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Eastern North Slope Dolly Varden Spawning and Over-wintering Assessment Feasibility.

Final Report for Study 00-002

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Summary Page

Title: Eastern North Slope Dolly Varden Spawning and Over-wintering Assessment Feasibility.

Study Number: FIS00-002

Geographic Area: Regions 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: $41,500.

Study Duration: June 2000 to March 2001.

Abstract: The feasibility of estimating the variability and validity of aerial surveys of overwintering aggregations of anadromous Dolly Varden in North Slope drainages of the Beaufort Sea was investigated. Five replicate aerial surveys of a 6.5 km index section of the Ivishak River were conducted in late September, and capture methods were evaluated for conducting a concurrent mark-recapture abundance estimate in the same index section. Spawning stock-specific genetic samples were collected from adult spawning condition fish in the Kongakut and Ivishak rivers for genetic analysis to evaluate the feasibility of estimating the stock composition of subsistence harvests from mixed-stock aggregations of anadromous Dolly Varden. The variability of replicate aerial surveys was relatively low, with the coefficient of variation for summed mean counts of less than 12%. Although a mark-recapture abundance estimate was not completed due to logistical problems, capture methods and timing indicated that an estimate could be obtained with low variability. The study also showed that stock-specific genetic samples could be collected for comparison with samples from subsistence harvests.

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

Project Data: Data for this study consist of genetic samples (fin clips), information on char captured and sampled (date and location of capture, method of capture, length and description of char), GPS coordinates of char spawning locations, and counts of spawning and overwintering char obtained during ground and aerial surveys. Biological samples are stored in 95% ethanol; sampling and survey information are stored in Microsoft Excel spreadsheets. U.S. Fish and Wildlife Service Fish Genetics Laboratory, 1011 East Tudor Road, Anchorage 99503 maintains genetic samples and data. Alaska Department of Fish and Game, Division of Sport Fish, 1300 College Road, Fairbanks, Alaska 99701 maintains Sampling and survey data. Access to biological samples and data is available upon request to the custodians.

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EXECUTIVE SUMMARY

Anadromous Dolly Varden *Salvilinus malma* are present in most of the eastern drainages of the Beaufort Sea from the Colville River eastward to the Firth and Babbage rivers in Canada. These populations appear to be comprised of genetically distinct spawning stocks, but over-winter, migrate, and feed in marine waters as mixed-stock aggregations. These fish make up an important part of the subsistence diet of residents of Kaktovik, Anaktuvuk, and Nuiqsut, and are harvested in mixed-stock fisheries in marine waters and from overwintering areas. There is currently little information on subsistence harvest levels or stock status of these populations, and much of the spawning and over-wintering habitat of these fish is located in federally managed waters.

The spawning stocks that contribute to these mixed-stock fisheries are geographically diverse, and logistically very hard to assess with any method other than aerial surveys of overwintering aggregations. While there is some historical aerial survey data of some index areas, the validity and variability of this method of assessment has never been tested. Although some subsistence harvest estimation has also been done in the past, because the subsistence fisheries that use these fish occur on mixed-stock aggregations, the effect of harvest levels on a specific spawning stock cannot be determined. There is some evidence that there is enough genetic diversity among different spawning stocks of these fish that the stock origin of an individual fish could be determined from mitochondrial DNA analysis of fin tissue.

This project investigated the feasibility of assessing the variability and validating aerial surveys of overwintering populations of anadromous Dolly Varden and of estimating the stock composition of subsistence harvests of Dolly Varden using mitochondrial DNA sampling. Replicate aerial surveys were done and a mark-recapture abundance estimate was attempted of an index area of overwintering fish on the Ivishak River, which contains one of the largest overwintering concentrations of Dolly Varden on the north slope. Genetic samples were collected from spawning condition fish and spawning locations were recorded and mapped on the Kongakut and Ivishak Rivers. The project also investigated the feasibility of alternate stock assessment methods such as weirs or counting towers.

This feasibility study showed that replicate aerial surveys of overwintering Dolly Varden conducted of an index area of the Ivishak River had relatively low variability (standard error of less than 12% of the mean count). Although a mark-recapture abundance estimate of the same index area on the Ivishak River could not be completed due to logistical problems, the study showed that a sufficient number of Dolly Varden could be sampled to successfully get an abundance estimate, given enough sampling effort and logistical support. The study also recorded spawning and overwintering locations, and showed that stock-specific genetic samples could be collected from spawning populations. The study indicated that alternate methods of abundance estimation such as a weir or counting tower were both scientifically and logistically difficult and cost-prohibitive.

This project was presented to and discussed at length with the North Slope Regional Advisory Council, as well as with staff of the North Slope Borough Wildlife Department. No formal arrangement could be reached to include the North Slope Borough Wildlife Department as a cooperator in this project, but input from the North Slope Regional Advisory Council and from subsistence users from Kaktovik was included in project planning.

This feasibility study showed that the capture and aerial survey methods used can estimate the variability of aerial surveys to assess overwintering stocks of Dolly Varden, and to establish the relationship between aerial survey counts and mark-recapture abundance estimation. The study also showed that spawning-stock-specific genetic samples could be collected from adult spawning Dolly Varden for evaluation of using genetic samples to estimate the stock composition of subsistence harvests.

Future research on anadromous Dolly Varden on the North Slope should include a series of three years of paired aerial survey and mark-recapture abundance estimates. Critical spawning and overwintering habitat should be identified and mapped. Major subsistence harvests should be estimated, and the stock contribution to those harvests should be estimated by comparing stock-specific genetic samples with genetic samples collected from those subsistence harvests.

