

**Fishery Data Series No. 09-40**

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**Evaluation of Rainbow Trout Tagged in Naknek River  
Drainage, 1999–2001**

by

**Craig J. Schwanke**

August 2009

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Alaska Department of Fish and Game

Divisions of Sport Fish and Commercial Fisheries



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<b>Weights and measures (metric)</b>		<b>General</b>		<b>Measures (fisheries)</b>	
centimeter	cm	Alaska Administrative Code	AAC	fork length	FL
deciliter	dL			mid eye to fork	MEF
gram	g	all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.	mid eye to tail fork	METF
hectare	ha			standard length	SL
kilogram	kg	all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.	total length	TL
kilometer	km				
liter	L	at	@	<b>Mathematics, statistics</b>	
meter	m	compass directions:		<i>all standard mathematical signs, symbols and abbreviations</i>	
milliliter	mL	east	E	alternate hypothesis	H <sub>A</sub>
millimeter	mm	north	N	base of natural logarithm	e
		south	S	catch per unit effort	CPUE
<b>Weights and measures (English)</b>		west	W	coefficient of variation	CV
cubic feet per second	ft <sup>3</sup> /s	copyright	©	common test statistics	(F, t, $\chi^2$ , etc.)
foot	ft	corporate suffixes:		confidence interval	CI
gallon	gal	Company	Co.	correlation coefficient (multiple)	R
inch	in	Corporation	Corp.	correlation coefficient (simple)	r
mile	mi	Incorporated	Inc.	covariance	cov
nautical mile	nmi	Limited	Ltd.	degree (angular)	°
ounce	oz	District of Columbia	D.C.	degrees of freedom	df
pound	lb	et alii (and others)	et al.	expected value	E
quart	qt	et cetera (and so forth)	etc.	greater than	>
yard	yd	exempli gratia (for example)	e.g.	greater than or equal to	≥
		Federal Information Code	FIC	harvest per unit effort	HPUE
<b>Time and temperature</b>		id est (that is)	i.e.	less than	<
day	d	latitude or longitude	lat. or long.	less than or equal to	≤
degrees Celsius	°C	monetary symbols (U.S.)	\$, ¢	logarithm (natural)	ln
degrees Fahrenheit	°F	months (tables and figures): first three letters	Jan,...,Dec	logarithm (base 10)	log
degrees kelvin	K	registered trademark	®	logarithm (specify base)	log <sub>2</sub> , etc.
hour	h	trademark	™	minute (angular)	'
hour	h	United States (adjective)	U.S.	not significant	NS
minute	min	United States of America (noun)	USA	null hypothesis	H <sub>0</sub>
second	s	U.S.C.	United States Code	percent	%
		U.S. state	use two-letter abbreviations (e.g., AK, WA)	probability	P
<b>Physics and chemistry</b>				probability of a type I error (rejection of the null hypothesis when true)	α
all atomic symbols				probability of a type II error (acceptance of the null hypothesis when false)	β
alternating current	AC			second (angular)	"
ampere	A			standard deviation	SD
calorie	cal			standard error	SE
direct current	DC			variance	
hertz	Hz			population	Var
horsepower	hp			sample	var
hydrogen ion activity (negative log of)	pH				
parts per million	ppm				
parts per thousand	ppt, ‰				
volts	V				
watts	W				

***FISHERY DATA SERIES NO. 09-40***

**EVALUATION OF RAINBOW TROUT TAGGED IN NAKNEK RIVER  
DRAINAGE, 1999–2001**

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## ABSTRACT

Rainbow trout *Oncorhynchus mykiss* were tagged with uniquely numbered anchor T-bar tags in the Naknek River during five seasonal periods in 1999, 2000, and 2001. Tagged rainbow trout were recaptured during these periods and during spring, summer, and fall of 1999, and spring 2000 and 2001. Data from individual rainbow trout recaptured in a period other than that of initial tagging were analyzed by 100 mm fork length classes for time elapsed between initial marking and recapture, movement, growth, development of sexual maturity, and repeat spawning. Rainbow trout moved within the Naknek River tributaries and into Naknek Lake. Annual growth decreased significantly ( $P = 0.006$ ) with increased length from a mean of 132 mm for the 201-300 mm fork length class to 16 mm for the 701-800 mm fork length class. The percent of fish that developed sexual maturity increased significantly with increasing fork length class ( $P < 0.0001$ ) to 100% for fish greater than 600 mm fork length. Not all rainbow trout exhibited annual repeat spawning.

