[c]			Harvested	
Year	Caught[b]	No.	(%)	Caught[a]	No.	(%)	Caught[b]	No.	(%)	Caught[b]	No.	(%)	Caught[b]	No.	(%)
1984[d]	3,464	710	20.5	2,911	1,250	42.9	5,112	580	11.3	4,200	930	22.1	15,687	3,470	22.1
1985[d]	3,398	880	25.9	2,653	850	32.0	5,410	1,500	27.7	3,520	710	20.2	14,981	3,940	26.3
1986	2,570	623	24.2	2,380	168	7.1	1,750	901	51.5	2,020	733	36.3	8,720	2,425	27.8
1987	2,220	522	23.5	3,450	670	19.4	6,430	629	9.8	3,870	364	9.4	15,970	2,185	13.7
1988	2,780	295	10.6	1,560	216	13.8	5,880	1,063	18.1	7,580	559	7.4	17,800	2,133	12.0
1989	2,020	481	23.8	2,230	354	15.9	6,470	829	12.8	6,870	253	3.7	17,590	1,917	10.9
1990	2,624	510	19.4	3,571	943	26.4	5,366	937	17.5	11,995	1,145	9.5	23,556	3,535	15.0
1991	3,672	516	14.1	3,844	1,123	29.2	7,930	940	11.9	18,108	740	4.1	33,554	3,319	9.9
1992	4,448	427	9.6	3,879	411	10.6	15,127	736	4.9	28,702	403	1.4	52,156	1,977	3.8
1993	6,190	1,149	18.6	5,556	580	10.4	12,651	653	5.2	37,755	192	0.5	62,152	2,574	4.1
1994	3,796	506	13.3	3,980	364	9.1	10,968	543	5.0	35,089	163	0.5	53,833	1,576	2.9
1995	4,516	620	13.7	4,087	440	10.8	13,072	780	6.0	33,475	310	0.9	55,150	2,150	3.9
1996	5,513	304	5.5	4,777	646	13.5	8,650	373	4.3	45,471	237	0.5	64,411	1,560	2.4
1997	7,411	739	10.0	6,641	539	8.1	20,047	632	3.2	61,053	0	0.0	95,152	1,910	2.0
1998	5,502	608	11.1	5,380	670	12.5	12,158	737	6.1	42,224	0	0.0	65,264	2,015	3.1
1999	11,415	1,516	13.3	8,325	695	8.3	32,050	1,573	4.9	50,189	0	0.0	101,979	3,784	3.7
2000	16,477	1,292	7.8	9,428	1,083	11.5	18,990	1,084	5.7	78,836	0	0.0	123,731	3,459	2.8
2001	11,216	987	8.8	7,473	868	11.6	22,392	567	2.5	51,130	0	0.0	92,211	2,422	2.6
2002	12,641	995	7.9	8,157	944	11.6	19,355	864	4.5	71,753	0	0.0	114,175	3,019	2.6
2003	12,844	1,026	8.0	10,913	700	6.4	41,204	372	0.9	54,552	0	0.0	123,049	2,278	1.9
2004	15,080	1,452	9.6	13,310	978	7.3	34,026	831	2.4	91,443	0	0.0	159,510	3,311	2.1
2005	14,119	953	6.7	11,585	647	5.6	34,675	607	1.8	57,936	267	0.5	126,264	2,517	2.0
2006	13,168	588	4.5	13,683	1,109	8.1	33,222	472	1.4	67,741	289	0.4	131,819	2,499	1.9
2007	11,829	542	4.6	18,832	769	4.1	52,701	684	1.3	90,757	661	0.7	178,970	2,666	1.5
2008	26,364	695	2.6	20,943	794	3.8	47,956	772	1.6	103,095	941	0.9	202,854	3,213	1.6
Average															
1984–2008	8,210	760	10.0	7,180	710	10.0	18,940	790	10.0	42,370	360	0.0	78,020	2,630	10.0
1999–2008	14,515	1,005	7.4	12,265	859	7.8	33,657	783	2.7	71,743	216	0.3	135,456	2,917	2.3
2004–2008	16,112	846	5.6	15,671	859	5.8	40,516	673	1.7	82,194	432	0.5	159,883	2,841	1.8

Source: Statewide Harvest Survey (Mills 1985-1994; Howe et al. 1995, 1996, 2001a-d; Walker et al. 2003; Jennings et al. 2004, 2006a-b, 2007, 2009a-b, 2010a-b)

[a] Numbers by section may not sum to total for 2002–2008. These years include catch and harvest estimates that include unspecified reaches.

[b] Catch estimates for 1984–1989 are unpublished estimates from the Statewide Harvest Survey (M. Mills, ADF&G, Division of Sport Fish, Research and Technical Services, Anchorage).

[c] Retention of rainbow trout was prohibited from 1997 through 2004.

[d] In 1984 and 1985, catch estimates were mistakenly reported as harvest in Mills 1985 and 1986. Numbers for harvest presented here are correct.

Table 2.–Regulation summary for the upper Kenai River rainbow trout fishery, 1977–2009.

Year	Open season	Bag limit		Gear restrictions
		Daily	Seasonal	
1977	Entire year	10; Only 2 > 20 inches	No limit	None
1978	Entire year	**10; Only 1 ≥ 20 inches**	No limit	None
1979	Entire year	10; Only 1 ≥ 20 inches	**2 ≥ 20 inches**	None
1980–1981	Entire year	10; Only 1 ≥ 20 inches	**5 ≥ 20 inches**	**Artifical lures (1 January–31 May)**
1982	**15 June–31 December**	**5; Only 1 ≥ 20 inches**	5 ≥ 20 inches	**None**
1983	15 June–31 December	5; Only 1 ≥ 20 inches	**2 ≥ 20 inches**	None
1984–1986	**15 June–31 October**	**3; Only 1 ≥ 20 inches**	2 ≥ 20 inches	**Artificial lures only**
1987–1988	15 June–31 October	**2; Only 1 ≥ 20 inches**	2 ≥ 20 inches	Artificial lures only
1989–1990	15 June–31 October	**1**; Must be ≥ 20 inches	2 ≥ 20 inches	**Single hook, artificial lures only**
1991–1992	15 June–31 October	**1; Must be ≥ 24 inches**	**2 ≥ 24 inches**	Single hook, artificial lures only
1993–1996	15 June–31 October	**1; Must be ≥ 30 inches**	**2 ≥ 30 inches**	Single hook, artificial lures only
1997–1998	**15 June–14 April**	**No retention**	**No retention**	Single hook, artificial lures only
1999–2001	**11 June–14 April**	No retention	No retention	Single hook, artificial lures only
2002–2004	**11 June–1 May**	No retention	No retention	Single hook, artificial lures only
2005–2009	11 June–1 May	**1; Must be < 16 inches**	**No limit**	Single hook, artificial lures only

Note: Bold print represents a new or altered regulation from the previous year. Additional restrictions are as follows: 1) 1997–1999, fishing closure between Kenai Lake and Sterling Highway mile 53 bridge, 1 January–14 June; 2) 2000–2004, fishing closure between Kenai Lake and Sterling Highway mile 53 bridge, 31 December–11 June; 3) 1999–2001, attractors must be free sliding on leader; 3) 2002–2009, attractors must be free sliding on leader or fixed on leader within 2 inches of hook.

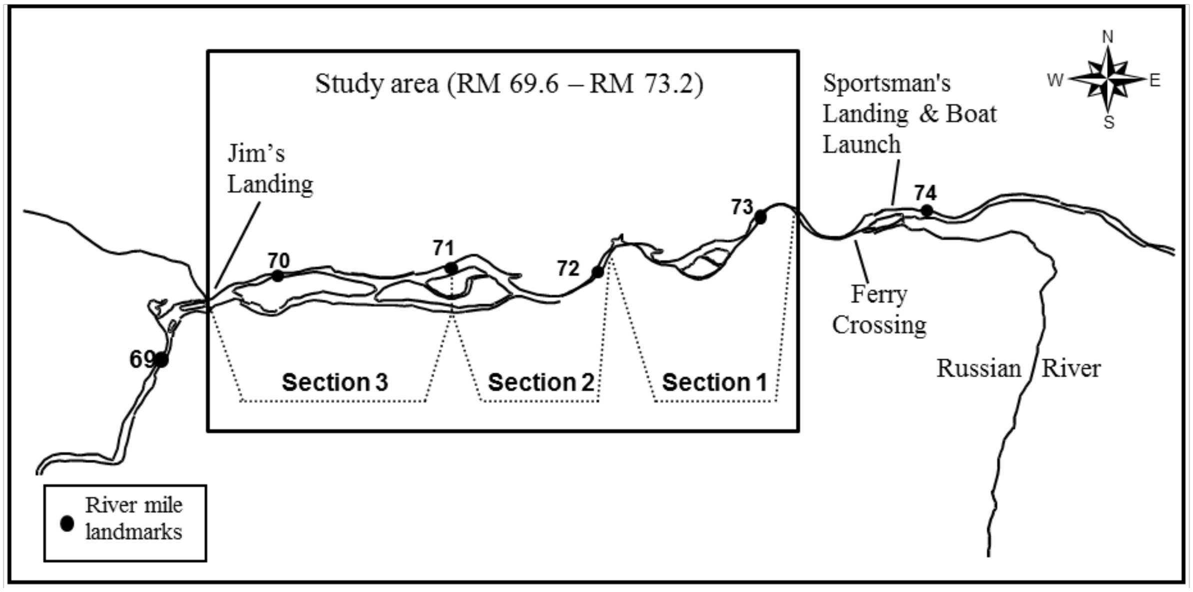

Figure 2.–Study area of the upper Kenai River, Alaska.

OBJECTIVES

The 2009 study was conducted to update the stock assessment of upper Kenai River rainbow trout and to evaluate the efficacy of the current management strategy. Results were compared to past surveys. The study objectives were as follows:

1) Estimate the abundance of rainbow trout at least 200 mm FL in the upper Kenai River between RM 73.2 ("Highway Hole") and RM 69.6 ("Jim's Landing") from 30 June through 30 July 2009.
2) Estimate the length composition of rainbow trout at least 200 mm FL in the upper Kenai River between RM 73.2 and RM 69.6 from 30 June through 30 July 2009.