INTRODUCTION

Anadromous Dolly Varden *Salvilinus malma* are found in many of the Beaufort Sea drainages of the north slope of the Brooks Range between the Colville River in Alaska east to the Firth and Babbage rivers in Canada (Figure 1). Previous genetic studies of anadromous Dolly Varden from North Slope drainages (Everett et al. 1997, Krueger et al. 1999) indicate that the entire North Slope Dolly Varden complex is made up of genetically distinct sub-populations, generally defined by separate drainages or groups of drainages. Anadromous Dolly Varden in northern Alaska have complex life history and movement patterns (DeCicco 1985, 1989, 1992, 1997, Craig 1977, Morrow 1980). Although individual drainages probably contain genetically distinct spawning stocks, these spawning stocks mix during summer feeding in marine waters and often overwinter in drainages other than their natal spawning stream (Reynolds 1997).

Residents of Kaktovik, Anaktuvuk Pass, and Nuiqsut harvest thousands of anadromous Dolly Varden annually in mixed-stock subsistence fisheries (Craig 1987, Pedersen 1990). Harvests of these fish represent up to 40% of all subsistence fish harvests in Kaktovik (Pedersen, 1990). These harvests target fish migrating in marine waters and in rivers, and in mixed-stock aggregations in overwintering areas. The spawning stocks that contribute to these fisheries are distributed among drainages from the Anaktuvuk River eastward to the Canadian border. Much of the spawning and overwintering habitat used by these stocks is within the Arctic National Wildlife Refuge.

There have been recent increases in the number of non-local sport anglers using these resources and in estimated sport harvests and catches, in conjunction with increased visitor use of a number of these rivers by both guided and unguided float trips. Visitor use of the Dalton Highway is also increasing, and a significant proportion of the entire Eastern North Slope Dolly Varden mixed stock complex overwinters in tributaries of the Sagavanirktok River, which is easily accessible at numerous points along the Dalton Highway.

These stocks utilize critical habitat for spawning and overwintering that may be limited (Craig 1989, Krueger 1999). Much of this habitat is located in areas that have a high potential for oil exploration and development. These activities could result in negative impacts from the common practices of utilizing large quantities of water for building ice roads, or the mining of gravel for drilling pads. This is especially of concern due to the limited amount of overwintering habitat utilized by large concentrations of overwintering Dolly Varden.

The ability to manage these mixed-stock fisheries is dependent on knowledge of the stock status of major spawning stocks that contribute to these fisheries and of the

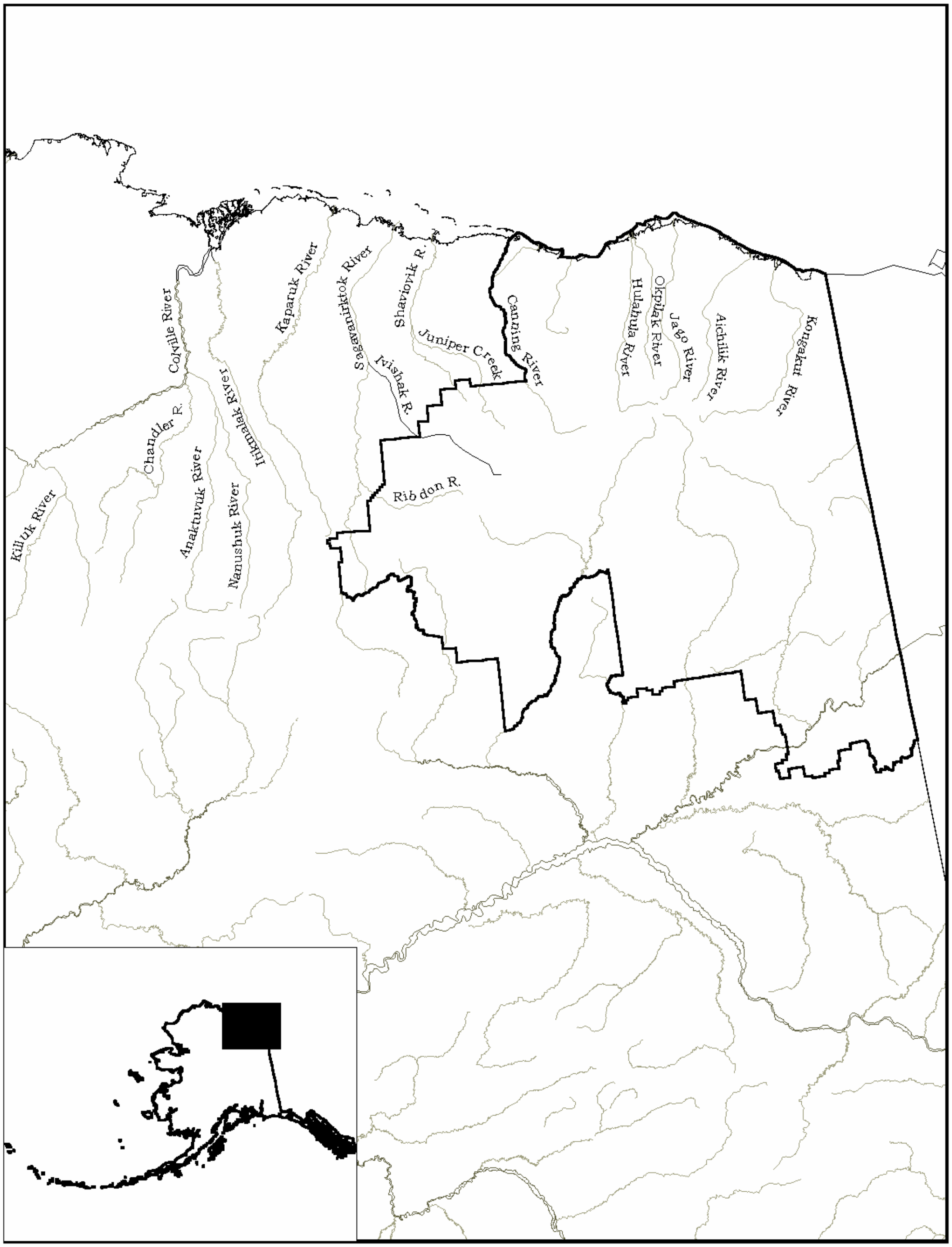

Figure 1. Map of the eastern North Slope of the Brooks Range and coastal plain showing major drainages containing anadromous Dolly Varden and the boundary of the Arctic National Wildlife Refuge.

stock composition of these harvests, that is, the proportional contribution of various spawning stocks to these harvests. Additionally, the ability to protect spawning stocks and overwintering aggregations during future resource development will be dependent on the knowledge of the location and timing of critical habitat needs of these stocks.