Key words: Rainbow trout, *Oncorhynchus mykiss*, Naknek River, Floy tag, growth, movement, recapture, maturity, repeat spawning.

## INTRODUCTION

The Naknek River drainage is in Southwest Alaska. A significant portion of this drainage consists of Naknek Lake and the outlet drainage of the Naknek River (Figure 1). A large portion of the drainage is in Katmai National Park and Preserve. Naknek Lake is a large oligotrophic body of water with a surface area of approximately 610 km<sup>2</sup> and a maximum depth of 173 m and the Naknek River flows approximately 60 km into Bristol Bay of the Bering Sea (Burgner et al. 1969; LaPerriere *Unpublished*<sup>1</sup>). The Naknek River drainage supports populations of five species of salmon *Oncorhynchus* and numerous resident fish species, including rainbow trout *Oncorhynchus mykiss*. A portion of the rainbow trout population has been found to migrate between Naknek Lake and Naknek River. Rainbow trout spawn in the upper 14 km of Naknek River between Rapids Camp and the outlet of Naknek Lake from early April through May. This spawning population comprises large (up to 920 mm TL) mature rainbow trout that migrate into the lake after spawning (Gwartney and Burger *Unpublished*<sup>2</sup>; Schwanke and Hubert 2003). Research indicates that these fish spend the summer in the lake and that many of them return to the Naknek River in the fall (Gwartney and Burger *Unpublished*; Schwanke and Hubert 2003).

The Naknek River flows by the towns of King Salmon and Naknek making it accessible to recreational angling. Due in part to its accessibility, the Naknek River sustains over 21,000 angler-days annually, the highest amount of angling of any fishery in Southwest Alaska (Howe et al. 2001). Salmon species are the target of most of the angling; however, the Naknek River is world famous for abundant, large rainbow trout (Dunaway and Fleischman 1996). Most rainbow trout fishing takes place in the upper 14 km between Rapids Camp and the outlet of Naknek Lake (Figure 1) and there are three periods of fishing activity annually: from break up in March to 9 April, 8 June to 30 June, and 15 August until the river freezes in October (Minard and Dunaway 1994). In addition, rainbow trout fishing occurs in Naknek Lake during the summer. The sport fish bag limit is five rainbow trout less than 457 mm TL (18 inches) per day from 1 November through 9 April and one fish less than 457 mm TL from 9 June through 31 October. Angling is also restricted to single-hook, artificial lures.

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<sup>1</sup> LaPerriere, J. D. *Unpublished*. Water quality inventory and monitoring-Katmai National Park and Preserve. Final report to the National Park Service, 1996. Alaska Cooperative Fish and Wildlife Research Unit, University of Alaska Fairbanks, Fairbanks, Alaska.

<sup>2</sup> Gwartney, L. A., and C. V. Burger. *Unpublished*. A radio tagging study of Naknek Drainage rainbow trout. Final Report to National Park Service, 1986. Alaska Department of Fish and Game, King Salmon.

