U.S. Fish & Wildlife Service

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Alaska Fisheries Technical Report Number 83

Togiak National Wildlife Refuge
Dillingham, Alaska
May 2005

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Dan Gwinn

Abstract

This project estimated the total abundance and potential spawner abundance of rainbow trout (*Oncorhynchus mykiss*) on the lower eight river miles of the Negukthlik River. A multiple capture event study design consisting of six four-day capture events was employed. Fish were captured, measured, sexed, given unique marks, and released during each capture event. Secondary sexual characteristics were recorded as evidence of spawning. Heterogeneity of capture probability was investigated with RELEASE test 2 and 3 and the model fit functions of program CAPTURE. Population closure was investigated with a chi-square based test for time-specific mark-recapture data. Abundance was estimated using a model incorporating temporal heterogeneity of capture probabilities. A total of 377 unique rainbow trout were sampled during the study. Approximately 20% of fish sampled showed evidence of spawning. Minimum fork length of spawners was 362mm. The estimated total abundance of rainbow trout in the study area was 816 (95% CI = {709 - 958}, SE = 63.19, CV = 7.74) and the estimated abundance of rainbow trout of minimum spawning size was 467 (95% CI = {385 - 592}, SE = 52.20, CV = 11.18).

Introduction

Concerns over the potential impacts of sport and subsistence fishing pressure on the rainbow trout population within the Negukthlik and Ungalikthluk Rivers have been expressed by state and federal biologists. These concerns exist because informal surveys and biological data from the mid-1980s and early 1990s indicated that this population was small and perhaps vulnerable to over harvest. Additionally, biological investigations of the rainbow trout of this system indicated a relative decrease of larger fish between 1989/90 and 2003 (Lisac 1996, Gwinn 2005). Further assessment of the rainbow trout population is needed to determine if past management actions have been successful and to evaluate the effects of future management actions.

The Negukthlik and Ungalikthluk Rivers have experienced fishing pressure from guided fishing tours since the late 1970s. In the mid-1980s, the use of the rivers increased when several sport fishing guides received permits to conduct fly-in day use and utilize one base camp, which provided overnight accommodations and motorboat access on the rivers. Guides reported a mean of 300 angler days from 1986 to 1994 with a peak in of 500 angler days 1987 (Togiak National Wildlife Refuge files). Currently, two guiding outfits use the river, one of which uses a semi-permanent base camp, but angling data after 1994 is incomplete because as of then guides were no longer required to report angling information.

In addition to the guided fishing pressure, the rivers sustained heavy unguided fishing pressure and harvest in 1984 and 1985, when commercial herring fishermen were idle, waiting for commercial openings, and ascended the rivers (Minard 1990). Over limits of sport caught

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rainbow trout and netting of the fish in the lower river were rumored to have occurred. In response to these reports and in conjunction with the assumption of a relatively small rainbow trout spawning population provided by Alaska Department of Fish and Game (ADFG), the Alaska Board of Fisheries enacted a spawning season closure on the rivers in 1987. Subsequent action taken by ADFG and the Board of Fisheries closed the river to all fishing from April 10 to June 7.

To further address concerns about the Negukthlik and Ungalikthluk Rivers' rainbow trout population, a study was conducted by the U.S. Fish and Wildlife Service in 1989 and 1990 (Lisac 1996). The objectives of this study were to document the age, weight and length composition of the rainbow trout population in the lower reaches of the Negukthlik and Ungalikthluk Rivers, to document movements of rainbow trout within the Negukthlik and Ungalikthluk Rivers, and to determine spawning and over-wintering habitat areas. Data from this study provided evidence that rainbow trout in the Negukthlik/Ungalikthluk system become densely concentrated in the lower Negukthlik River during the spring spawning season and are potentially vulnerable to over-harvest in this area. This study also provided a baseline description of the length structure of the rainbow trout in this system.

