Fishery Data Series No. 91-9

Abundance and Composition of Northern Pike, Harding Lake, 1990

by

Alan Burkholder

May 1991

Alaska Department of Fish and Game

Division of Sport Fish

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[1] This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-6, Study R-3-4(c).

The Fishery Data Series was established in 1987 for the publication of technically oriented results for a single project or group of closely related projects. Fishery Data Series reports are intended for fishery and other technical professionals. Distribution is to state and local publication distribution centers, libraries and individuals and, on request, to other libraries, agencies, and individuals. This publication has undergone editorial and peer review.

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ABSTRACT

The northern pike *Esox lucius* population in Harding Lake was sampled in May 1990. Abundance of northern pike greater than 449 millimeters fork length was estimated to be 1,283 fish (standard error of the estimate was 145 fish). Density of northern pike greater than 449 millimeters was estimated to be 1.28 fish per hectare. No "memorable" or "trophy" northern pike were found in Harding Lake. Although variation in mean length-at-age statistics were noted for northern pike sampled intermittently from 1969 through 1990, no consistent trends were apparent. The largest proportions of northern pike sampled greater than 449 millimeters in length were ages 6 (33 percent) and 7 (31 percent). The oldest northern pike sampled was 10 years of age. Sex composition of the population was not determined because the timing of sampling was past the time of peak spawning, and extrusion of sex products in sampled northern pike was limited. Available harvest information and results of the mark-recapture experiment (Spring 1990) indicate that recent recreational harvests of northern pike in Harding Lake cannot be sustained by the existing northern pike population.

Key Words: Northern pike, *Esox lucius*, Harding Lake, abundance, mark-recapture, Relative Stock Density, length-at-age.

INTRODUCTION

The harvest of northern pike *Esox lucius* by recreational fishermen in Alaska has increased in recent years. In the 13 year period from 1977-1989, the estimated statewide harvest of northern pike increased from 11,982 to 23,440 (Figure 1). Between 75% and 90% of the annual harvest of northern pike comes from the Arctic-Yukon-Kuskokwim Region (AYK) with 65% from the Tanana River drainage (Mills 1979-1990). The northern pike sport fishery in 1989 with the largest consumptive harvest (statewide) occurred at Harding Lake (Mills 1990).

The limited availability of northern pike fishing opportunities along the road system of the Tanana Valley and an increasing demand for this species has most likely contributed to the increased total angler effort and northern pike harvest in Harding Lake. A total of 1,707 angler days were expended in 1984 (Mills 1985) and 766 northern pike were harvested (along with 428 burbot *Lota lota* and 65 stocked landlocked coho salmon *Oncorhynchus kisutch*). By 1989, total effort for all species had grown to 4,935 angler days (Mills 1989) and harvest was estimated at 1,764 northern pike and 735 fish of other species (Table 1). Concern over increases in use and harvest of northern pike in Harding Lake prompted the Alaska Department of Fish and Game (ADFG) to initiate a study of the northern pike stock in 1990.

This report summarizes research on the abundance and composition of northern pike in Harding Lake in 1990. This report also summarizes information collected during intermittent sampling of northern pike residing in Harding Lake since 1961.

Study Area

Harding Lake is located 54 km (72 km by road) southeast of the city of Fairbanks, near the confluence of the Salcha and Tanana rivers. It has a circular shape except for a prominent point in the middle of the southern shoreline. Access to the lake is provided by three roads that turn in off the Richardson Highway, which passes just to the west (Figure 2). One of the roads leads to a campground maintained by the Alaska Department of Natural Resources. The other two access roads connect with Salchacket Drive, which encircles approximately three fourths of the shoreline. There is no road access to the north shore. Some recreational users travel to the lake in floatplanes. Over 50% of the shoreline is ringed by private cabins, homes, and other human development. Docks, rafts, and boatlifts dot the inhabited areas of the shoreline in the summertime. The campground on the northwestern shoreline has a boat launch and channel, a swim beach, numerous campsites and parking spots, athletic fields, and some undeveloped areas for hiking and unstructured outdoor recreation.