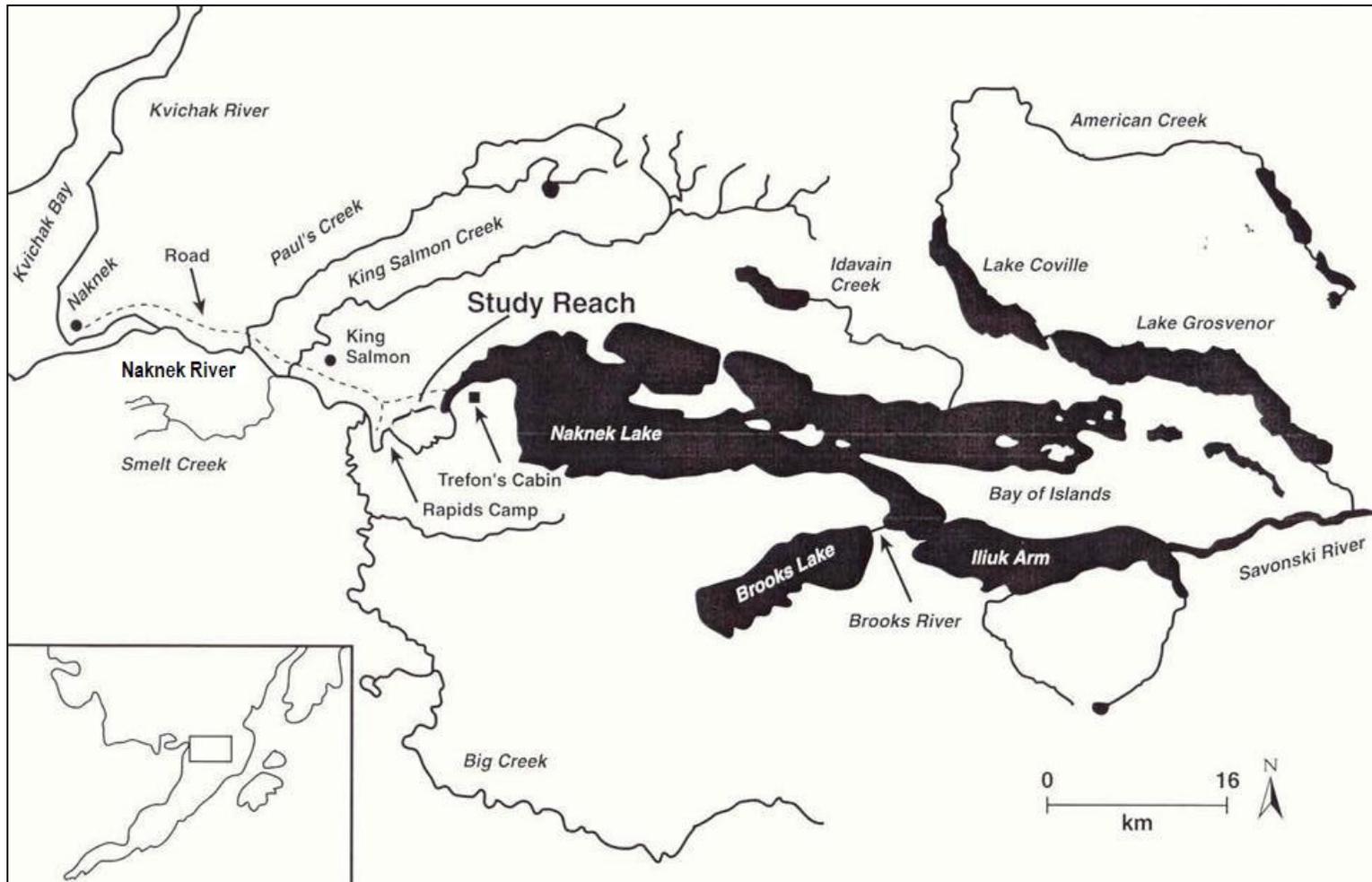


Figure 1.-The Naknek River drainage, Southwest Alaska.

The rainbow trout fishery of the Naknek River is managed under the guidelines of the Southwest Alaska Rainbow Trout Management Plan (Minard and Delaney 1989). This plan was implemented to protect the biological integrity of wild trout stocks while maximizing recreational and economic potential. A stable trophy rainbow trout fishery has been maintained since the implementation of this management plan by the Alaska Department of Fish and Game (ADF&G).

Periodically ADF&G, Sport Fish Division conducts stock assessment studies for rainbow trout on the Naknek River. Data collected during these studies are used to estimate stock characteristics such as length frequency distribution, length at maturity, proportion sexually mature, and the abundance of fish in the stock. These assessments include the tagging of captured rainbow trout. Large numbers of rainbow trout were tagged in the Naknek River drainage during studies conducted in 1999, 2000, and 2001. As a result of these tagging studies a large database of approximately 3,000 tagged fish exists. Many fish marked during these studies were subsequently recaptured, but recapture data were not analyzed prior to this report.

Analysis of data in this report provides information on stock characteristics of Naknek River rainbow trout. Information expected to be gained from such an analysis includes movement patterns, growth, development of sexual maturity, and frequency of repeat spawning.

## **OBJECTIVES**

Objectives of this report are to: (1) determine how many rainbow trout were marked each year during the spring, summer, and fall from 1999 through 2001; (2) create a summary table of tagging and recovery information by location in the drainage; and (3) create a marking and recapture history for recaptured fish comparing locations, dates, lengths, and maturity of captures. This information is used to discuss movements, growth, development of sexual maturity, and the occurrence of repeat spawning of rainbow trout in the Naknek River.