In 2003, the Federal Subsistence Board adopted regulations liberalizing subsistence rod and reel harvest regulations for rainbow trout in the Bristol Bay Region. Previously, subsistence harvest of rainbow trout with rod and reel in this region was managed by the state sport fishing regulations. Under this previous system, harvest and possession limits varied among different drainages. Before the 2003 regulation change, the Negukthlik and Ungalikthluk River drainage was closed to all fishing from April 10 to June 7. From June 8 to Oct 31, no rainbow trout could be retained and from November 1 to April 9 the daily limit was five per day and five in possession. Under federal regulations implemented in 2003, two rainbow trout may be harvested per day and two may be in possession during April 10 through October 31 and five may be harvested and five may be in possession during November 1 through April 9. This increases the daily legal harvest of rainbow trout from zero to two per day during the spawning season when fish are aggregated and are most vulnerable to over harvest.

In response to these regulation changes, the Togiak Refuge revisited the Negukthlik and Ungalikthluk Rivers to assess the length composition of the rainbow trout populations in 2003 (Gwinn 2005). This study revealed that although the rainbow trout population appears to be healthy, there has been a shift in its length composition of fish. Larger rainbow trout have experienced a decrease in relative abundance since 1989 and 1990. Length composition estimates can be useful for tracking changes in size composition but may often be misleading because absolute abundance is unknown. To form a more complete picture of the state of rainbow trout in the Negukthlik and Ungalikthluk Rivers, a measure of absolute abundance of spawning fish is necessary. This information is necessary for in-season managers, the Bristol Bay Regional Advisory Council, and Federal Subsistence Board to evaluate management actions and maintain a healthy fish population

Objectives

1. Estimate the abundance of the lower river rainbow trout spawning population of the Negukthlik River.
2. Estimate the length composition of spawning rainbow trout.

Study Area

The Negukthlik and Ungalikthluk Rivers are located within the Togiak National Wildlife Refuge, approximately 12 miles southeast of the villages of Togiak and Twin Hills between the Togiak and Kulukak Rivers (Figure 1). The Negukthlik River flows south from the tundra headwaters for approximately seven miles into two shallow lakes interconnected by a 0.25 mile section of the river. The river then continues south for approximately 12 miles, joining the Ungalikthluk River approximately two miles upstream of Togiak Bay. The Ungalikthluk River originates in the mountains between the Pungokepuk Creek and Kulukak River drainages and flows south for approximately 22 miles before being joined by the Negukthlik River. Chinook (*Oncorhynchus tshawytscha*), coho (*Oncorhynchus kisutch*), pink (*Oncorhynchus gorbuscha*), chum (*Oncorhynchus keta*), and sockeye salmon (*Oncorhynchus nerka*) utilize both rivers for spawning and rearing. Estimates of sockeye salmon escapements for 2001 were 2,220 and 4,680 for the Negukthlik River and Ungalikthluk River, respectively; estimates of Chinook salmon escapements for 2001 were 603 and 185 for the Negukthlik River and Ungalikthluk River, respectively; and estimates of chum salmon escapements for 2001 were 550 and 10,960 for the Negukthlik River and Ungalikthluk River, respectively (Browning et al. 2002). Other fish that inhabit the Negukthlik and Ungalikthluk Rivers include Dolly Varden (*Salvelinus malma*), northern pike (*Esox lucius*), Arctic grayling (*Thymallus arcticus*), and round white fish (*Prosopium cylindraceum*).

The Negukthlik and Ungalikthluk Rivers are believed to contain one population of rainbow trout. Lisac (1996) utilized radio telemetry to define the spawning, overwintering, and summering areas of fish sampled in the Negukthlik River. Rainbow trout were found to aggregate in the lower eight river miles of the Negukthlik River during the winter. They remained in this stretch of the river through the spawning time and then distributed throughout both river systems during the summer. Based on the information provided by Lisac (1996), the lower eight river miles of the Negukthlik River was selected as the sampling area of this study.