Although 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, and1983; Underwood et al. 1996), the only information gathered in the recent past on the stock status of north slope Dolly Varden is limited to aerial surveys of several overwintering index areas on the Anaktuvuk, Ivishak, and Kongakut rivers (Table 1). These surveys have 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.

Table 1. Aerial estimates of Arctic char from the Ivishak, Anaktuvuk, and Kongakut rivers of the North Slope. No surveys were done for years not listed. Survey aircraft was either a helicopter (H) or fixed wind aircraft (Super Cub; S).

Year	Date	Ivishak River	Anaktuvuk River	Kongakut River	Survey Aircraft	Survey Rating	Data Source
1971	22-Sept.	24,470			H	Good	Yoshihara 1973
1972	24-Sept.	11,937			H	Good	Yoshihara 1972
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

Conducting traditional stock assessment (abundance estimation) on stocks that are so geographically diverse is too expensive to be cost effective. Aerial surveys of established index areas are a cost effective method of conducting at least a minimal assessment of the stocks contributing to these important subsistence fisheries. Although aerial surveys provide stock information for 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.

Several authors have described 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 could 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 investigated the feasibility of estimating the variability of repeated aerial surveys conducted by the same observers of the same spawning/overwintering aggregation, and concurrently conducted a traditional mark-recapture abundance estimate of this same spawning/overwintering aggregation. This information would allow managers to determine the reliability and validity of using aerial surveys as an index of stock abundance. The study also evaluated the likelihood of success of alternative abundance-based stock assessment methods such as weirs or counting towers. Aerial surveys and abundance estimation were done at the Ivishak River, a tributary of the Sagavanirktok River.

The project investigated the feasibility of collecting stock-specific mitochondrial DNA 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 could be used to estimate the stock contribution of different spawning stocks to those harvests. Genetic samples were collected from spawning-condition adult Dolly Varden from the Kongakut and Ivishak rivers.

The study indicated that a mark-recapture abundance estimate could be conducted concurrently with replicate aerial surveys in the Ivishak River after upstream migration of overwintering Dolly Varden is complete. The study also successfully collected stock-specific genetic samples from the Kongakut and Ivishak rivers.

OBJECTIVES

Project objectives were to:

1) Estimate the variability of replicate aerial surveys of a spawning/overwintering aggregation on the Ivishak River conducted by the same observer under similar conditions during the same time period.
2) Estimate the abundance and size composition of Dolly Varden within one discrete spawning/overwintering 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, Ivishak, Lupine, and Echooka Rivers and collect GIS mapping data for all verified and

new locations. Evaluate locations and methods for future abundance-based stock assessment.

4) Collect fin clips from Dolly Varden from the Kongakut, Hulahula, Anaktuvuk, and Ivishak Rivers.

METHODS

Aerial Survey Variability Estimation

Five replicate aerial surveys of a 6.5 km index area of the Ivishak River (Figure 2) were conducted from September 19-25. 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 counted. Although all channels were not counted, during all counts, the same river channel was 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 5 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 5 km index area. The count from each observer was summed as the daily total count.

Aerial Survey Validation (Mark-Recapture Assessment)

A mark-recapture abundance estimate of this same aggregation (the same 6.5 km index section) was attempted using a Petersen two-event estimator. Adult fish were captured using beach seines, measured, and marked with a small fin-clip. Fish were marked during a four-day period, and were to be recaptured after a three-day mixing period. Logistical problems prevented a sample from being taken for the recapture event, and it was not possible to obtain an abundance estimate. The assumptions, procedures, and methods that were to be used for estimating abundance are included as a portion of the methods section of the Investigation Plan for this project, which is attached as Appendix A.

In order to evaluate fish movement during the experiment, the 6.5 km index area was divided into three sections prior to the marking event beginning. 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 for snout to fork length. Length, date, fin clip, and stream section were recorded for each fish captured. Fish were given different fin clips depending on capture section to evaluate movement.

Spawning and Overwintering Locations.

Spawning locations were identified 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 database overlaid with USGS 1:63,000 maps. For each location, the approximate number of fish observed and the date observed were recorded.

Genetic Stock Identification Baseline Sampling.

Stock-specific samples were collected during August 14-21, 2000 from the Kongakut River, and during September 15-18, 200 from the Ivishak River. Adult fish in spawning condition were captured using seines or hook-and-line gear using single-hook lures. Fin clips (about 6 mm^2) were taken from 72 fish from the Kongakut and 104 fish from the Ivishak. 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.

