Regional Operational Plan SF.2A.2018.06

Operational Plan: Middle Kenai River Rainbow Trout Abundance, 2018

by

Robert Begich

May 2018

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

REGIONAL OPERATIONAL PLAN SF.2A.2018.06

OPERATIONAL PLAN: MIDDLE KENAI RIVER RAINBOW TROUT ABUNDANCE, 2018

by
Robert Begich
Alaska Department of Fish and Game, Division of Sport Fish, Soldotna

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1565

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Robert Begich,
Alaska Department of Fish and Game, Division of Sport Fish,
43961 Kalifornsky Beach Road, Suite B, Soldotna, AK 99669-8276

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SIGNATURE/TITLE PAGE

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Title	Name	Signature	Date
Project leader	Robert Begich		
Project leader	Tony Eskelin		
Biometrician	Adam Reimer		
Research Coordinator	Tim McKinley		

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ABSTRACT

The goals of this study are to assess the abundance, size structure, and maturity of rainbow trout in the middle Kenai River from Moose River to Skilak Lake during the spawning period from the beginning of May to the beginning of June 2017. Results of this study will be used to provide information about rainbow trout that is presently unknown, such as efficient capture methods and locations for rainbow trout assessment during spring and rainbow trout abundance, size structure, and maturity in this river section. This information will serve as a baseline for future assessments of rainbow trout abundance in the middle Kenai River.

Key words: rainbow trout, *Oncorhynchus mykiss*, abundance, length composition, mark–recapture, middle Kenai River.

INTRODUCTION

The Kenai River drainage (Figure 1) is the most heavily utilized system for freshwater sport fishing in Alaska. Although many anglers participate in the river's salmon fisheries, the Kenai River drainage also supports a major rainbow trout (*Oncorhynchus mykiss*) fishery.

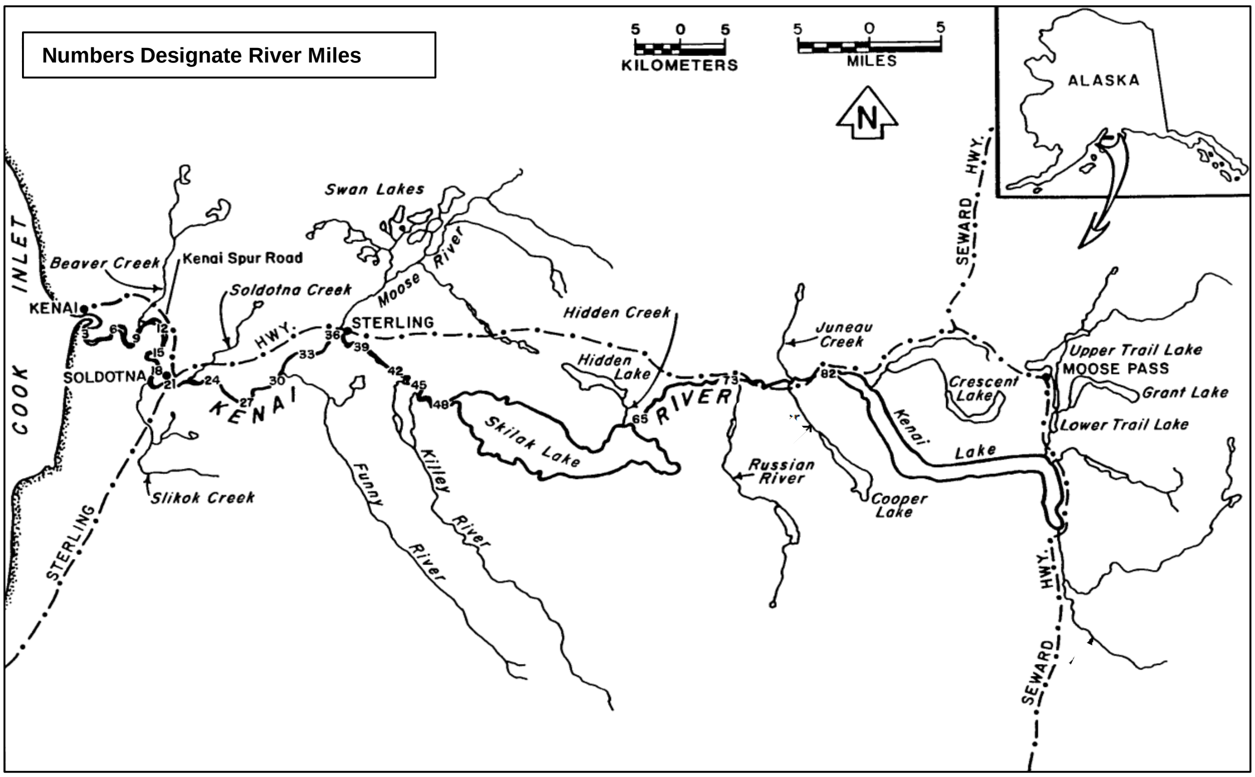

Figure 1.–Map of the Kenai River drainage.