In addition, the study had the following tasks:

1) Estimate the abundance of rainbow trout between 200 mm and 400 mm FL in the upper Kenai River from RM 73.2 to RM 69.6. Current regulations allow harvest of 1 rainbow trout less than 16 inches (~400 mm) per day, so this estimate determines the proportion of the population that is susceptible to harvest.
2) Estimate the abundance of rainbow trout at least 300 mm FL in the upper Kenai River between RM 73.2 and RM 69.6. This estimate is comparable to past surveys that have estimated the abundance of rainbow trout at least 300 mm FL.
3) Examine all captured rainbow trout for external scars or deformities, especially those on the head that may indicate previous hooking injuries.
4) Examine all captured rainbow trout for external parasites.

METHODS

Rainbow trout were captured in the upper Kenai River between RM 73.2 (“Highway Hole”) and RM 69.7 (“Jim’s Landing”) from 30 June through 30 July 2009. Two 3–5 person crews working from drift boats captured fish using hook-and-line gear and bait. Sampling was conducted three consecutive days per week, approximately eight hours per day for five weeks with each week representing a separate capture event. The study area was divided into three geographic sections (Figure 2): 1) RM 73.2–RM 72.1 (“Highway Hole” to and including “Windy Point”), 2) RM 72.1–RM 71.0 (downstream of “Windy Point” to and including “Whirlpool Hole”), and 3) RM 71.0–RM 69.6 (downstream of “Whirlpool Hole” to “Jim’s Landing”). Geographic sections from previous rainbow trout surveys (1986–1987, 1995, 2001) were used, although there were slight differences in the boundaries of all four surveys. Each geographic section received fishing time approximately proportional to length.

Upon capture, each fish was guided into a landing net, the hook was removed, and the fish was transferred to and restrained in a tagging cradle (Larson 1995) within a tote of river water, and fork length was measured. Rainbow trout at least 200 mm FL were marked (tagged) with individually numbered Floy[1] T-Anchor tags, inserted on the left side between the basal rays of the dorsal fin. In addition, the adipose fin was excised on all tagged fish as a secondary mark to assess tag loss. Tagged fish were released immediately and in close proximity to their location of capture. Fish were monitored upon release to ensure they had gained enough mobility to swim away. If a fish did not recover from tagging, was bleeding from the gills, or otherwise deemed unlikely to survive, the marked fish was released and the tag number was censored (removed from analysis) from the dataset.

Capture and recapture data were recorded on handheld computers. The tag number, location (fishing hole), geographic section, fork length, sex, presence of copepod parasites, color, and any suspected previous hooking injuries (i.e., mouth or eye damage) were recorded for all captured rainbow trout. Time spent fishing in each geographic section was recorded by the computer and monitored to distribute fishing effort approximately proportional to area.

ABUNDANCE

A mark–recapture model was used to estimate abundance. The sampling goal was based on an assumed abundance of 8,500 fish at least 200 mm FL within the study area (King and Breakfield 2007). The simulation module from Program MARK (White and Burnham 1999) was used to determine the sample size needed; true and estimation models were set as Schnabel models. Sample size was determined to be 210 rainbow trout per week to estimate abundance within 25% of the true value 95% of the time. The study was originally planned for six weeks. Inseason analyses showed objective criteria would likely be met after the fifth week of sampling and consequently the study was ended.

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[1] Product names used in this publication are included for completeness but do not constitute product endorsement.

The assumptions necessary to estimate abundance with a Schnabel closed population model (Seber 1982) are as follows:

1) The population was closed with no additions or losses among capture events (no recruitment, death, immigration, or emigration).
2) All fish had an equal capture probability within all capture events or marked fish mixed completely with unmarked fish after marking.
3) Marking did not affect capture probability in subsequent capture events.
4) Marks (tags) were not lost between events.
5) All marked fish recaptured during subsequent capture events were correctly identified and recorded.

Several measures were taken to minimize violation of the assumption of closure (assumption 1). Sampling was conducted when the rainbow trout population had stabilized to feed for the summer. Natural mortality was assumed to be low during the summer and within the study period. By regulation, rainbow trout less than 16 inches could be harvested but it was assumed that marked and unmarked fish would be captured and harvested in similar proportions, mitigating the effects of harvest on the abundance estimate. The closure test of Otis et al. (1978) and of Stanley and Burnham (1999) was not used because fishing mortality during the study could create misleading results. Catch-and-release mortality and emigration from the study area may have occurred but it was also assumed that both would affect the marked and unmarked portion of the population equally. However, immigration of unmarked fish into the study area would bias estimates of abundance. If the marked proportion remained stable or declined over sampling periods, this would signify immigration had occurred. Movement of marked fish within the study area was monitored. Large-scale movements within the study area would indicate that immigration and or emigration likely occurred.

The assumption of equal probability of capture or mixing among locations (a component of assumption 2) was tested by examining the recapture rate of fish tagged among the three locations (3 × 2 chi-square test: location versus recaptured or not recaptured). If the probability of capture among locations was constant or if fish mixed, then the recapture rates among locations should not vary. Mixing of fish among locations was also tested by a 3 × 3 chi-square test (location versus location).

Huggins models (Amstrup et al. 2005) allow the incorporation of a length selectivity effect directly into an abundance estimation model, thereby negating the need for length stratification. The models can also accommodate different length selectivity among events, if necessary. In this study, Huggins models were fitted through Program MARK, and the Akaike's information criterion (AIC; e.g., Burnham and Anderson 2002) was used for model selection. Differences in size selectivity among time intervals were tested using an Anderson-Darling test (Conover 1980), and by visual examination of cumulative length probability plots over events. River discharge observations were also used to determine when length selectivity may have likely changed due to differing fishing conditions. Also, a chi-square test was used to test the assumption of equal probability of recapture among length categories.

Captured fish were carefully handled and marked to minimize these effects on the probability of capture in subsequent periods (assumption 3). It was assumed that marked fish would not become "gear shy" after marking; this phenomenon was tested by including a behavior effect in the suite of models used in the MARK analysis. The adipose fin was clipped as a secondary mark to assess tag loss (assumption 4). Finally, tag numbers were carefully read and recorded to maximize detection of marked fish (assumption 5).

After evaluation of the assumptions, rainbow trout abundance was estimated with Program MARK. The best estimator in MARK was selected based on comparing the AIC of a suite of models that allowed 1) probability of capture to change over time, 2) behavior effects, 3) length selectivity that may or may not change over time, and d) Pledger models, which allow different probability of capture among subpopulations; only 2 subpopulations were considered (Pledger 2000). Models that assumed constant probability of capture among grouped subsets of contiguous events were also investigated.

LENGTH COMPOSITION

The proportion of rainbow trout in length class *j* and its variance were estimated as a binomial proportion (Cochran 1977):

$$\hat{p}_j = \frac{n_j}{n}, \tag{1}$$

and

$$\text{var}(\hat{p}_j) = \frac{\hat{p}_j(1-\hat{p}_j)}{n-1}, \tag{2}$$

where

n_j = the number of rainbow trout $\geq$200 mm of length class *j*, and

n = the total number of rainbow trout $\geq$200 mm measured for length.

The abundance of rainbow trout by length class was estimated as a product of 2 random variables:

$$\hat{N}_j = \hat{N}\,\hat{p}_j, \tag{3}$$

and its variance was estimated as follows (Goodman 1960):

$$\text{var}(\hat{N}_j) = \hat{N}^2\,\text{var}(\hat{p}_j) + \hat{p}_j^{\,2}\,\text{var}(\hat{N}) - \text{var}(\hat{p}_j)\,\text{var}(\hat{N}). \tag{4}$$

When a length-based model (Huggins model with length covariate) was chosen for abundance estimation, estimated length composition was adjusted to account for the implied length selectivity. The proportion of the population in length category *j* for event *i* was calculated after weighting each sampled length by the inverse of its estimated probability of capture:

$$\hat{p}_{ij} = \frac{\sum_{k=1}^{n_i} \frac{1}{\hat{c}_{ik}} I(j)}{\sum_{k=1}^{n_i} \frac{1}{\hat{c}_{ik}}}, \tag{5}$$

where

c_{ik} = probability of capture of the k^{th} fish in the sample from event i and

$I(j)$ = an indicator function, where $I(j)$ = 1 for fish falling in j^{th} length category and where $I(j)$ = 0 otherwise.

The estimated probability of capture, $\hat{c}_{ik}$, was back-calculated from the fitted logit model that described effects of length and time on probability of capture (see Appendix A1). The $\hat{p}_{ij}$ were then combined over events as follows:

$$\hat{p}_j = \sum_{i=1}^{5} w_i \hat{p}_{ij} , \tag{6}$$

where w_i is the proportion of the total sample taken in event i (5 events total). It is noted that these weights were very similar over events for the 2009 study.

The standard error of the adjusted $\hat{p}_j$ was estimated through simulation. The RMark software package was used to conduct the simulation. RMark is an extension to Program MARK that allows fitting of the models available in MARK within the framework of the programming language R. This arrangement allows tailored simulations, such as required in this case. Essentially, M bootstrap capture histories were selected and for each, the model originally chosen in MARK was fitted in RMark. The above adjusted length compositions were then calculated for each bootstrap realization. The standard error of the length composition for category j was then calculated as follows:

$$\mathrm{var}(\hat{p}_j) = \frac{\sum_{l=1}^{M} (\hat{p}_{jl} - \overline{\hat{p}}_j)^2}{M-1} , \tag{7}$$

where $\hat{p}_{jl}$ denotes the length composition for the l^{th} bootstrap realization.

The RMark code used to estimate fish-specific probabilities of capture is presented in Appendix A1.

HOOKING INJURIES

All rainbow trout captured during this study were examined for external scars or deformities, especially damage around the head that may be related to previous hooking injuries (e.g., missing maxilla, missing or damaged eye). Only previous hooking injuries were recorded.