Methods

Field Sampling

During the week of April 26, 2004, a temporary field camp was established approximately 0.75 miles downstream of the Negukthlik River and Ungalikthluk River confluence. Sampling occurred on the eight river mile section of the Negukthlik River immediately upstream of its confluence with the Ungalikthluk River (Figure 1). To help maintain equal sampling effort throughout the study area, eight strata were established, each stratum was one river mile in length. The strata boundaries were marked with survey ribbon and as GPS waypoints. Two teams of three researchers sampled one stratum each per day (7-9 hours/day) using standard angling techniques. Within strata, researchers sampled all habitats in proportion to the apparent distribution of fish. Selection of specific terminal tackle was made collectively by the team, with the objective of maximizing rainbow trout catch in all size and age classes. This sampling schedule allowed the full eight river miles of the study area to be sampled in four days with an effort of about 21-27 angler hours per river mile per day. The mark-recapture experiment consisted of six 4-day capture events. Sampling proceeded in this fashion from May 4 through June 1, 2004. All fish captured and returned to the river greater than 250mm fork length (FL, from tip of snout to the fork of the tail) were tagged with an individually numbered Floy anchor tag. Tag number was recorded at the time of initial attachment and at each subsequent capture. Partial clips of one pelvic fin were employed as a secondary mark to document tag loss. Upon initial capture, fork length of all rainbow trout was measured and recorded to the nearest millimeter. The length of recaptured fish was not re-measured. The date, time, and coordinates of each capture were recorded. Sex and maturity of fish were determined externally based on coloring, head shape, girth-to-length ratio, and presence of ovipositor, eggs, or milt.

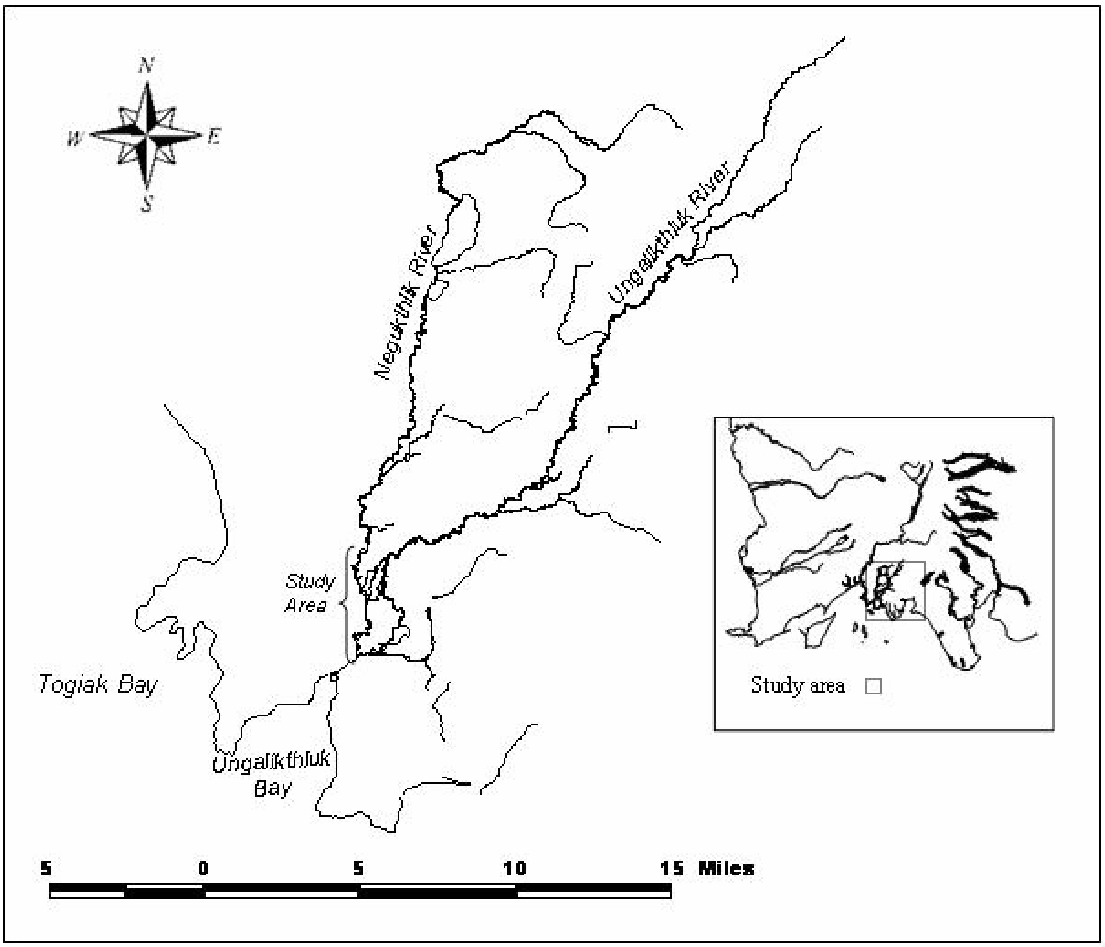

Figure 1. Negukthlik and Ungalikthluk Rivers and study area.

