Regional Operational Plan SF.2A.2017.08

Operational Plan: Middle Kenai River Rainbow Trout Abundance

by

Robert Begich

May 2017

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.2017.08

OPERATIONAL PLAN: MIDDLE KENAI RIVER RAINBOW TROUT ABUNDANCE

by
Robert Begich

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

May 2017

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

This document should be cited as follows:
Begich, R. 2017. Operational Plan: Middle Kenai River rainbow trout abundance. Alaska Department of Fish and Game, Regional Operational Plan ROP.SF.2A.2017.08, Anchorage.

SIGNATURE/TITLE PAGE

Project Title:	Middle Kenai River Rainbow Trout Abundance
Project leader(s):	Robert Begich
Division, Region and Area	Sport Fish, Region II, Northern Kenai Peninsula
Project Nomenclature:	
Period Covered	May 2017 to March 2018
Field Dates:	May–June 2017
Plan Type:	Category II

Approval

Title	Name	Date
Project leader	Robert Begich	4/28/17
Biometrician	Adam Reimer	4/28/17
Research Coordinator	Tim McKinley	4/28/17

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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.

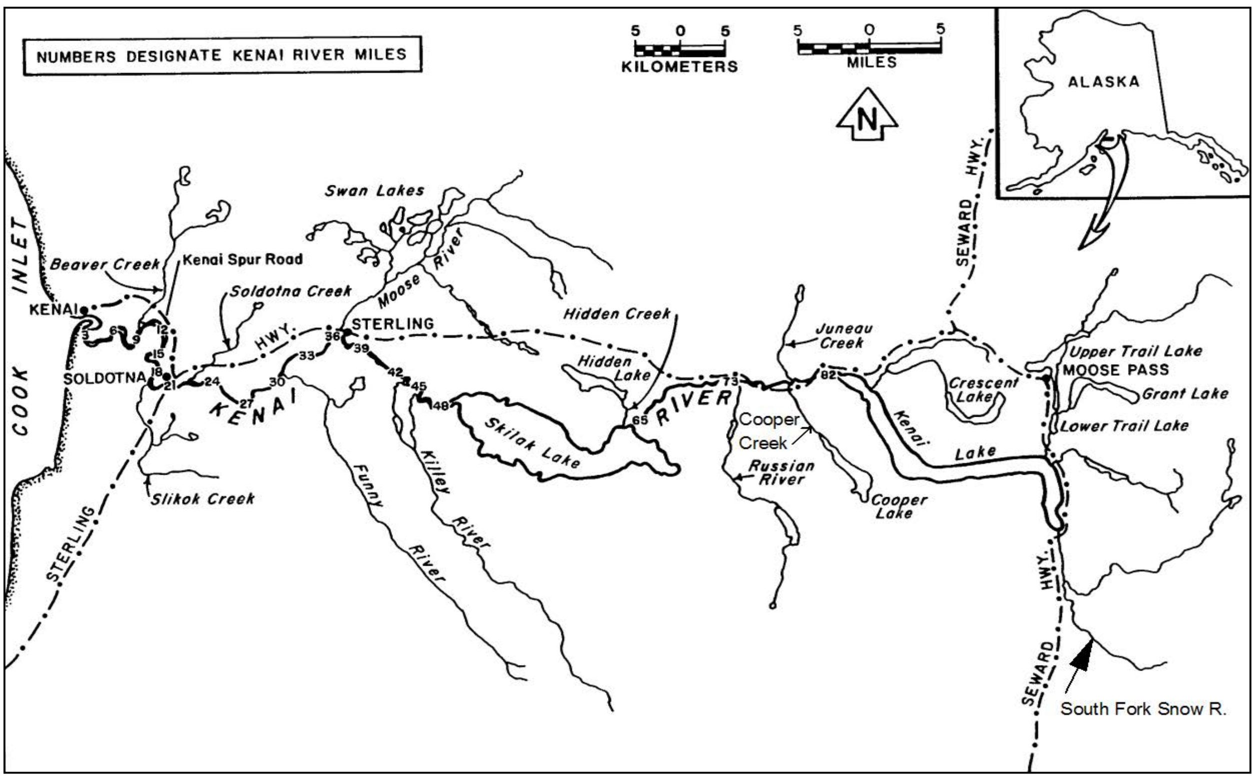

Figure 1.–Map of the Kenai River drainage.