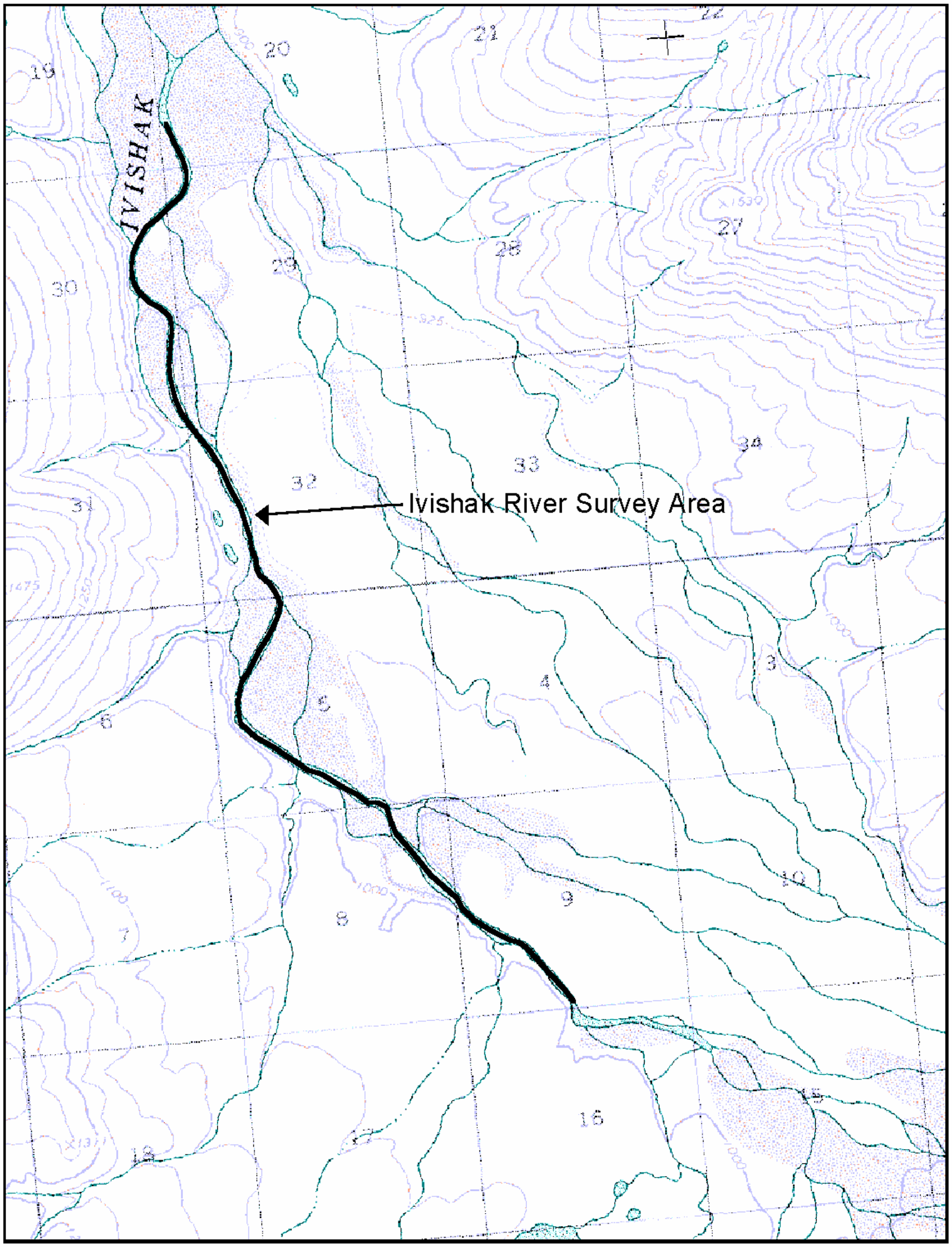

Figure 2. Map of the Ivishak River, Alaska, showing the boundaries of the 6.5 km index area.

RESULTS

Aerial Survey Variability Estimation

The five aerial surveys conducted of the 6.5 km index area of the Ivishak River yielded the counts in Table 2. The mean summed count was 4,530 fish with a standard error of 238. Counts by observer 1 were consistently higher than counts by observer 2, and less variable than counts by observer 2.

Table 2. Aerial counts of Dolly Varden Char in a 6.5 km index reach of the Ivishak River, September 2000.

Survey Date	Observer 1 Count	Observer 2 Count	Summed Count	Daily Mean	Between Observer Std. Dev.	Between Observer CV
9/19/00	2,600	2,300	4900	2,450	212	9%
9/20/00	2,200	1,900	4100	2,050	212	10%
9/21/00	2,250	1,600	3850	1,925	460	24%
9/23/00	2,600	2,500	5100	2,550	71	3%
9/25/00	2,450	2,250	4700	2,350	141	6%
Mean Counts	2,420	2,110	4,530			
Within Observer Std Dev.	189	357	533			
Within Observer CV	8%	17%	12%			

Aerial Survey Validation (Mark-Recapture Assessment)

A total of 1,122 Dolly Varden were captured, marked, and measured between September 19 and September 25, 2000. The mean length of fish captured was 452 mm fork length. The smallest fish captured was 335 mm fork-length and the largest was 745 mm fork-length. Most fish captured were between 360 and 500 mm (Figure 3).