Length Composition

Length composition of spawning fish was estimated using data collected exclusively from fish showing secondary sexual characteristics. Only data collected from original captures was used. No correction for growth during the study period was employed. Based on the rainbow trout growth observed by Harper *et al*. (2004), it was believed that growth was negligible. Fish were assigned to 50mm length classes and the proportion of mature and immature fish in each length class was calculated for future comparisons with this population.

Abundance Estimation

Two data sets were created and fit to a closed model using the model selection tests offered by program CAPTURE (Rexstad and Burnham 1991, Otis *et al.* 1978). One data set consisted of all fish sampled and released during the study. The second data set represented the potential spawning population and was built as a subset of the data gathered from fish with a fork length greater than or equal to the smallest individual sampled showing evidence of spawning. A closed population mark-recapture model was selected from the seven models offered by program CAPTURE (Otis *et al*. 1978, White *et al*. 1982, Chao 1989, Rexstad and Burnham 1991, Chao *et al*. 1992). Each model can account for specific variability or combination of specific variability in capture probabilities. The variation they account for are (1) variation in capture probability among capture occasions (t), (2) variation in capture probability among individuals (h), (3) variation in capture probability between marked and unmarked individuals (b), and (4) the null model, accounting for no variation in capture probability (o). The following models are available for estimating: M_o, M_t, M_h, M_b, M_{bh}, M_{tb}, and M_{th}. The assumptions of the null model (M_o) are as follows:

1. The population does not experience additions or deletions (demographic and geographic closure).
2. Marks are not lost or missed.
3. Capture probability is homogeneous among individuals in the population and through time.

Demographic/Geographic Closure and Heterogeneity

Temporal aspects of the experimental design were believed to minimize violations to the assumption of demographic and geographic closure. Sampling occurred over a narrow period of time of 29 days, limiting the effects of mortality and recruitment. Additionally, the sampling period occurred during early spring concurrent with rainbow trout spawning. During this time, mature fish aggregate in spawning areas, limiting movement of fish and minimizing violations to geographic closure.

To determine whether the population exhibited acceptable geographic and demographic closure, a test of closure for time-specific mark-recapture data (Stanley and Burnham 1999) was employed. This analysis uses chi-square goodness of fit tests that compare the fit of model M_t (Darroch 1958, Otis et al. 1978) to a no recruitment model (Pollock et al. 1990), a constrained version of the Jolly-Seber model with no mortality, and the Jolly-Seber model (Jolly 1965; Seber 1965) as alternatives. This test can not only be used to determine if closure is violated but can be broken into components and subcomponents to determine what the nature of the violation was and when it occurred. The proportion of recaptures among total captures within capture occasions was examined as supporting evidence of closure violations or lack thereof.

Heterogeneity of capture probability was investigated with model fit tests associated with program CAPTURE and program RELEASE. Program CAPTURE uses model goodness of fit tests based on multinomial distributions, between-model tests based on likelihood ratio tests, and a classification function based on discriminant analysis for the model selection criterion (Rexstad and Burnham 1991, Otis *et al.* 1978, McDonald *et al.* 1981). These analyses result in a ranking, from 0-1, of competing models and in essence tests for effects of the varying types of heterogeneity.