The surface elevation of Harding Lake is 217 m. Surface area of the lake is 1,000 ha, and maximum depth is 43 m. In addition to hillside runoff, the lake is fed by springs, permafrost seeps, and two inlets. One of the inlets is from adjacent Little Harding Lake. The other is the East Inlet, draining a 2,580 ha basin to the east. There is no outlet to the adjacent Salcha River, but flow into small areas of adjacent wetlands has been observed during high water periods. The littoral zone, defined herein to be the area from the

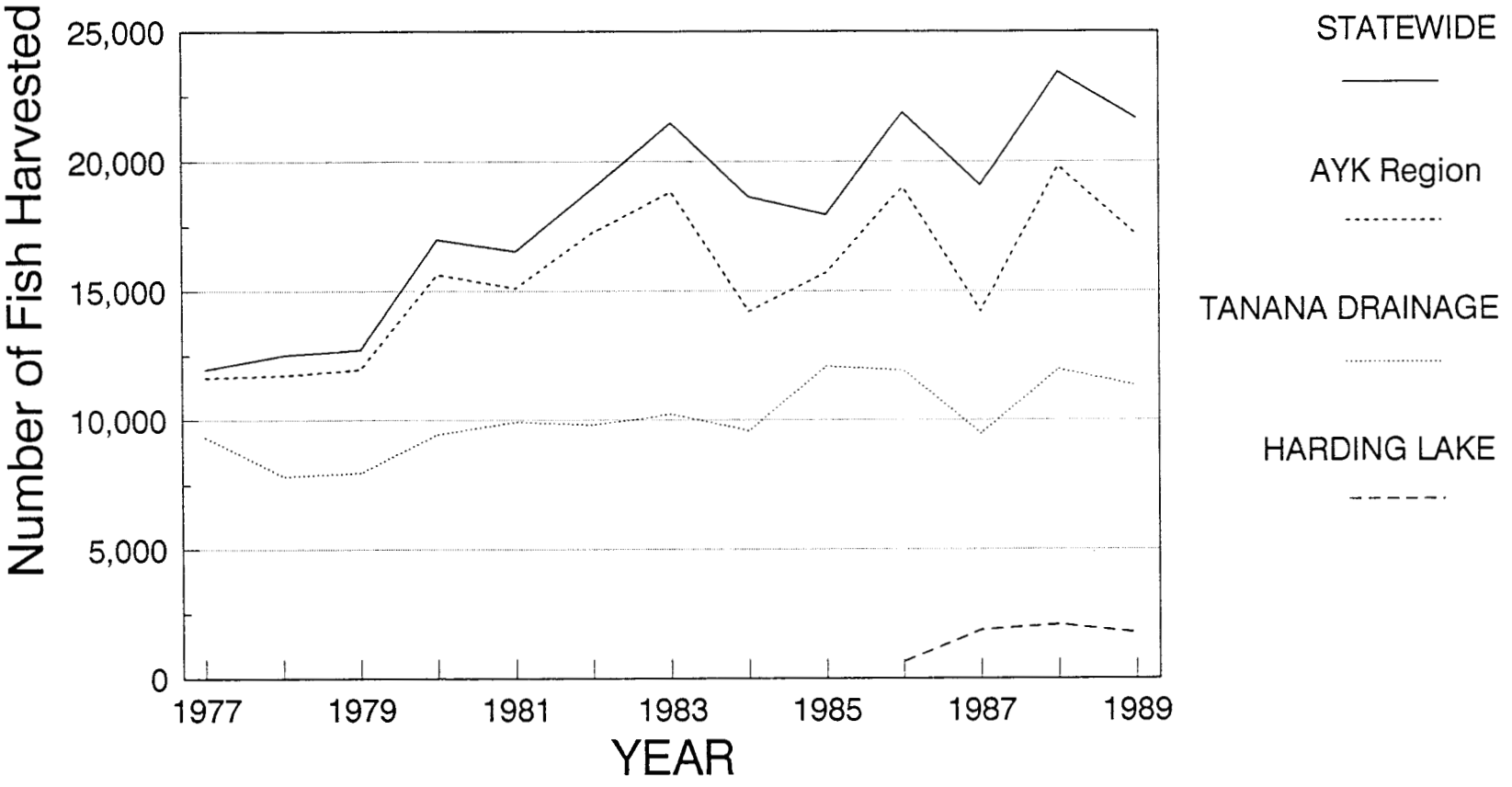

Figure 1. Harvest of northern pike in Alaska, AYK Region, Tanana drainage, and Harding Lake from 1977 through 1989 (Mills 1979 - 1990).

