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Eastern North Slope Dolly Varden Genetic Stock Identification and Stock Assessment.

Annual Report for Study 01-113

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Annual Report Summary Page

Title: Eastern North Slope Dolly Varden Genetic Stock Identification and Stock Assessment.

Study Number: FIS01-113.

Investigator(s)/Affiliation(s): Tim Viavant/Alaska Department of Fish and Game, Division of Sport Fish.

Management Regions: Region 10 (North Slope).

Information Type: Stock Status and Trends.

Issue(s) Addressed: Lack of stock status and structure information to support federal subsistence fishery management of char.

Study Cost: $198,900.

Study Duration: June 2001 to May 2002.

Abstract: Dolly Varden are an important subsistence fishery resource for North Slope residents. This anadromous char species has a complex life history in which mixed stock aggregates winter in freshwater, making stock assessment difficult. Objectives of this study are to examine the variability and efficiency of aerial surveys of discrete wintering aggregations; verify known and identify undocumented spawning and wintering sites in several rivers; and collect fin clips from spawning aggregations to characterize population structure. Replicate aerial counts of wintering Dolly Varden within a 28 km section of Ivishak River were conducted during September 20001. The mean summed count for two observers over all subsections was 10,932 Dolly Varden (standard error, 314). This represented about 22% of a Baily mark-recapture estimate that indicated 49,523 Dolly Varden (standard error, 7,277) were present. Forty Dolly Varden were also fitted with radio tags in the Ivishak River during September 2001 to evaluate movement during the mark-recapture experiment and identify wintering sites during 2002. Dolly Varden fitted with radio tags moved substantially, primarily upstream, and remained within the 28-the index area during aerial surveys. Specific locations of wintering sites will be determined during April 2002. Spawning locations were identified in the Echooka and Saviukviak rivers. Fin clips were taken from 106 Dolly Varden from the Echooka River and 30 from the Saviukviak River.

Key Words: Dolly Varden *Salvelinus malma*, mitochondrial DNA, wintering abundance, spawning location, subsistence fishery, North Slope.

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TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

INTRODUCTION

This is the first annual progress report of a three year study of anadromous Dolly Varden on the North Slope of the Brooks Range, and reports results of the first year of the full three year study. Information regarding a feasibility study done prior to the full three-year study is reported in the final report of the feasibility study (Viavant 2001).

Anadromous Dolly Varden *Salvelinus malma* are an important component of the arctic ecosystems of the North Slope of the Brooks Range. These fish have complex life history and movement patterns (DeCicco 1985, 1989, 1992, 1997; Craig 1977; Morrow 1980). Dolly Varden spawn and rear in fresh water, and spawning areas are frequently associated with groundwater upwelling. They migrate to the ocean at age 3-5, and from that age on, spend the summers in the ocean feeding, but return to fresh water to overwinter, regardless of whether they spawn that year.

Adults spawn from mid July through early October, and generally do not spawn in consecutive years (Yoshihara 1973). In general, most drainages appear to contain spawning stocks that spawn in late summer (late July through late August) and in late fall (late September through mid October). Adults may overwinter in drainages other than their natal spawning drainage (Reynolds 1997), but have high fidelity to their drainage of origin for spawning. Genetic studies of anadromous Dolly Varden from North Slope drainages (Everett et al. 1997; Krueger et al. 1999) indicated that there are distinct genetic differences among spawning stocks from individual drainages or groups of drainages.

These fish provide for significant subsistence harvests in the villages of Kaktovik, Nuitsuq, and Anaktuvuk Pass (Craig 1987; Pedersen 1990). Harvests of these fish represent up to 40% of all subsistence fish harvests in Kaktovik (Pedersen 1990). These populations also support limited sport fisheries, with average yearly harvests of 1,000 fish and average catches of 5,300 fish from the entire North Slope from 1994 to 1999 (Burr 2000). The majority of sport effort, catch, and harvests come from the Sagavanirktok River, which is easily accessible at numerous points along the Dalton Highway.

The fidelity to natal drainage and the results of previous genetic studies indicate that Dolly Varden populations in North Slope drainages are separate spawning stocks. Because of their life history, the majority of both subsistence and sport harvests of these fish come from mixed-stock aggregations, either during summer feeding in marine waters, or from overwintering aggregations in fresh water, or during migration between fresh and marine waters. Because individual spawning stocks may be small, but harvests occur from large mixed-stock aggregations, it is difficult to judge the effects of harvests on a particular spawning stock.

These fish are distributed widely in the Beaufort Sea drainages between the Colville River and the Canadian border (Figure 1). Although their distribution is widespread among North Slope drainages, the extent of their distribution within and among drainages has not been completely cataloged. Because of their complex life history, these fish are highly dependant on critical

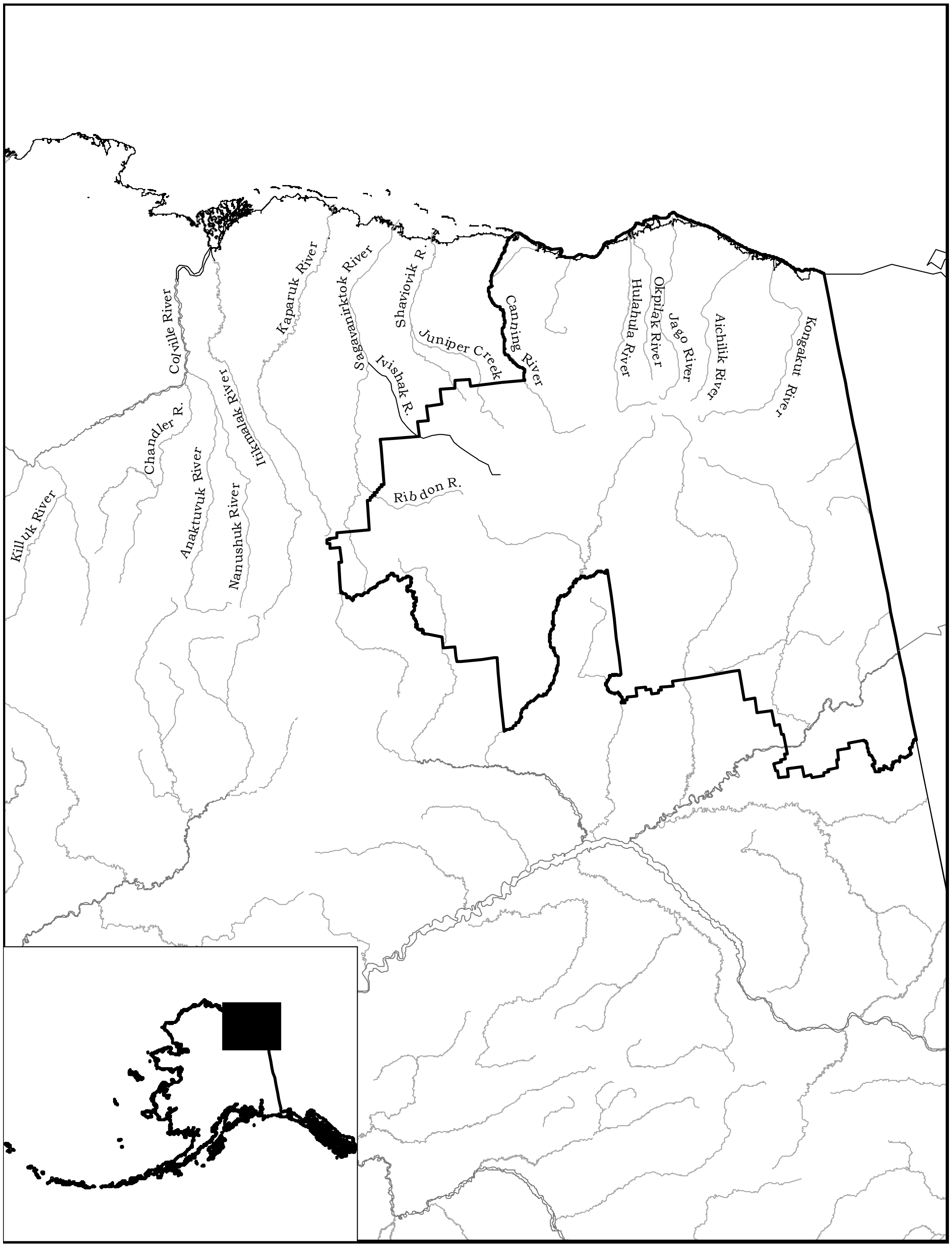


Figure 1. Map of the eastern North Slope of the Brooks Range and coastal plain showing major drainages containing anadromous Dolly Varden and the boundary of the Arctic National Wildlife Refuge.

spawning and wintering habitat that is probably limited (Craig 1989; Krueger 1999), and has also not been completely cataloged. Much of this habitat is located in areas that have a high potential for oil exploration and development.

In order to manage these mixed-stock fisheries, abundance information is needed for major wintering aggregations that contribute to these fisheries. In addition, estimates of the stock composition of these harvests, that is, the proportional contribution of various spawning stocks to these harvests, are also needed. Because much of the critical habitat that support these stocks is in areas subject to oil and other resource development, the ability to protect spawning stocks and overwintering aggregations during future resource development will be dependent on knowledge of the location and timing of critical habitat needs of these stocks.

A great deal of research has been done on the life history and distribution of Dolly Varden on the North Slope (Yoshihara 1972 and 1973; Furniss 1974; Craig 1977 and 1989; McCart 1980; Bendock 1980, 1982, 1983; Underwood et al. 1996). Very little research has been done on stock status (abundance or length/age composition). The only recent information on stock status of North Slope Dolly Varden consists of aerial surveys of several overwintering index areas on the Anaktuvuk, Ivishak, and Kongakut rivers (Table 1). These surveys only provided a relative index of abundance, and have never been validated as to their repeatability or their relationship to abundance as determined by other more traditional assessment methods.

Because of their life history and distribution, it is logistically very difficult and extremely expensive to conduct traditional mark-recapture, or escapement type abundance estimation on these fish populations. Aerial surveys of established index areas are a cost effective method of conducting a repeated (over time) assessment of the stocks contributing to these important subsistence fisheries. While aerial surveys provide stock information that is logistically feasible at a reasonable cost, the variability of the method has not been fully determined, nor has the relationship of aerial surveys to a more reliable method of abundance estimation been established.