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
Average																		
2011–2015	17,670	660	4.0	20,130	570	3.0	58,250	410	0.7	87,160	330	0.4	410	30	12.1	183,620	1,980	1.1
2006–2015	16,060	630	4.3	18,720	680	3.9	55,670	550	1.0	87,980	420	0.5	2,230	40	6.7	180,670	2,320	1.3
1984–2015	9,830	730	11.0	9,790	670	10.7	28,010	740	7.5	52,420	350	3.8				101,360	2,520	6.0

Source: 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 (2011–2015) catch of rainbow trout in each Kenai River section is nearly 2-fold 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 a 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 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 while 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 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 the 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 increases the quality of the fishery. Consequently, evaluating change to regulations is of interest to managers. Past rainbow trout assessments have focused mainly on the upper Kenai River where regulations 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 (in 1986–1987, 1995, 2001, and 2009) of rainbow trout 200 mm or greater in total length in a section of the upper Kenai River , and these were used as indices of the entire upper Kenai River rainbow trout population (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 stabilized. In addition, the recent assessments showed that the population had a more uniform distribution of fish among size classes than the rainbow trout size 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.

The 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 length in an approximately 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 rainbow trout 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 the 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 spawning of Kenai River rainbow trout has been found to occur during a short period of time and in a short section of the river, assessment during this time and place is extremely valuable for the management of rainbow trout in the Kenai River. Yet the abundance and size structure of the Kenai River rainbow trout population has not been assessed during the spawning period, and in addition, it would be valuable to obtain an abundance index for the population during this time and place because telemetry results 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. Results of this study will address these needs and will provide information about rainbow trout that is presently unknown, such as efficient capture methods and locations for rainbow trout during spring and rainbow trout abundance, size structure, and maturity. This information will 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 (Torpedo Slough) and RM 48 (Rainbow Alley) from May 1 through June 2 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 (Torpedo Slough) and RM 48 (Rainbow Alley) from May 1 through June 2 such that the estimates are within 5 percentage points of the true value 95% of the time.

SECONDARY OBJECTIVES (TASKS)

1) Examine all captured rainbow trout for external sexual characteristics to determine maturity.
2) Examine all captured rainbow trout for external scars or deformities on the head that may indicate hook injuries.
3) Examine all captured rainbow trout for external parasites.

METHODS

STUDY DESIGN

Abundance

A mark–recapture experiment will be conducted to estimate abundance. Rainbow trout will be captured in the middle Kenai River between RM 45 (Torpedo Slough) and RM 48 (Rainbow Alley) from May 1 through approximately June 2. Based on previously gathered telemetry information (Larson and Hansen 2000), rainbow trout are concentrated and sedentary in this area during this prespawning and spawning period prior to migrating to summer rearing and feeding areas downstream after spawning. Two 3 person crews working from powerboats 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, a beach seine will also be incorporated into this study design to learn if seining is an efficient method to capture rainbow trout while they are aggregated prior to and during spawning 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 in length will be marked with an individually numbered Floy T-anchor tag[1] and an adipose finclip and released as near as possible to the location of capture.