Heterogeneity was further tested with program RELEASE test 2 and test 3 contained within program MARK (White and Burnham 1999). Although RELEASE test 2 and test 3 are designed to test for heterogeneity in open populations, complete population closure is rarely if ever possible. These tests are therefore useful and can provide insight into the heterogeneity present in all multiple occasion mark-recapture data. The program RELEASE tests are chi-square based goodness of fit tests that are used to detect violations of the homogeneity assumptions of the Jolly-Seber model (Jolly 1965; Seber 1965). Test 2 is sensitive to heterogeneity of capture probability among individuals in the population while test 3 is sensitive to heterogeneity of apparent survival among individuals in the populations. Both tests are sensitive to behavioral responses and temporary emigration. Two hypotheses were tested:

1. The probability of capture at time t_{i+1} is dependent on whether the animal was captured at time t_i (conditional on survival from ti to $_{ti+1}$).

2. Timing of recapture is dependent on whether the animal was caught at time t_i or before.

Differences found in all tests were considered significant at an alpha level of 0.05.

Results

Biological Data

From May 4 through June 1, 2004, 377 unique rainbow trout were captured, tagged and released. A total of 102 unique recaptures were made. No examined fish showed any sign of tag loss. Fish captured ranged between 252 and 727mm FL. The mean FL was 409mm (SE = 5.09) and the median FL was 381mm. Of the 377 unique fish, 74 exhibited signs of sexual maturity. The minimum fork length of sexually mature fish was 362mm. The proportion of fish of this size or greater was 59.68% and accounted for 225 of the unique captures. The proportion of fish exhibiting signs of spawning increased with length (Figure 2). The stock density and cumulative length frequency distribution of spawning fish is depicted in Figure 3.

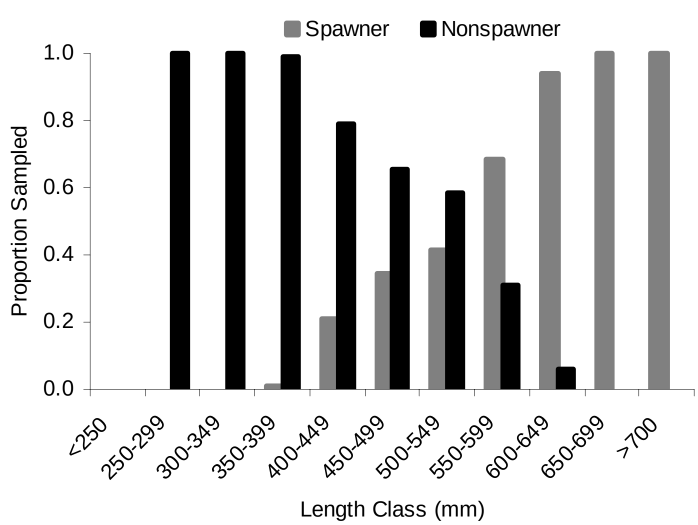

Figure 2. Proportion of fish showing evidence of spawning in 50mm length classes.

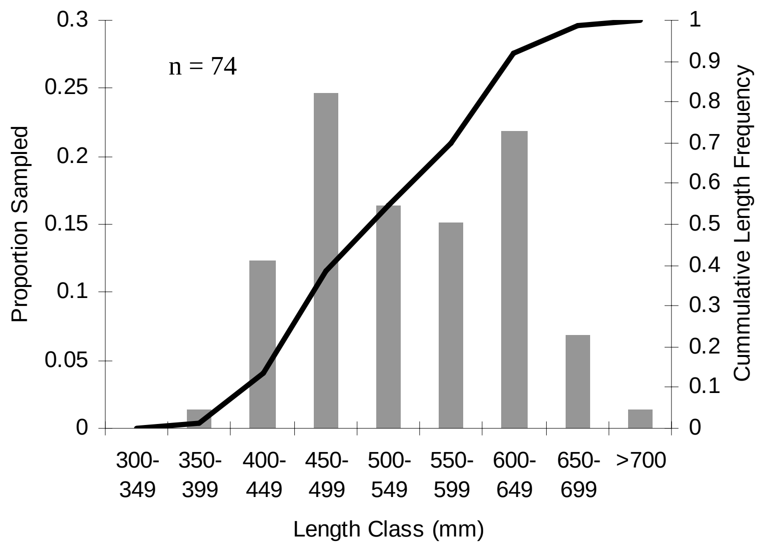

Figure 3. Stock density and empirical distribution of spawning rainbow trout.