There have been a number of studies of the subsistence fisheries that utilize these stocks (Craig 1987; Pedersen et al 1985; Jacobson and Wentworth 1982). Harvest information is limited (Pedersen 1990), and little is known about the stock composition of these harvests. Because the stocks that contribute to these fisheries appear to be genetically distinct, the relative contribution to these harvests may be estimated by comparing genetic samples taken from fin clips of harvested fish to a genetic baseline of the major spawning stocks that contribute to these fisheries.

This project is intended to estimate the precision of aerial surveys of overwintering aggregations, and to determine the relationship between aerial survey abundance estimates and traditional mark-recapture abundance estimates of the same overwintering aggregations. The project is also intended to collect stock-specific mitochondrial DNA

Table 1. Aerial estimates of Arctic char from the Ivishak, Anaktuvuk, and Kongakut rivers of the North Slope.[a]

Year	Date	Ivishak River	Anaktuvuk River	Kongakut River	Survey Aircraft	Survey Rating	Data Source
1971	22-Sept.	24,470			H	Good	Yoshihara 1972
1972	24-Sept.	11,937			H	Good	Yoshihara 1973
1973	11-Sept.	8,992			H	Excellent	Furniss 1975
1974	10-Sept.	11,000			H	Not Rated	Furniss 1975
1975	22-Sept.	8,306			H	Not Rated	Bendock ADFG files
1976	22-Sept.	8,570			H	Fair	Bendock ADFG files
1979	22-Sept.	24,403	15,717		S	Excellent	Bendock 1980
1981	22-Sept.	24,873	10,536		S	Excellent	Bendock 1982
1982	22-Sept.	36,432	6,222		S	Excellent	Bendock 1983
1983	22-Sept.	27,820	8,743		S	Excellent	Bendock and Burr 1984
1984	22-Sept.	24,818	5,462		S	Excellent	Bendock and Burr 1985
1986	No survey			8,900	?	Not Rated	Millard USFWS files
1989	22-Sept.	12,650		6,355	H	Good	DeCicco ADFG files
1993	3-Sept.	3,057			H	Good	Millard USFWS files
1995	27-Sept.	27,036		14,080	H	Good	Burr ADFG files

[a] No surveys were done for years not listed. Survey aircraft was either a helicopter (H) or fixed wind aircraft (Super Cub; S).

genetic samples from major spawning stocks that contribute to subsistence fisheries. If these spawning stocks show sufficient genetic separation from one another, similar genetic samples taken from subsistence harvests will be used to estimate the stock contribution of different spawning stocks to those harvests. The project will also verify known spawning and overwintering locations, identify new locations, and catalog and map critical spawning and overwintering habitat.

OBJECTIVES

Project objectives are to:

1) Estimate the variability of replicate aerial surveys of a spawning-wintering aggregation on the Ivishak River conducted by the same observers under similar conditions during the same time period.

2) Estimate the abundance and size composition of Dolly Varden within one discrete spawning-wintering aggregation (same as objective 1) on the Ivishak River such that the abundance estimate is within 20% of the true value 90% of the time.

3) Verify known spawning and overwintering locations on the Anaktuvuk, Hulahula, Kongakut, Aichilik, Canning, Ivishak, and Echooka Rivers, collect GIS mapping data for all verified and new locations, and evaluate locations and methods for future abundance-based stock assessment.
4) Collect fin clips from Dolly Varden from North Slope drainages to characterize the population structure of Dolly Varden using mitochondrial genetic markers and test the performance of the genetic baseline to determine the potential for stock composition estimation of mixed stock subsistence harvests.

METHODS

Aerial Survey Variability Estimation

Five replicate aerial surveys of a 28-km index area of the Ivishak River (Figure 2) were conducted from September 19-23. Counts were conducted from a helicopter by two observers, each counting only the fish present on one side of the river. Each observer counted the same side of the river during each survey. In portions of the river where multiple channels existed, the main channel with the majority of the fish present was marked and counted. Although all channels were not counted, during all counts, the same marked river channels were counted during each survey. These replicate counts were conducted after upriver migration was judged to be essentially complete, based on aerial surveys that determined the absence of new fish migrating upstream from below the 28-km index area. This judgment was based on the presence of less than 10% of the number of fish counted in the assessment area present in the 10-km reach of river immediately below the 28-km index area.

The index area counted was divided into three subsections, corresponding to the subsections used in the concurrent mark-recapture estimate, and counts were subtotaled for each subsection. To eliminate conscious or unconscious bias during counts, replicate counts were conducted with the face plates of the counting devices covered, and the totals recorded by the helicopter pilot, so that the observers were not aware of their individual section or daily total counts until after all five replicate counts were complete.

Mark-Recapture Abundance Estimation

A mark-recapture abundance estimate of this same aggregation (the same 28 km index area) was conducted using an unstratified Bailey modified Petersen two-event estimation procedure (Seber 1982). Adult fish were captured using beach seines, measured, and marked with a small fin-clip and an opercular punch. In areas with multiple channels, the mark-recapture estimate was

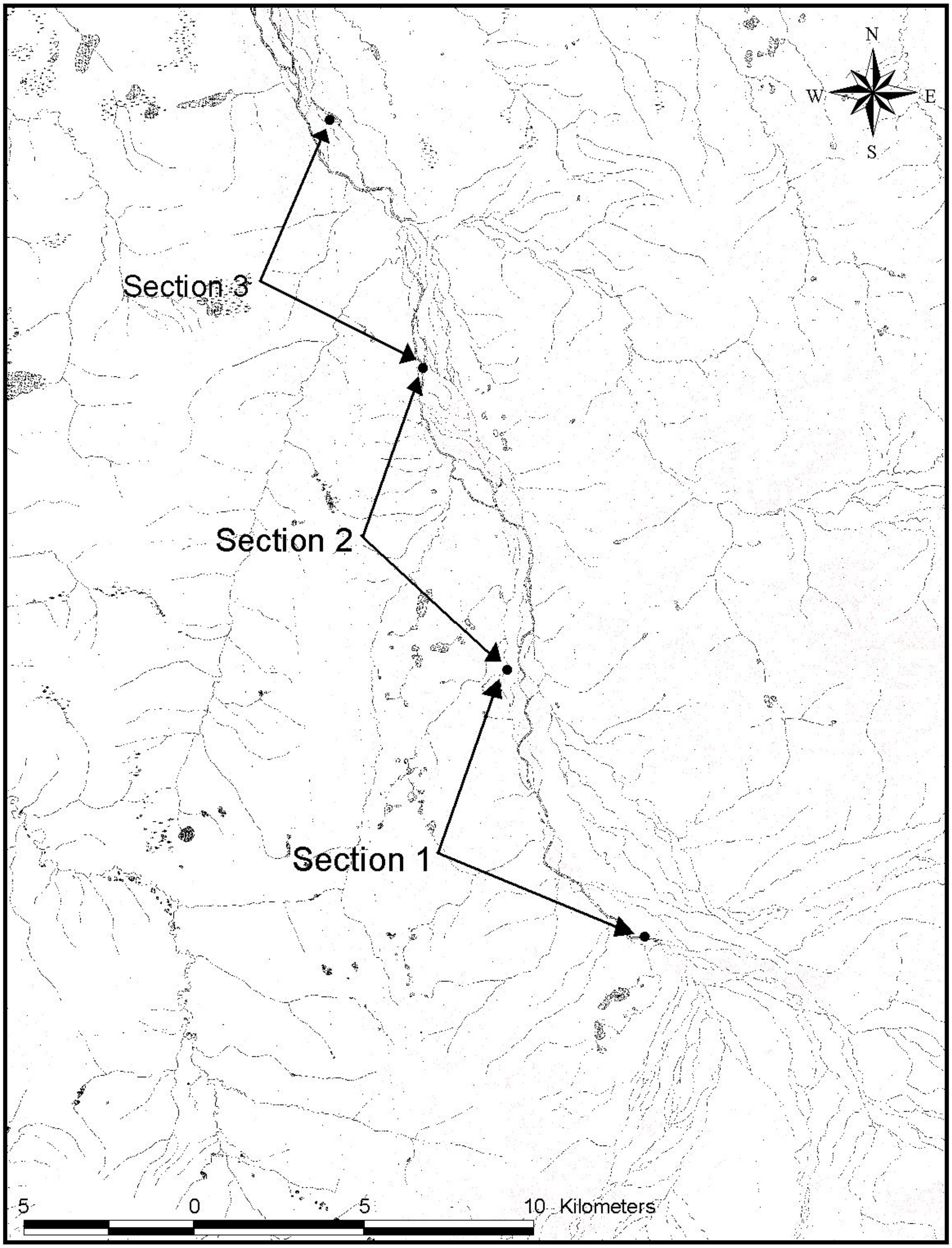


Figure 2. Map of the Ivishak River, Alaska, showing the boundaries of the 28-km index area.

conducted in the same marked channels identified and counted during aerial survey counts. Fish were marked during a seven-day period, and were recaptured by a second crew during a seven-day period that began after a two-day mixing period. In order to attempt to increase precision, a second recapture event took place over a three-day period that began seven days after the marking event. Since there were not enough recaptures from the second event captured in section two and three, comprehensive diagnostic procedures could not be conducted for that estimation. In addition, including the results would not have improved the precision of the estimate, so those data were not included in the analysis.

In order to evaluate fish movement during the experiment, the 28-km index area was divided into three approximately equal subsections prior to the marking event. Fish were given different fin clips depending on capture section to evaluate movement. Length, date, fin clip, and stream section were recorded for each fish captured. Data from the mark-recapture portion of the study was recorded on tagging length mark-sense forms. All Dolly Varden captured were measured to the nearest 5 mm from snout to tail fork. Four radio-tagged fish were recaptured during the first recapture event, but because those fish were marked separately from the marking event, those recaptures were not included in the analysis for the abundance estimation.

Diagnostic tests and estimation procedures were performed on data for the marking and the first and second recapture events. All diagnostic tests were evaluated at the alpha level of 0.05. We evaluated the assumption that there was no size selectivity within the sizes sampled during the mark or recapture events by comparing: a) the length distributions of all fish caught, marked, and released during the marking event and those marked fish recaptured during the recapture event (MvR); and b) the length distributions of all fish caught, marked and released during the marking event and all fish caught and examined during the recapture event (MvC).