Rainbow trout catch and harvest have been estimated by the Alaska Department of Fish and Game (ADF&G) Statewide Harvest Survey (SWHS) since 1984 when 15,687 rainbow trout were estimated caught in the drainage (Table 1). Annual catch remained relatively stable until the 1990s when it increased dramatically. The mean estimated catch for 2011–2015 was 183,619 (Alaska Sport Fishing Survey database [Internet]. 1996– . Anchorage, AK: Alaska Department of Fish and Game, Division of Sport Fish [cited April, 2017). Available from: http://www.adfg.alaska.gov/sf/sportfishingsurvey/.). The estimated catch of 241,651 in 2015 rainbow trout was an all-time high.

Table 1.–Historical catch and harvest estimates for Kenai River rainbow trout (1984–2007).

	Cook Inlet to Soldotna Bridge			Soldotna Bridge to Moose River			Moose River to Skilak Outlet			Skilak Inlet to Kenai Lake [a]			Kenai River reach not specified [b]			Kenai River total		
Year	C	H	% H	C	H	% H	C	H	% H	C	H	% H	C	H	% H	C	H	% H
1984 [c]	3,464	766	22.1	2,911	644	22.1	5,112	1,130	22.1	4,200	928	22.1	ND	ND	ND	15,687	3,468	22.1
1985 [c]	3,398	880	25.9	2,653	850	32.0	5,410	1,500	27.7	3,520	710	20.2	ND	0	ND	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	ND	ND	ND	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	ND	ND	ND	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	ND	0	ND	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	ND	10	ND	17,590	1,927	11.0
1990	2,624	510	19.4	3,571	943	26.4	5,366	937	17.5	11,995	1,145	9.5	0	0	0.0	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	31	10	32.3	33,585	3,329	9.9
1992	4,448	427	9.6	3,879	411	10.6	15,127	736	4.9	28,702	403	1.4	ND	ND	ND	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	0	0	0.0	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	ND	ND	ND	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	ND	ND	ND	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	ND	ND	ND	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	ND	ND	ND	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	ND	ND	ND	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	ND	ND	ND	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	ND	ND	ND	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	ND	ND	ND	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	2,269	216	9.5	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	3,536	180	5.1	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	5,651	50	0.9	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	7,949	43	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	4,005	41	1.0	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	4,851	10	0.2	178,970	2,666	1.5
2008	26,385	696	2.6	20,943	794	3.8	47,956	772	1.6	103,095	941	0.9	4,496	11	0.2	202,875	3,214	1.6
2009	11,502	625	5.4	16,165	543	3.4	67,940	828	1.2	102,745	399	0.4	3,280	59	1.8	201,632	2,454	1.2

-continued-

Table 1.–Page 2 of 2.

	Cook Inlet to Soldotna Bridge			Soldotna Bridge to Moose River			Moose River to Skilak Outlet			Skilak Inlet to Kenai Lake [a]			Kenai River reach not specified [b]			Kenai River total		
Year	C	H	% H	C	H	% H	C	H	% H	C	H	% H	C	H	% H	C	H	% H
2011	19,849	571	2.9	27,305	464	1.7	80,908	318	0.4	71,088	374	0.5	615	0	0.0	199,765	1,727	0.9
2012	16,119	843	5.2	23,866	878	3.7	47,253	396	0.8	81,349	386	0.5	856	37	4.3	169,443	2,540	1.5
2013	11,140	464	4.2	13,174	461	3.5	52,992	400	0.8	90,301	446	0.5	435	0	0.0	168,042	1,771	1.1
2014	12,123	616	5.1	14,216	502	3.5	43,059	273	0.6	69,629	135	0.2	166	93	56.0	139,193	1,619	1.2
2015	29,097	797	2.7	22,093	534	2.4	67,020	648	1.0	123,441	286	0.2	0	0	0.0	241,651	2,265	0.9
2016	23,241	834	3.6	25,492	860	3.4	43,042	599	1.4	78,149	169	0.2	1,011	0	0.0	170,935	2,462	1.4
Average																		
2012−2016	18,344	711	4.2	19,768	647	3.3	50,673	463	0.9	88,574	284	0.3	494	26	12.1	177,853	2,131	1.2
2007−2016	17,068	654	4.2	19,903	659	3.4	56,653	561	1.0	89,022	403	0.4	1,035	34	6.7	184,581	2,312	1.3
1984−2016	10,235	736	10.7	10,267	674	10.5	28,469	738	7.3	53,204	343	3.7				103,471	2,519	5.8

Source: Mills 1985-1994; Howe et al. 1995, 1996; Statewide Harvest Survey from the Alaska Sport Fishing Survey database [Internet]. 1996– . Anchorage, AK: Alaska Department of Fish and Game, Division of Sport Fish [cited April, 2017). Available from: http://www.adfg.alaska.gov/sf/sportfishingsurvey/.