## **METHODS**

Tagging occurred during the spring, summer, and fall of 1999; spring of 2000; and spring of 2001 (Table 1). Spring, summer, and fall capture periods were: 20 March to 30 May; 1 June to 21 August; and 22 August to 15 October, respectively. Rainbow trout were captured with hook and line during all periods in 1999, and a combination of gillnets, beach seines, or hook and line during 2000 and 2001.

Periods of capture were identified from electronic data files of rainbow trout tagged in the upper Naknek River from 1999 through 2001. Rainbow trout were captured with hook and line, gillnets, or beach seines and were tagged with individually numbered anchor T-bar tags manufactured by Floy<sup>TM3</sup>, measured to the nearest millimeter FL, location of capture was recorded, and sexual maturity of fish captured during the spring was determined as described by Schwanke and Hubert (2004). Sexually mature fish were defined as fish that were capable of spawning during the spring of capture. The total number of rainbow trout tagged during each period was determined from electronic data files of tagged rainbow trout. Effort expended for each gear type during capture periods in the springs of 2000 and 2001 were reported in Schwanke and Hubert (2004). Effort was not recorded for any other time periods.

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<sup>3</sup> Product names used in this report are included for scientific completeness but do not constitute product endorsement.

Table 1.—Summary of rainbow trout captured and tagged in upper Naknek River and Naknek Lake by sampling periods and gear type, 1999–2001.

Sampling gear type	Sampling periods																		All Combined	
	1999						2000						2001							
	Spring		Summer		Fall		Spring		Summer		Fall		Spring		Summer		Fall			
	Captured	Tagged	Captured	Tagged	Captured	Tagged	Captured	Tagged	Captured	Tagged	Captured	Tagged	Captured	Tagged	Captured	Tagged	Captured	Tagged		
Hook and line	553	542	166	152	300	254	837	741	114	6	1 <sup>a</sup>	1 <sup>a</sup>	9	7	144	16	3 <sup>c</sup>	3 <sup>c</sup>	2,127	1,722
Gillnet	ND	ND	ND	ND	ND	ND	516	475	ND	ND	1 <sup>b</sup>	1 <sup>b</sup>	504	497	1 <sup>c</sup>	1 <sup>c</sup>	ND	ND	1,022	974
Beach seine	ND	ND	ND	ND	ND	ND	448	238	ND	ND	ND	ND	542	372	ND	ND	ND	ND	990	610
Total	553	542	166	152	300	254	1,801	1,454	114	6	2	2	1,055	876	145	17	3	3	4,139	3,306

*Note:* Sampling periods = spring (20 Mar to 30 May), summer (01 Jun to 21 Aug), and fall (22 Aug to 15 Oct); Captured = all rainbow trout captured and examined for tags; Tagged = rainbow trout that were already tagged at capture (recapture) or received a tag at capture; "ND" = no data because no attempts were made to collect it with the gear type.

4

<sup>a</sup> Fish caught by sport anglers.

<sup>b</sup> Fish caught in subsistence gillnet.

<sup>c</sup> Fish caught in commercial gillnet.

Recaptured fish included fish captured with hook and line, gillnets, or beach seines by ADF&G personnel and reports of captured tagged fish from the public. Data recorded from rainbow trout recaptured by ADF&G personnel included the tag number, FL (millimeter), location, and sexual maturity. Data from rainbow trout captured by anglers were limited to tag number, location, and date. Due to lack of size data these recaptures were only examined for location of recapture within the drainage. Data from rainbow trout recaptured in a period other than that of initial tagging were examined for changes in time, movement, growth, and sexual maturity since their initial capture. Additional periods when captures occurred but tagging was not conducted were created to categorize recaptured rainbow trout. These periods were: Naknek Lake during the summer of 1999, 2000, and 2001; Naknek River during the summer of 2000 and 2001; and Naknek River during the fall of 2000 and 2001. Seasonal dates of recapture were the same as the capture periods previously identified.

The time between marking and recapture of each recaptured rainbow trout was determined in number of months and weeks. Time elapsed was described as the number of months and weeks separated by a dash. For example, 12 months and 2 weeks was depicted as 12-2.

The movement of rainbow trout within the drainage was determined by examining change of location between the mark and the recapture sites. Naknek Lake was considered a separate location from Naknek River.