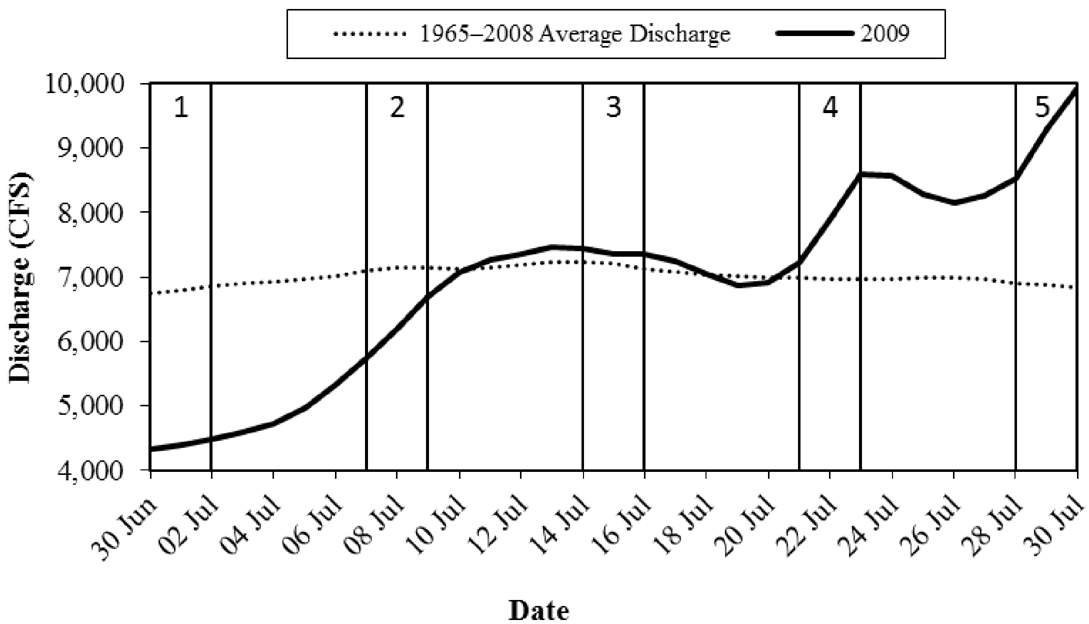
PARASITES

All rainbow trout captured during this study were examined for the presence of parasitic copepods of the genus *Salmincola*, most often found attached to gill filaments, opercula, tissues within the mouth cavity, and on fins.

RESULTS

FISH CAPTURE

Two crews with up to five anglers each captured and sampled rainbow trout for three consecutive days per week (event). A minimum of 264 rainbow trout were captured during each event, which was more than adequate to satisfy the predetermined sample size goal of 210 fish per event. River discharge (measured at the U.S. Geological Survey gauging station at Cooper Landing) varied widely during the five-week study from approximately 40% below mean historical discharge during the first event, to near average by the third event, and up to 35% above average by the final (fifth) event (Figure 3). The number of fish captured was nearly equal for each of the first three events (mean = 330 fish) when river discharge was average to below average. The number of captures then declined during each of the final two events (mean = 271 fish) when river discharge was abnormally high.



Note: Numbered vertical boxes correspond to weekly capture events. Discharge measured in cubic feet per second (CFS).

Figure 3.–Kenai River discharge at Cooper Landing, 30 June–30 July 2009.

A total of 1,533 rainbow trout at least 200 mm FL were captured. Tags were applied to 1,373 fish; additionally, 160 previously marked fish (recaptures) were captured (Table 3). Among the recaptures, 148 fish were recaptured once and 6 were recaptured twice. No fish were recaptured in more than 2 different capture events. Section 1 had the most captures (582, 38%) followed by section 3 (511, 33%) and section 2 (440, 29%) (Table 4). The proportion recaptured by river section was similar, varying from 0.098 in section 3 to 0.108 in section 1.

Table 3.–Capture history of upper Kenai River rainbow trout at least 200 mm FL, 30 June–30 July 2009.

	Event[a]					
Statistic	1	2	3	4	5	Total
Captured	324	332	335	278	264	1,533
New tags	324	311	296	238	204	1,373
Recaptures[b]	0	21	39	40	60	160
At large	0	324	635	931	1,169	1,373
Recaptures / Captures		0.063	0.116	0.144	0.227	
Recaptures / At Large		0.065	0.061	0.043	0.051	

[a] Dates sampled during event: 1 = 30 June and 1–2 July; 2 = 7–9 July; 3 = 14–16 July; 4 = 21–23 July; 5 = 28–30 July.

Table 4.–Number and proportion of rainbow trout at least 200 mm FL tagged and recaptured by river section in the upper Kenai River index area, 30 June–30 July 2009.

River section[a]	New tags	Recaptures	Total	Proportion recaptured	Proportion of all recaptures	Proportion of all captures
1	519	63	582	0.108	0.394	0.380
2	393	47	440	0.107	0.294	0.287
3	461	50	511	0.098	0.313	0.333
Total	1,373	160	1,533	0.104		

[a] Section 1 = RM 72.1–73.2; Section 2 = RM 71.0–72.1; Section 3 = RM 69.6–71.0.

TEST OF ASSUMPTIONS

The proportion of fish carrying a mark increased linearly with each event (R^2 = 94%, $P < 0.05$) (Table 3; Figure 4), supporting the assumption that the population was closed during the study. The proportion of recaptures that occurred outside the original capture section was considerable: 0.17, 0.19, and 0.28, respectively for sections 1–3 (Table 5). In total, 21% of recaptures were of fish outside of the section in which they were tagged (Table 5). Due to this movement within the study area, some movement outside of the study area was considered plausible. To further investigate movement outside of the study area, crews sampled a 3-mile stretch of river upstream of the study area for an additional day in event 4. A total of 37 fish were sampled including one tagged fish. The fish was tagged at the upstream boundary of the study area and recaptured approximately 1 RM above the study area. We were not able to investigate downstream movement out of the study area because of near flood stage water levels that occurred during the final two events, leading to safety concerns regarding traveling and sampling within the Kenai River canyon.

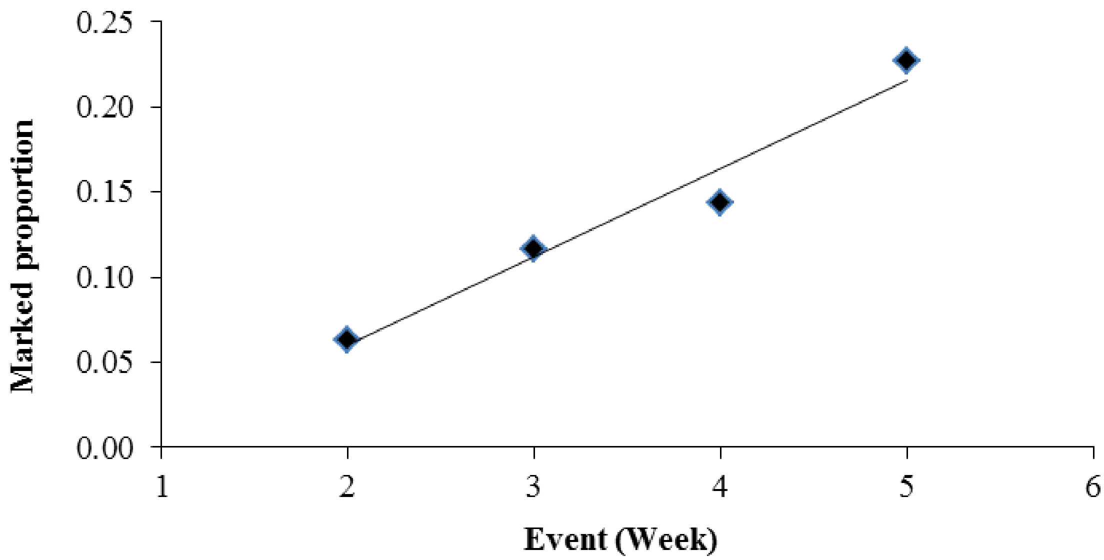


Figure 4.–Proportion of rainbow trout at least 200 mm FL marked in each capture event in the upper Kenai River index area, 30 June–30 July 2009.

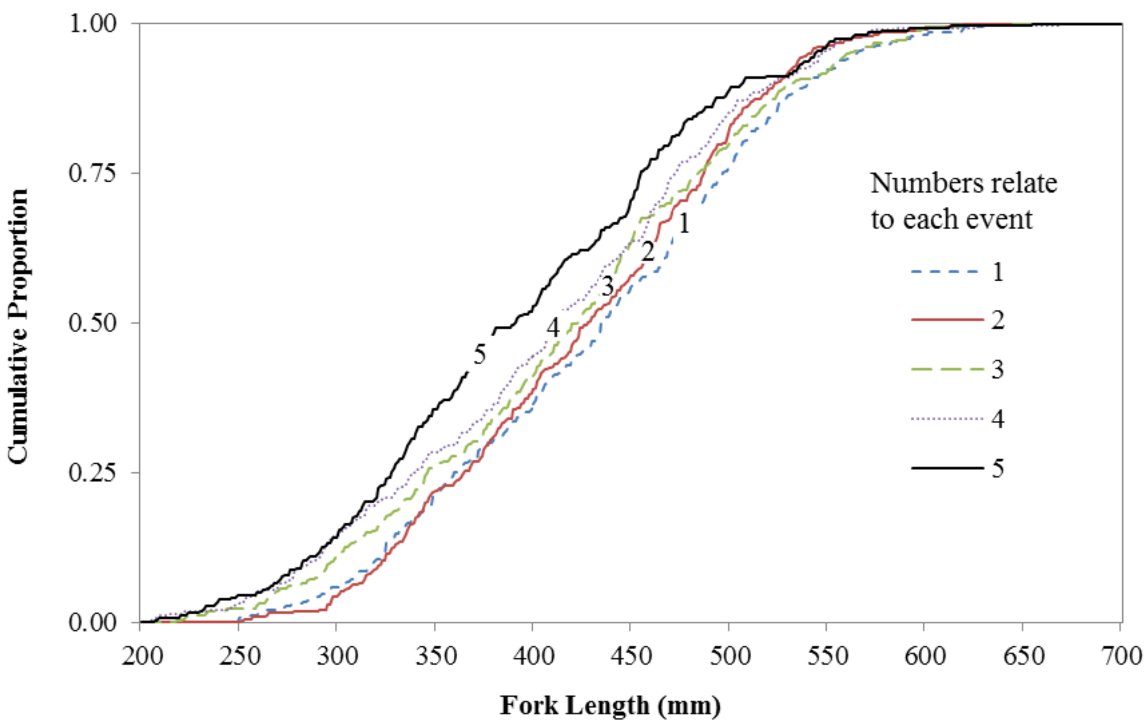
Table 5.–Movement of rainbow trout at least 200 mm FL between river sections in the upper Kenai River index area, 30 June–30 July 2009.