Note: ND indicates no data available.

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

[b] SWHS began consistently reporting in 2002.

[c] In 1984 and 1985, catch estimates were mistakenly reported as harvest in Mills (1985–1986). Corrected harvest numbers are presented here.

Historically, participation in the rainbow trout fishery was much higher in the section between Kenai and Skilak lakes (referred to as upper Kenai River henceforth) and it supported the majority of the catch. By the late 1990s the other sections of the river became popular including the section from the Moose River to Skilak Lake (referred to as middle Kenai River henceforth (Figure 1). The recent 5-year average (2012–2016) catch of rainbow trout in each Kenai River section is a little less than twice the historical average (Table 1).

Regulations in Kenai River have a long history and have generally become more conservative with time. The fishery in the upper Kenai River changed from a harvest fishery to a trophy fishery where maximum size limits changed incrementally from 20 inches in 1989 to 30 inches by 1993 before a catch-and-release only regulation was adopted in 1997. A similar but less restrictive trend toward conservative regulations also occurred for the middle Kenai River in 1987 when new regulations reduced the bag limit from 3 fish to 2 fish of which only 1 could be 20 inches or greater in total length. An annual limit of 2 fish 20 inches or more in total length also applied. The middle Kenai River bag limit decreased again in 1993 to 1 fish of any size with an annual limit of 2 rainbow trout over 20 inches in total length. In 2005, the Alaska Board of Fisheries (BOF) modified regulations for the entire Kenai River drainage rainbow trout fishery by adopting a daily bag limit of 1 fish with a maximum size limit that differed by river section. In the Upper Kenai River, the maximum size limit was set at 16 inches in total length whereas in the middle Kenai River, the maximum size limit was set at 18 inches in total length. With the new maximum size limits, no annual limit applied to either river section. During 2017, the middle Kenai River maximum size limit was reduced from 18 inches to 16 inches in total length.

Aside from the wide application of regulations restricting the daily bag limit and size of rainbow trout anglers could harvest, a season closure that closes sections of the river to fishing for rainbow trout during the spawning period has been part of the historical management framework of the fishery. From 1959 to 1964, the closure was from April 1 through late May. Fishing was allowed during the spring spawning season from 1965 through 1981. Beginning in 1982, the spring closure was reestablished with a longer closure that prohibited fishing for rainbow trout from January 1 through June 14. From 1984 to 1988, this closure was extended in regulation to begin November 1 through June 14. In 1997, the winter fishery was again allowed in all flowing waters of the middle Kenai River below the Killey–Kenai rivers confluence from June 15 through April 14. Restructuring of the spring closure continued in 2005 when a season closure from May 2 through June 10 was adopted. In 2008, the spring closure in the middle Kenai River was reduced in area to cover only the area from approximately river mile (RM) 46 upstream to Skilak Lake at RM 50. In 2014, the middle Kenai River spawning closure was extended downstream to cover the area from approximately RM 44 upstream to Skilak Lake at RM 50. Finally, the closure was slightly modified in 2017 to begin May 1 rather than May 2. The spring closure reduces the fishing activity on adult rainbow trout during the reproductive segment of the rainbow trout life cycle. The basis for this regulation is to provide mature rainbow trout that have survived natural and fishing mortality though the year the greatest chance to successfully reproduce.

Based on regulatory history, special regulations have been popular with anglers because of the potential for such regulations to increase both the abundance and size of fish in the population, which can increase the quality of the fishery. Consequently, evaluating changes to the regulations is of interest to managers. Past rainbow trout assessments have focused mainly on the upper Kenai River where regulation changes were more dynamic and catch of rainbow trout was greater than other sections of the Kenai River. For these assessments, ADF&G estimated the midsummer abundances during 1986–1987, 1995, 2001, and 2009 of rainbow trout 200 mm or greater in fork length (FL; nose to fork of tail) in a section of the upper Kenai River, and these were used as indices of the entire upper Kenai River rainbow trout population because migration is minor during midsummer and closed population estimators of abundance can be used (Lafferty 1989; Hayes and Hasbrouck 1996; King and Breakfield 2007; Eskelin 2013). Results showed that the rainbow trout abundance increased from 1986 to 2001 and then stabilized. In addition, the more recent assessments show that the rainbow trout population has a more uniform distribution among size classes than distributions from the 1986–1987 assessments. In addition, the later assessments indicated the population comprised a greater proportion of fish in the 450–550 mm size range than the former assessments. Based on these findings, it was concluded that more conservative regulations had a positive effect on abundance and size of fish in the population.