The change in length of each rainbow trout from the time of initial tagging to the time of recapture was determined by subtracting initial length from length at recapture. This provided an estimate of growth from time of tagging to time of recapture. Estimates were derived by separating recaptured fish into 100-mm FL classes based on length at initial tagging. Change in length was determined for fish recaptured by 3-month time periods after initial capture.

The number of recaptured fish that differed in sexual maturity from the spring of initial tagging and spring of recapture was determined. This included those fish that were not sexually mature at initial capture and were sexually mature at recapture, and fish that were sexually mature at initial tagging and not at the time of recapture. Change in sexual maturity was determined for 100-mm FL classes. In addition, the time elapsed between initial tagging and recapture was identified. This sexual maturity analysis only included tag and recapture data from the spring tagging periods when sexual maturity could be identified.

## **RESULTS**

A reexamination of Division of Sport Fish electronic data files showed a total of 4,139 rainbow trout were captured during nine periods from the spring of 1999 through the summer of 2001 on the Naknek River and Naknek Lake with hook and line, gillnet and beach seine (Table 1). Of these fish, 3,306 rainbow trout had a tag at the time of capture or were tagged at capture. Tagging of rainbow trout occurred during five periods from the spring of 1999 through the spring of 2001.

A total of 200 rainbow trout were identified in the electronic data files as recaptured between 1999 and 2001 (Table 2). ADF&G personnel made the majority of these recaptures. An additional 29 recaptures were reported by anglers, one recapture was reported by a subsistence user, and one recapture was reported by a commercial fisherman. The majority of recaptures occurred during the springs of 2000 and 2001, when ADF&G personnel intensively sampled the upper Naknek River. The majority of the 200 recaptures were captured in the upper Naknek River between Rapids Camp and Naknek Lake and 20 were captured in Naknek Lake. The time elapsed between marking and recapture varied from 2 weeks to over 25 months (Table 3).

Table 2.–Summary of rainbow trout recaptures in Naknek River drainage by sampling period and location, 1999–2001.

Recapture			Number of rainbow trout recaptured by tag deployment year and sampling period									
Year	Sampling period <sup>a</sup>	Location	1999			2000			2001			All combined
			Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall	
1999	Summer	Naknek River	3				ND	ND		ND	ND	3
		Naknek Lake	1	0			ND	ND		ND	ND	1
	Fall	Naknek River	8	1			ND	ND		ND	ND	9
2000	Spring	Naknek River	36	8	15		ND	ND		ND	ND	59
	Summer	Naknek River	0	0	0	1	ND	ND		ND	ND	1
		Naknek Lake	1	0	0	3	ND	ND		ND	ND	4
Fall	Naknek River	0	0	0	1	ND	ND		ND	ND	1	
2001	Spring	Naknek River	16	1	2	82	ND	ND		ND	ND	101
	Summer	Naknek River	0	0	1	1	ND	ND	1	ND	ND	3
		Naknek Lake	0	0	1	4	ND	ND	10	ND	ND	15
Fall	Naknek River	0	0	1	2	ND	ND		ND	ND	3	
Total recaptures			65	10	20	94	ND	ND	11	ND	ND	200

<sup>a</sup> Sampling periods = spring (20 Mar to 30 May), summer (01 Jun to 21 Aug), and fall (22 Aug to 15 Oct); ND = no data because no attempts were made to collect it.

Table 3.—Mean increase in length of recaptured Naknek River rainbow trout by length class and time elapsed in months from spring, 1999–2001.

Fork length class (mm) Statistic	Time elapsed (months)					
	2 to 5	6 to 9	10 to 13	14 to 17	18 to 21	22 to 25
201-300						
Mean length gain			132.3			
Standard error			13.9			
Sample size			3			
301-400						
Mean length gain		82.0	70.5	161.0		
Standard error		28.9	13.4	—		
Sample size		4	6	1		
401-500						
Mean length gain	17.5	58.2	54.2		105.0	139.9
Standard error	17.5	14.0	5.1		—	27.4
Sample size	2	6	19		1	7
501-600						
Mean length gain	57.5	48.5	49.7	101.0		102.5
Standard error	3.5	16.9	6.6	—		28.5
Sample size	2	4	30	1		4
601-700						
Mean length gain	0.4	5.2	21.6	26.3		32.8
Standard error	2.9	4.3	2.9	11.3		5.1
Sample size	7	9	51	3		8
701-800						
Mean length gain	2.8	6.0	15.6			2.0
Standard error	3.1	2.0	6.3			5.0
Sample size	4	2	16			2

Note: "—" = value can not be computed due to limitations of the data.