Table 1. Sport fishing effort and harvest of fish from Harding Lake, 1983 through 1989[a].

Year	Number of Anglers	Number of Trips	Number of Days Fished	Harvest By Species[b]							
				LL	LT	AC	RT	GR	SF	NP	BB
1983	—	—	708	—	—	—	—	—	—	178	157
1984	436	1,219	1,707	65	—	—	—	—	—	766	428
1985	583	910	850	35	—	—	—	—	—	503	—
1986	1,590	1,758	2,064	—	24	—	—	—	—	673	—
1987	3,371	4,032	5,125	—	—	—	118	79	—	1,886	53
1988	2,599	3,806	3,256	—	55	—	73	—	73	2,092	73
1989	2,976	4,098	4,935	—	119	141	456	—	—	1,764	10

[a] Data source is Mills (1985-1991).

[b] LL = Landlocked coho salmon, LT = lake trout *Salvelinus namaycush*, AC = Arctic char *Salvelinus alpinus*, RT = rainbow trout *Onchorhynchus mykiss*, GR = Arctic grayling *Thymallus arcticus*, SF = *sheefish Stenodus leucichthys nelma*, NP = northern pike, BB = burbot.

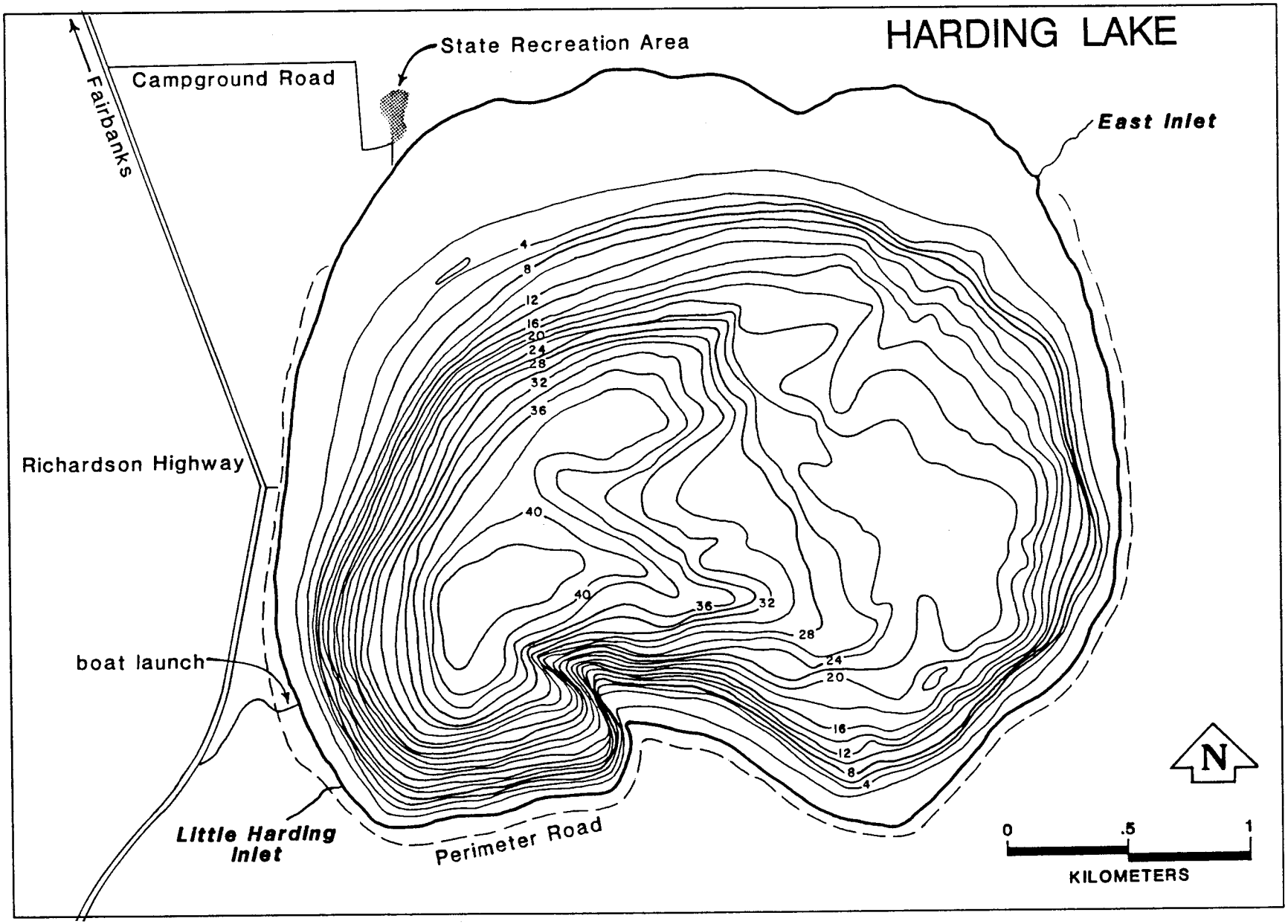

Figure 2. Depth contours of Harding Lake and means of access.

shallows to the outer margins of the deep weedbeds (*Potamageton* sp.) at 5 m underlies 33% of the surface area of the lake.

Indigenous species include northern pike, burbot, least cisco *Coregonus sardinella*, and slimy sculpin *Cottus cognatus*. Introduced species include lake trout, coho salmon, sockeye salmon *Onchorhynchus nerka*, rainbow trout, sheefish, and Arctic char.

Information has been gathered from northern pike during the course of fisheries evaluations and assessments through the years, but no major studies specifically targeting the northern pike population in Harding Lake occurred prior to 1990. Northern pike captured during previous test netting operations for other species have been sampled and distribution, ingested food items, and some length composition (Appendix A1) and length-at-age (Appendix A2 through A14) information has been compiled and included in various ADFG reports. The largest northern pike documented from Harding Lake was a 1,140 mm, 13.62 kg female taken with a test fishery gill net in 1976. Few northern pike over 5 kg have been documented by such surveys.

Objectives

The goal of this project is the collection and analysis of appropriate data concerning abundance and composition of northern pike to promote an assessment of stock status of the species in Harding Lake. This assessment will be used to develop appropriate sport fishing regulations that are consistent with recreational use options as developed through the public management planning process.

The specific objectives for the 1990 research program were to estimate:

(1) abundance of northern pike (299 mm and longer); and,

(2) sex, length, and age composition of northern pike.

In addition mean length-at-age of northern pike was estimated.

METHODS

Northern pike were captured in Harding Lake during spring breakup. Sampling was scheduled during this period because northern pike concentrate in shallow water while spawning and catch-per-unit-effort (CPUE) of sampling gear was greatest in other lakes sampled at this time in past years (Peckham and Bernard 1987; Clark 1988). Two sampling events (a marking event and a recapture event) were conducted at Harding Lake (14 through 25 May and 29 through 31 May). Sampling gear included fyke nets, floating and sinking variable mesh gill nets, and a backpack electrofishing apparatus used to herd northern pike into gill nets in shallow water.

All captured northern pike were examined for the presence of Floy tags and/or fin clips. These fish were measured to the nearest mm fork length (FL). Untagged northern pike judged to be in a healthy condition were released after

being marked with a Floy FD-68 internal anchor tag inserted at the base of the dorsal fin and with a partial pelvic fin clip. Sex was determined by the presence of sex products or by external characteristics as described in Casselman (1974). Fish for which sex could not be determined were recorded as "sex unknown".

Scales were removed from each live fish (except recaptures from current year tagging). Scales were taken from a zone adjacent to but not on the lateral line above the pelvic fins as described by Williams (1955). Scales were placed in labled coin envelopes. Scales were removed from coin envelopes in the Fairbanks laboratory, cleaned, and two scales per fish were mounted on gummed cards. The cards were used to make scale impressions on acetate sheets using a Carver press at 137,895 kPa (20,000 psi) heated to 93°C for 30 seconds. Scales were read on a Micron 770 microfiche reader and ages recorded in accordance with age identification criteria established by Williams (1955) and Casselman (1967). All dead fish were dissected to verify sex and maturity through examination of the gonads. Scales, vertebrae, and cleithra were taken from each dead fish for subsequent aging, and stomach contents of dead fish were noted on scale envelopes. Age, sex, length, tag, date, gear type, lake area, and fin clip data were recorded on Tagging Length Version 1.0 mark-sense forms during the sampling process.