The assumptions, procedures, and methods that were used for estimating abundance followed normal sampling and data analysis protocols (Appendix A; Seber 1982)

Radiotelemetry

Forty fish were implanted with radio tags in the Ivishak River on September 14-16, 2001, to evaluate fish movement during the mark-recapture abundance estimate, and to identify specific overwintering sites during April 2002. Ten non-spawning fish were implanted near the lower end of each of the two upper subsections of the 28-km index area, 11 fish were implanted near the lower end of the lowest subsection of the 28-km index area, 3 fish were implanted about 4-km below the bottom of the index area, and three fish were implanted into spawning condition fish in the upper Saviukviak and upper Ivishak River (Figure 3). These radio-tagged fish (except those implanted in spawning condition fish) were located on September 17, 20, and 23. GPS (latitude/longitude) coordinates were recorded for all fish located.

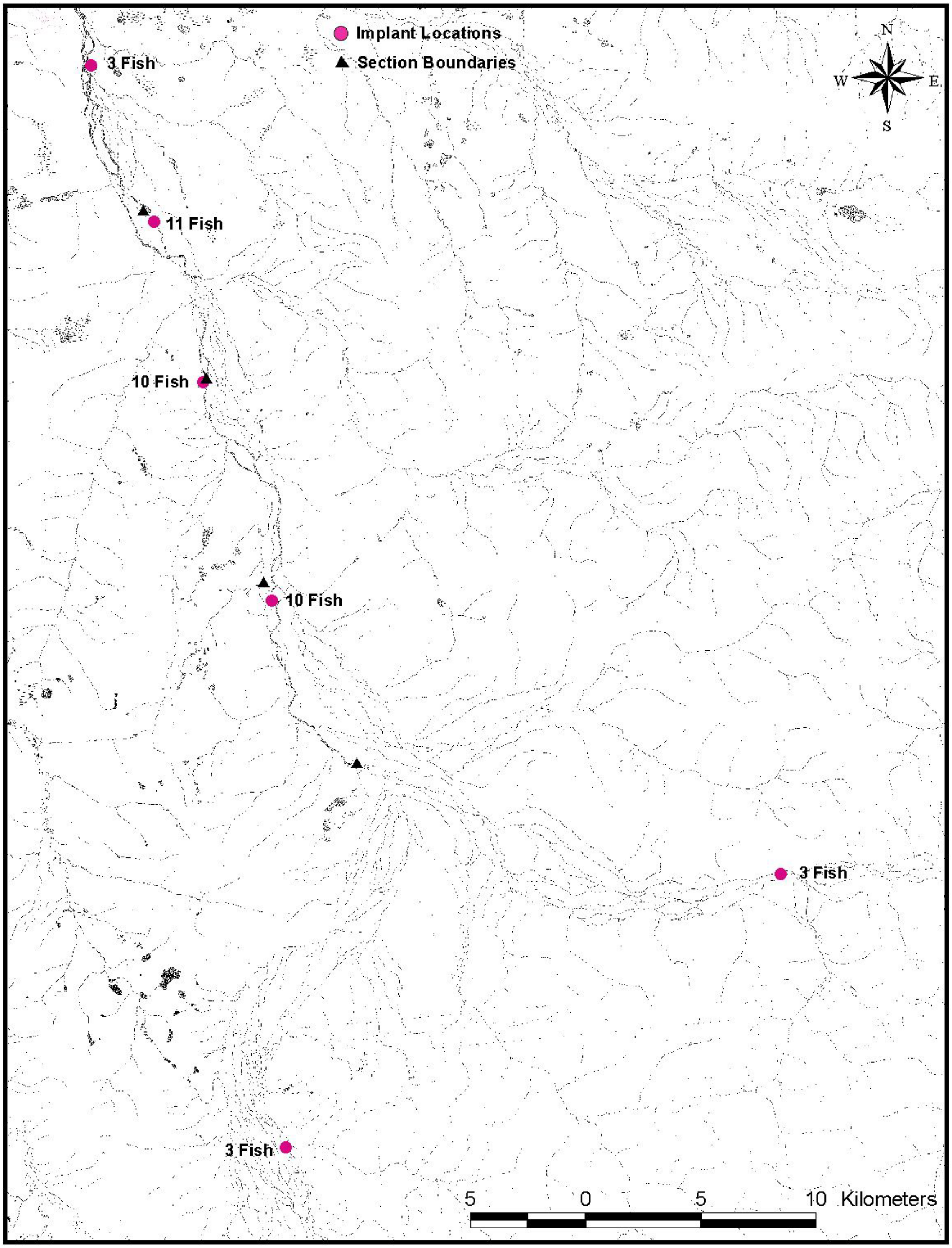


Figure 3. Locations where radio-tagged Dolly Varden were captured and implanted in the Ivishak and Saviukviak rivers, September, 2001.

Spawning and Overwintering Locations and Genetic Stock Identification Baseline Sampling

Spawning locations were identified in the Echooka and Saviukviak rivers by aerial and ground surveys, and all recorded locations were verified by on-the-ground capture and examination of fish to ensure that fish were in spawning condition. Fish on spawning locations were captured with both hook-and-line and seine. GPS coordinates were recorded for all verified spawning locations. These coordinates were entered into a GIS (geographic information system) database overlaid with USGS 1:63,000 maps. For each location, the approximate number of fish observed and the date observed were recorded.

Stock-specific samples were collected during September from the Echooka and Saviukviak rivers. Adult fish in spawning condition were captured using seines or hook-and-line gear using single-hook lures. Attempts to collect stock-specific genetic samples from the Hulahula River during August were unsuccessful due to high water conditions. Fin clips were stored in individual vials of 90% ethanol. Samples were delivered to the USFWS Fish Genetics Lab at 1011 East Tudor Road, Anchorage for genetic analysis.

RESULTS

Aerial Survey Variability Estimation

The five aerial surveys conducted of the 28-km index area of the Ivishak River yielded the counts in Table 2. The mean summed count for both observers over all subsections was 10,932 fish with a standard error of 314, or less than 3% of the mean. Counts were highest in Section 1 and lowest in Section 3. Variability of summed counts (both observers) was different among sections, with the lowest variability in Section 1. Observer 1 (left bank) counted less fish than observer 2, and observer 1 counts were more variable than observer 2 counts.

Mark/Recapture Abundance Estimation

A total of 1,404 Dolly Varden were captured, marked, and measured between September 14 and September 20, 2001 (Table 3). A total of 1,551 fish were captured and examined during the first recapture event, between September 16 and 22, 2001. A second recapture event was conducted from September 21 to 23, and an additional 406 fish were captured and examined. During the first recapture event, a total of 43 marked fish were recaptured.

Table 2. Aerial counts of Dolly Varden Char in a 28-km index reach of the Ivishak River, September 2001.

Replicate Date	Survey Conditions	Section	Observer	Section Count	Section Total	Replicate Total
9/19/2001	Excellent	1	1	2,400	6250	10450
			2	3,850		
		2	1	920	3340	
			2	2,420		
		3	1	210	860	
			2	650		
9/20/2001	Excellent	1	1	2,840	7,650	12,085
			2	4,810		
		2	1	1,390	3,215	
			2	1,825		
		3	1	520	1,220	
			2	700		
9/21/2001	Good	1	1	3,960	7,765	10,415
			2	3,805		
		2	1	910	2,110	
			2	1,200		
		3	1	240	540	
			2	300		
9/22/2001	Good	1	1	3,130	7,865	10,595
			2	4,735		
		2	1	1,245	1,985	
			2	740		
		3	1	470	745	
			2	275		
9/23/2001	Good	1	1	4,570	8,920	11,115
			2	4,350		
		2	1	1,030	1,335	
			2	305		
		3	1	660	860	
			2	200		

Summary Statistics by Section and Observer

	Section 1	Section 2	Section 3	Summed Counts
Mean Count	7,690	2,397	845	10,932
Standard Error	425	383	110	314
Standard Error as Percent of Mean[1]	5.5	16	13.1	2.8

1 Coefficient of Variability (CV)

Table 3. Marking and recapture history from 2001 Ivishak River Mark/Recapture abundance experiment.

	Section	# Marked	# Examine	Number Recaptured from Previous Event			
				Sec 1 mark	Sec 2 mark	Sec 3 mark	Recaptures
Marking Event							
	1	821	0	0	0	0	
	2	323	0	0	0	0	
	3	260	0	0	0	0	
Total Mark		1,404					
Second Event							
Recap 1	1	0	950	16	11	0	27
Recap 1	2	0	475	0	2	10	12
Recap 1	3	0	126	0	0	4	4
Total Examined			1,551				
Total Recaptures							43
Third Event							
Recap 2	1	0	324	2	3	0	5
Recap 2	2	0	30	0	0	0	0
Recap 2	3	0	52	0	0	1	1
Total Examined			406				
Total Recaptures							6

Kolmogorov-Smirnoff tests were performed to evaluate the null hypotheses of no difference between the size distributions for each of these comparisons. When using data pooled from all three sections of the river we failed to reject the null hypothesis for both MvR (p=0.1191) and MvC (p=0.4167) tests. Across the entire experimental area we detected no significant difference between size distributions of fish caught during the marking and 1st recapture event.

Observations of radio-tagged fish, repeated aerial surveys, and tag recoveries during the mark/recapture experiment all indicate a significant movement of fish from Section 2 to Section 1 and from Section 3 to Section 2 between the two sampling events. Also, the recapture data indicate that nearly half the fish present in Section 2 during the marking event had moved into Section 1 by the time the recapture event was conducted, with a movement of similar magnitude occurring from Section 3 to Section 2. This suggests mixing within the study area.

When we evaluated the tests for consistency for the Peterson type estimator we concluded that the Bailey modified Peterson estimator is the appropriate method. We rejected the null hypotheses that movement patterns between river sections were uniform (p<0.0001) and that recapture probabilities for fish marked in different river sections are uniform (p<0.0001). However, because we failed to reject the null hypothesis that the marked to unmarked fish ratios are uniform across sections of the river (p=0.9051), the conditions required for the use of the unstratified estimator were met (Appendix A). Results of the Bailey estimator yielded a point estimate of 49,523 fish with a standard error of 7,277.