Rainbow trout recaptures were primarily reported in the Naknek River and Naknek Lake; however, there were angler reports of tagged rainbow trout from tributaries of the Naknek River. In June 2001, two tagged rainbow trout in the 401-500 mm FL class were captured by an angler in lower Paul's Creek (rkm 20, Figure 1). United States Fish and Wildlife personnel, operating a weir approximately 35 km up Big Creek from its confluence with Naknek River (Figure 1), reported three tagged rainbow trout. Two of these fish were in the 401-500 mm FL class and one was in the 701-800 mm FL class. Two of these fish, including the largest, were reported during the fall period and one during late summer 2001. No tags were reported from other areas of

Naknek River drainage that support populations of rainbow trout, such as Idavain Creek and Brooks River (Figure 1).

The number of samples varied for each monthly category with fish recaptured 10-13 months after initial tagging accounting for the largest number of samples (Table 3). In addition, fish recaptured 10-13 months after tagging provided the best indicator of growth since a difference between summer and winter growth rates would not bias results. The growth of fish between 10 and 13 months was greatest for rainbow trout in the 201-300 mm FL classes (132.3 mm, SE = 13.9) and declined for all subsequently larger length classes to 15.6 mm (SE = 6.3) for the 701-800 FL class (Table 3, Figure 2). A weighted regression of mean length gain on the six length categories was significant ( $P = 0.006$ ). The fitted model was: mean length gain =  $115.7 - 18.3 * (\text{Length Category})$ ; weights used in the regression were the inverse of the estimated variance of the mean length measurements. Addition of a quadratic term was not warranted ( $P = 0.18$ ).

A total of 21 fish recaptured during the spring became sexually mature after initial marking during a previous spring. The percent of total immature fish tagged during a spring that subsequently became sexually mature varied by length class (Table 4). Rainbow trout in the 201-300 and 301-400 mm FL classes did not show sexual maturity. As length class increased the percent of recaptured fish that showed sexual maturity increased from 43% for the 401-500 FL class to 100% for the 601-700 FL and 701-800 FL classes (Table 4) and the smallest fish that became sexually mature was 480 mm FL at the time of recapture. A logistic regression analysis showed the effect of size class (six levels) on the maturity to be very significant ( $P < 0.0001$ ); the fitted logistic regression is  $\log(P(\text{Mature})/1-P(\text{Mature})) = -9.02 + 2.53 (\text{Length Category})$ .

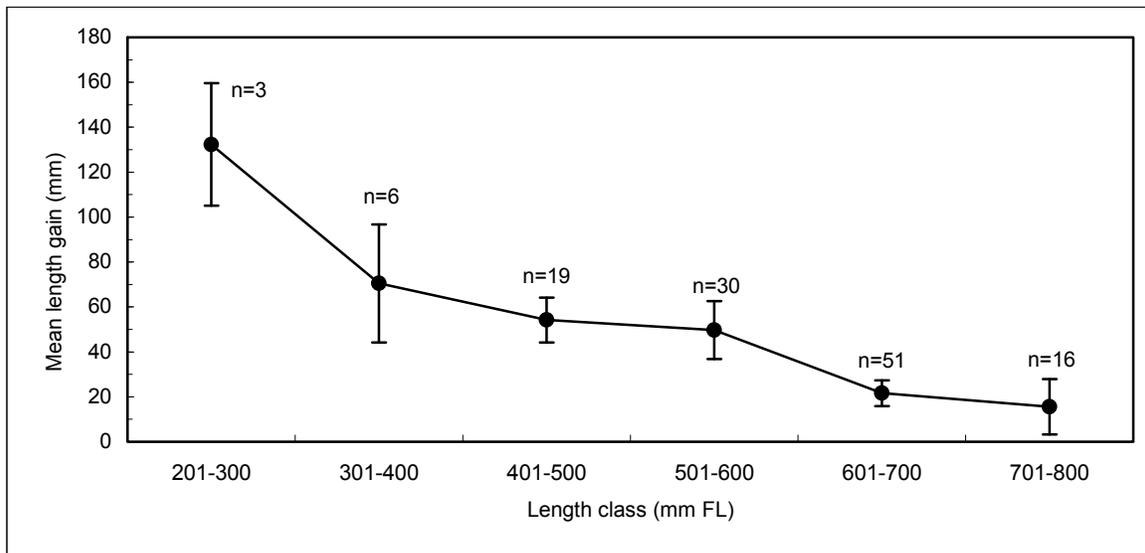
## DISCUSSION

The number of rainbow trout captured and recaptured during each period varied greatly and was related to sampling effort. The springs of 1999, 2000 and 2001, and the fall of 1999 received the most effort by ADF&G personnel during rainbow trout population assessment studies, whereas the remainder of the data was collected opportunistically by staff and anglers.