Abundance

The assumptions necessary for accurate estimation of abundance in a closed population are listed in Appendix B. Assumption 1 could not be tested and was assumed to be valid. Assumption 2 was assured of validity by double marking of northern pike. The chi-square statistic was used to examine assumptions 3 and 5. Assumption 4 could not be tested. Kolmogorov-Smirnov goodness of fix tests were used to analyze the mark-recapture data for significant bias due to gear selectivity (Appendix 2). Gear selectivity was indicated for both sampling events for northern pike > 299 mm ($P < 0.005$ and $P < 0.005$) and no fish < 450 were recaptured. Therefore, only the abundance of northern pike greater than 449 mm in Harding Lake was estimated using the modified Petersen abundance estimator (Chapman 1951). The approximate variance of this estimate is taken from Seber (1982).

$$\hat{N} = \frac{(C+1)(M+1)}{(R+1)} - 1; \text{ and,} \qquad (1)$$

$$\hat{V}[N] = \frac{\hat{N}(C-R)(M-R)}{(R+1)(R+2)}; \qquad (2)$$

where:

C = number of fish captured during recapture event;

M = number of fish marked during marking event;

R = number of fish recaptured during recapture event.

Length, Sex, and Age Composition

The lengths of northern pike were grouped into Relative Stock Density categories defined by Gabelhouse (1984). The categories were: "stock" size 300 to 524 mm; "quality" size, 525 to 654 mm; "preferred" size, 655 to 859 mm; "memorable" size, 860 to 1,079 mm; and "trophy" size, 1,080 mm and longer. The proportions of the population in each length, age, and sex category were estimated with the following equations (Cochran 1977):

$$\hat{p}_j = n_j/n \tag{3}$$

where:

n = the number of fish sampled to estimate length, sex, or age composition;

n_j = the number of sampled fish in group j; and

$\hat{p}_j$ = the estimated fraction of the fish in group j.

Variances of these proportions were calculated as:

$$\hat{V}[p_j] = \frac{\hat{p}_j(1 - \hat{p}_j)}{n - 1} \tag{4}$$

The estimated abundance of northern pike by group was calculated as:

$$\hat{N}_j = \hat{p}_j \hat{N} \tag{5}$$

The variance for $\hat{N}_j$ is a sum of the exact variance of a product from Goodman (1960):

$$\hat{V}[N_j] = V[p_j]N^2 + V[N]p_j^2 - V[p_j]V[N]) \tag{6}$$

Length-at-Age

Mean length-at-age was calculated as the arithmetic mean for all (male and female combined) northern pike. Variances and standard errors for mean lengths were also calculated using standard normal procedures.

RESULTS

From 14 May to 25 May, 421 northern pike were captured, tagged, and released. During the recapture event (May 29 - 31) 198 northern pike were collected and examined for tags and fin clips; 49 of these fish were marked.

Tests of Assumptions for a Petersen Estimator

The following results were based on a series of statistical tests (Appendix B) on data from the mark-recapture experiment.

Gear Bias:

No selectivity in the second sampling event was indicated for northern pike > 449 mm (Kolmogorov-Smirnov two sample test on lengths of marked versus lengths of recaptured fish; $P = 0.31$; Figure 3). Since the length distribution of marked fish > 449 mm was different from the length distribution of all fish > 449 mm captured during the second sampling event (Kolmogorov-Smirnov two sample test on lengths of fish captured and marked during the first sampling event versus lengths of fish captured in the second sampling event $P < 0.001$; Figure 4), and since no size selectivity was observed in the second sampling event, sampling gear used in the first sampling event was size-selective. Therefore, the estimate of abundance was not stratified by length categories, but only those northern pike collected during the second sampling event were used for estimating proportions in length and age composition estimates (discussed below).

Closed Population:

The marked-to-unmarked ratio of northern pike > 449 mm was not significantly different in the three sample areas of Harding Lake during the second sampling event ($\chi^2 = 1.39$; df = 2; $0.10 < p < 0.25$; Table 2). Therefore, either all fish had an equal probability of being marked during the first sampling event, or marked northern pike mixed completely with unmarked northern pike between the two sampling events.

Abundance Estimate

Based on the results of the above tests, abundance was estimated using the modified Peterson mark-recapture estimator (Chapman 1951). The estimated abundance of northern pike in Harding Lake > 449 mm was 1,283 fish (SE = 145 fish).