The mean length of all fish captured was 447 mm fork length. The smallest fish captured was 225 mm fork-length and the largest was 710 mm fork-length. Most fish captured were between

350 and 560 mm (Figure 4). Fish recaptured during the second event ranged from 255 mm to 600 mm.

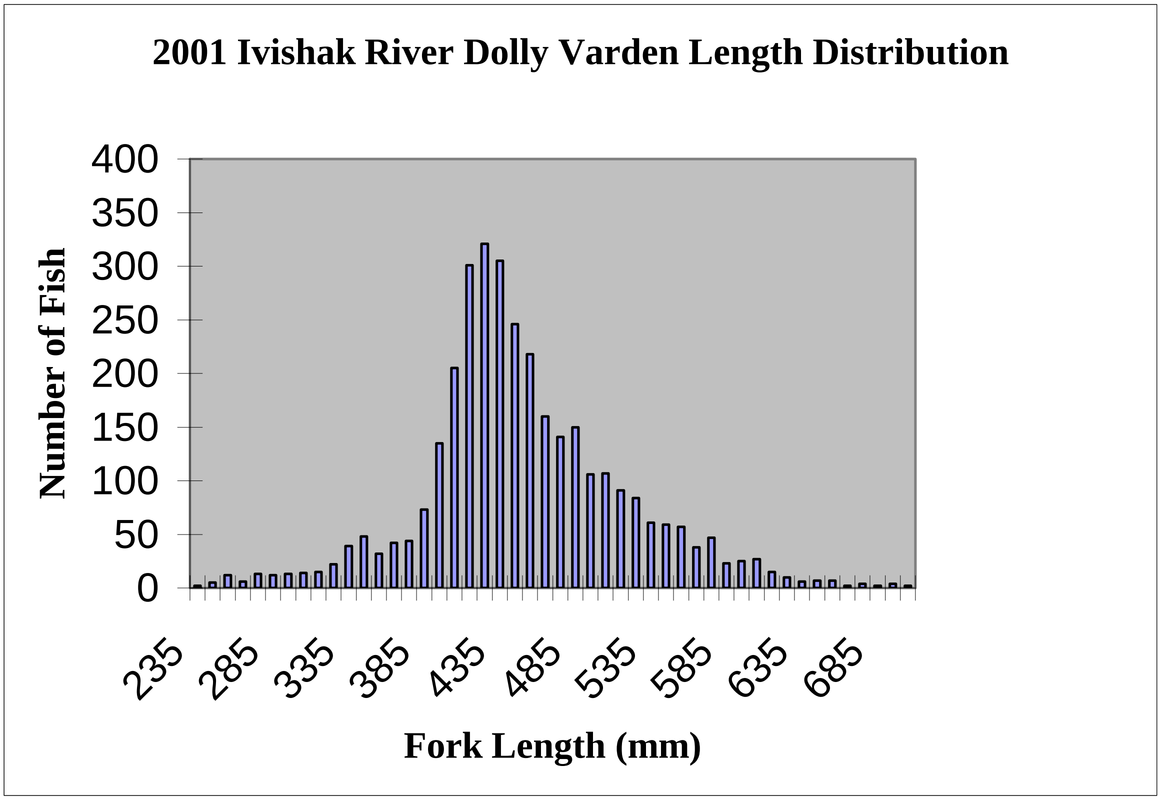


Figure 4. Length distribution of overwintering anadromous Dolly Varden captured in the Ivishak River, September 2001.

Radio telemetry

Radio-tagged fish were located on September 17, 20, and 23, except that spawning condition fish tagged in the upper Ivishak and Saviukviak were not located after being implanted. Most tagged fish had moved upstream from the location they were tagged by September 17 (Figure 5). Several fish that were radio-tagged at the same location moved together, and were located very near each other on subsequent dates.

One fish tagged in section two moved downstream approximately 8 km into section one between September 17 and September 20 (Figure 6), but that fish had moved approximately 12 km back upstream into section two by September 23 (Figure 7). All radio-tagged fish except one had moved upstream by September 23, with most tagged fish in section one or the upper half of

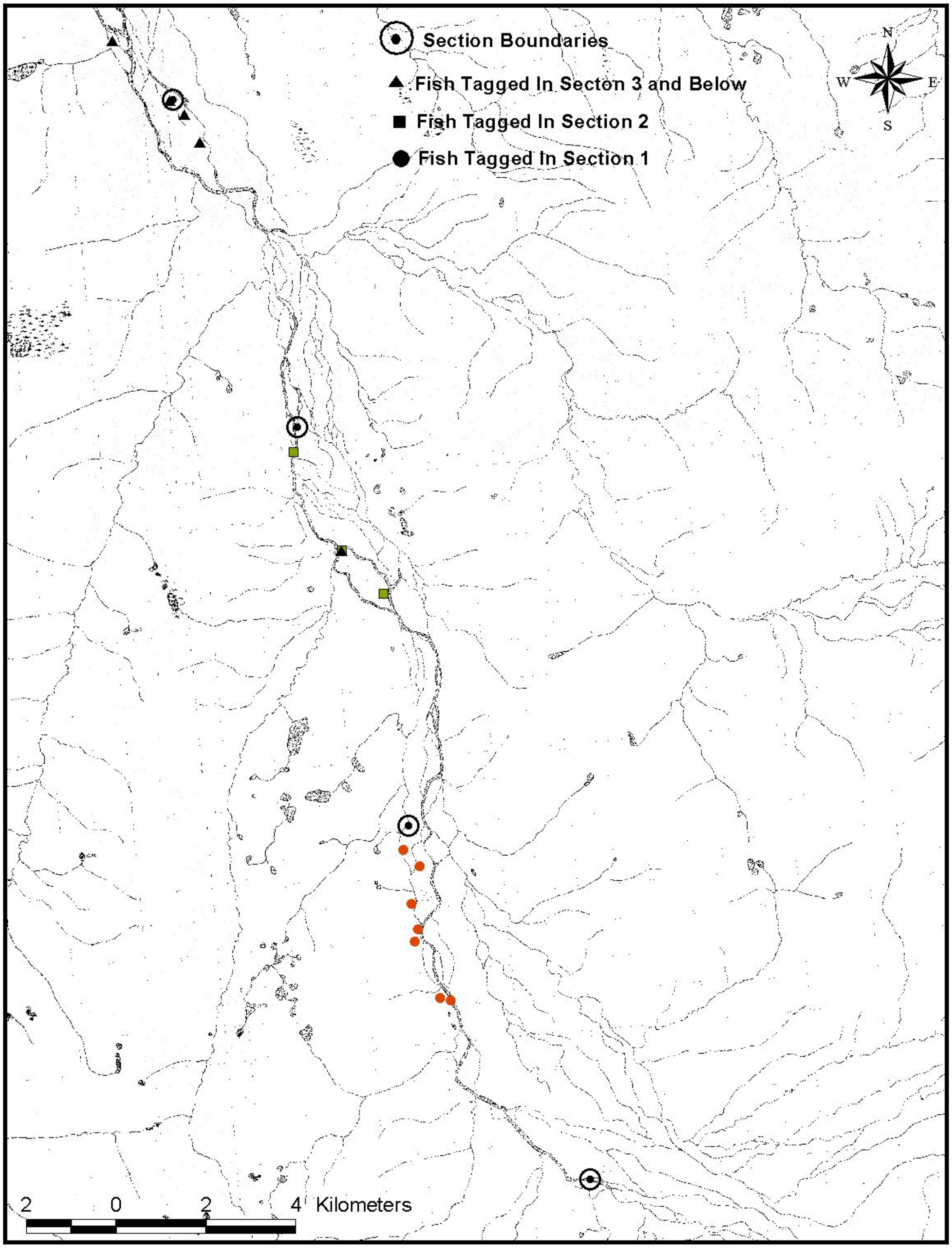


Figure 5. Locations of radio-tagged Dolly Varden in the Ivishak River, Alaska, September 17, 2001.