Telemetry studies (Gwartney and Burger *Unpublished*<sup>4</sup>; Schwanke and Hubert 2003) have indicated that the majority of rainbow trout tagged in the Naknek River move between Naknek River and Naknek Lake. However, recapture data indicate that some fish do exhibit movement into other tributaries in the drainage. Although tag numbers were not recorded, reports of recaptured fish in Paul's Creek and Big Creek by the public or other agencies indicate that rainbow trout tagged in the mainstem of the Naknek River do exhibit some movement into tributaries of the Naknek River. Past analysis of drainage-wide tagging data indicated that some movement into Idavain Creek and Brooks River occurs: from April 1981 through August 1985, one rainbow trout tagged in the Naknek River was recaptured in Idavain Creek and one in Brooks River (Gwartney *Unpublished*<sup>4</sup>).

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<sup>4</sup> Gwartney, L. A. *Unpublished*. Naknek drainage rainbow trout study in the Katmai National Park and Preserve. Final Report to National Park Service, 1985. Alaska Department of Fish and Game, Anchorage, Alaska.



Note: Error bars are 95% confidence intervals.

Figure 2.-Increase in mean length of recaptured Naknek River rainbow trout 10-13 months after initial capture, spring 1999–2001.

Table 4.-Number of tagged sexually immature rainbow trout by length class and the number and percentage of these fish that were or were not sexually mature when recaptured 12 months later in Naknek River, 1999–2001.

Initial capture and tag deployment		Recaptured fish (12 months later)			
Fork length class (mm)	Number of immature fish	Mature		Immature	
		Number	Percent	Number	Percent
201-300	3	0	0	3	100
301-400	6	0	0	6	100
401-500	14	6	43	8	57
501-600	11	10	91	1	9
601-700	2	2	100	0	0
701-800	3	3	100	0	0

Sexual maturity data of rainbow trout provided information about repeat spawning of fish and the length at which Naknek rainbow trout reach sexual maturity. Some fish developed sexual maturity in the 401-500 mm FL class. The smallest fish that developed sexual maturity by the time of recapture was 480 mm FL. All fish greater than 600 mm FL that were sexually immature during the spring of initial capture were sexually mature during the spring of recapture. One fish of 22 that exhibited a change in sexual maturity was sexually mature at initial tagging during a spring period, but was not sexually mature in a subsequent spring period. This suggests that not all fish spawn annually. Only one fish was captured in the Naknek River during the spring that exhibited this trait suggesting that annual repeat spawning may occur in most sexually mature fish. However, there were large fish captured each spring that were not sexually mature. These fish were only captured in the river near the outlet of Naknek Lake. It is possible that large fish that did not exhibit annual repeat spawning were present in Naknek Lake and periodically entered the Naknek River near the outlet. In addition, some post-spawn rainbow trout tagged with radio transmitters during the spring of 2001 remained in Naknek Lake during the spring of 2002 suggesting that they are not repeat spawners (Schwanke and Hubert 2003). Sampling did not occur in other locations of the drainage during the spring to locate fish that were not spawning. As a result, it is difficult to determine how prevalent non-repeat spawning is in the population with the recapture data available.

In summary, recapture data provided insight about the movement, growth, and development of sexual maturity of rainbow trout in the Naknek River. Movement of tagged rainbow trout occurred within the Naknek River, Naknek Lake and to lesser extent tributaries of the Naknek River. Declining growth rate with age or increased length as exhibited in this study is a common phenomenon in fish species (Van Den Avyle and Hayward 1999) and most fish became sexually mature at a length greater than 500 ml FL. There were some limitations to the data since intensive sampling was not conducted during all seasonal periods each year. However, the number of recaptures documented and analyzed by this study provided additional information to previous studies and increased knowledge of the life history of rainbow trout in the Naknek River.

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