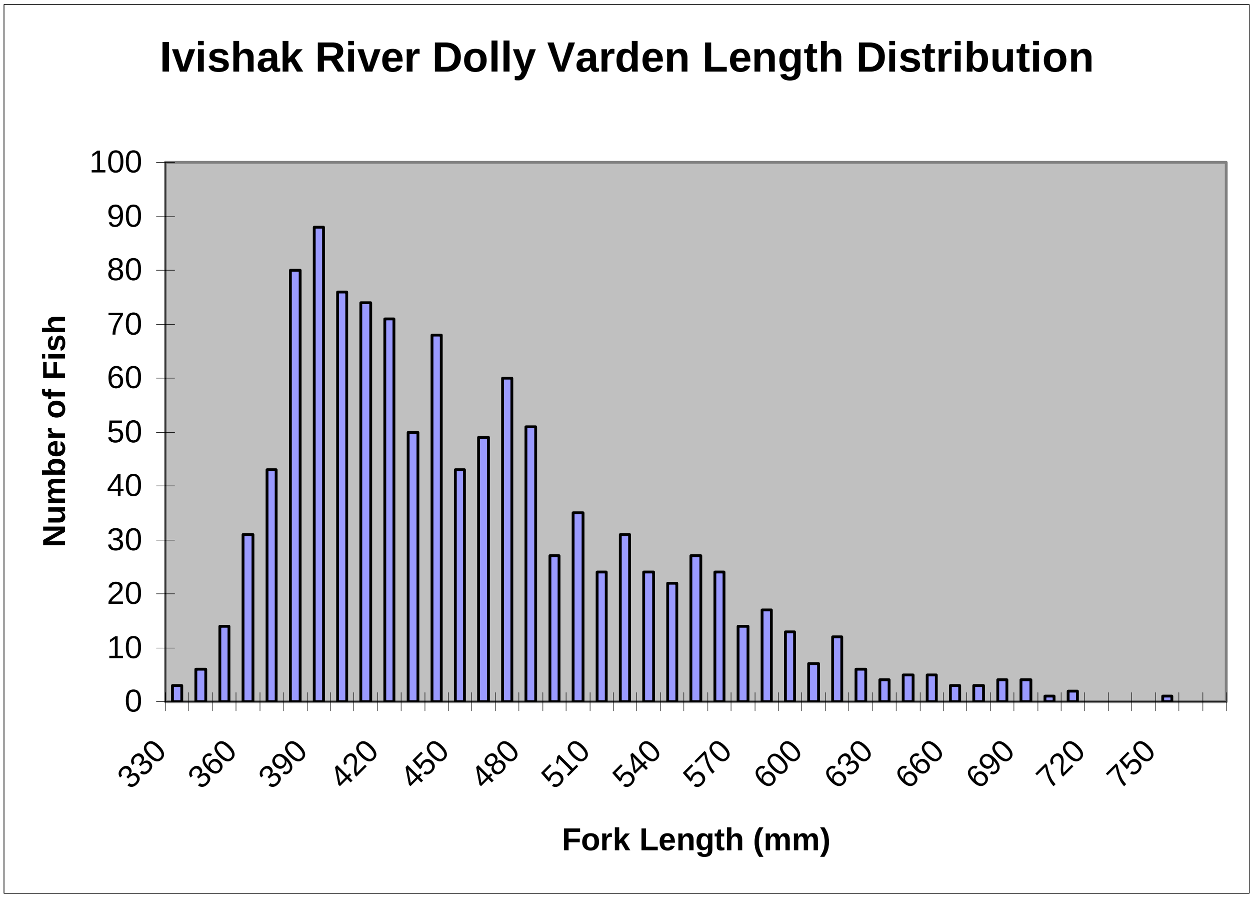

Figure 3. Length distribution of overwintering anadromous Dolly Varden captured in the Ivishak River, September 2000.

Spawning and Overwintering Locations and Genetic Stock Identification Baseline Sampling.

Spawning locations were recorded on the Ivishak and Kongakut rivers at the sites marked on Figures 4 and 5. All of the fish captured at these locations were in spawning condition, and fish were also observed engaging in digging redds at these locations. Genetic samples were collected from 72 fish from the Kongakut and 104 fish from the Ivishak.