River section of capture[a]	River section of recapture 1	2	3	Total recaptures	Number outside original capture section	Proportion outside original capture section
1	52	7	4	63	11	0.17
2	3	38	6	47	9	0.19
3	9	5	36	50	14	0.28
Total	64	50	46	160	34	0.21

[a] Section 1 = RM 72.1–73.2; Section 2 = RM 71.0–72.1; Section 3 = RM 69.6–71.0.

Despite the observed movement inside and outside of the study area, the tag recovery pattern did not reflect complete mixing; a chi-square test of the hypothesis of complete mixing was rejected (P ≈ 0). A chi-square test was also used to test the hypothesis that the recapture rate was equal among the three sampling sections and found no evidence to the contrary ($\chi^2 = 0.45$, df = 2, P = 0.7; Table 4). Because there was a combination of approximately even probability of capture among locations and also some mixing, abundance could be estimated without stratification by location.

An Anderson Darling test was used to test the hypothesis of equal length distributions among events. The test was significant (t = 10.3; $P \approx 0$), suggesting that capture selectivity due to length changed during the study. Overall, smaller fish were caught in the last event (Figure 5) than in any other event. The Anderson Darling test remained significant, although less so (P = 0.004) when the fifth event was deleted. With respect to overall length selectivity (no temporal variable), the probability of recapture was significantly different among length categories (χ^2 = 11.1, P = 0.011, df = 3). Recapture rates increased with size group and were 0.06, 0.09, 0.13 and 0.14 for the fork length categories 200–299 mm, 300–399 mm, 400–499 mm, and $\geq$500 mm, respectively (Table 6). These results indicate that fish capture was selective towards larger fish and that length selectivity changed over events.



Note: Event 1 = 30 June and 1–2 July; event 2 = 7–9 July; event 3 = 14–16 July; event 4 = 21–23 July; event 5 = 28–30 July.

Figure 5.–Cumulative length distributions for captured rainbow trout during each event in the upper Kenai River index area, 30 June–30 July, 2009.

Table 6.–Number of rainbow trout captured, number recaptured, and proportion recaptured by fork length group (100 mm increments).

Length group (mm)	Number captured	Number recaptured	Proportion recaptured
200–299	138	8	0.06
300–399	451	41	0.09
400–499	533	70	0.13
$\geq$500	251	35	0.14
Total	1,373	154	

MODEL SELECTION

A suite of models was fitted in MARK using the "Huggins Closed Captures," "Huggins Heterogeneity," and "Huggins Full Closed Captures with Heterogeneity" data types. The models incorporated the possibility of a behavior component, unobserved heterogeneity (using 2-point mixture models of Pledger [2000]), a length component (Huggins observable heterogeneity), and that probability of capture may have changed over events.

Models that included unobservable heterogeneity, behavior components, or both were not supported by the data (according to AIC). Among the 23 candidate models, the one with the highest AIC weight (0.35) was chosen for abundance estimation. This model was one in which 1) the probability of capture was constrained to be equal among the first 3 events (there was also a positive and equal effect of length on capture during the first 3 events because larger fish had a higher probability of capture), and 2) the length effect in the fourth and fifth events differed (slope and intercept) from that in the first 3 events and also between each other. The MARK design matrix for this model is presented in Appendix A2. The next 2 best supported models based on AIC weight were similar in structure to the chosen model. The second best supported model was one in which the probability of capture was constrained to be equal for the first 2 events with a positive and equal effect of length on capture; probability of capture was allowed to vary for the last 3 events, each with differing length effects. The third best model constrained probability of capture to be equal for the first 3 events with a positive and equal effect of length on capture; probability of capture was also constrained to be equal between the last 2 events, with a positive, but different effect of length on capture. These 3 models represented 93% of the AIC weight and gave almost identical results. Therefore, to simplify interpretation of model selection and results, model averaging was not used.

The following equations describe the probability of capture for fish *i* in each event as dictated by the chosen model (Equation 8 corresponds to event 1, Equation 9 to event 2, etc.):

$$\log\left(\frac{p_{1i}}{1-p_{1i}}\right) = \beta_1 + \beta_4\left(Length_i\right); \tag{8}$$

$$\log\left(\frac{p_{2i}}{1-p_{2i}}\right) = \beta_1 + \beta_4\left(Length_i\right); \tag{9}$$

$$\log\left(\frac{p_{3i}}{1-p_{3i}}\right)=\beta_1+\beta_4\left(Length_i\right); \tag{10}$$

$$\log\left(\frac{p_{4i}}{1-p_{4i}}\right)=\beta_1+\beta_2+\beta_3+\left(\beta_4+\beta_5+\beta_6\right)\left(Length_i\right); \tag{11}$$

$$\log\left(\frac{p_{5i}}{1-p_{5i}}\right)=\beta_1+\beta_2+\left(\beta_4+\beta_5\right)\left(Length_i\right). \tag{12}$$

The fitted model indicated a positive effect of length on selection probability for the first 3 events (β_4 is positive). The effect of length on selection probability was smaller for the fourth event and almost non-existent for the fifth event. Parameter estimates and estimates of real parameters for event k (p_{ki}) are shown in Table 7. A plot of predicted probability of capture by length for each event is shown in Figure 6.

Table 7.–Parameter estimates for the model chosen to estimate abundance of rainbow trout at least 200 mm FL in the upper Kenai River index area, 30 June–30 July 2009.

Parameter type	Estimate	SE	Lower bound	Upper bound
Parameter				
β_1	−4.6715757	0.4220415	−5.4987771	−3.8443744
β_2	1.5779683	0.3413976	0.908829	2.2471076
β_3	−0.781193	0.4185155	−1.6014834	0.0390973
β_4	0.0045125	9.45E-04	0.0026596	0.0063655
β_5	−0.0044373	8.33E-04	−0.0060707	−0.002804
β_6	0.0020823	0.0010203	8.25E-05	0.0040821
Real Parameter[a]				
p_1	0.057	0.0046	0.049	0.067
p_2	0.057	0.0046	0.049	0.067
p_3	0.057	0.0046	0.049	0.067
p_4	0.048	0.0046	0.040	0.058
p_5	0.045	0.0043	0.037	0.054

[a] Real parameters correspond to the rows of the design matrix (see Appendix A2; note that *p* and *c* are identical [no behavior effect]); Real parameter estimates were calculated at the mean length value of 414.52 mm FL.

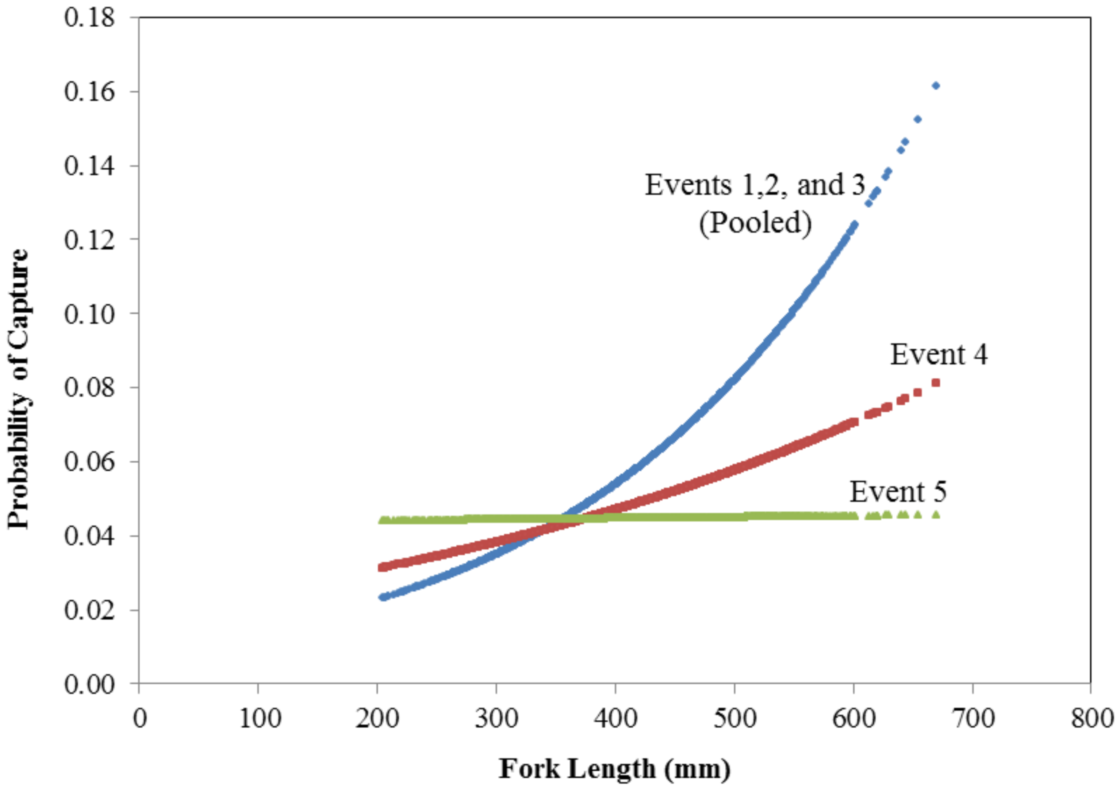


Figure 6.–Predicted probability of rainbow trout capture vs. fork length (mm) for each event in the upper Kenai River index area, 30 June–30 July, 2009. Events 1, 2, and 3 are pooled.