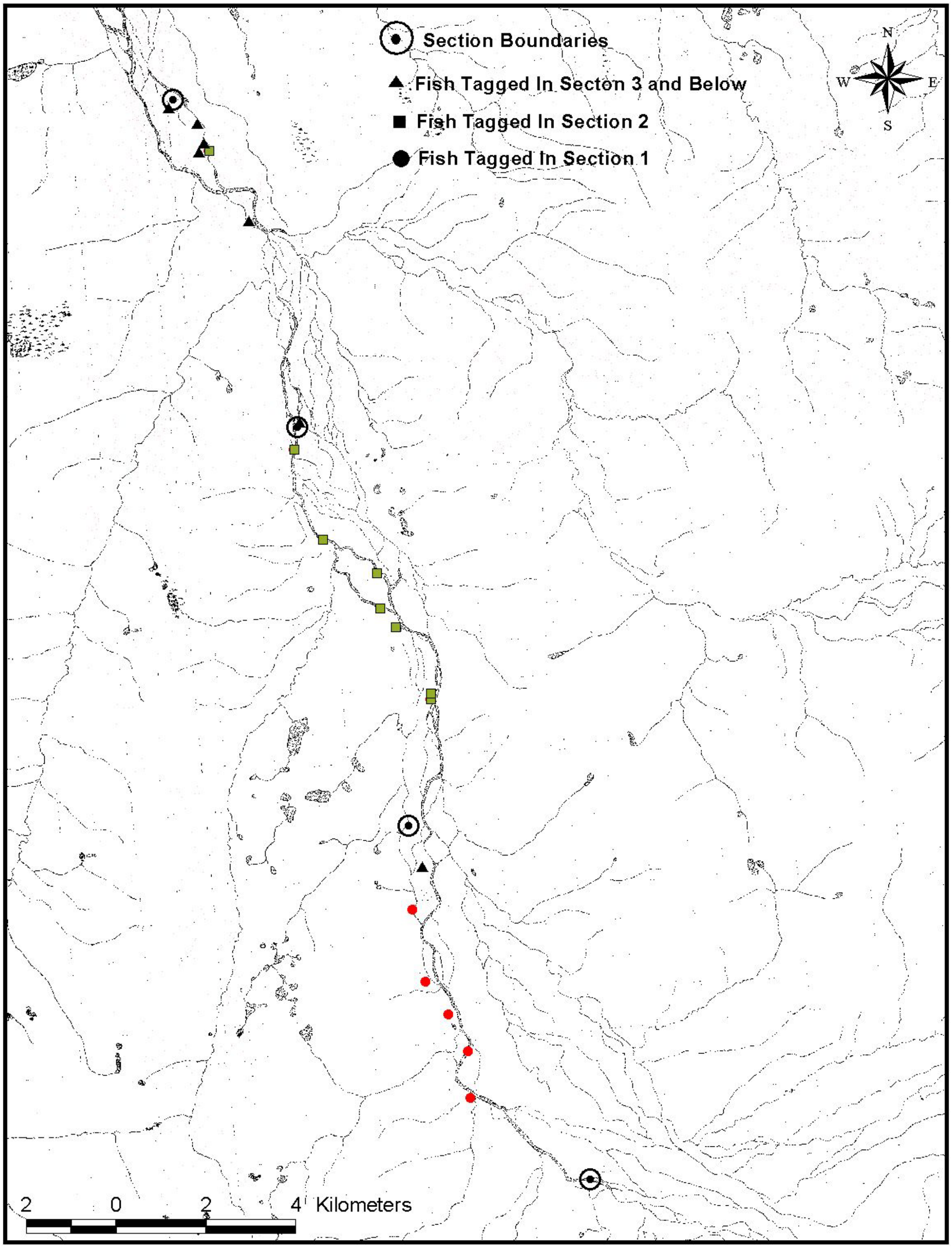


Figure 6. Locations of radio-tagged Dolly Varden in the Ivishak River, Alaska, September 20, 2001.

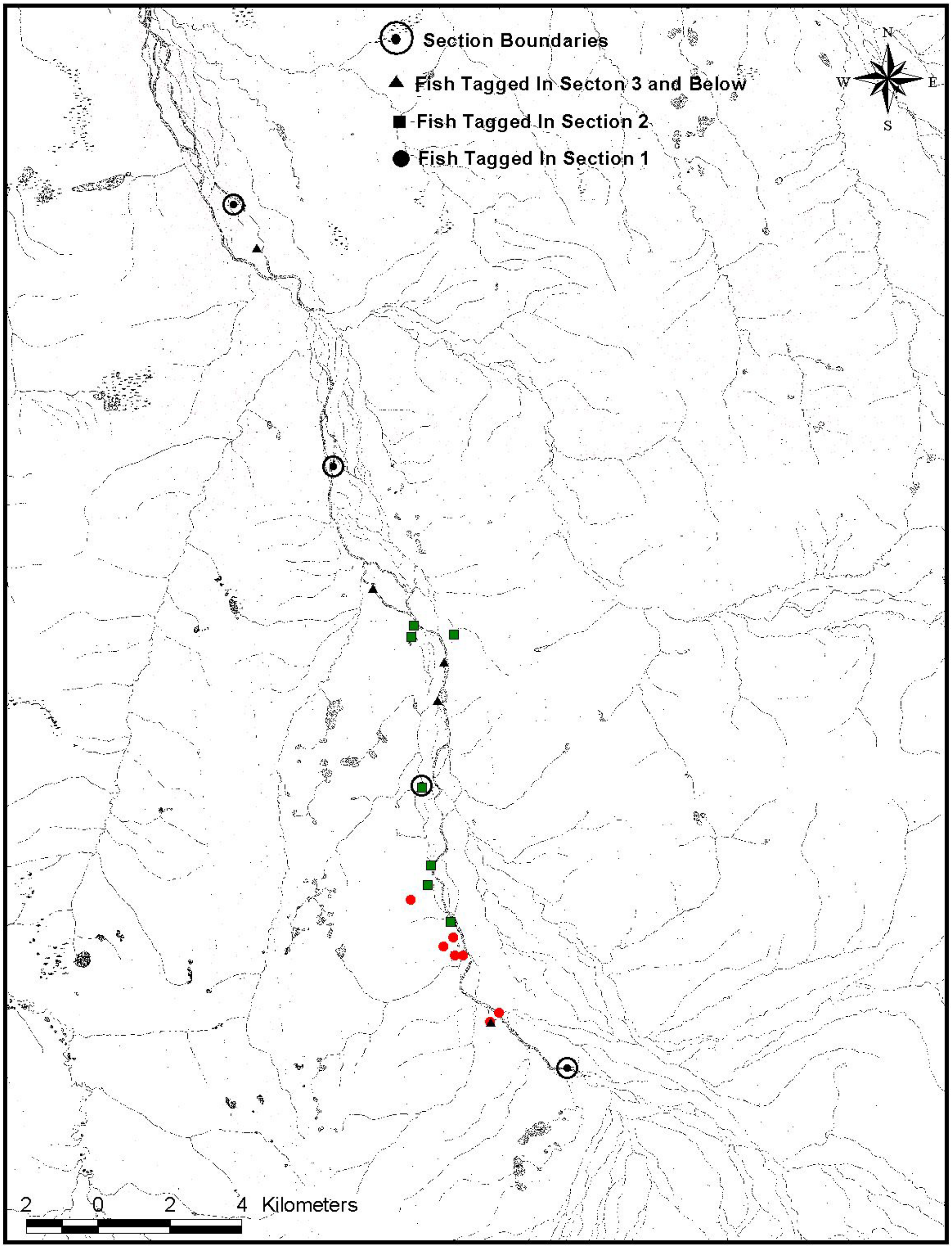


Figure 7. Locations of radio-tagged Dolly Varden in the Ivishak River, Alaska, September 23, 2001.

section two. One of the three fish tagged below section three had moved into the upper half of section one by September 23.

Spawning and Overwintering Locations and Genetic Stock Identification Baseline Sampling

Spawning locations were identified in the Echooka and Saviukviak rivers (Figure 8). The GPS coordinates and approximate numbers of fish at each location are listed in Appendix B. Overwintering locations will not be determined until after radio-tagged fish are located in the Ivishak River during April of 2002. Fin clips (about 6 mm^2) were taken from 106 fish from the Echooka River and 30 fish from the Saviukviak River.

DISCUSSION

Aerial Survey Variability Estimation

The total index area counts of all sections for both observers from the five replicate aerial counts showed that such counts are relatively precise, with the Coefficient of Variability (CV) of the summed mean counts less than 3%. Because each observer was only counting one side of the river, this study was not intended to measure within-observer variability or between-observer variability. The aerial counts clearly indicated that fish were moving upstream during the period that counts were made. This was also indicated by the recapture history during the abundance estimate, and by the locations of radio-tagged fish. This movement would confound any measures of variability except for between total index area counts.

The total index area counts from 2001 showed a much lower variability than the counts made of a 6.5 km index area during the feasibility study for this project (Viavant 2001). This could be related to counting fish over a much larger area (28 km vs. 6.5 km), and could also be related to observer experience. Variability was much lower than that from counts of pink salmon *Onchorynchus gorbuscha* by multiple observers in Southeast Alaska (Jones 1995), but much of that difference is probably due to the large number of observers in that study, and the much higher densities of fish being counted.

The total index area counts from the aerial surveys represent 22% of the abundance as estimated by the mark-recapture experiment. Taking into account the variability in both methods, the aerial surveys counted between 16 and 28 percent of the abundance as estimated by the mark-recapture experiment. This range represents the 95% confidence interval for the ratio of the average aerial count to the mark-recapture abundance estimate calculated using the Delta method (Seber 1982).

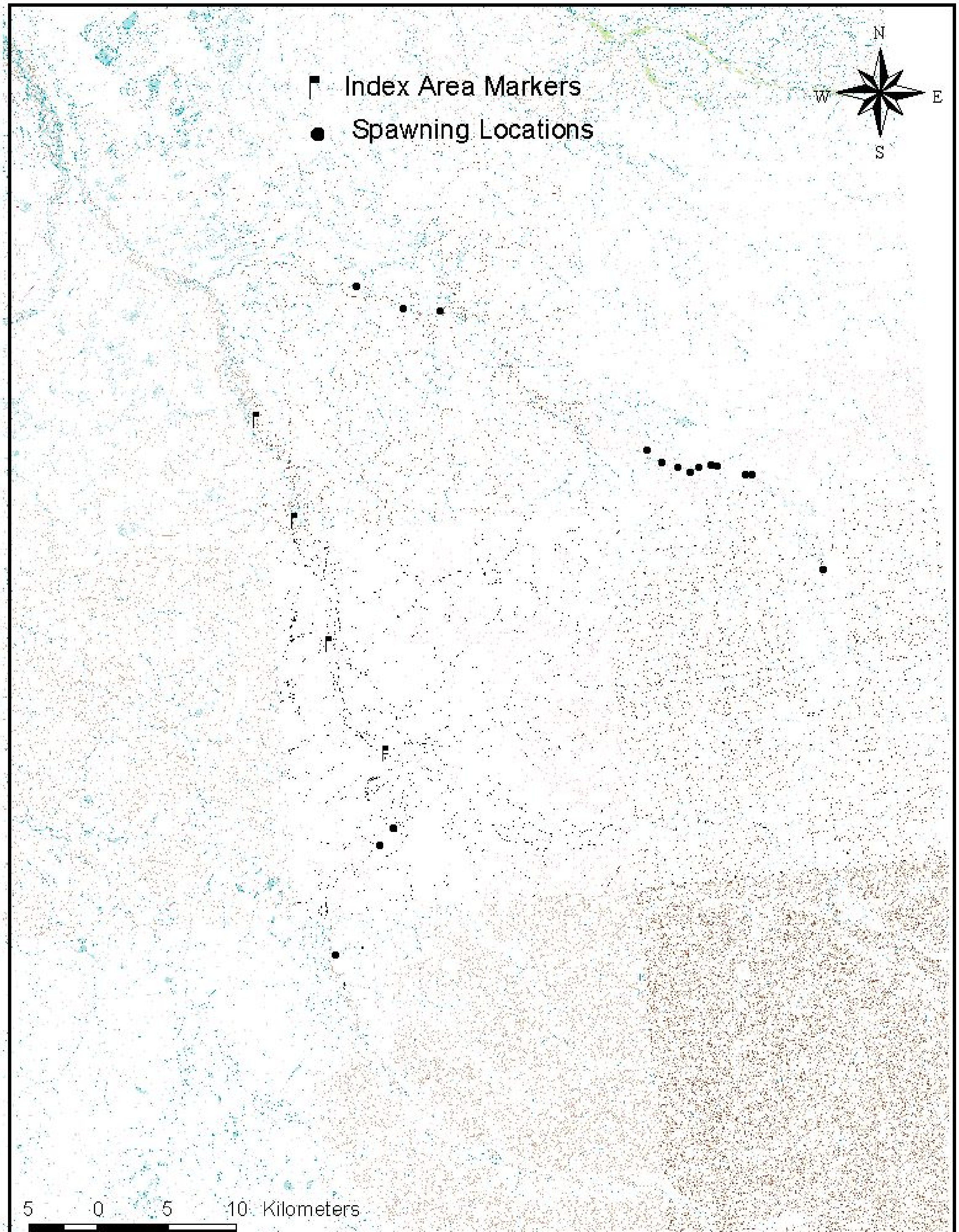


Figure 8. Dolly Varden spawning locations in the Echooka and Saviukviak rivers, Alaska, September 2001.