Each week will represent a separate sampling event. Sampling will be conducted at least 4 days per week (e.g., Monday–Thursday). A hiatus between sampling events will allow mixing of fish during a time of year when telemetry data suggests rainbow trout may be relatively sedentary. The approximately three miles of river section of interest will be divided into 3 approximately 1-mile sections (Figure 2): Section 1 will be Torpedo Slough (RM 45) to Upper Killey River (RM 45.9), Section 2 will be Upper Killey River (RM 45.9) to Super Hole (RM 47), and Section 3 will be Superhole (47) to Rainbow Alley (RM 48). Radiotelemetry data indicate that Sections 2 and 3 contain larger numbers of spawning rainbow trout. Section 1 probably contains smaller numbers of spawning rainbow trout but is included in the study design to align the abundance estimate with the fishing closure designed to protect spawning rainbow trout. The project leader will ensure that all 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 in

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

sections with higher abundance should help equalize capture probabilities over sections with different population densities.

Figure 2.–Middle Kenai River study area with 3 subsections.

Image source: Google Earth © 2016.

Sample Size for Abundance Estimates

The previous midsummer abundance estimate of rainbow trout ≥200 mm for RM 40 to RM 48 was 7,883 fish (Larson and Hansen 2000). While our study area is thought to be the spawning location for fish that summer both within and downstream of the study area, it's unknown how abundance has changed in this area. Because of the time elapsed since abundance was last estimated in this area, we simulated datasets assuming closed populations ranging from 4,000 to 10,000 rainbow trout ≥200 mm with weekly captures of 175–250 fish per week. Program MARK (White and Burnham 1999) was used to determine expected precision under each combination of abundance and sample size. If approximately 250 fish are captured per week, we would expect to meet our objective criteria with populations as large as 10,000 rainbow trout, with smaller populations requiring smaller weekly captures (Table 2). In general, objective criteria should be satisfied when the probability of capture is >0.25, which is reasonable given past experience with these capture techniques. When similar methods were used to estimate abundance of rainbow trout ≥200 mm for RM 69.7 to RM 73.2, probability of capture for average length fish ranged from 0.045 to 0.057 and weekly sample sizes exceeded 250 fish per week (Eskelin and Evans 2013).

Table 2.–Simulation results for closed population abundance estimates of Kenai River rainbow trout assuming populations of 4,000–10,000 fish and weekly captures of 175–250 fish.

		True abundance			
Weekly capture	Parameter	$N = 4000$	$N = 6000$	$N = 8000$	$N = 10000$
250 fish					
	Mean abundance estimate	4,018	5,996	8,093	10,014
	Mean relative precision	0.14	0.18	0.21	0.24
	Probability of capture	0.063	0.042	0.031	0.025
225 fish					
	Mean abundance estimate	4,032	6,031	8,137	10,303
	Mean relative precision	0.16	0.20	0.24	0.27
	Probability of capture	0.056	0.038	0.028	0.023
200 fish					
	Mean abundance estimate	4,001	6,064	8,233	10,236
	Mean relative precision	0.18	0.23	0.27	0.30
	Probability of capture	0.050	0.033	0.025	0.020
175 fish					
	Mean abundance estimate	4,117	5,990	7,984	10,343
	Mean relative precision	0.21	0.26	0.31	0.35
	Probability of capture	0.044	0.029	0.022	0.018

Note: All simulations considered a closed population of 5,000 fish with 5 capture occasions. Shaded areas indicate combinations where objective criteria would be satisfied.

Immigration during the first few weeks of the study period is possible based on radiotelemetry data collected in 2009. If immigration is substantial, simulation results suggest abundance estimation with an open population model would satisfy objective criteria for populations as small as 4,000 rainbow trout when probability of capture is 0.05. Because closed population models in MARK include some options not available for open population models (individual covariates, different probabilities of capture and recapture) it may be preferable to truncate the first few sampling events so that the assumption of closure is justified. If the study were reduced to 4 events, simulation results suggest relative precision criteria would be satisfied for populations as small as 4,000 fish with a probability of capture of 0.05. If the study were reduced to 3 events, simulation results suggest relative precision criteria would be satisfied for populations as small as 8,000 fish with a probability of capture of 0.05 and as small as 6,000 fish with a probability of capture of 0.06.