Middle Kenai River rainbow trout abundance was estimated by Lafferty (1989) as well as by Larson and Hansen (2000). Based on these studies, the midsummer abundance of rainbow trout 200 mm or greater in fork length in an approximate 10-mile section of the middle Kenai River from Naptowne Rapids at RM 40 upstream to Skilak Lake at RM 50 increased from 1,750 fish in 1987 to 7,883 fish in 1999 (Larson and Hansen 2000). From 2010 to 2011, radio telemetry methods were used to monitor seasonal movements of adult rainbow trout in the middle Kenai River. During the summer of 2010, radio tags were surgically implanted into large rainbow trout ≥500 mm FL captured between RM 18 and RM 40. Tagged fish were tracked via fixed telemetry stations and by boat until the summer of 2011. Results showed that tagged adult rainbow trout moved upriver near Skilak Lake to overwinter and probably spawned from May into June, although maturity samples were not collected from tagged fish (Tony Eskelin, ADF&G Sport Fish Biologist, Soldotna, personal communication). The 2011 overwintering area was similar to the overwintering area reported by Palmer (1998). Furthermore, telemetry results showed nearly all radiotagged rainbow trout were aggregated during the month of May through early June in a relatively short section of the middle Kenai River downstream of Skilak Lake from approximately RM 45 to RM 48 where they are susceptible to capture and sampling.

Because little is known about the abundance and size structure of rainbow trout population present in the Kenai River downstream of Skilak Lake during May through early June, the study described in this operational plan was initiated during May of 2017 and will continue in 2018. An important aspect of this study is to develop reliable data collection methods and population estimators of abundance that can be used to periodically index rainbow trout abundance downstream of Skilak Lake. Results from 2017 confirmed previous telemetry studies of high densities of rainbow trout from approximately RM 45 to RM 48. Preliminary estimates of abundance using open population estimators that allow for entrance and emigration to and from the study area indicate that approximately 46,975 rainbow trout ≥200 mm FL used the study area during the month of May through early June (Adam Reimer, ADF&G Sport Fish, Soldotna, personal communication). It is important for ADF&G to continue to assess the rainbow trout population in the middle Kenai River downstream of Skilak Lake to develop and provide a reliable abundance index. Telemetry results in 2017 and prior show that the overwintering population below Skilak Lake may be the source of rainbow trout for the entire lower Kenai River fisheries from Skilak Lake downstream to Cook Inlet. For example, tag recoveries by the sport fishing public for fish released with tags during the 2017 study ranged from 31 miles downstream to 29 miles upstream of the study area. Results from this 2018 study will build upon this work to refine the study area, sampling methods, and data analysis methods to serve as a baseline for future assessments of rainbow trout abundance in the middle Kenai River downstream of Skilak Lake.

OBJECTIVES

PRIMARY OBJECTIVES

1) Estimate the abundance of rainbow trout ≥200 mm fork length (FL) in the middle Kenai River between RM 45.5 (Torpedo Creek Mouth) and RM 47.5 (upper Super Hole) from May 1 through June 8, such that the estimate is within 25% of the true abundance 95% percent of the time.
2) Estimate the length composition of rainbow trout ≥200 mm FL in the middle Kenai River between RM 45.5 (Torpedo Creek Mouth) and RM 47.5 (upper Super Hole) from May 1 through June 8, such that the estimates are within 5 percentage points of the true value 95% of the time.

SECONDARY OBJECTIVE

1) Examine all captured rainbow trout for external sexual characteristics to determine maturity.

METHODS

STUDY DESIGN

Abundance

A mark–recapture experiment will be conducted to estimate abundance using an open population model. Rainbow trout will be captured in the middle Kenai River between RM 45.5 (Torpedo Creek Mouth) and RM 47.5 (upper Super Hole) from May 1 through approximately June 8, 2018. Based on past studies (Larson and Hansen 2000), the density of rainbow trout in this area during the prespawning and spawning periods increases as spring progresses because fish move into and through the area prior to summer. Two 3 person crews working from drift or power boats will capture fish using hook-and-line gear. Although previous Kenai River rainbow trout assessments have employed hook-and-line methods exclusively to capture rainbow trout, an entanglement net made of 2-inch monofilament webbing will also be incorporated into this study design to learn if seining is an efficient method to capture rainbow trout in this section of the middle Kenai River. Both of these methods are most efficient on relatively shallow gravel bars, which are also preferred spawning and staging habitat for rainbow trout. Fish ≥200 mm FL will be marked with an individually numbered Floy[1] T-anchor tag and an adipose fin clip and released as near as possible to the location of capture.

Each week will represent a separate sampling event. Sampling will be conducted 5 days per week Monday–Friday. A 2-day hiatus between sampling events will allow mixing of fish. The approximately 2½ mile study area will be divided into 2 sections at the start of the sampling season based on knowledge about the number of specific locations in each section where rainbow trout were caught consistently in 2017 (Figure 2). The project leader will ensure that all

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

fishable areas within each section are sampled during each event, with effort proportional to the amount of fishable waters in each section. Increases in catch per unit effort from locations within a section with higher abundance should help equalize capture probabilities over the study area because population densities may vary over the duration of the study.

Figure 2.–Middle Kenai River rainbow trout study area, 2018.