Because the aerial counts were conducted over a fixed set of river channels, and because fish were moving during the period counts were made, some undercounting is likely due to fish present in channels that are not counted. Some undercounting is also likely due to the heterogeneous distribution of fish, resulting in some areas of extremely high fish density.

Despite these sources of uncertainty, the low variability between the total index area counts suggests that the method may provide a repeatable index of abundance. Future paired aerial surveys and mark-recapture estimates will indicate whether the proportion counted during aerial surveys shows consistency over repeated paired estimates.

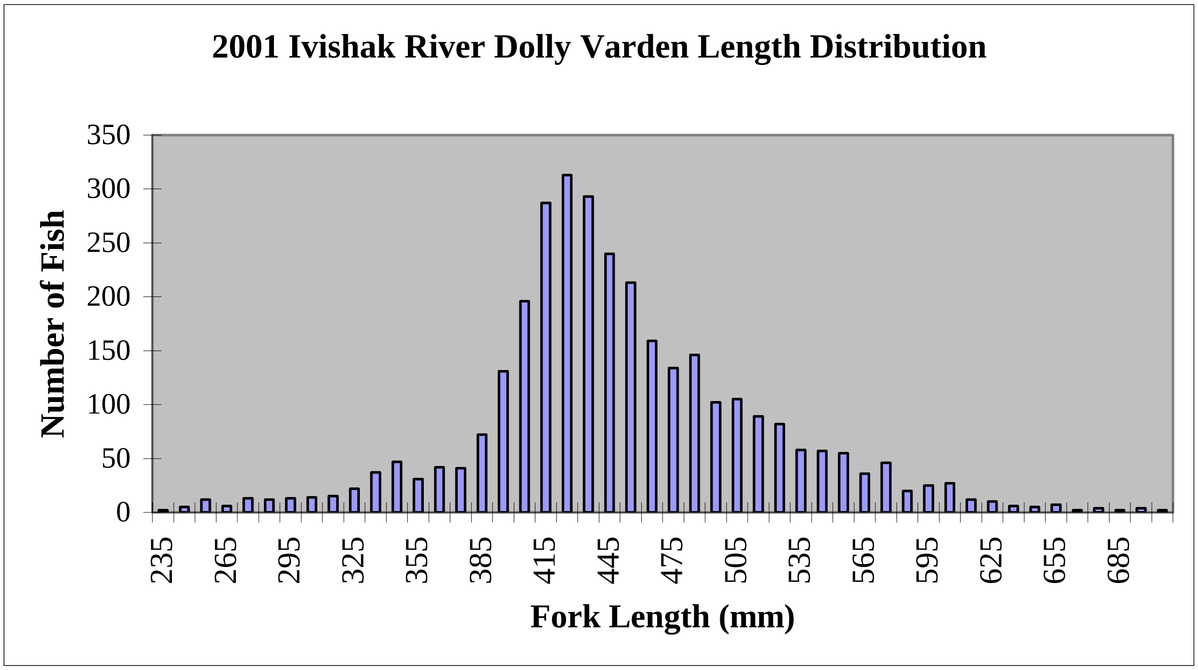
Mark/Recapture Abundance Estimation

There were substantial experimental results from analyzing the marking and first recapture events, even though the estimate did not meet the precision objectives in the study plan. There was not adequate data from the second recapture event to conduct comprehensive diagnostic procedures when using either the marking event or the first recapture event for marks. Because of an insufficient number of marked fish to test for size selectivity, data from the second recapture event were not used for estimating abundance. The diagnostics from the marking event and the first recapture event indicated that the best option was to report the Bailey estimate of 49,523.

Size data were pooled from the marking and first recapture event to estimate size composition according to the procedures in the Sampling and Data Analysis Protocols (Appendix A). Given the diagnosis of size selectivity when comparing the first and second recapture events, size data from the second recapture event were not included with the other two samples. The mean length of fish caught during 2001 was almost identical to the mean length of fish caught in 2000 (452 mm in 2000 and 447 mm in 2001).

The length distribution of fish caught (excluding the second recapture event) was somewhat different from that of the fish captured in 2000 (Figure 9). There were no fish caught in 2000 smaller than 300 mm, while a number fish of that size were caught in 2001. Fish over 650 mm made up a smaller proportion of all fish caught in 2001 than in 2000. Differences in length distributions between 2000 and 2001 could be related to several factors, but should not be due to gear selectivity, since both years' collections were made with the same gear. It is possible that larger fish tend to migrate earlier or occupy portions of the overwintering area higher in the drainage, since the collections from 2000 were from only section one of the index area studied in 2001.

The length distribution of the fish caught in 2001 was similar to that reported by Yoshihara (1972, 1973), with the mean lengths for all collections being within 50 mm. The length distribution of fish caught in 2001 was very slightly bi-modal with a small peak at 350 mm. Samples collected by Yoshihara (1973) also were bimodal, with a small peak at 325 mm.



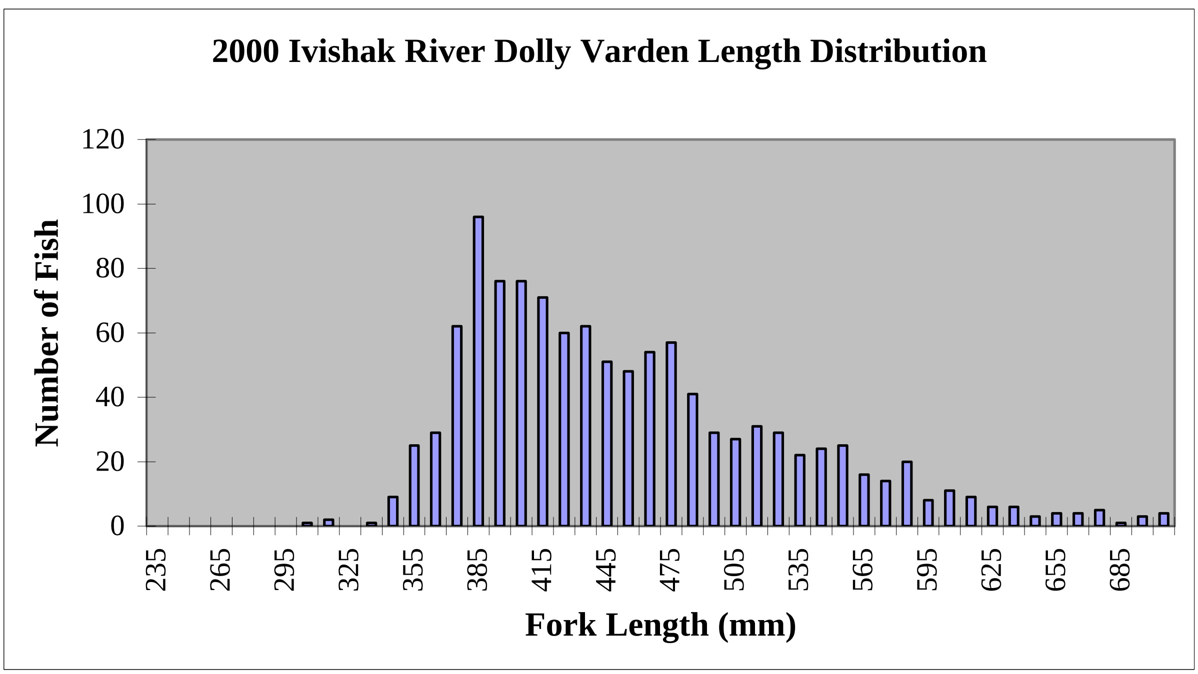


Figure 9. Length distribution of overwintering anadromous Dolly Varden captured in the Ivishak River, September 2000 (n = 1,122), and September 2001 (n = 2,955).

Radio telemetry

The movements of the 34 fish radio-tagged within and just below the assessment area showed that there was substantial movement of fish during the assessment, and that this movement was almost exclusively upstream. One fish tagged in Section three did not move during the entire experiment, however, this fish was not mortality, since the recapture crew captured it alive on September 21, in the same location it was tagged. No fish tagged in section one moved upstream out of the index area, indicating that although there was substantial upstream movement during the experiment, marked fish probably did not move out of the index area. This was supported by the absence of fish above the index area during aerial counts.

Although fish radio-tagged at spawning locations were not subsequently located, none of those fish had moved downstream into the index area during the experiment. Because these fish had not yet spawned by September 20, it was not expected that these fish would have left the spawning locations. These fish will be located in April 2002, to determine if they overwinter upstream near the spawning locations, or if they move downstream and overwinter in the same location as the non-spawning fish. Specific wintering sites will be determined by locating all radio-tagged fish during April of 2002.

Spawning and Overwintering Locations and Genetic Stock Identification Baseline Sampling

Spawning locations of Dolly Varden in the Ivishak, Echooka, and Saviukviak rivers appear to be widely dispersed, and primarily in the upper reaches of the drainages, within the foothills or mountains of the Brooks Range. In general, most spawning groups consist of less than 100 fish. No fish that were observed in spawning condition in these drainages after September 20 had spawned yet, and no spawning behavior was observed. Spawning sites in the extreme upper reaches of these drainages were not located during 2001, but attempts to identify such spawning sites will be made in 2002.