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

1) The population is closed with no additions or losses between sampling events (through recruitment, death, immigration, or emigration).

2) All rainbow trout have an equal capture probability during each sampling event or marked rainbow trout mix completely with unmarked rainbow trout between capture events.
3) Marking does not affect capture probability in subsequent capture events.
4) Marks (tags) are not lost between events.
5) All marked rainbow trout recaptured during subsequent capture events are correctly identified and recorded.

Assessment of Assumptions: Closed Population

Closure assumptions can be violated by immigration, recruitment, emigration, or mortality. This section of the Kenai River is closed to all fishing from May 1 through June 10 so mortality due to harvest will not occur during the study. Likewise, recruitment into the population of rainbow trout >200 mm total length from births or growth is probably negligible given the duration and timing of the project.

Study dates were chosen to coincide with the spring prespawning and spawning period of rainbow trout so that extensive violation of the closure assumption due to immigration or emigration is minimized. In 2011, radiotelemetry data indicate rainbow trout move into the study area during the month of May and stay within the study area until June. Movement to the outside of the boundary below the study area (below RM 45) as well as movement into the study area from the boundary above the study area (above RM 48) may occur depending upon timing of the spawning period in 2017. An early spawning period may result in significant emigration to downstream summer feeding areas prior to the targeted end date of the study on June 2. A late spawning period may result in significant immigration from upstream overwintering areas after the targeted start date of the study on May 1.

Significant departures from the closed population assumption will be tested by modeling capture histories in POPAN using parametrization for the open population mark–recapture experiment and using Akaike information criteria (AIC) to compare models. In the POPAN parametrization (Schwarz and Arnason 1996), 3 parameters describe a mark–recapture experiment with i capture events; 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 b_i; φ, 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. Using this parametrization, models with $b – 1 = 1$ imply no immigration, models with constant $\varphi = 1$ imply no apparent mortality through either natural mortality or emigration.

To assess the sensitivity of this strategy, we simulated data sets with increasing levels of immigration and emigration, estimated abundance with and without assuming closure, and tallied the number of simulations where we correctly identified that migration had occurred.

In 2011, 30% of the rainbow trout present in the study area during the month of May were already present on May 3; another 30% entered prior to May 10; and the remaining 40% entered prior to May 16. These entry probabilities can be represented by $b = (0.3, 0.3, 0.4, 0, 0)$ in the POPAN framework. Our simulation results (Table 3) suggest we could correctly identify if immigration had occurred using AIC model selection and that open model abundance estimates had less bias and 95% confidence intervals had better coverage probability than abundance estimates that assumed closure. If larger percentages of fish were present prior to the first sampling event, AIC model selection would probably still be successful at detecting immigration even when bias and coverage probabilities between the open and closed model estimates grow smaller and coverage probabilities converge.

Table 3.–Simulation results from 1,000 capture histories for a population with immigration between events.

	Entrance probability (*b*)			
	(0.7, 0.3, 0, 0, 0)	(0.5, 0.3, 0.2, 0, 0)	(0.3, 0.3, 0.4, 0, 0)	(0.2, 0.3, 0.5, 0, 0)
AIC correct	0.949	1	1	1
Open population model				
Mean abundance	5,104	5,122	5,100	5,162
Abundance CI coverage probability	0.94	0.95	0.96	0.95
Closed population model				
Mean abundance	5,264	5,447	5,740	6,020
Abundance CI coverage probability	0.93	0.92	0.85	0.76

In 2011, 15% of the rainbow trout that were present within the study area during May emigrated during the last week of May. Emigration would manifest itself in the POPAN framework as a lower apparent survival during weeks when emigration occurred (Table 4). Simulation results suggest a low probability of detecting 15% emigration combined with natural mortality of 10%, where $\boldsymbol{\varphi}$ = (.9, .9, .9, .765), during the last week of the study using AIC model selection. Emigration at higher rates would be successfully detected, although both open and closed models had small bias and large coverage probabilities at all levels of emigration.