Expected precision—Abundance

In 2017, we used the POPAN parametrization (Schwarz and Arnason 1996) of the Jolly-Seber open population model to estimate the abundance of Kenai River rainbow trout ≥200 mm FL present between RM 45.0 and RM 48.0 from May 2 to June 8. The estimate was stratified by length with estimates of 32,027 (SE 9,740) trout 400 mm FL or smaller and 14,948 (SE 2,417) trout greater than 400 mm FL. The imprecision of the 2017 abundance estimates was driven by lower probability of capture than anticipated and model uncertainty.

To estimate expected precision for the 2018 field season, we used 2017 parameter estimates to simulate 30 datasets under several assumed abundances and probabilities of capture, estimated abundance for each simulation, and reported average sample size and relative precision for each scenario (Table 2). True abundance was set to approximate 2017 estimates (30,000 small fish and 15,000 large fish) as well as populations 33% smaller (20,000 small fish and 10,000 large fish) and larger (40,000 small fish and 20,000 large fish). Probability of capture was set to approximate 2017 estimates (0.017 for small fish and 0.025 for large fish) as well as 2 simulations where small fish probability of capture increased (0.020 and 0.026) and one simulation where both large and small fish probability of capture increased (0.030 for both). These increases are consistent with improvements in sampling technique and reduction in sampling area planned for the 2018 season. Simulation results suggest we will meet our precision objectives for large fish if the population size is at least 15,000 fish or if the population size is only 10,000 fish but the probability of capture increases to 0.03. The precision objective for small fish will only be achieved if the population size is at least 30,000 fish and probability of capture of small fish is 0.26 or greater.

These probabilities of capture were not achieved for small fish in 2017; when similar methods were used to estimate abundance of rainbow trout ≥200 mm FL for RM 69.7 to RM 73.2, probability of capture ranged from 0.045 to 0.057 (Eskelin and Evans 2013). Three changes will be made in 2018 to increase the probability of capture on all sizes of fish and small fish in particular. First, the sampling area will be reduced to omit sections near the 2017 boundaries where sampling gear was inefficient and catch rates were low. Second, a new gear type will be introduced (seine) designed to reduced size selectivity. Lastly, as the second year of the project, we anticipate sampling efficiency to improve.

Table 2.–Average relative precision and number of trout marked for 30 simulated datasets using each combination of 3 population sizes and 4 probabilities of capture.

True abundance (small; large) [a]	Statistic	Probability of capture (small; large)			
		0.017; 0.026	0.020; 0.026	0.026; 0.026	0.030; 0.030
20K; 10K					
	Relative precision (small; large)	0.64; 0.35 [b]	0.46; 0.34 [b]	0.35; 0.34 [b]	0.29; 0.29 [c]
	Trout marked	1,663	1,840	2,105	2,472
30K; 15K					
	Relative precision (small; large)	0.48; 0.28 [d]	0.35; 0.29 [d]	0.27; 0.28 [c]	0.24; 0.24 [c]
	Trout marked	2,501	2,750	3,160	3,720
40K; 20K					
	Relative precision (small; large)	0.38; 0.25 [d]	0.31; 0.24 [d]	0.24; 0.24 [c]	0.20; 0.20 [c]
	Trout marked	3,315	3,642	4,233	4,940

[a] "K" means 1,000.

[b] Objective criteria would be missed for both size classes.

[c] Objective criteria would be met for both size classes.

[d] Objective criteria would be missed for only the small size class.

Mark–Recapture Assumptions

The assumptions necessary to estimate abundance with an open population model are as follows (Seber 1982):

1) Capture probabilities are the same for all animals (marked and unmarked) at each sampling occasion (sampling events last 5 days).
2) Survival probabilities are the same for all animals (marked and unmarked) between each pair of sampling events.
3) Marked trout do not lose their tags between events and marked trout recaptured during subsequent capture events are correctly identified and recorded.
4) Sampling time is instantaneous.
5) The study area is constant.

Equal probability of capture is the most important assumption in a mark–recapture experiment. Probability of capture is likely to vary as a function of fish characteristics, marking event characteristics, or both. These variations can be modeled as described in the "Data Analysis" section below. Assumption 1 will be violated if probability of capture changes after marking, although we have no evidence of behavioral effects in tagged rainbow trout captured with similar techniques (Eskelin and Evans 2013). Capture techniques and sampling effort will be consistent throughout the study so that tagged and untagged fish will be exposed to similar sampling. Also, tagged and untagged fish will have an opportunity to mix during the 2 days between sampling events.

Survival probabilities are also likely to be equal for tagged and untagged fish. Catch and release mortality is low for sport caught rainbow trout, and for seined fish, the mesh size will be too small to cause damage to gill filaments. Careful and rapid processing when capturing and handling fish will minimize stress for tagged fish after release.

The assumption of no tag loss will be tracked by clipping the adipose fin from all rainbow trout (≥200 mm FL) caught and tagged. This secondary mark will allow testing the assumption of no tag loss. The crew will carefully examine and record data for each caught fish to negate problems with marked fish not being properly detected and recorded (Appendix A1).