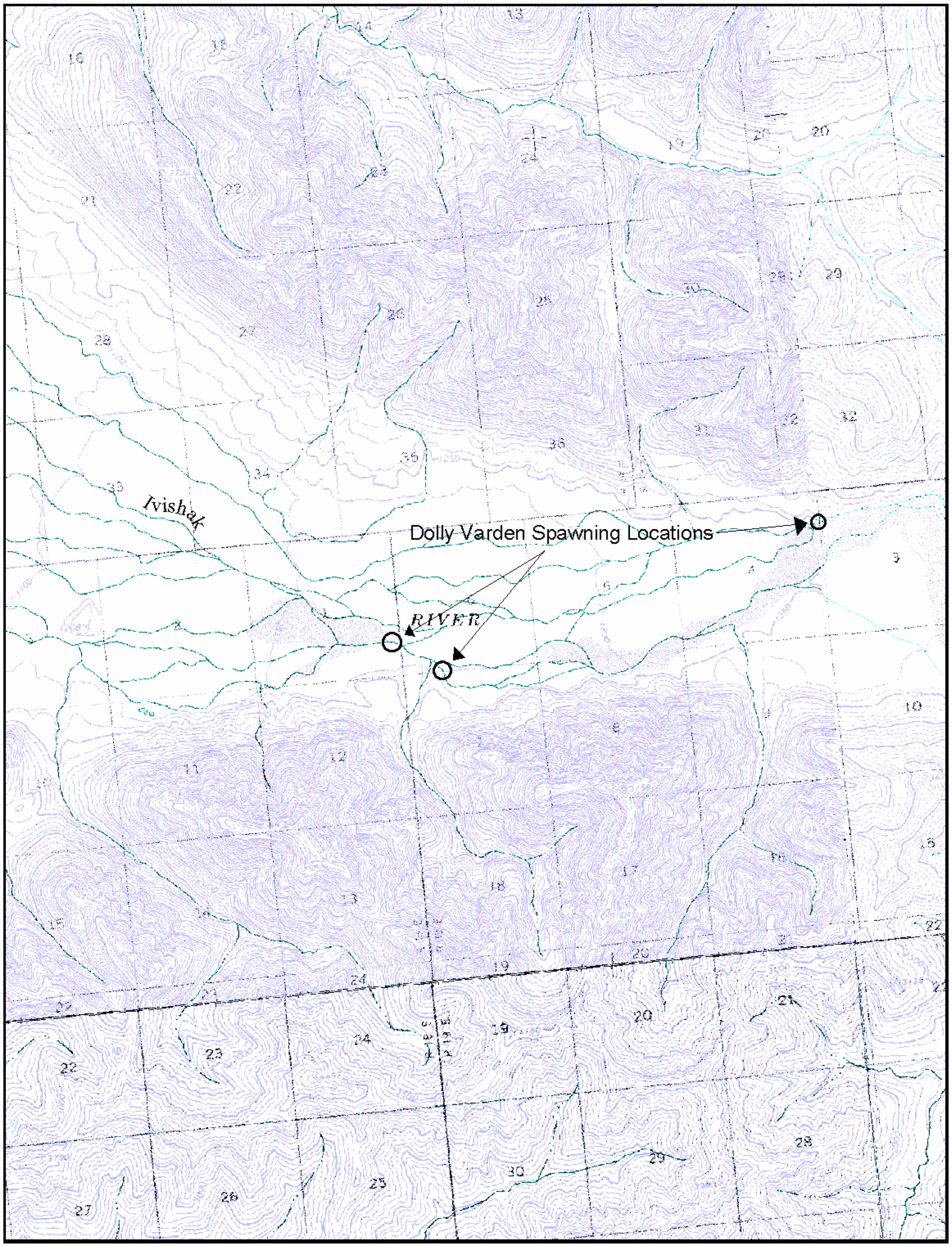

Figure 4. Map of the Ivishak River, Alaska, showing Dolly Varden spawning locations.

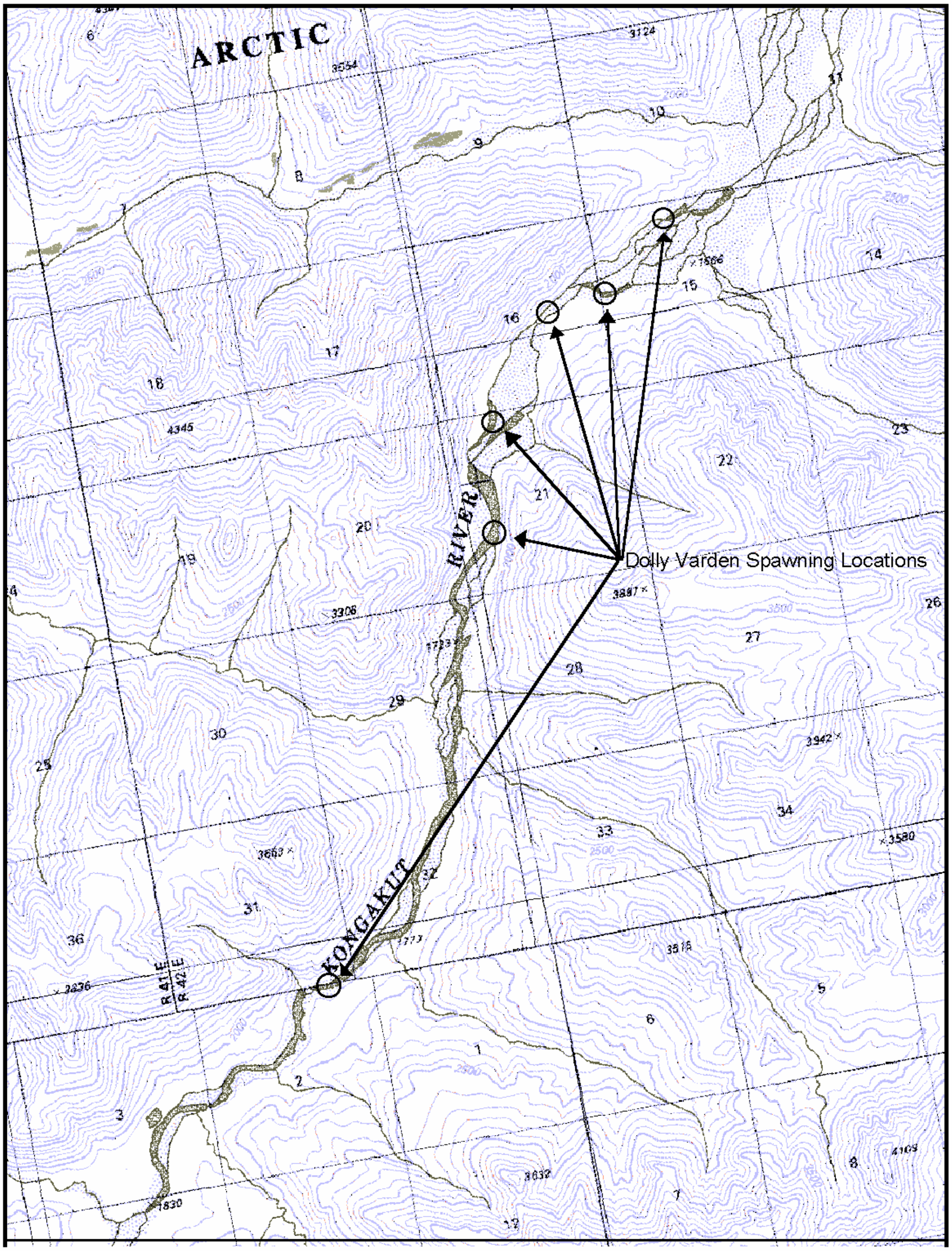

Figure 5. Map of the Kongakut River, Alaska, showing Dolly Varden spawning locations.

DISCUSSION

This study indicates that aerial surveys of Dolly Varden overwintering in the Ivishak River are relatively precise. The Coefficient of Variability (CV) of the summed mean counts was less than 12%. This compares with CVs for summed aerial mean counts of pink salmon *Onchorynchus gorbuscha* by multiple observers in Southeast Alaska of around 50% (Jones 1995). This lower variability is at least in part likely to be a function of a much smaller number of observers, since the number of observers in the study by Jones (1995) was between six and thirteen, and the relative CVs of those summed mean counts tended to be smaller with fewer observers. It is also likely that the lower variability was related to differences in the number of fish present and the size of the area counted, since the counts from the Jones (1995) study were, in general, of an order of magnitude more fish in a much smaller area.