Table 4.–Simulation results from 1000 capture histories for a population with emigration prior to the last capture event.

	Apparent survival (φ)		
	(0.9, 0.9, 0.9, 0.765)	(0.9, 0.9, 0.9, 0.63)	(0.9, 0.9, 0.9, 0.36)
AIC correct	0.23	0.84	1.00
Open population model			
Mean abundance	5,095	5,078	5,037
Abundance CI coverage probability	0.95	0.95	0.96
Closed population model			
Mean abundance	5,084	5,096	5,130
Abundance CI coverage probability	0.96	0.95	0.96

Assessment of Assumptions: Probability of Capture and Mixing

Variation in probability of capture due to size

It is possible that rainbow trout ≥200 mm will have different probabilities of capture due to size. When hook-and-line gear was used in an upper Kenai River rainbow trout mark–recapture study in 2009, size was a predictive covariate for probability of capture during some capture events although a similar experiment conducted in 2001 did not find a relationship between size and probability of capture (Eskelin and Evans 2013). Our experimental design includes beach seines, which may be less selective than hook-and-line gear.

Modeling approaches to dealing with variation in the probability of capture due to size will depend on if the population is open or closed to immigration. If the population can be considered closed, then we can use a group of models commonly referred to as "Huggins models" (Huggins 1989, 1991) to test whether length affected probability of capture and to incorporate the length effect in abundance estimation, should it be significant. These models will be fitted in Program MARK with model choice based on AIC.

If the population is open to immigration, we will identify length groups with homogenous probabilities of capture and estimate abundance for each group in 1 overall analysis.

Variation in probability of capture over sections

The assumption of equal probability of capture or mixing among locations (a component of Assumption 2) will be tested by examining the recapture rate of fish tagged among the 3 locations (3 × 2 chi-square test: location versus recaptured or not recaptured). If the probability of capture among locations is constant or if fish mix, then the recapture rates among locations should not vary. Mixing of fish among locations will also be tested by a 3 × 3 chi-square test (location captured versus location recaptured). If there is no mixing of marked individuals among sections and recapture rates differ by section, then study sections will be defined as groups in the Program MARK analysis, providing abundance by section in one overall analysis.

Assessment of Assumptions: Marking Effects on Capture Probability

Careful and rapid processing by the marking crew when capturing and handling fish will minimize stress and violation of this assumption. If the population can be considered closed, it will be possible to model a behavioral effect (probability of recapture differs from probability of capture) and use AIC to choose between models.

Assessment of Assumptions: Mark Loss

The assumption of no tag loss will be tracked by clipping the adipose fin from all rainbow trout (≥200 mm) caught and tagged. This secondary mark will allow testing of the assumption of no tag loss.

Assessment of Assumptions: Data Collection

Careful examination and recording of data by the crew of each fish caught will negate problems of marked fish not being properly detected and recorded.

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; with finite population correction factor based on a population size of 8,000). These criteria will be easily achieved because all captured rainbow trout will be measured for length and we anticipate sampling at least 875 fish in the abundance estimation component (5 weeks × 175 fish per week).

DATA COLLECTION

Rainbow trout will be captured with hook-and-line as well as by beach seine used from shore. 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 attempted manual resuscitation) or dead will not be tagged. However, biological data will be collected from any dead fish and these fish will be collected for the ADF&G aquatic education program. A minimum of 2 to 3 people will be assigned to each of 2 boats. Crewmembers will complete the following tasks for all fish captured:

1) Tag rainbow trout >200 millimeters with an individually numbered Floy T-Anchor tag and remove the adipose fin (see Appendix A1 for details). A recaptured recently finclipped fish with no tag present will be recorded as a tag loss and given a new tag.
2) Record the catch sublocation within the study area as well as note locations where fish are more readily captured, especially by beach seine.
3) Record method of capture: hook-and-line or beach seine.
4) Examine all rainbow trout for tags and an adipose fin.
5) Measure fork length (FL) to the nearest millimeter; determine sex, record observations of damage,injury, or scars on the head, eyes, or mouth that may be indicative of previous hooking; record presence or absence of copepod parasites; assess and record maturity of all rainbow trout captured (presence of milt or eggs, coloration; see Appendix B1).
6) Record all field data associated with activities 1-4 above on Allegro CX handheld computers or data sheets. (Appendices B1–B2).