Genetic samples from spawning-stock-specific Dolly Varden were collected from these drainages, as well as from the Kongakut River in 2000. These samples will be analyzed for the development of marker regions that distinguish stocks from drainages or groups of drainages. If sufficient genetic differences exist among spawning stocks, as previous research indicates (Everett et al. 1997, Krueger at al. 1999), samples collected from subsistence fisheries (that target mixed stock aggregations) in Kaktovik in 2001 will be analyzed. Combined with subsistence harvest estimation, these samples could be used to estimate stock contribution to subsistence harvests, and the relative impact these harvests have on specific stocks.

CONCLUSIONS

1. Replicate aerial counts of overwintering Dolly Varden within a 28-km section of the Ivishak River had relatively low variability, and these aerial counts represented approximately 22% of the abundance in the same 28-km section as measured by mark-recapture methods.

2. The overwintering aggregation of Dolly Varden in the Ivishak River in the fall of 2001 was 49,523 (SE = 7,277).

3. Stock specific genetic samples can be collected with non-lethal methods (fin tissue samples) to develop a Dolly Varden genetic baseline database for this region, however, collections of spawning adults may be logistically cost prohibitive, and collections of emergent young-of-the-year juveniles may have to be used in place of spawning adults.

RECOMMENDATIONS

1. Replicate aerial surveys combined with concurrent mark-recapture abundance estimates of overwintering Dolly Varden in the established 28-km index area of the Ivishak River should be conducted for at least two more years. Having paired aerial and mark/recapture estimates of overwintering abundance for three successive years may help to establish the relationship between the two methods. For the purposes of determining proper sample size for mark-recapture abundance estimates, twice the initial aerial survey is not adequate by may be five times the initial aerial survey based on data from 2001.

2. The specific locations of critical spawning and overwintering habitat used by anadromous Dolly Varden in Beaufort Sea drainages should be verified, recorded, and mapped in a GIS database.

3. Spawning-stock-specific genetic samples should be collected from the remaining major Dolly Varden spawning stocks for which collections do not yet exist or are not yet complete (Anaktuvuk, Nanushak, Aichilik, Canning, Hulahula, Kavik, Lupine, Ribdon, Saviukviayak, upper Sagavanirktok, and Shaviovik rivers). Mitochondrial DNA from those samples should be analyzed to establish a library of marker regions that could be compared with genetic samples from subsistence Dolly Varden fisheries on the North Slope to estimate the stock composition of those harvests.

4. Subsistence harvests of Dolly Varden in the communities of Kaktovik and Nuiqsut should be estimated for a minimum of two consecutive years, and genetic samples should be collected from those harvests to attempt to estimate the stock composition of those harvests (see recommendation 3).

ACKNOWLEDGEMENTS

I thank the U.S. Fish and Wildlife Service, Office of Subsistence Management for providing $198,900 in funding support for this project through the Fisheries Resource Monitoring Program, under agreement number 701811J333, and for constructive comments during review of the Investigation Plan. I also thank the North Slope Borough Regional Advisory Council for supporting the project, and the North Slope Borough Fish and Wildlife Management Committee and Department of Wildlife for support and assistance in project planning. I also thank the staff of the USFWS Arctic National Wildlife Refuge and the Fairbanks Fishery Resources Office for advice during planning and logistical support. Thanks to the Alaska Division of Fish and Wildlife Protection for the use of their facilities on the North Slope, and thanks to the field staff of the Alaska Department of Fish and Game for the hard work they provided in difficult working conditions.

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APPENDIX A

Mark/Recapture Abundance Estimation Methods

This document presents the sampling and data analysis protocols for a portion of a research project funded by the U.S. Fish and Wildlife Service, Office of Subsistence Management. The entire project is described in the Fisheries Investigation Plan titled Eastern North Slope Dolly Varden Genetic Stock Identification and Stock Assessment. The entire project will evaluate the use of Mitochondrial DNA analysis of Dolly Varden to estimate stock contribution to subsistence harvests and compare aerial surveys with traditional mark-recapture abundance estimation.

This portion of the project is intended to evaluate the variability of replicate aerial surveys of overwintering Dolly Varden in a 28-km section of the Ivishak River, and to determine the relationship between those aerial surveys and a traditional mark-recapture abundance estimate of Dolly Varden in that same 28-km section.

The objectives of this portion of the study are:

1) To estimate the variability of replicate aerial surveys of the overwintering aggregation of Dolly Varden (within a fixed 28-km area) on the Ivishak River conducted by the same observers under similar conditions during the same time period.

2) To estimate the abundance and size composition of Dolly Varden in the overwintering aggregation (same geographic area as objective 1) on the Ivishak River such that the abundance estimate is within 20% of the true value 90% of the time.

METHODS

The boundaries of the index area will be established according to the distribution of overwintering Dolly Varden as determined by an initial aerial survey. Aerial surveys and mark-recapture abundance estimation will occur within the same index area. Both methods of evaluation will be conducted after upstream migration into the index area is judged to be essentially complete, based on when aerial surveys indicate the absence of new fish below the selected overwintering area. The criteria used to make this judgment will be the presence of less than 10% of the number counted in the assessment area present in the 10-km reach immediately below the assessment area.

This index area of approximately 28-km will be mapped using a data-logging GPS. The index area will be divided into three sub-sections, each approximately 9 km of river. The boundaries of each sub-section will be prominently marked. In areas with multiple channels, the channel containing the majority of fish will be marked, and all assessment will occur in those marked channels only. During the initial aerial surveys, the total number of fish in the index area will be estimated, and the proportion of the total within each sub-section.

Aerial Surveys

One large discrete spawning/overwintering aggregation on the Ivishak River will be aerially surveyed five replicate times to estimate the variability of aerial counts. The same observers under as similar conditions as possible will conduct replicate surveys, within as short a time period as possible (i.e. within 5 days). Surveys will all be conducted from a helicopter. To the extent practical, all aerial surveys will be conducted under similar weather and lighting conditions. The weather conditions (wind and cloud cover), water clarity, and date and time of each survey will be recorded for each survey.

Each aerial count will be taken using mechanical counters. The setting of the counter prior to survey will be set to a number unknown to the observers, and the display of the mechanical counters will be covered so that the observers will not know the outcome of each count. At the end of each survey, the counts will be determined and recorded by a designated data keeper. The counts from all surveys will remain known only to the designated data keeper until all surveys are completed.

Estimation of Abundance

A mark-recapture abundance estimate of the 28-km index area will be conducted using a Bailey modified Petersen two-event estimator. Adult fish will be captured using beach seines, and marked with a small fin-clip. One crew working from the upstream boundary of the index area downstream will mark fish during an seven-day period, and fish will be examined for marks by a second crew working from the upstream boundary of the index area downstream after a two day mixing period.

The mark-recapture assessment will address abundance and composition estimate objectives.

The assumptions necessary for an accurate estimate of abundance in this experiment are that (taken from Seber 1982):

1. the population will be closed (no change in the number of Dolly Varden in the population during the experiment);
2. all Dolly Varden will have the same probability of capture during the marking event or in the recapture event, or marked and unmarked fish mix completely between marking and recapture events;
3. marking of Dolly Varden will not affect their probability of capture in the recapture sample;
4. Dolly Varden will not lose their mark between the marking and recapture events; and,
5. all marked Dolly Varden will be reported when recovered in the recapture sample.

Sampling is designed (short overall study duration and short sampling hiatus) to lessen risks associated with assumption 1. The 28-km study area will be sampled in 8-10 days to reduce the likelihood of natural mortality. The likelihood and effects of migration cannot be totally assured, particularly with fall-run Dolly Varden, however, the experiment will not begin until after aerial surveys indicate that there are no fish below the assessed area, which will indicate the migration upstream is complete. This assumption will also be partially examined through comparison of the marked-to-unmarked ratios in the lowermost sampled area (subject to immigration from downstream areas), and examination of catch patterns relative to the upstream and downstream sampling locations. Additionally, evaluation of movement patterns of radio-tagged fish will also be used to assess the validity of this assumption.

The hypothesis that fish captured during the marking sample have the same length frequency distribution as fish captured in the recapture sample will be tested. There are four possible outcomes of these two tests; either one or both of the samples are biased or neither is biased. Possible actions for data analysis are outlined in Appendix Table 1. Results of this test will address the validity of assumption 2 and 3 in relation to unequal catchability by length.

Because capture probabilities can differ significantly among areas, assumption 2 will also be examined using the three tests of consistency described by Seber (1982). If one of the three tests is not significant than an unstratified Bailey modified Petersen estimator will be used to estimate abundance. If there is movement between areas, but all three of the consistency tests are significant, then a Darroch (1961) estimator will be used. If no movement between subsections of the index area occur and all these tests are significant then a stratified Bailey modified Peterson estimate will be used after testing for consistency and length bias between strata (see Seber 1982, section 3.1.2, pages 61-62).

In the unlikely event that substantial movement completely out of the index area (and by inference movement into the index area) occurs between the mark and the recapture event then the modified Petersen-Bailey estimator of Evenson (1988) will be used (given the results of the other assumption tests described here and the assumptions of this method as described in Evenson 1988). In this case the capture-recapture data will be reorganized into three equal area sub-sections prior to hypothesis testing and analysis.

The last two assumptions are validated by the sampling methods used. Assumption 4 is assured because all fish are marked by a partial finclip, which cannot grow back during the study. Assumption 5 is assured by careful examination of all fish for finclips.

The modified Petersen estimator of Bailey (1951, 1952) is used to estimate abundance:

$$\hat{N} = \frac{n_1(n_2 + 1)}{(m_2 + 1)} \qquad (1)$$

where:

$\hat{N} =$ abundance of Dolly Varden in the Ivishak River study area;

n_1= number of Dolly Varden marked and released during the first event;

n_2= number of Dolly Varden examined for marks during the second event; and,

m_2= number of Dolly Varden recaptured in the second event.

Variance of this estimator is calculated by (Bailey 1951, 1952):

$$V\left[\hat{N}\right] = \frac{(n_1)^2 (n_2 + 1)(n_2 - m_2)}{(m_2 + 1)^2 (m_2 + 2)}. \tag{2}$$

Length Composition in Mark-Recapture Assessment

Testing of assumptions necessary for accurate abundance estimation may also reveal biases in length composition samples. Unequal catchability by length may bias estimates of length composition. Length composition is used to apportion the population estimate into length classes; length information collected during either the marking sample, the recapture sample, or both samples will be used to calculate length composition, depending on the tests described in Appendix A1.