Sampling events will last for 5 days with 2 days between events such that the interval of time between capture can differ for individual trout. This time difference is unlikely to translate into differential survival because apparent survival has been close to 100% in all Kenai River rainbow trout studies, and simulation studies have shown parameter estimates are robust to violations of the instantaneous sampling assumption (Hargrove and Borland 1994).

A fixed study area will be used throughout the experiment.

Expected Precision—Length Composition

To attain the desired precision of ±5 percentage points 95% of the time for fork length (FL) composition, a minimum of 480 rainbow trout need to be sampled (Thompson 1987). These criteria will be easily achieved because all captured rainbow trout will be measured for length, and we anticipate sampling over 1000 fish for abundance estimation (Table 2).

DATA COLLECTION

Rainbow trout will be captured with hook and line as well as by drifting entanglement or seine nets. Captured fish will be tagged and biological information will be collected from each fish as described below before it is released back to the water. Fish that are visibly injured (bleeding from mouth or gills, lethargic, or not responsive to manual resuscitation) or dead will not be tagged. Although not used in this project, biological data will be collected from dead fish for the ADF&G aquatic education program.

A minimum of 2 to 3 people will be assigned to each boat to complete the following tasks:

1) Tag rainbow trout $\geq$200 millimeters with an individually numbered Floy T-Anchor tag and remove the adipose fin (Appendix A1). A recaptured recently finclipped fish with no tag present will be recorded as a tag loss and given a new tag.
2) Record the sublocation of capture within the study area as well as note locations where fish are more readily captured, especially by beach seine or entanglement net.
3) Record method of capture (hook and line vs. net).
4) Examine all rainbow trout for tags and an adipose fin.
5) Measure FL to the nearest millimeter; determine sex (based on external morphology) and maturity (based on color and presence or absence of milt or eggs) of all rainbow trout captured.
6) Record all field data associated with activities 1–4 above on Allegro2 handheld computers or data sheets. (Appendices B1–B3).

DATA REDUCTION

All data will be entered by keypad into preset fields on an Allegro2 GEO handheld computer (Appendix B1). After sampling each day, the data from the handheld computers will be downloaded using Juniper Systems software onto a desktop PC. In the event the handheld computer is disabled or lost, data will be recorded on a waterproof paper form (Appendices B2 and B3). An attempt will be made review the data at least once per week to correct obvious errors. The project biologist will create an ASCII text file and capture history file for analysis in Program MARK and SAS.

DATA ANALYSIS

Abundance

The R package RMark will be used to estimate abundance with the POPAN parametrization of the Jolly-Seber model. In the POPAN parametrization (Schwarz and Arnason 1996) 4 parameters describe a mark–recapture experiment with *i* capture events: N, the total number of animals to enter the study area and survive until the next sampling event, **b**, a vector of length *i* which sums to 1 and describes the percentage of the population entering the study area prior to sampling event *i*, **phi**, a vector of length *i*-1 describing apparent survival between sampling events, and **p**, a vector of length *i* describing the probability of capture during each sampling event.

The most general form of the POPAN Jolly-Seber model we will consider (**phi**$_{\text{time}}$, **p**$_1$, **b**$_{\text{time}}$) allows separate estimates for apparent survival and entry probability for each capture occasion but assumes a constant probability of capture[2]. Goodness of fit for this model will be assessed using a parametric bootstrap procedure to compare the observed model deviance to a distribution of model deviances generated using simulated data (Williams et al. 2002). The bootstrapping procedure begins by generating parameter maximum likelihood estimates (MLE) for the (**phi**$_{\text{time}}$, **p**$_1$, **b**$_{\text{time}}$) model given the observed capture history. Capture histories simulated using those parameter MLEs and the assumed model structure will exactly satisfy model assumptions. Approximately 100 simulated capture histories are then refit to the (**phi**$_{\text{time}}$, **p**$_1$, **b**$_{\text{time}}$) model. If the observed deviance is between the 5th and 95th percentile of simulated deviances, the model fits the data. If the model fails to fit the data, a quasilikelihood approach will be employed (Williams et al. 2002).

Heterogeneity amongst rate parameters (**b**, **phi**, **p**) can be handled by using a generalized linear model to write each parameter as a linear function of covariates using a logit or multinomial logit link function. Covariates can be categorical or continuous and vary between events or between groups. For example, in 2017, a top preforming model (**phi**$_1$, **p**$_{\text{level*fl}}$, **b**$_{\text{temp*fl}}$) included constant survival but probability of capture as a function of the following:

$$\log\left(\frac{p_{ig}}{1-p_{ig}}\right) = \beta_0 + \beta_2 G + \beta_3 level_i + \beta_4 level_i G, \quad (1)$$

Where $p_{ig}$is the probability of capture for length group g during event i, $level_i$ is the water level during event i, and G is an indicator variable for one of the two length groups. The covariates tested in 2017 had some theoretical basis. Water level generally increases throughout out the project as the season progresses, and furthermore, capture probability is thought to decrease with increasing water level. We used 2 length categories (<400 mm and ≥400 mm FL) because recapture rates were similar within those length groups and because 400 mm FL is a rough approximation of the boundary between mature and immature trout. Entrance probability is handled similarly except for the use of a multinomial logit link because of the sum-to-one constraint. Entrance probability is thought to vary with temperature because migration is related to spawning and spawning is probably related to temperature. In 2018, models containing various combinations of these 3 covariates (length group, water level, and water temperature) as well as other more parsimonious parameter structures will be considered.