DATA REDUCTION

All mark–recapture and biological data will be recorded on field forms as previously described or Allegro handheld computers (Appendix B2). The crew leader is responsible for ensuring the data are complete and accurate. At the end of each day of sampling, the crew leader will go over the data and correct obvious errors. The crew leader will also tally the number of rainbow trout caught, the number tags released, the number of recaptured fish, note the time fished per section, total hours worked, and any equipment problems. Daily tallies provided by the tagging crews will be used to track crew and inseason project performance. Additionally, these data will allow staff to keep a running tally, in the form of a contingency table, of tags deployed and recovered on a daily basis.

Field forms will be given to the project biologist and the data will be downloaded onto the project biologist's computer. The project biologist will create an ASCII text file and capture history file for analysis in Program MARK and SAS. An Excel file will also be created for volunteer tag returns. The project biologist will retain final edited copies of the field forms and will create an electronic tag database file.

DATA ANALYSIS

Abundance

Only mark–recapture data collected by the field crew will be used to estimate abundance. Results of the tests described earlier will indicate if assumptions have been met and which model will provide the most unbiased estimate of abundance. Of primary importance will be determining if the population can be considered closed.

If the closure assumption is satisfied (as indicated by AIC model selection in the POPAN parametrization), then the closed population suite of models in Program MARK will be used to estimate abundance. We will use a Huggins type model (Huggins 1989, 1991) to assess the effect of length on probability of capture and will use the associated Horvitz-Thompson-derived abundance estimate if necessary. Results of the section tests will be used to assess the need to stratify the data by section. If stratification by section is required (probability of capture among sections within sampling events is different and mixing did not occur), estimation will be conducted by assigning each section as a "group" in Program MARK and providing abundance by section in 1 overall analysis. AIC model selection will be used to determine the best model within Program MARK.

If the closure assumption is not satisfied (as indicated by AIC model selection in the POPAN parametrization), then 1 of 2 options will be chosen depending on the extent of immigration. If immigration is limited to the first sampling event, simulation results suggest it may be preferable to drop the first sampling event, reducing the capture histories to a 4-event mark–recapture and proceed as outlined for closed populations above. If immigration spans several events, the open population suite of models (Jolly-Seber models) in Program MARK will be used to estimate abundance. In this case, heterogeneity in capture probability related to size will be handled by creating length groups in the analysis. If stratification by section is required (probability of capture among sections within sampling events is different and mixing did not occur), estimation will be conducted by assigning each section as a "group" in Program MARK, providing abundance by section in 1 overall analysis. AIC model selection will be used to determine the best model within Program MARK.

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:

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

and

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

where

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

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

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

$$\hat{N}_j = \hat{N}\hat{p}_j, \quad (3)$$

and its variance (Goodman 1960):

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

If a length-based model (Huggins model with length covariate) was chosen for abundance estimation, estimated length composition will adjusted to account for the implied length selectivity following the methods described in (Eskelin and Evans 2013).

SCHEDULE AND DELIVERABLES

A general schedule for completion of tasks is outlined below.

Dates	Activity
April 1–April 28 (Staff)	Procure equipment for the field season.
May 1 (All Staff)	Field season preparation and preseason training.
May 2–June 2 (All Staff)	Mark–recapture population estimate.
June 5 (All Staff)	Prepare equipment for winter storage.
October 1 (Begich)	Tagging data edited and error checked.
December 1 (Begich)	Final population estimates.
January 1 (Begich)	Fishery Data Series (FDS) report submitted and data archived.
March 1 (Begich)	2018 operation plan.