Demographic/Geographic Closure and Heterogeneity

Using the chi-square based test of closure, we checked for demographic and geographic closure of the population. Although overall violations of closure could not be rejected (chi = 9.065, p = 0.337), analysis of subcomponents of the test indicated that closure could be rejected between one of five inter-capture occasion periods (Table 1). This suggested additions to the population between capture occasion 3 and 4 (chi = 5.66, p = 0.017). The presence of these additions was corroborated by a decrease in the proportion of recaptures during capture occasion four (Figure 4). All other p values of the subcomponents analysis were relatively large giving little indication that population closure was violated to any large extent (Table 1).

Table 1. Results of Stanley and Burnham (1999) test of closure, (A) no recruitment model vs Jolly-Seber model and (B) no mortality model vs Jolly-Seber model.

A.

No Recruitment model vs Jolly-Seber model

Occasion	Chi-square	df	p-value
2	0.29476	1	0.58719
3	0.21527	1	0.64267
4	5.65587	1	0.01740
5	1.22116	1	0.26913

B.

No Mortality model vs Jolly-Seber model

Occasion	Chi-square	df	p-value
2	0.01647	1	0.89788
3	0.13325	1	0.71508
4	2.89129	1	0.08906
5	0.27919	1	0.59723

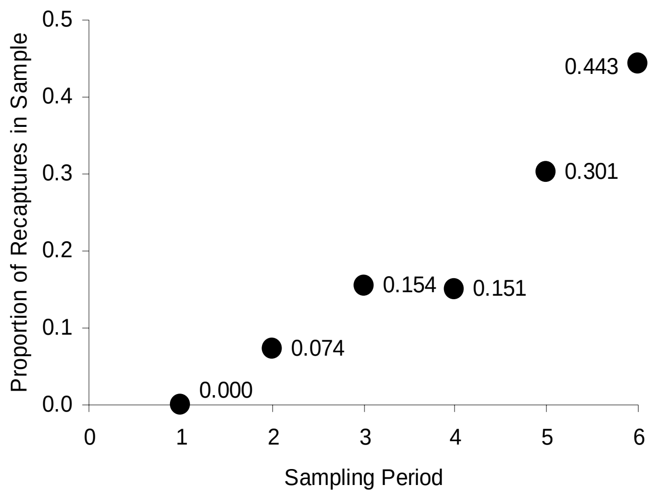

Figure 4. Proportion of recaptures in the total sample of each 4-day capture occasion.

Heterogeneity of capture probability was investigated with program RELEASE test 2 and test 3. Results of test 2 indicated that, on a given capture occasion, there was no significant dependence of capture probability on the time of previous capture. For all capture occasions tested, test 2 rejected the null hypothesis of time of recapture being dependent on time of capture (Table 2). Although, insufficient data restricted our ability to use test 3 for specific capture occasions, the cumulative tests results of test 3 indicated that over all capture occasions there was no significant dependence of apparent survival on the time of previous capture (chi = 3.92, p = 0.6865).

Table 2. Summary of RELEASE test 2 goodness of fit results.

RELEASE Test 2.c

Occasion (i)	Chi-square	df	p-value
1	3.6373	3	0.3034
2	3.8662	2	0.1447
3	2.8062	1	0.5572
Cummulative	7.6041	6	0.2686

Abundance Estimation

A data set containing mark-recapture histories from all individuals sampled and a data set containing a subset of mark-recapture histories from all individuals of minimum spawning size sampled were created for abundance estimation. Due to sparse data and the nested nature of these data sets, only the full data set of all mark-recapture histories was used for model selection. Although model fit tests in program CAPTURE apportioned the greatest support for model M_{th} and the second greatest support for model M_{tb} as the models that best describe the data, model M_t was chosen as the most likely model (Table 3). Models accounting for heterogeneity were rejected based on the program RELEASE tests of heterogeneity of capture probability and the small difference in the magnitude of the abundance estimates between models that did account and the reduced models that did not account for this effect. Models accounting for behavioral effects were also rejected because of the program RELEASE tests of heterogeneity and because of the inconsistencies of the magnitudes of abundance estimates among models accounting for this effect (Table 3). Using model M_t, the estimated abundance of rainbow trout in the study area was 816 (95% CI = {709 -- 958}, SE = 63.19, CV = 7.74) and the estimated abundance of rainbow trout of minimum spawning size was 467 (95% CI = {385 -- 592}, SE = 52.20, CV = 11.18).