The within observer variability in daily counts was substantially different between the two observers, with the CV of the mean counts for observer 2 just over twice that of observer 1. Other studies of variability between aerial counts have found within observer coefficients of variability between 0% and 42% (Bevan 1961, Jones 1995). It is not clear why one observer had higher variability in counts, but it could be related to experience (observer 1 had experience conducting aerial counts, and observer was counting for the first time). Since the counts by the two observers were conducted at the same time from the same aircraft, other factors such as light and flying conditions were identical, and should not have contributed to differences in count variation.

The CV for between observer daily counts ranged from 3% to 24%, which is less than the 30% to 96% reported by Jones (1995). This, like the differences in CVs for summed counts between the two studies, was probably related to the number of observers and the numbers of fish being counted.

Because the mark-recapture abundance estimate could not be completed, the results do not address the accuracy of the aerial survey counts. The mark-recapture abundance estimate could not be completed due to the dependence on air transport to reach the sampling site. The results did show that if sampling crews were based at the Ivishak River and did not depend on air transport for daily access to the river, sufficient numbers of fish could be captured to meet the sample size objectives in the original Investigation Plan. This indicates that mark-recapture abundance estimation could provide a population estimate with relatively low variance.

The length distribution of the fish that were caught was similar to that reported by Yoshihara (1972, 1973), with the mean lengths for all collections being within 50 mm. The most notable differences in length distribution between the earlier collections from the Ivishak River and this study was that no fish under 335 mm fork length was captured in this study, while the samples collected by Yoshihara (1973) in September was slightly bi-modal, with a small peak at 325 mm, contained fish as small as 210 mm. It is unclear why we did not capture fish smaller than 335 mm. The gear used by Yoshihara (1973) included variable mesh gill-nets and seines, but gear type should not have prevented us from capturing smaller fish, since the seines used in this study were one inch mesh, which is small enough to catch fish down to around 250 mm. It is possible that Dolly Varden overwintering in the Ivishak River could segregate geographically by size, and since we only sampled a relatively small portion of the river, we may have missed smaller fish. It is also possible that poor recruitment could have resulted in very poor year-class, but this is unlikely, since previous research on Dolly Varden life history on the north slope (Yoshihara 1972, 1973, Furniss 1974, Craig 1977) showed that fish from the same year class smolt at different ages.

Genetic samples from spawning-stock-specific Dolly Varden can be collected in a non-destructive manner. These samples can 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), similar samples can be collected from subsistence fisheries that target mixed stock aggregations. Combined with subsistence harvest estimation, these samples can be used to estimate stock contribution to subsistence harvests, and the relative impact these harvests have on specific stocks.

CONSULTATIONS AND CAPACITY DEVELOPMENT

This project was presented to and discussed with the North Slope Regional Advisory Council, the North Slope Borough (NSB) Fish and Game Management Committee, and staff from the NSB Department of Wildlife Management. Due to a lack of available staff from the NSB Wildlife Management Department, no formal arrangement was made to include the NSB Department of Wildlife Management as a cooperator in this study. Input from the North Slope Regional Advisory Council and from subsistence users from Kaktovik on the locations and timing was included in planning of the study.

CONCLUSIONS

1. Replicate aerial counts of overwintering Dolly Varden within a 6.5 km section of the Ivishak River had relatively low variability and the amount of this variability differed between observers.

2. It appears feasible to obtain independent estimates of overwintering Dolly Varden abundance through the use of mark-recapture experiments and aerial surveys.

3. The use of a weir or counting tower to estimate overwintering Dolly Varden would be technically, logistically, and financially difficult to conduct. An estimate of this type also would include fish migrating to three major tributaries of the Ivishak River, and could not be compared with aerial surveys, unless those aerial surveys were of the entire drainage. It would be cost-prohibitive to conduct replicates of aerial surveys of the entire drainage.

4. 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.

RECOMMENDATIONS

1. The variability and validity of aerial surveys of overwintering Dolly Varden should be established by conducting replicate aerial surveys on the Ivishak River in conjunction with a mark-recapture abundance estimate. These paired methods of estimating overwintering abundance should be conducted for three successive years to establish the relationship between the two methods. In order to reduce error due to fish movement, the abundance estimate and aerial surveys should be conducted over an area that includes the majority of the overwintering population (approximately 25 km), rather than just a 6.5 km index area. Crews conducting the mark-recapture abundance estimate should operate from a field camp on the Ivishak River rather than depending on air transport from the Dalton Highway.

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 major Dolly Varden spawning stocks (Anaktuvuk, Aichilik, Canning, Echooka, Hulahula, Ivishak, Kavik, Kongakut, Lupine, Ribdon, Saviukviayak, 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 support and funding for this study under cooperative agreement 701810J241. I also thank the staff of the U.S. Fish and Wildlife Service, Arctic National Wildlife Refuge and the Fairbanks Fishery Resources Office for advice 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 unpleasant working conditions.

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APPENDIX A

Mark-Recapture Abundance Estimation Methods

A mark-recapture abundance estimate of this same aggregation will be conducted using a Petersen two-event estimator. Adult fish will be captured using beach seines and hook and line gear, and marked with a small fin-clip. Fish will be marked during a four day period, and recaptured after a four day mixing period.

The mark-recapture assessment will address abundance and composition estimate objectives. Although this is an initial study, the relatively small area where fish are present will make conducting a mark-recapture study possible with limited resources.

The assumptions necessary for accurate estimation of absolute abundance in a closed population are as follows (taken from Seber 1982):

1. The population is closed (no change in the number of Dolly Varden in the population during the estimation experiment);
2. All Dolly Varden have the same probability of capture in the marking sample or in the recapture sample, or marked and unmarked fish mix completely between marking and recapture events;
3. Marking of Dolly Varden does not affect their probability of capture in the recapture sample;
4. Dolly Varden do not lose their mark between the marking and recapture events; and,
5. All marked Dolly Varden are 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 7 to 10 km study area can be sampled in 3-4 days, which will 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 be begun until after aerial surveys determine that there are no fish below the assessed area still migrating upstream. 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.