ABUNDANCE ESTIMATION

For the upper Kenai River study area in 2009, the model described by equations 8–12 in Program MARK gave an abundance estimate for rainbow trout at least 200 mm FL as 5,916 fish (SE 481; 95% CI = 5,067–6,961 fish). Other top models yielded similar results. The density of rainbow trout at least 200 mm FL in the study area was approximately 1,020 fish/RKM or 1,640 fish/RM.

The abundance of rainbow trout at least 300 mm FL was estimated to be 5,106 fish (SE 354), calculated as the product of the estimated proportion of fish at least 300 mm FL (0.863) and the overall abundance of fish at least 200 mm FL (5,916; Table 8). A different analysis using Program MARK and sampled fish at least 300 mm FL yielded an abundance estimate of rainbow trout at least 300 mm FL of 4,941 fish (SE 387; 95% CI = 4,257–5,778 fish). The two different methods produced abundance estimates that were within 4% of each other. For fish at least 300 mm FL, only the first abundance estimate of 5,106 fish (SE 431) will be reported hereafter. The density of rainbow trout at least 300 mm FL in the study area was approximately 880 fish/RKM or 1,420 fish/RM.

Table 8.–Estimated abundance and proportion of rainbow trout by fork length class in the upper Kenai River study area, 30 June–30 July 2009.

Length class (mm)	Number caught	Raw proportion[a]		Adjusted proportion[b]		Abundance[c]	
		Estimate	SE	Estimate	SE	Estimate	SE
200–249	31	0.023	0.004	0.029	0.007	172	44
250–299	110	0.080	0.007	0.108	0.013	639	93
300–349	239	0.174	0.010	0.205	0.016	1,213	136
350–399	217	0.158	0.010	0.174	0.012	1,029	110
400–449	269	0.196	0.011	0.187	0.011	1,106	111
450–499	271	0.197	0.011	0.172	0.013	1,018	113
500–549	161	0.117	0.009	0.089	0.010	527	73
550–599	61	0.044	0.006	0.030	0.005	177	33
≥600	14	0.010	0.003	0.006	0.002	35	12
Totals							
≥200	1,373	1.000		1.000		5,916	481
≥300	1,232	0.897	0.008	0.863	0.017	5,106	354
<400[d]	597	0.435	0.013	0.516	0.028	3,053	366

[a] Raw proportions represent actual catch.

[b] Adjusted proportions account for length selectivity; see Equation 5 in text.

[c] Estimates of abundance are based on adjusted proportions.

[d] A fork length of 400 mm is a close approximation to 16 inches total length (TL). Rainbow trout less than 16 inches TL are susceptible to harvest.

Comparison with Past Studies

Different estimation techniques, such as Program CAPTURE (Rexstad and Burnham 1992) which lacks the flexibility of Program Mark, have been used in past studies. We were able to reanalyze data from 2001 using the same techniques used in this report. Using the new modeling techniques on 2001 data, we estimated the population size of rainbow trout at least 300 mm FL to be 6,365 fish for 2001, within 3% of the published estimate of 6,167 fish. Therefore, comparisons of results between 2001 and 2009 are considered robust. However, we were unable to reanalyze data from earlier studies so comparisons of results from 2009 to those from 1986, 1987, and 1995 are less robust.

For rainbow trout at least 200 mm FL, the 2009 abundance estimate (5,916 fish) is significantly lower (30%; $P < 0.005$) than the 2001 estimate (8,553 fish; Table 9), but not significantly different from the 1986 and 1987 estimates (abundance of fish in the 200–299 mm length range was not estimated in 1995).

For fish at least 300 mm FL, the 2009 abundance estimate was higher than that found in 1986 and 1987 ($P < 0.05$); however for fish at least 300 mm FL, estimated abundance has not significantly changed over the last 3 surveys (1995, 2001, and 2009; Table 9; Figure 7).

Table 9.–Historical abundance estimates of rainbow trout in the upper Kenai River index area, 1986–2009.

	Number of rainbow trout			
Year	≥200 mm	SE	≥300 mm	SE
1986	3,640	456	2,520	363
1987	4,950	376	3,472	482
1995	N/A	N/A	5,598	735
2001[a]	8,553	806	6,365	625
2009	5,916	481	5,106	431

Note: N/A = not available.

[a] Data from 2001 were reanalyzed using modeling techniques in program MARK that were unavailable in 2001.

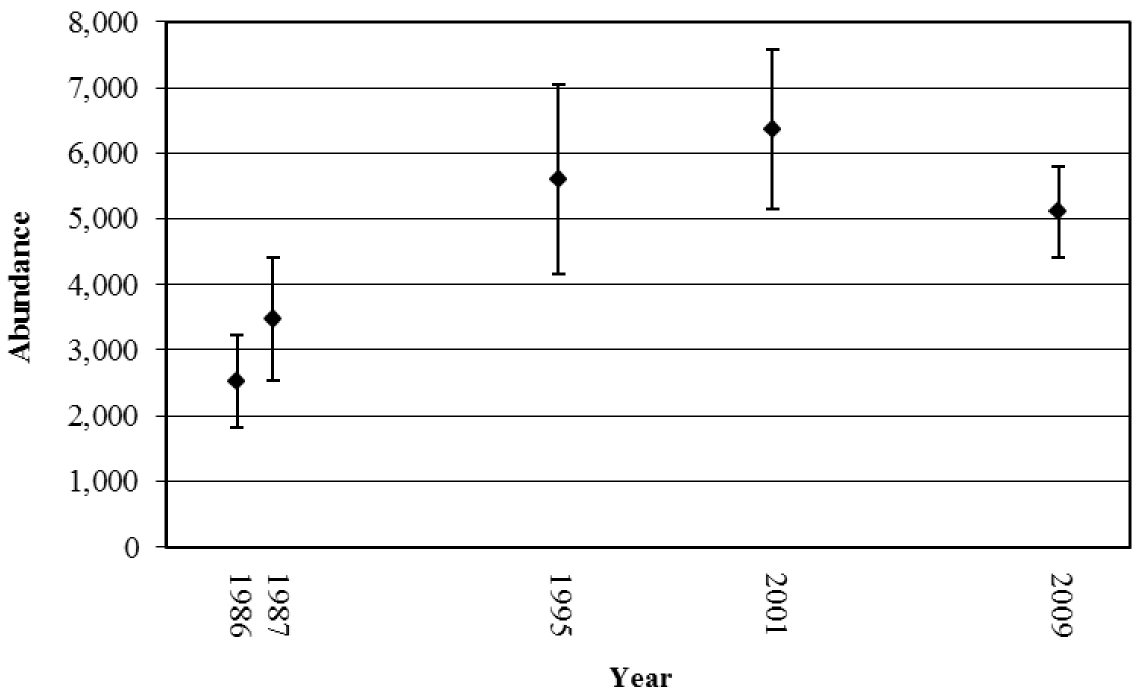


Figure 7.–Historical rainbow trout abundance estimates for fish at least 300 mm FL in the upper Kenai River index area, 1986–2009.

LENGTH COMPOSITION

Length compositions are presented as raw and adjusted proportions; the adjustment was needed to account for differential length selectivity prevalent in the 2009 data (Table 8). Sampling was generally selective towards larger fish and consequently adjustments were required to account for that selectivity. It appears that length selectivity was prevalent during the first 4 events and not the last event (Figure 6). The resulting adjustments increased the estimated number and proportion of rainbow trout less than 400 mm FL and conversely decreased the estimated number and proportion of fish at least 400 mm FL in the population. Only adjusted length statistics are reported hereafter.

A comparison of length composition and abundance by length class to all previous surveys in the same area for rainbow trout at least 300 mm FL is presented in Table 10 and Figure 8. Because not all previous surveys accounted for rainbow trout in the 200–299 mm fork length range, an additional comparison of 2001 and 2009 abundance by length class for rainbow trout at least 200 mm FL is presented in Table 11 and Figure 9. For fish at least 300 mm FL, the length composition in 2009 was skewed slightly towards larger fish compared to 2001, but was similar to the composition found in 1995 (Figure 8; Table 10). Abundance of rainbow trout at least 450 mm FL in 2009 was nearly identical to that in 1995 and 2001, but not so for rainbow trout less than 450 mm FL. We found a decrease of 40% or an estimated 2,803 fewer fish in 2009 versus 2001 for the 200–449 mm range (Table 11).

Using 400 mm FL as a close approximation to 16 inches TL, as defined in regulation, approximately 52% of the population of rainbow trout at least 200 mm FL was susceptible to harvest in 2009 (Table 8).

Table 10.–Estimated abundance of rainbow trout (≥300 mm FL) and proportion by year and fork length class in the upper Kenai River index area, 1986–2009.

Length class (mm)	Abundance					Cumulative abundance				
	1986	1987	1995	2001	2009[a]	1986	1987	1995	2001	2009[a]
300–349	821	697	1,449	1,729	1,213	821	697	1,449	1,729	1,213
350–399	801	1,009	1,277	1,771	1,029	1,622	1,706	2,726	3,500	2,242
400–449	444	1,009	1,070	1,609	1,106	2,066	2,715	3,796	5,109	3,348
450–499	158	368	1,050	1,032	1,018	2,224	3,083	4,846	6,141	4,366
500–549	143	212	539	462	527	2,367	3,295	5,385	6,603	4,893
550–599	112	117	146	96	177	2,479	3,412	5,531	6,699	5,070
≥600	41	61	66	0	35	2,520	3,473	5,597	6,699	5,106
	Proportion					Cumulative proportion				
300–349	0.33	0.20	0.26	0.26	0.24	0.33	0.20	0.26	0.26	0.24
350–399	0.32	0.29	0.23	0.26	0.20	0.64	0.49	0.49	0.52	0.44
400–449	0.18	0.29	0.19	0.24	0.22	0.82	0.78	0.68	0.76	0.66
450–499	0.06	0.11	0.19	0.15	0.20	0.88	0.89	0.87	0.92	0.86
500–549	0.06	0.06	0.10	0.07	0.10	0.94	0.95	0.96	0.99	0.96
550–599	0.04	0.03	0.03	0.01	0.03	0.98	0.98	0.99	1.00	0.99
≥600	0.02	0.02	0.01	0.00	0.01	1.00	1.00	1.00	1.00	1.00

[a] Data from 2009 were adjusted based on relative recapture rates.