Table 3. Closed model comparison with program CAPTURE model selection ranks.

Model Description	Model	N	SE(N)	CV(N)	95% LL	95% UL	Rank
jack knife	Mh	924	52.19	5.65	832	1036	0
Chao	Mh	892	86.73	9.72	748	1091	0
Null	Mo	822	64.10	7.80	714	966	0.08
Generalized Removal	Mbh	2195	1920.94	87.51	711	10299	0.16
Pollock and Otto	Mbh	697	43.82	6.29	622	794	0.16
Zippin	Mb	2204	1940.06	88.02	711	10407	0.24
Darroch	Mt	816	63.19	7.74	709	958	0.31
Burnham	Mtb	536	61.23	11.42	454	706	0.83
Chao	Mth	815	66.64	8.18	703	966	1

Discussion

It is common in fisheries and wildlife studies for abundance estimates to be viewed as point estimates with little attention paid to confidence limits by many professionals and the public. The abundance estimates produced by this study should be viewed less as point estimates of 816 fish and 467 spawning size fish and more as a 95% probability of the abundance existing between 709-958 rainbow trout and 385-592 spawning size rainbow trout. With this understanding a more realistic picture of the rainbow trout population of the Negukthlik River can be observed.

Population closure was investigated by subjecting the mark-recapture data to the test of closure provided by Stanley and Burnham (1999). This evaluation provided some evidence of violation to the closure assumption, but these violations appeared to be minimal given the nature of the study population and the study area. The population was sampled during spawning when adult rainbow trout aggregate. Sampling during the spawning period is a common fisheries strategy that minimizes the magnitude of movement in and out of the study area. Regardless, the study area was not bordered by any physical barriers to fish movement. Past studies indicate that mature rainbow trout migrate from the Negukthlik River past the downstream border of the study area and enter the Ungalikthluk River only after the spawning time (Lisac 1996). Thus, this behavioral pattern suggests that the lower limit of the study area truly was the population's geographic southern border. The upstream border of the study area was open to fish passage and therefore should be acknowledged as a potential area of free movement in and out of the study area.

The test of closure offered by Stanley and Burnham (1999) has the ability to not only detect an overall violation to the closure assumption but is broken into components that can provide information regarding the nature of the violations. Although the Stanley and Burnham (1999) test statistic and component statistics indicated that model M_t was a more appropriate model than the no recruitment model and no mortality model, small p values indicated possible additions between sampling occasion 3 and 4. Large p values associated with the remaining subcomponents of the test indicate that a violation of the closure assumption was unlikely between all other capture occasions (Table 1).

The effects of closure violations on closed model abundance estimates are dependent on the nature of the violation and the magnitude. If movement of animals in and out of the study area is random, abundance can be estimated without bias. On the other hand, if movement in and out of the study area is Markovian, the resultant estimates are likely to be biased in a positive direction (Kendal 1999). The magnitude of this bias is dependent on the magnitude of the closure violation. Since the Negukthlik River study area was only open to passage on the upstream and downstream border and animals rarely distribute themselves randomly in the environment, it is likely that any movement of fish in and out of the study area would conform to a Markovian distribution, introducing positive bias into the estimates. Additionally it is likely that the rate of movement across these borders is small, minimizing the bias introduced into the estimates. Until more comprehensive tests of closure are developed, it will remain difficult to detect violations to the assumption of closure and it will remain difficult to quantify the consequences of these violations.