After a variety of models have been identified and fit to the data, model selection will proceed using Akaike's Information Criteria (AIC) as an optimization criterion:

$$AIC = -2\log\left[L\left(\hat{\theta}\middle|y\right)\right] + 2K. \quad (2)$$

[2] A model with time varying probability of capture is not estimable because some parameters are confounded.

Where $L(\hat{\theta}|y)$ is the likelihood of the parameter maximum likelihood estimates ($\hat{\theta}$) given the data of interest (y) and where K is the number of parameters in the model. The relative differences in AIC between each model and the minimum AIC in the model set ($\Delta_i = AIC_i - AIC_{min}$) are used to rank models where Akaike weights,

$$w_i = \frac{\exp\left(-\Delta_i/2\right)}{\sum_{m=1}^{R} \exp\left(-\Delta_m/2\right)}, \qquad (3)$$

provide a normalized measure of the evidence that model *i* is the most appropriate model out of the *R* models considered. Akaike weights close to 1 indicate one model is favored while several models with similar weights indicate several different parameter structures explain the data equally well. In this case, model averaging may be appropriate (Williams et al. 2002).

Length Composition

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

$$\hat{p}_j = \frac{n_j}{n}, \qquad (4)$$

and

$$\operatorname{var}(\hat{p}_j) = \frac{\hat{p}_j(1-\hat{p}_j)}{n-1}, \qquad (5)$$

where

n_j = the number of rainbow trout ≥200 mm of length class *j*, and

n = the total number of rainbow trout ≥200 mm measured for length.

The abundance of rainbow trout ≥200 mm by length class will be estimated as a product of 2 random variables as follows:

$$\hat{N}_j = \hat{N}\hat{p}_{j,} \qquad (6)$$

Its variance was calculated as follows (Goodman 1960):

$$\operatorname{var}(\hat{N}_j) = \hat{N}^2 \operatorname{var}(\hat{p}_j) + \hat{p}_j^2 \operatorname{var}(\hat{N}) - \operatorname{var}(\hat{p}_j)\operatorname{var}(\hat{N}). \qquad (7)$$

If length groups are used to estimate abundance the same procedure will be used for each length group.

SCHEDULE AND DELIVERABLES

Dates	Activity
April 1–April 28	(Staff) Procure equipment for the field season.
May 1	(All staff) Field season preparation and preseason training.
May 1–June 8	(All staff) Mark–recapture population estimate field work.
June	(All staff) Prepare equipment for winter storage.
November 1	(Begich) Tagging data edited and error checked.
December 1	(Reimer) Final population estimates.
March 1	(Begich) Fishery Data Series (FDS) report submitted and data archived.

REPORTING

The results of this project will be presented in an Alaska Department of Fish and Game, Divison of Sport Fish, Fishery Data Series report.

RESPONSIBILITIES

Principal Investigator

Robert Begich, Fishery Biologist III

This position will serve as the project supervisor. Ensures equipment is procured, supervises tagging crew, supervises collection and processing of data, edits and analyses data, and authors year-end FDS report.

Consulting Biometrician

Adam Reimer, Biometrician II

Provides guidance on sampling design and data analysis. Assists with the preparation of the operational plan, data analysis, and year-end report.

Tagging Crew

Tony Eskelin, Fishery Biologist II, May 1–June 8.
Jeff Perschbacher, Fishery Biologist I, May 7–June 1.
Vacant, NP-Fish and Wildlife Technician II, May 1–June 15.
Vacant, NP-Fish and Wildlife Technician II, May 1–June 15.
Vacant, NP-Fish and Wildlife Technician II, May 1–June 15.
Vacant, NP-Fish and Wildlife Technician II, May 1–June 15.

Duties: Prepare and maintain all field equipment. Collect field data as outlined in the operational plan. The crew is responsible for adhering to sampling schedules, and will complete collection and review errors and submit data to the project biologist.

BUDGET SUMMARY

Proposed FY18 costs:

Line item	Category	Budget ($K)
100	Personal Services	19.9
200	Travel	0.0
300	Contractual	0.0
400	Commodities	3.3
500	Equipment	0.0
Total		23.2

Funded personnel FY18:

PCN	Name	Level	Budget ($K)
11-NP	<Vacant>	FWT II	1.7
11-NP	<Vacant>	FWT II	1.7
11-NP	<Vacant>	FWT II	1.7
11-NP	<Vacant>	FWT II	1.7
Total			6.8

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APPENDIX A: TAGGING PROCEDURES

Appendix A1.–Tagging procedures for handling and inserting tags.