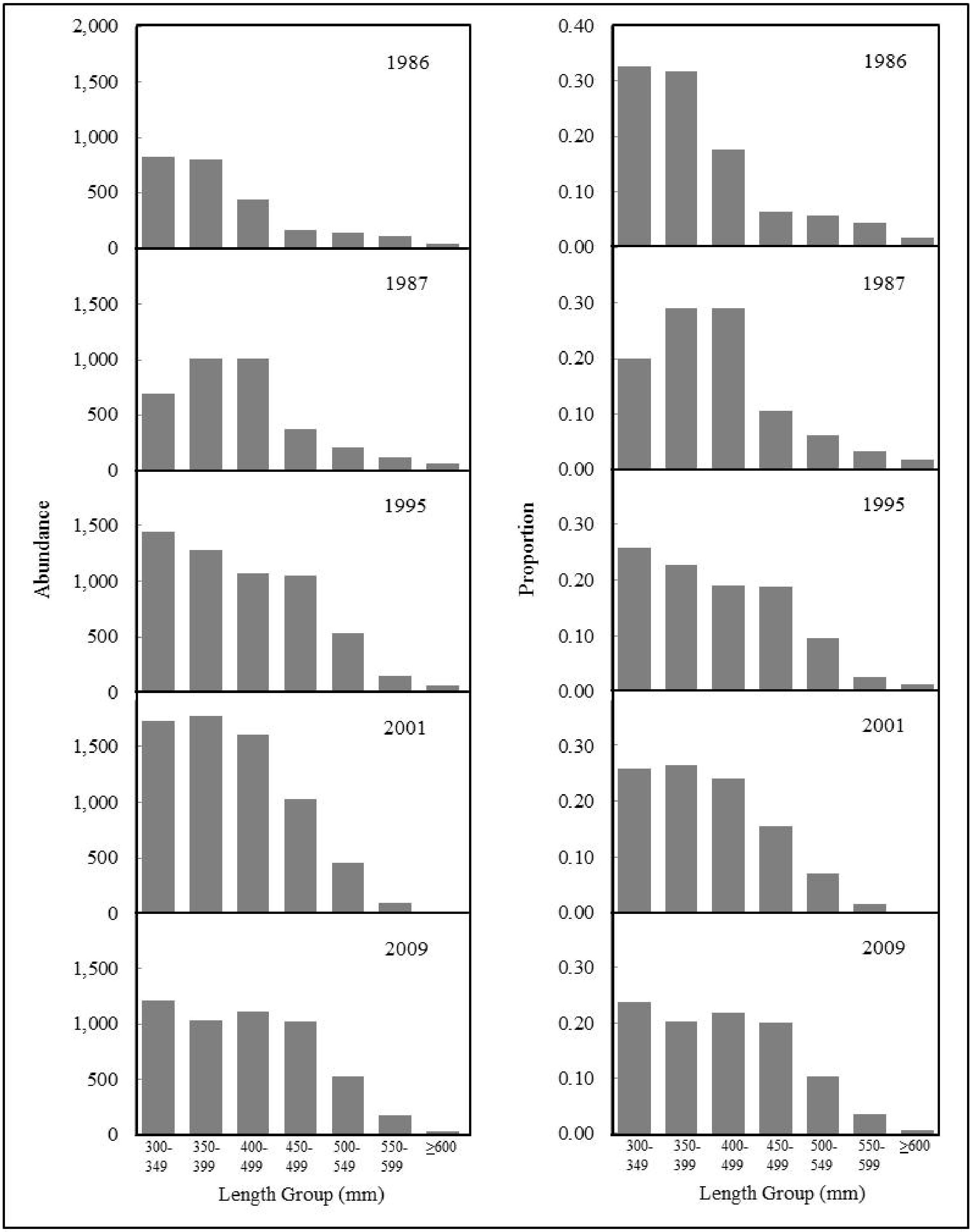


Figure 8.–Historical abundance and length composition of rainbow trout at least 300 mm FL in the upper Kenai River index area, 1986–2009.

Table 11.–Abundance and proportion of rainbow trout at least 200 mm FL by length class in the upper Kenai River study area, 2001 and 2009.

Length class (mm)	2001		2009	
	Estimate	SE	Estimate	SE
200–249	570	78	172	44
250–299	1,284	145	639	93
300–349	1,729	186	1,213	136
350–399	1,771	190	1,029	110
400–449	1,609	175	1,106	111
450–499	1,032	122	1,018	113
500–549	462	67	527	73
550–599	96	25	177	33
>600	0	0	35	12

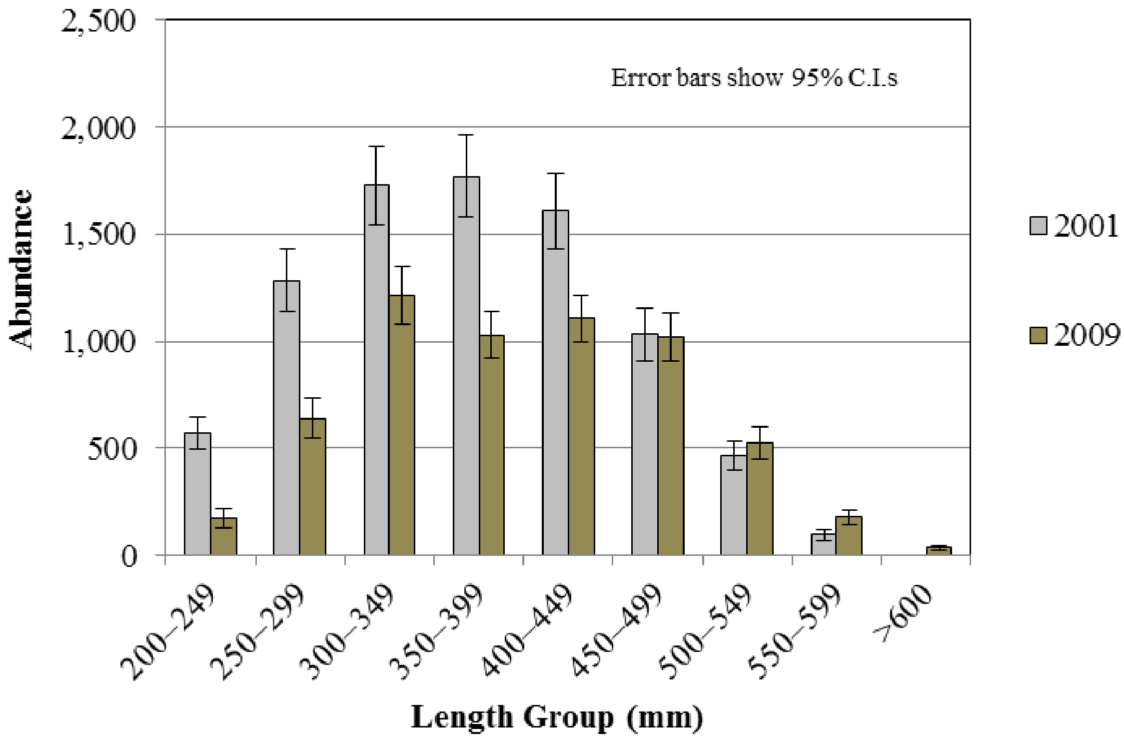


Figure 9.–Abundance and fork length composition of rainbow trout at least 200 mm FL by length class in the upper Kenai River index area, 2001 and 2009.

HOOKING INJURIES

In 2009, a total of 1,375 rainbow trout at least 200 mm FL were examined for previous hooking injuries. Hooking injury was detected in 1,014 fish (74%; Table 12). The proportion of rainbow trout observed with a hooking injury increased with fish size (Table 12).

Table 12.–Number and proportions of rainbow trout at least 200 mm FL observed with suspected previous hooking injuries by fork length class, 30 June–30 July 2009.

Length class (mm)	Injury No	Injury Yes	Total	Proportion with injury
200–249	24	5	29	0.17
250–299	74	38	112	0.34
300–349	108	124	232	0.53
350–399	59	154	213	0.72
400–449	48	219	267	0.82
450–499	28	241	269	0.90
500–549	11	160	171	0.94
550–599	9	58	67	0.87
≥600	0	15	15	1.00
Total	361	1,014	1,375	0.74

PARASITES

A total of 1,378 rainbow trout at least 200 mm FL were examined for copepod parasites in 2009. Parasites were observed on 792 fish (57%; Table 13). Like hooking injuries, the proportion of rainbow trout observed with parasites increased with fish size to the extent that 100% of captured rainbow trout at least 600 mm FL had at least one parasite (Table 13).

Table 13.–Number and proportions of rainbow trout at least 200 mm FL observed with copepod parasites by fork length class, 30 June–30 July 2009.

Length class (mm)	Parasites No	Parasites Yes	Total	Proportion with parasites
200–249	24	5	29	0.17
250–299	92	20	112	0.18
300–349	147	85	232	0.37
350–399	99	114	213	0.54
400–449	125	142	267	0.53
450–499	71	198	269	0.74
500–549	20	153	173	0.88
550–599	8	60	68	0.88
≥600	0	15	15	1.00
Total	586	792	1,378	0.57

DISCUSSION

This study was conducted to assess the stock status of upper Kenai River rainbow trout, which involved estimation of abundance and size composition, and documentation of parasites and hooking injuries. We also examined possible relationships between abundance and size composition, estimated the proportion of the population susceptible to harvest under the current management strategy, and made comparisons to past studies.