Model fit tests suggest that the homogeneity assumptions of model M_t were met to an acceptable degree. Heterogeneity of capture probability did not appear to play a large role in the capture histories. RELEASE test 2 and 3 indicated no significant dependence of capture probability or apparent survival on time of capture or recapture. The only differential capture probability that we chose to account for in the modeling procedures was the variability among capture occasions. Although this variability in capture probability did not appear to influence the final estimates to a large degree (Table 3), we chose to account for it in the model because program CAPTURE model selection functions indicated that temporal heterogeneity may have occurred and the presence of this variability made logical sense given the nature of the field sampling procedures

The estimated abundance of spawning size rainbow trout, though small, is likely sufficient to support the system. Whether this small estimated abundance of spawning size fish should be a concern to resource managers is dependent on other confounding factors. The shifting length composition of rainbow trout in this system to favor shorter length fish (Gwinn 2005) could be an indication of resource overuse and when compounded with a small abundance estimate of spawning size fish, strengthens the argument that concern by resource managers and users is appropriate. Even so, this argument is partially dependent on the assumptions that the area sampled contains the only spawning group in the system and that the area sampled encompassed this entire spawning group, which is presently unclear.

Although Lisac (1996) found strong evidence that the spawning area of rainbow trout on the Negukthlik River is confined to the lower eight river miles, the possibility remains that other spawning areas exist within the system. One area of suspect is the headwaters of the Negukthlik River. Lisac (1996) implanted one radio transmitter in a mature rainbow trout in 1989 in the upper reaches of the Negukthlik River and found that it did not migrate to the lower eight river miles during the spawning period of the following year. Additionally it is known that large mature rainbow trout distribute themselves in high concentrations in the headwaters of the Negukthlik River during the summer months (Gwinn 2005). Although neither of these observations provide direct evidence of a second spawning population, the possibility cannot be discounted and must be taken into consideration.

Furthermore, the defined sampling area of this study may not have encompassed the entire spawning group in the lower Negukthlik River. There was a high concentration of rainbow trout showing evidence of spawning within the defined stream reach, but these fish were distributed throughout the entire length of the study area. Since no sampling occurred outside the study area, it is unknown how spawning fish were distributed in the entire system during the time of the study.

Regardless of the magnitude of the estimated abundance of spawning size rainbow trout, the Negukthlik/Ungalikthluk drainage is isolated and small and warrants attention by resource managers. The Negukthlik River is easily accessible by float plane in the upper reaches where large proportions of spawning size rainbow trout aggregate during the summer months (Gwinn 2005). These fish are relatively large in size by comparison with other Refuge rainbow trout populations which are highly sought by anglers. Similarly, the lower reaches of the Negukthlik and Ungalikthluk River are easily accessible by float plane and skiff with jet drive outboard. These areas also harbor a large proportion of spawning size fish during the summer months, making them vulnerable to anglers.

The recent regulation change that allows for a daily harvest and possession limit of two rainbow trout by subsistence rod and reel from April 10 to October 31 does not affect the allowed harvest by sport fishing users, but allows subsistence harvest by rod and reel during the most vulnerable time period of this population. The result of this regulation change on the rainbow trout of the Negukthlik and Ungalikthluk drainage is difficult to predict. During the rainbow trout spawning period, the system is difficult to access from the nearby villages of Togiak and Twin Hills by either snowmachine or boat, thus minimizing the likelihood of overexploitation. Regardless, this population should be closely monitored in the future to evaluate any potential changes in the length composition and spawner abundance. Future studies should repeat the monitoring efforts employed by Refuge staff in 2003 and 2004 for future evaluation of this rainbow trout population. Additionally, an investigation of the number of spawning populations within the system through the use of genetics techniques is advisable to bring clarity to the rainbow trout population structure of this system.

Acknowledgements

Thanks are extended to a number of Togiak Refuge staff: Troy Jaecks, Travis Elison, John Kerr, Larry Barnes, Carl Lunderstadt, and Mark Lisac. Thanks go out to Bruce King, Richard King, and Jeffery Breakfield who assisted during the sampling of fish. Thanks are extended to U.S. Fish and Wildlife Service Office of Subsistence Management Fisheries Monitoring Program for funding this study under Project no. FIS 04-401. We would like to thank reviewers Jason Dye, Jeff Bromaghin, Mark Lisac, and Pat Walsh who provided useful comments.

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