If case I (Appendix A1) from inference testing occurs, no adjustments to length data will be necessary and data from both events will be pooled. If case II occurs, only length data from the recapture event will be used to estimate composition. If the population is closed between sampling events the abundance estimate is germane to both sampling events. For these two scenarios the proportion of fish at length is calculated as:

$$\hat{p}_k = \frac{y_k}{n} \tag{1}$$

where:

$\hat{p}_k =$ the proportion of Dolly Varden that are within length class k;

n_k = the number of Dolly Varden sampled that are within length class k and,

n = the total number of trout sampled.

The variance of this proportion is estimated as (from Cochran 1977, page 52):

$$\hat{V}[\hat{p}_k] = \frac{\hat{p}_k (1 - \hat{p}_k)}{n - 1} \left(1 - \frac{n}{\hat{N}}\right) \tag{2}$$

If case III from inference testing occurs, both mark and recapture samples are biased. If case IV occurs the recapture sample is biased and the status of the mark sample is unknown. If case III occurs, length data from both samples will be pooled and adjustments made to these data. If case IV occurs and the stratified and unstratified abundance estimates are dissimilar, length data from the recapture sample will be used to estimate composition. These data must also be adjusted for bias due to length-selectivity. To adjust length data, the proportion of fish in each length class is calculated by summing independent abundances for each length class and then dividing by the summed abundances for all length classes. First the conditional proportions from the sample are calculated:

$$\hat{p}_{ik} = {}^{n_{ik}}\!/_{n_i} \tag{3}$$

where:

n_i = the number sampled from length strata *i* in the mark-recapture experiment;
n_{ik} = the number sampled from length class *k* that are within length strata *i*; and,
$\hat{p}_{ik}$ = the estimated proportion of fish in length class *k* within length strata *i*.
$\hat{p}_{ik}$

The variance calculation for $\hat{p}_{ik}$ is identical to equation 4 (with appropriate substitutions).
If stratification is necessary, length and age proportions of proportions for Dolly Varden will be estimated using:

$$\hat{p}_k = \sum_{i=1}^{j} \frac{\hat{N}_i}{\hat{N}} \hat{p}_{ik} \tag{4}$$

The variance of $\hat{p}_k$ is approximated using the Delta method (Seber 1982) by:

$$\hat{V}[\hat{p}_k] \approx \sum_{i=1}^{j} (\hat{p}_{ik} - \hat{p}_k)^2 \frac{\hat{V}[\hat{N}_i]}{\hat{N}^2} + \sum_{i=1}^{j} \left(\frac{\hat{N}_i}{\hat{N}} \right)^2 \hat{V}[\hat{p}_{ik}] \tag{5}$$

where: $\hat{N}_i$ = the abundance of Dolly Varden in stratum *i*; and

$\hat{N}$ = total abundance of Dolly Varden.

Sample size

The sample sizes for the entire mark-recapture experiment will be determined according to Table 1, depending roughly on the number of fish counted in the index area during initial aerial surveys. Assuming that aerial surveys typically underestimate the number of fish present in the assessed areas, the population size used will be assumed to be approximately 100% higher than the number counted during the aerial survey immediately preceding the marking event. Sample size was determined according to procedures outlined by Robson and Regier (1964). Ideally, the total sample size for each event will be apportioned to each of the three sub-sections according to the relative abundance within each section.

Data Collection and Reduction

Sampling effort will be distributed during both the marking event and recapture event by systematic sampling. A seine haul will be made approximately every 350 m, with seine hauls alternating between east and west river banks. All fish captured in each seine haul will be measured and marked during both the marking and recapture events.

Appendix Table A1. Sample sizes needed to meet objective criteria for abundance estimate of spawning/overwintering aggregation within the Ivishak River.

Observed Aerial Survey Count Just Prior to Marking Event	Assumed Population Size	Number to Mark during 1st Event	Number to Examine for Marks during Second Event	Percentage of Population Marked or Examined during the 2 events	Expected Number of Recaptured Fish during 2nd Event	Expected Number of Unique Fish Examined
0-1,875	2,500	**358**	**358**	14.3%	51	665
1,876-3,125	5,000	**529**	**529**	10.6%	55	1,003
3,126-4,375	7,500	**660**	**660**	8.8%	57	1,263
4,376-5,625	10,000	**772**	**772**	7.7%	59	1,485
5,626-6,875	12,500	**870**	**870**	7.0%	60	1,680
6,876-8,125	15,000	**959**	**959**	6.4%	60	1,858
8,126-9,375	17,500	**1,040**	**1,040**	5.9%	61	2,019
9,376-10,625	20,000	**1,117**	**1,117**	5.6%	61	2,173
10,626-11,875	22,500	**1,188**	**1,188**	5.3%	62	2,314
11,875-13,125	25,000	**1,256**	**1,256**	5.0%	62	2,450
13,126-16,875	30,000	**1,382**	**1,382**	4.6%	64	2,700
16,876-23,125	40,000	**1,605**	**1,605**	4.0%	64	3,146
>23,126	50,000	**1,802**	**1,802**	3.6%	65	3,539

In order to evaluate the effects of fish movement during the experiment, the 26-km index area will be divided into three sub-sections, which will be numbered from upstream (section 1) to downstream (section 3). Fish will be given different marks during the marking event according to the section of capture. These marks will be as follows:

Sub-section 1	Left Pectoral fin clip
Sub-section 2	Right Pectoral fin clip
Sub-section 3	Left Ventral fin clip

In addition to these marks, each fish will be marked with a left opercular punch, to aid data collectors in identifying previously marked fish. All fish will be marked with a upper caudal fin clip during the recapture event so that fish will not be sampled more than once.

In addition to evaluating fish movement by differential marking by section, radio tags will be implanted into 10 fish captured near the downstream end of each section. These fish will be radio-tagged just prior to the beginning of the marking event. The locations of these fish will be determined by GPS, and recorded every third day after radio tagging for the duration of the experiment. Approximately 15% of all fish marked during the marking event will be tagged with an individually numbered floy tag. These tags will be distributed by tagging every 7th fish handled.

Data from the mark-recapture portion of the study will be recorded on tagging length mark-sense forms. All Dolly Varden captured will be measured to the nearest 5 mm for snout to fork length. Sex will be determined from external characteristics only for spawning condition fish. Event (mark vs. recapture), date, sub-section, location (1 km stream reach) of capture, fin clip, and tag number and color (if needed) will be recorded. Information regarding fishing effort will include number, location, and date of seine hauls.

The project biologist will edit all mark-sense forms twice for stray marks, incomplete marks, coding errors, and omissions. Coding errors include incorrect dates, transposed or nonsensical lengths, and transposed tag numbers within a series. Omissions include missing digits in lengths, dates, survey area, survey site, species code, gear type, and fishery. After editing, all mark-sense forms will be sent to Alaska Department of Fish and Game (ADF&G), Research and Technical Services (RTS) for processing.

Upon completion, RTS will return data (DTA) files to the project biologist. The DTA files will also be edited for coding errors, omissions, and out-of-bounds lengths using Microsoft Excel. The corrected DTA files will be archived with RTS. From the corrected DTA files, a database (DBF) file will be created.

The project biologist will edit all field notebooks and maps for errors in a similar manner as the mark-sense forms. Data from field notebooks and maps will be transferred to Microsoft Excel spreadsheet files (XLS) for analysis and archival. Spreadsheet files will be archived with RTS. The Federal Contract report will be prepared in Microsoft Word.

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Appendix Table A2. Methodologies for alleviating bias due to gear selectivity by means of statistical inference.

	Result of first K-S test[a]	Result of second K-S test[b]
Case I[c]		
	Fail to reject H_o	Fail to reject H_o
	Inferred cause: There is no size-selectivity during either sampling event.	
Case II[d]		
	Fail to reject H_o	Reject H_o
	Inferred cause: There is no size-selectivity during the second sampling event, but there is during the first sampling event.	
Case III[e]		
	Reject H_o	Fail to reject H_o
	Inferred cause: There is size-selectivity during both sampling events.	
Case IV[f]		
	Reject H_o	Reject H_o
	Inferred cause: There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.	

[a] The first K-S (Kolmogorov-Smirnov) test is on the lengths of fish marked during the first event versus the lengths of fish recaptured during the second event. H° for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish recaptured during the second event.

[b] The second K-S test is on the lengths of fish marked during the first event versus the lengths of fish captured during the second event. H° for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish sampled during the second event.

[c] Case I: Calculate one unstratified abundance estimate, and pool lengths and ages from both sampling event for size and age composition estimates.

[d] Case II: Calculate one unstratified abundance estimate, and only use lengths and ages from the second sampling event to estimate size and age composition.

[e] Case III: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Pool lengths and ages from both sampling events and adjust composition estimates for differential capture probabilities.

[f] Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Estimate length and age distributions from second event and adjust these estimates for differential capture probabilities.

APPENDIX B

North Slope Dolly Varden Spawning Locations

River	Date	Latitude (Degrees)	Latitude (Minutes)	Latitude (Decimal Minutes)	Longitude (Degrees)	Longitude (Minutes)	Longitude (Decimal Minutes)	Approximate Number of Fish
Echooka	9/19/01	147	59	80	69	24	42	40
	9/19/01	147	54	90	69	23	40	30
	9/19/01	147	50	96	69	23	16	40
	9/19/01	147	28	79	69	16	46	45
	9/19/01	147	30	16	69	16	98	50
	9/19/01	147	27	12	69	16	17	45
	9/19/01	147	24	85	69	16	09	50
	9/19/01	147	23	46	69	16	13	35
	9/20/01	147	22	83	69	16	07	150
	9/20/01	147	25	79	69	15	95	35
	9/20/01	147	19	89	69	15	65	50
	9/20/01	147	19	22	69	15	62	45
	9/20/01	147	12	72	69	11	62	40
Saviukviak	9/16/00	148	01	07	69	03	19	35
		148	02	62	69	02	55	40
		148	07	90	68	57	22	35