Abundance estimation was complicated by the apparent size selectivity of this study's capture methods, which correlated with water level. Selectivity towards larger fish occurred during the first 3 events when river discharge was average to below average. Selectivity diminished during the last 2 events when discharge increased to near flood levels. We suspect that during low water levels, selectivity occurred because of our sampling gear and techniques, including the use of bait in a non-bait area and because all fish were easily accessed. When discharge increased, it is possible that sampling was not as effective due to swifter, deeper water and consequently smaller fish on average were captured. The lack of evidence of size selectivity in the 2001 study may have been due to the abnormally high water levels observed throughout that study. It is not known how selectivity affected estimates of abundance and length composition from the 1986, 1987, or 1995 studies, making comparisons difficult; it is noted that the Huggins selectivity models and Program Mark were unavailable for the latter studies.

Program MARK enabled us to detect and incorporate length selectivity in the estimation of abundance without having to revert to stratification, which often involves difficult choices in the definition of strata and sometimes results in much lower precision of the abundance estimate. Selectivity-based adjustments to observed length composition were also possible using the new modeling techniques. Previously, such adjustments have been made by combining stratum-specific abundance estimates with stratum-specific length composition estimates; the result again suffers from difficulty in choice of strata and lower precision. We suggest using Program Mark in future such studies and invoking RMark for variance estimation of length composition estimates (Appendix A1).

Overall, it appears that the studied population remains above levels seen in the mid- to late 1980s and the number of larger sized ($\geq$450 mm FL) fish, capable of spawning in 2009, was comparable to estimates from the 1995 and 2001 surveys. However, the number of smaller sized (<450 mm FL) fish has declined. The significant decline in abundance of fish less than 450 mm FL compared to 2001 is noteworthy because of potential future impacts to the population as cohorts age. Based on past aging of Kenai River rainbow trout, nearly all age 1–4 fish and approximately half of age 5 fish are less than 450 mm FL.

Due to the length of time between assessments, determining the population dynamics and relationships between abundance and length composition of this stock is difficult. Two potential factors responsible for the decline in the number of small fish may be the 2005 regulatory change that allowed harvest of fish less than 16 inches and also the increased catch-and-release mortality resulting from the higher numbers of fish caught. However, the degree to which natural processes such as floods, salmon escapements, water temperature, predation, and other factors affect survival and recruitment is unknown, further confounding an explanation.

The high proportion of fish exhibiting a hooking injury is evidence of heavy fishing pressure exerted by this highly popular sport fishery. It is likely that each trout in this section of river is caught multiple times every year. The observed increase in catch necessarily translates into increased mortality, although it is not known if the increased mortality is skewed towards smaller fish. On one hand, our 2009 observations that hook-and-line fishing can be selective for larger fish suggests a greater proportional decline in larger fish with increased catch; on the other hand, smaller fish may be inherently more susceptible to catch-and-release mortality than larger fish. Furthermore, because we used bait and fishing regulations do not allow the use of bait, the length composition found in this study might not reflect what is captured by the general public over time. The regulation allowing harvest of fish less than 16 inches can only partially explain the decline in abundance of small fish. An average of only 432 fish was estimated to have been harvested annually from 2004 through 2008 for the entire upper Kenai River. This number represents only 7% of the estimated abundance of fish at least 200 mm FL within the index area; the percentage would be even smaller still for the entire upper Kenai River. Fortunately, anglers most often utilize catch-and-release techniques for Kenai River rainbow trout regardless of imposed regulations. It is doubtful that considerable increases in harvest will occur even though approximately half the rainbow trout population is susceptible to harvest and no annual limits are imposed on anglers.

Parasitic copepods from the genus *Salimincola*, most often found attached to gill filaments or opercula, were frequent on captured fish, with over half of the captured fish being observed with at least 1 parasite. It is not known if this parasite is adversely impacting the population and if so, to what degree. Levels of infestation were similar for both the 2001 and 2009 surveys so it is doubtful that parasites are causing any major die-offs. Generally, infestations with this parasite do not cause significant fish mortality if infestations are not severe with only minimal damage to gill tissue (Meyers et al. 2008). Many captured fish in this study were observed with significant infestations, sometimes with 20 or more parasites attached to gill filaments and opercula. Captured fish with significant infestations were alive and feeding, suggesting future survival. However, fish that have died from such infestations cannot be captured and censused.

The apparent condition of many fish captured during this study was poor. Many fish were thin, had multiple partially healed sores from hooking injuries, had parasites, and were lethargic. It is apparent that this population has significant pressure placed on it, potentially adversely affecting the overall health of the population. The upper Kenai River rainbow trout fishery is considered sustainable but future population assessments should investigate fish condition as well as abundance and length composition. Due to size selectivity, future studies should alter sampling gear and techniques in an attempt to capture a more representative sample of the population. We suggest not using bait exclusively and to concentrate fishing closer to shore during lower water levels. Another study is warranted in the next several years due to poor fish condition and the observed decline in abundance of small fish that may impact future population size as they age.

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REFERENCES CITED

Amstrup, S. C., T. L. McDonald, and B. F. J. Manly. 2005. Handbook of capture-recapture analysis. Princeton University Press, Princeton, NJ.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. 2nd edition. Springer-Verlag, New York.

Cochran, W. G. 1977. Sampling techniques. 3rd edition. John Wiley and Sons, New York.

Conover, W. J. 1980. Practical nonparametric statistics. 2nd edition. John Wiley and Sons, New York.

Goodman, L. A. 1960. On the exact variance of products. Journal of the American Statistical Association 55:708-713.

Hayes, S. R., and J. J. Hasbrouck. 1996. Stock assessment of rainbow trout in the upper Kenai River, Alaska, in 1995. Alaska Department of Fish and Game, Fishery Data Series No. 96-43, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds96-43.pdf

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 No. 96-32, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds96-32.pdf

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 No. 95-24, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds95-24.pdf

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 No. 97-29 (revised), Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds97-29(revised).pdf

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 No. 98-25 (revised), Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds98-25(revised).pdf

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001c. Revised Edition. Participation, catch, and harvest in Alaska sport fisheries during 1998. Alaska Department of Fish and Game, Fishery Data Series No. 99-41 (revised), Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds99-41(revised).pdf

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001d. Participation, catch, and harvest in Alaska sport fisheries during 1999. Alaska Department of Fish and Game, Fishery Data Series No. 01-08, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds01-08.pdf

Jennings, G. B., K. Sundet, and A. E. Bingham. 2007. Participation, catch, and harvest in Alaska sport fisheries during 2004. Alaska Department of Fish and Game, Fishery Data Series No. 07-40, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds07-40.pdf

Jennings, G. B., K. Sundet, and A. E. Bingham. 2009a. Estimates of participation, catch, and harvest in Alaska sport fisheries during 2005. Alaska Department of Fish and Game, Fishery Data Series No. 09-47, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/FDS09-47.pdf

Jennings, G. B., K. Sundet, and A. E. Bingham. 2009b. Estimates of participation, catch, and harvest in Alaska sport fisheries during 2006. Alaska Department of Fish and Game, Fishery Data Series No. 09-54, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/FDS09-54.pdf

Jennings, G. B., K. Sundet, and A. E. Bingham. 2010a. Estimates of participation, catch, and harvest in Alaska sport fisheries during 2007. Alaska Department of Fish and Game, Fishery Data Series No. 10-02, Anchorage. http://www.adfg.alaska.gov/FedAidpdfs/Fds10-02.pdf

Jennings, G. B., K. Sundet, and A. E. Bingham. 2010b. Estimates of participation, catch, and harvest in Alaska sport fisheries during 2008. Alaska Department of Fish and Game, Fishery Data Series No. 10-22, Anchorage. http://www.adfg.alaska.gov/FedAidpdfs/FDS10-22.pdf

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 No. 04-11, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds04-11.pdf

Jennings, G. B., K. Sundet, A. E. Bingham, and D. Sigurdsson. 2006a. Participation, catch, and harvest in Alaska sport fisheries during 2002. Alaska Department of Fish and Game, Fishery Data Series No. 06-34, Anchorage. http://www.adfg.alaska.gov/FedAidpdfs/fds06-34.pdf

Jennings, G. B., K. Sundet, A. E. Bingham, and D. Sigurdsson. 2006b. Participation, catch, and harvest in Alaska sport fisheries during 2003. Alaska Department of Fish and Game, Fishery Data Series No. 06-44, Anchorage. http://www.adfg.alaska.gov/FedAidpdfs/fds06-44.pdf

King, B. A., and J. A. Breakfield. 2007. Stock assessment of rainbow trout in the upper Kenai River, Alaska, in 2001. Alaska Department of Fish and Game, Fishery Data Series No. 07-14, Anchorage. http://www.adfg.alaska.gov/FedAidpdfs/fds07-14.pdf

Lafferty, R. 1989. Population dynamics of rainbow trout, Kenai River, Alaska. Master's thesis, University of Alaska, Juneau.

Larson, L. 1995. A portable restraint cradle for handling large salmonids. North American Journal of Fisheries Management 15:654-656.

Meyers, T. R., T. Burton, C. Bentz, and N. Starkey. 2008. Common diseases of wild and cultured fishes in Alaska. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fish Pathology Laboratory, Anchorage.