Validity of assumptions 2 and 3, relative to the effect of capture gear, will be examined for both capture-induced behavior (i.e. gear avoidance or attraction) and size selectivity. Because capture probabilities can differ significantly by gear type, assumptions 2 and 3 will be validated by chi-square tests on Recapture-to-Catch ratios (R/C) and Recapture-to-Mark (R/M) ratios of fish captured by angling or by beach seine. If necessary, subsequent abundance estimation may be stratified by gear-types. Validity of assumptions 2 and 3, relative to size selectivity by gear, is tested with a series of two-sample Kolmogorov-Smirnov (KS) tests generated from the mark-recapture data. The first hypothesis tested is that all marked fish have the same probability of capture in the recapture sample. If this test is significant, the recapture sample is biased and the data are partitioned into 2 size classes. To maximize the difference in capture probability between size classes, a series of chi-squared tests is performed. The length at stratification that produces the largest chi-squared test statistic is used to delimit the size classes. Population estimates are generated for each size class and these independent estimates summed to estimate the entire population. If the KS test does not detect a significant difference, the data need not be partitioned and a single population estimate will suffice.

The second hypothesis tested is that fish captured during the marking sample have the same length frequency distribution as fish captured in the recapture sample. 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 A1.

Because capture probabilities can differ significantly among areas, assumption 2 is further validated by chi-square tests on Recapture-to-Catch ratios (R/C) and Recapture-to-Mark (R/M) ratios. If no movement between strata occurs and both of these tests are significant, then a stratified Bailey modified Petersen estimate of population abundance will be used. If some movement between strata is found by location of recaptures, then tests for consistency of a Petersen estimate will be performed (Seber 1982, page 438). If all three of the consistency tests are significant, then a Darroch (1961) estimate will be used. If one of the three tests is not significant than an unstratified Bailey modified Petersen estimate will be used.

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:

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

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):

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

<u>Length Composition in Mark-Recapture Assessment</u>

Testing of assumptions necessary for accurate abundance estimation may also reveal biases in length composition samples. Because length information is collected during mark-recapture sampling, bias in mark-recapture samples also indicates bias in length data. Length composition is used to apportion the population estimate into length classes, so that length information collected during the marking sample, the recapture sample, or both samples may be used to calculate length composition.

If case I from inference testing occurs, no adjustments to length data are necessary and data from both events may be pooled. If case II occurs, length data from the recapture event must 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 using equations (3) and (4):

$$\hat{p}_k = \frac{y_k}{n} \tag{3}$$

where:

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

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

n = total number of trout sampled.

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

$$\hat{V}[\hat{p}_k] = \frac{\hat{p}_k(1-\hat{p}_k)}{n-1}\left(1-\frac{n}{\hat{N}}\right) \tag{4}$$

If case III or case IV from inference testing occurs, either mark and recapture samples are biased or the recapture sample is unbiased and the status of the mark sample is unknown. If case III occurs, length data from both samples can 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 must 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:

$$\hat{p}_{ik} = {n_{ik}}/{n_i} \tag{5}$$

where:

n_i = number sampled from length strata *i* in the mark-recapture experiment;

n_{ik} = number sampled from length class *k* that are within length strata *i*; and,

$\hat{p}_{ik}$ = estimated proportion of fish in length class *k* within length strata *i*.

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:

$$\hat{p}_k = \sum_{i=1}^{j} \frac{\hat{N}_i}{\hat{N}} \hat{p}_{ik} \tag{6}$$

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

$$\hat{V}[\hat{p}_k] \approx \sum_{i=1}^{j} (\hat{p}_{ik} - \hat{p}_k)^2 \frac{\hat{V}[\hat{N}_i]}{\hat{N}^2} + \sum_{i=1}^{j} \left(\frac{\hat{N}_i}{\hat{N}} \right)^2 \hat{V}[\hat{p}_{ik}] \tag{7}$$

where:

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

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

Sample size

Sample sizes will vary according to Table 2, depending roughly on the number of fish counted in the area during aerial surveys. Assuming that aerial surveys may underestimate the number of fish present in the assessment area, the assumed population size used will be approximately 100% higher than the number counted during the aerial survey immediately preceding the marking event. Sample size ranges determined according to Robson and Regier (1964).

Table 2. Sample size range to estimate abundance of the spawning/overwintering Dolly Varden aggregation within the Ivishak River such that the estimate is within 20% of the true value 90% of the time.

Observed Aerial Survey Count Just Prior to Marking Event	Assumed Population Size	Number to Mark during First Event	Number to Examine for Marks during Second Event	Percentage of Population Marked or Examined during the Two events	Expected Number of Recaptured Fish during Second 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	25,000	**1,256**	**1,256**	5.0%	62	2,450

To evaluate fish movement during the mark-recapture experiment, fish will be marked with partial fin clips as follows:

Marking event-downstream section right pectoral,
Marking event-middle section left pectoral,
Marking event-upstream section right ventral,
Recapture event-all stream sections left ventral.

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APPENDIX B

North Slope Dolly Varden Spawning Locations

River	Date	Latitude (Degrees)	Latitude (Minutes)	Latitude (Seconds)	Longitude (Degrees)	Longitude (Minutes)	Longitude (Seconds)	Approximate Number of Fish
Kongakut	8/17/00	142	3	9.40205	69	2	42.6693	60
		141	59	54.1173	69	4	45.4118	75
		141	59	38.8091	69	5	16.093	50
		141	58	46.4411	69	5	44.3413	90
		141	57	53.2924	69	5	47.2148	100
		141	56	55.4305	69	6	5.6712	40
Ivishak	9/24/00	147	43	4.4936	69	2	3.6978	120
		147	42	18.1438	69	1	51.4149	160
		147	35	57.0191	69	2	32.1419	85