Upon capture, rainbow trout will be placed in plastic tubs filled with river water. After fish are tagged and sampled, they will be placed back into the tub for observation. Sampled trout will be released unharmed as near as possible to the original location of capture.

The condition of all captured rainbow trout will be assessed. Rainbow trout with deep scars or lesions, damaged gill filaments, visibly bleeding, lethargic condition, or otherwise appearing unlikely to survive will not be tagged. Rainbow trout less than 200 mm TL will be sampled for biological information but will not be tagged.

Rainbow trout that are 200 mm TL or greater and judged to be in viable condition will have a uniquely-numbered, Floy FD-94, T-anchor tag inserted in the basal rays of the dorsal fin on the left side. To insert a tag, the needle of the tag gun will be placed on the left side of fish about one-eighth inch below the rear base of the dorsal fin. The needle will be pushed into the fish in a forward and slightly downward direction so that it penetrates between the basal rays of the fin. Once the needle is in the fish, the gun can be squeezed to insert the tag. Upon tag insertion, the needle can be removed from the fish and the fish can be checked that the tag is firmly installed. Scissors will be used to remove the adipose fin on all tagged rainbow trout. To ensure the correct tag numbers and lengths are recorded for each fish, staff recording data will repeat the tag number and biological data verbally to the staff tagging and measuring the fish so the data can be verified. Staff tagging, measuring, and examining fish to determine maturity will provide the data in the same order to prevent errors during data recording.

Tags are easily placed in rainbow trout when tagging guns are kept clean, needles are sharp, and the tags are undamaged. The condition of the tag guns will be checked each day to ensure tag guns are clean and lubricated. Needles will be replaced immediately when dull or damaged and tags will be kept in order and stored where they can't be bent or damaged.

APPENDIX B: DATA COLLECTION

Appendix B1.–Instructions for Allegro2 GEO handheld computer and data map for ASCII text file.

Data field name	Start column	End column	Comma column	Description
Year	1	4	5	Four digit year
Month	6	7	8	Two digit month
Day	9	10	11	Two digit day
Location	12	15	16	River mile to nearest tenth
Length	17	19	20	Three digit length
Tag number	21	26	27	Tags may be up to 6 digits
Sex of fish	28	28	29	Unknown=0, Male=1, Female=2
Maturity	30	30	31	Unknown=0, Immature=0, Mature=1
Adipose clip	32	32	33	Record what it has when fish is released, Clipped=1, Not clipped=0
Tag loss	34	34	35	Adipose fin missing when captured=1, otherwise=0
Recap	36	36	37	Tag present when captured=1 no tag present when captured=0
Fate	38	38	39	Fish not viable or fish died after capture =1, otherwise 0
Capture method	40	40	41	Hook and line=1, Net=2

Appendix B2.–Instructions for filling out the Kenai River rainbow trout mark–recapture form.

Date: Write in current date.

Location: Write in **"**Middle Kenai River".

Method: Write in **"**Hook and Line or Seine".

Collectors: Collectors initials.

Water Temp: Water temperature each day is not required to be recorded. Remote loggers will be deployed in the study area at the start of the project and retrieved at the end of the project.

Time: Time when water temperature taken.

Page: Write in the number consecutively for each sampling day

Catch Location (subsection): Put in location of capture (see description).

Catch sublocation	Description
"1"	Torpedo Creek (RM 45.5) to project marker 46
"2"	Project marker to upper Super hole (RM 47.5)

Length: Fork length to the nearest millimeter; measure the fish from the tip of snout to the fork of the tail.

AD Clip: Put a checkmark when adipose fin is clipped or PRE if adipose fin is already missing or clipped upon capture.

Sex: Mark one of the following based on examination of sexual characteristics, external morphology, or both.

1 = male

2 = female

U = unknown

Maturity: Visually examine captured rainbow trout for presence of one or more of the following:

Immature (I): immature rainbow trout, silver, no visible presence of milt or eggs.

Mature (M): mature rainbow trout, dark (green) coloration, milt or eggs and/or ovipositor, enlarged soft stomach/abdomen visibly present.

Recap: Put an "R" if fish is already tagged or adipose fin is missing upon capture.

Floy Tag#: Record Floy tag number.

Tag Loss: Put a checkmark when upon capture adipose fin is clipped and no tag is present.

Fate: Record "1" for yes mortality.

Comments: This is a voluntary field to record any observations of interest about fish or catch location.

Appendix B3.–Mark–recapture field form, 2018.

Date: Collectors: Page ______ of _______

Time: Gear:

Fish #	Catch Location	Length (mm)	Floy Tag #	Sex	Maturity	Ad Clip	Tag Loss	Recap	Fate	**Comments**
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										