Mills, M. J. 1985. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report 1984-1985, Project F-9-17(26)SW-I-A, Juneau. http://www.adfg.alaska.gov/FedAidPDFs/FREDf-9-17(26)SW-I-A.pdf

Mills, M. J. 1986. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report 1985-1986, Project F-10-1(27)RT-2, Juneau. http://www.adfg.alaska.gov/FedAidPDFs/FREDf-10-1(27)RT-2.pdf

Mills, M. J. 1987. Alaska statewide sport fisheries harvest report, 1986. Alaska Department of Fish and Game, Fishery Data Series No. 2, Juneau. http://www.adfg.alaska.gov/FedAidPDFs/fds-002.pdf

Mills, M. J. 1988. Alaska statewide sport fisheries harvest report, 1987. Alaska Department of Fish and Game, Fishery Data Series No. 52, Juneau. http://www.adfg.alaska.gov/FedAidPDFs/fds-052.pdf

Mills, M. J. 1989. Alaska statewide sport fisheries harvest report, 1988. Alaska Department of Fish and Game, Fishery Data Series No. 122, Juneau. http://www.adfg.alaska.gov/FedAidPDFs/fds-122.pdf

Mills, M. J. 1990. Harvest and participation in Alaska sport fisheries during 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-44, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds90-44.pdf

Mills, M. J. 1991. Harvest, catch, and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-58, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds91-58.pdf

Mills, M. J. 1992. Harvest, catch, and participation in Alaska sport fisheries during 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-40, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds92-40.pdf

Mills, M. J. 1993. Harvest, catch, and participation in Alaska sport fisheries during 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-42, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds93-42.pdf

Mills, M. J. 1994. Harvest, catch, and participation in Alaska sport fisheries during 1993. Alaska Department of Fish and Game, Fishery Data Series No. 94-28, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds94-28.pdf

REFERENCES CITED (Continued)

Otis, D. L., K. P. Burnham, G. C. White, and D. R. Anderson. 1978. Statistical inference from capture data on closed animal populations. Wildlife Monograph No. 62.

Palmer, D. E. 1998. Migratory behavior and seasonal distribution of radio-tagged rainbow trout in the Kenai River, Alaska. U.S. Fish and Wildlife Service, Alaska Fisheries Technical Report No. 46, Kenai, Alaska.

Pledger, S. 2000. Unified maximum likelihood estimates for closed capture-recapture models using mixtures. Biometrics 56:434-442.

Rexstad, E., and K. Burnham. 1992. User's guide for the interactive program CAPTURE. Colorado Cooperative Fish and Wildlife Unit, Fort Collins, CO 80523. 29 pp. (includes Program CAPTURE).

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters. 2nd edition. Griffin and Company, Ltd. London.

Stanley, T. R., and K. P. Burnham. 1999. A closure test for time-specific capture-recapture data. Environmental and Ecological Statistics 6(2):197-209.

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. http://www.adfg.alaska.gov/FedAidPDFs/fds03-05.pdf

White, G. C., and K. P. Burnham. 1999. Program Mark: Survival estimation from populations of marked animals. Bird Study 46 Supplement, 120-138.

APPENDIX A: RMARK CODE AND MARK DESIGN MATRIX

Appendix A1.–RMark code used to estimate fish-specific probabilities of capture for rainbow trout at least 200 mm FL, upper Kenai River, 2009.

RMark Commands are in **BOLD;** comments are not in bold.

Bring in MARK .inp file
rbinp=convert.inp("c:\\WORK\\UK_RBT_2009_GT200MM_CAPHIST_LENGTH_T1T5.INP",covariates="Length")

The variable rbinp has the following structure (capture history, Fequency and Length of fish(mm):

```
      ch    freq  Length
1     01000   1   602
2     10000   1   307
3     10010   1   363
4     11000   1   511
.................
1373 00001   1   314
```

Create processed data list- The variable rbproc is an object containing information similar to that entered into the first screen in the MARK GUI interface.
rbproc=process.data(rbinp,model="Huggins")

Create design data list (ddl), a list of dataframes
rbddl=make.design.data(rbproc)

Force equal probability of capture in first 3 events
rbddl$p$High=1
rbddl$p$High[rbddl$p$time==1|rbddl$p$time==2|rbddl$p$time==3]=0
Ensure no behavior component (recap prob=capture prob)
rbddl$c$High=1
rbddl$c$High[rbddl$c$time==2|rbddl$c$time==3]=0

Force different probability of capture for event 4 and for event 5
rbddl$p$Four=0
rbddl$p$Four[rbddl$p$time==4]=1
rbddl$c$Four=0
rbddl$c$Four[rbddl$c$time==4]=1

Specify model ; this specification defines the design matrix that the MARK Fortran code need to fit the model;
p.time=list(formula=~High+Four+Length+High*Length+Four*Length, share=TRUE)

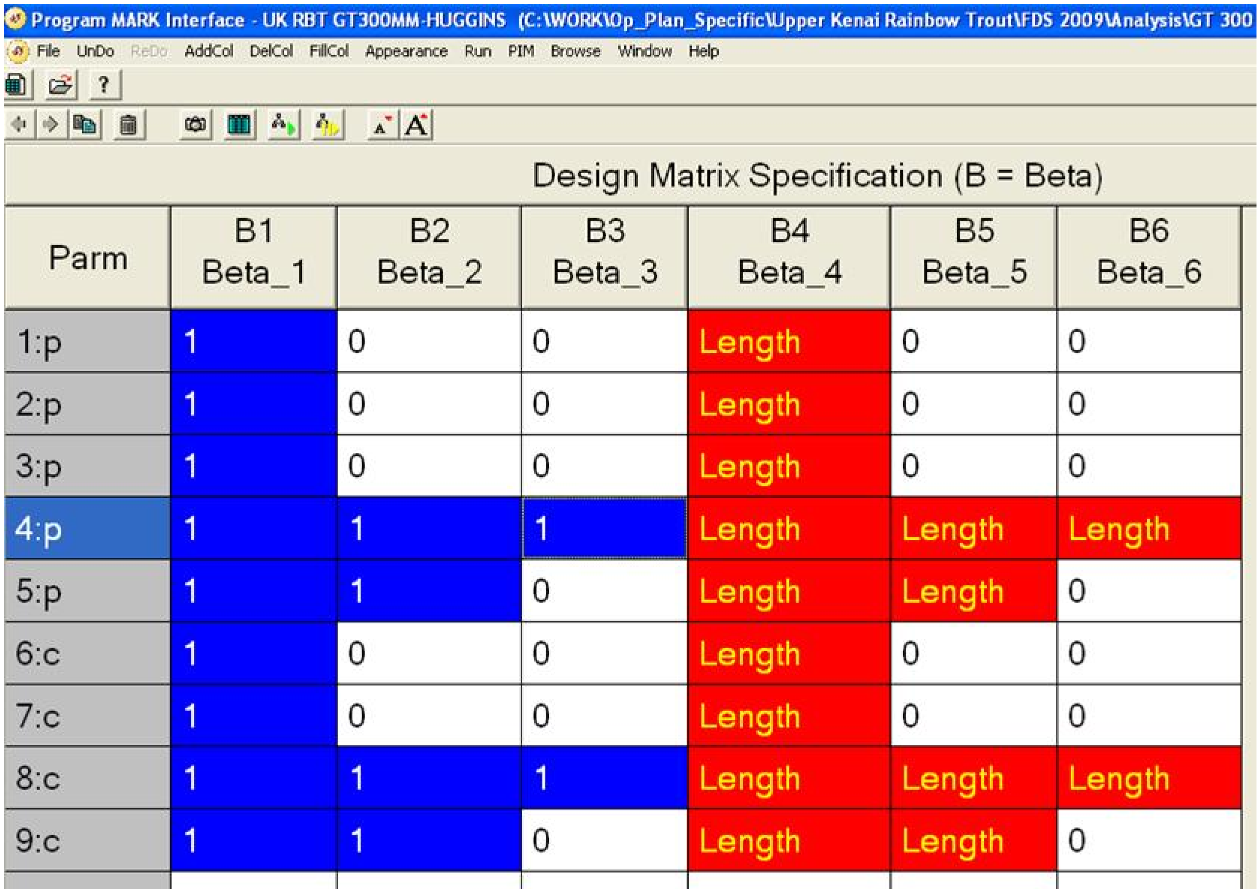
Invoke MARK Fortran executable code (same machinery used in MARK)
RBTModel=mark(rbproc,ddl=rbddl,model.parameters=list(p=p.time),covariates="Length",output=FALSE)

Beta Point Estimates (See Equations 8-12)
b1= RBTModel$results$beta$estimate[1]
b2= RBTModel$results$beta$estimate[2]
b3= RBTModel$results$beta$estimate[3]
b4= RBTModel$results$beta$estimate[4]
b5= RBTModel$results$beta$estimate[5]
b6= RBTModel$results$beta$estimate[6]

Vectors of fish-specific probability of capture (back-calculated from logit model fit; evi is vector of lengths for event i
p1=exp(b1+b4*ev1)/(1+exp(b1+b4*ev1)) # Length-Adjusted Capture probs Event 1
p2=exp(b1+b4*ev2)/(1+exp(b1+b4*ev2)) # Length-Adjusted Capture probs Event 2
p3=exp(b1+b4*ev3)/(1+exp(b1+b4*ev3)) # Length-Adjusted Capture probs Event 3
p4=exp(b1+b2+b3+b4*ev4+b5*ev4+b6*ev4)/(1+exp(b1+b2+b3+b4*ev4+b5*ev4+b6*ev4)# Length-Adjusted Capture probs Event 4
p5=exp(b1+b2+b4*ev5+b5*ev5)/(1+exp(b1+b2+b4*ev5+b5*ev5)) # Length-Adjusted Capture probs Event 5

The above fish-specific probabilities were then used to adjust length composition estimates using Equations 5 and 6.

Appendix A2.–MARK design matrix of chosen model used to estimate abundance of rainbow trout at least 200 mm FL, upper Kenai River, 2009.



Design Matrix Specification (B = Beta)

Parm	B1 Beta_1	B2 Beta_2	B3 Beta_3	B4 Beta_4	B5 Beta_5	B6 Beta_6
1:p	1	0	0	Length	0	0
2:p	1	0	0	Length	0	0
3:p	1	0	0	Length	0	0
4:p	1	1	1	Length	Length	Length
5:p	1	1	0	Length	Length	0
6:c	1	0	0	Length	0	0
7:c	1	0	0	Length	0	0
8:c	1	1	1	Length	Length	Length
9:c	1	1	0	Length	Length	0

Note: Huggins Closed Data Type was used; see Methods for meaning of Beta parameters.