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

RESPONSIBILITIES

Principal Investigator

Robert Begich, Fishery Biologist III, 1 January–31 December

Duties: This position will serve as the project supervisor for all personnel involved. Ensures equipment is procured, supervision of tagging crew, supervises collection and processing of data, edits data and analysis and author year-end FDS report.

Consulting Biometrician

Adam Reimer, Biometrician II, 1 January–31 December

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

Tagging Crew

Vacant, NP-Fish and Wildlife Technician II, May 1–15 June.

Vacant, NP-Fish and Wildlife Technician II, May 1–15 June.

Vacant, NP-Fish and Wildlife Technician II, May 1–15 June.

Vacant, NP-Fish and Wildlife Technician II, May 1–15 June.

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 all data forms and review them for errors before submitting them to the project biologist.

BUDGET SUMMARY

Proposed FY 17 costs:

Line item	Category	Budget ($K)
100	Personal Services	15.6
200	Travel	0.0
300	Contractual	1.0
400	Commodities	3.6
500	Equipment	0.0
Total		20.2

Funded Personnel FY17:

PCN	Name	Level	Funded man months
11-NP	<Vacant>	FWT II	1.5
11-NP	<Vacant>	FWT II	1.5
11-NP	<Vacant>	FWT II	1.5
11-NP	<Vacant>	FWT II	1.5
Total			6.0

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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 millimeters in length will be sampled for biological information but will not be tagged.

Rainbow trout that are 200 millimeters or greater in length and judged to be in viable condition will have a uniquely-numbered, Floy FD-68B T-anchor tag inserted in the basal rays of the dorsal fin on the left side. To insert a tag, place the needle of tag gun on left side of fish about one-eighth inch below the rear base of the dorsal fin. Push the needle 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, squeeze the gun to insert the tag. Remove the needle from the fish and check that the tag is firmly installed in the fish. Use scissors to remove the adipose fin on all tagged rainbow trout.

Tags are easily placed in rainbow trout when tagging guns are kept clean, needles are sharp, and the tags are undamaged. Clean and lubricate tag guns at the end of each day. Replace needles immediately when dull or damaged. Keep tags in order and stored where they can't be bent or damaged.

APPENDIX B: MARK–RECAPTURE FORM

Appendix B1.–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: Take water temperature reading at 12:00 break (deg. C).

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 Slough (RM 45) to Upper Killey River (RM 45.9)
"2"	Upper Killey River (RM 45.9) to Super Hole (RM 47)
"3"	Superhole (47) to Rainbow Alley (RM 48)
"4"	Above Rainbow Alley (RM 48) to Skilak Lake (RM 50)
"0"	Below Torpedo Slough (RM 45) to Third Hole (RM 32)

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 and external morphology.

M = male

F = 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 ovipositor, enlarged soft stomach and abdomen visibly present.

Parasites: Yes (Y) or No (N) on the presence of parasites on the gill filaments.

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.

Previous Hooking Injury: Yes (Y) or No (N) if damage to mouth, eyes, head is present and visible from a previous hooking injury from fishing.

Fate: Leave blank or record "M" for mortality.

Comments: Note any injuries other than described above, fin erosion, body scars, lethargic, mort, released not tagged, etc. Note if necessary specific areas of capture for different capture methods i.e. beach seine.

Appendix B2.–Mark–recapture field form.

Kenai River Rainbow Trout Field Sampling Form

Date: Water Temp: Page ______ of _______

Location: Time:

Collectors:

Fish #	Catch Location	Length (mm)	AD Clip	Sex	Maturity	Parasites	Recap	Floy Tag #	Tag Loss	Hooking Damage	Capture Method	Fate	**Comments**
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													

Tag Loss - √ if adipose fin is clipped and no tag is present when caught.

AD Clip - √ when adipose fin clipped, or pre for pre-existing clip.