Length

Ninety percent of the northern pike > 449 mm captured in the second event were < 700 mm (Figure 4). No memorable or trophy size northern pike were captured. For northern pike > 449 mm, 64% sampled were in the quality RSD category, however the proportion of fish in the quality and larger categories are overly represented because we were unable to capture tagged fish < 450 mm in sufficient numbers. The proportion of the sample > 449 mm in the stock and preferred size categories was 18% in each (Table 3).

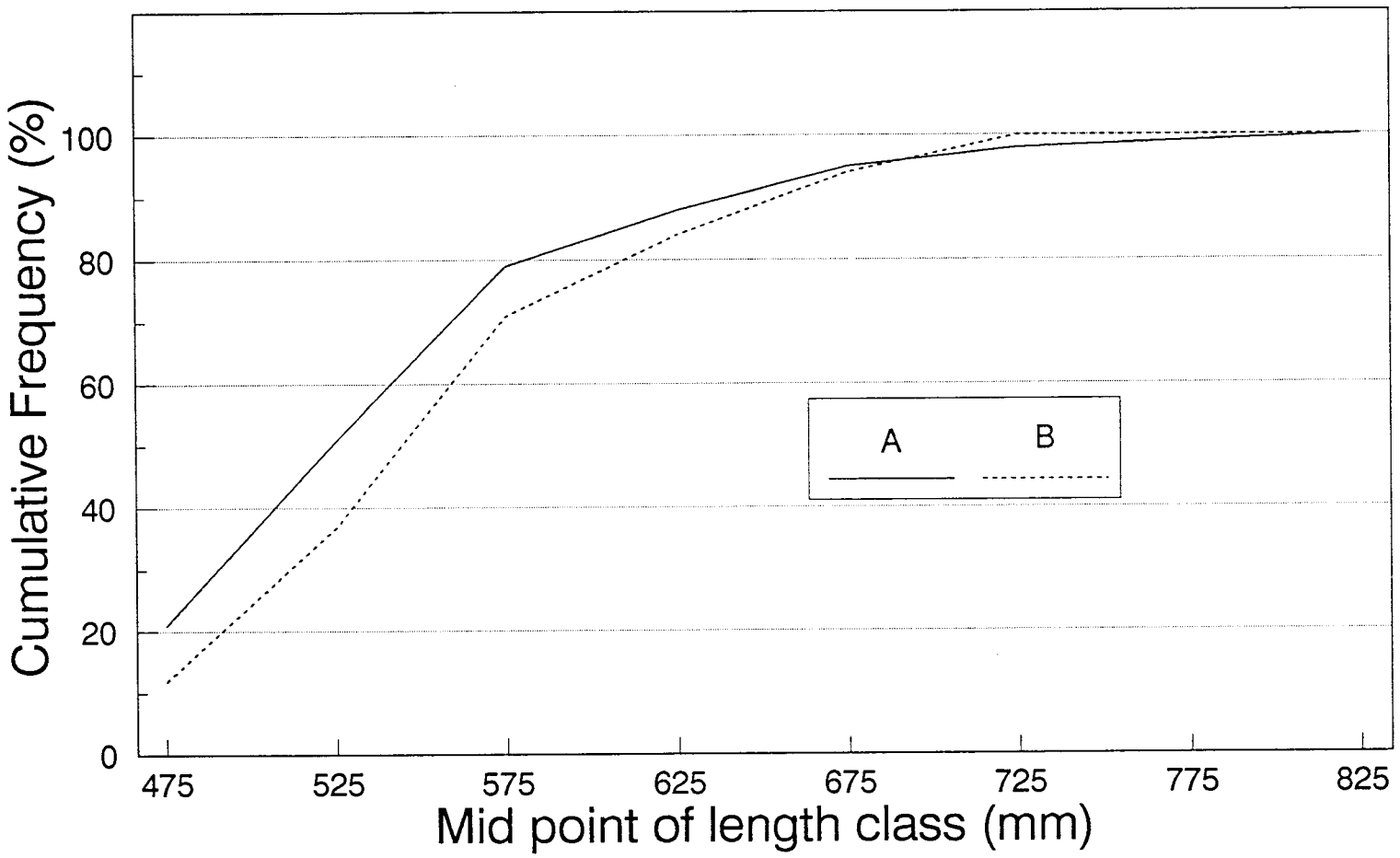

Figure 3. Cumulative frequency (%) for northern pike > 449 mm marked and released in event one (A) and northern pike marked in event one and recaptured in event two (B).

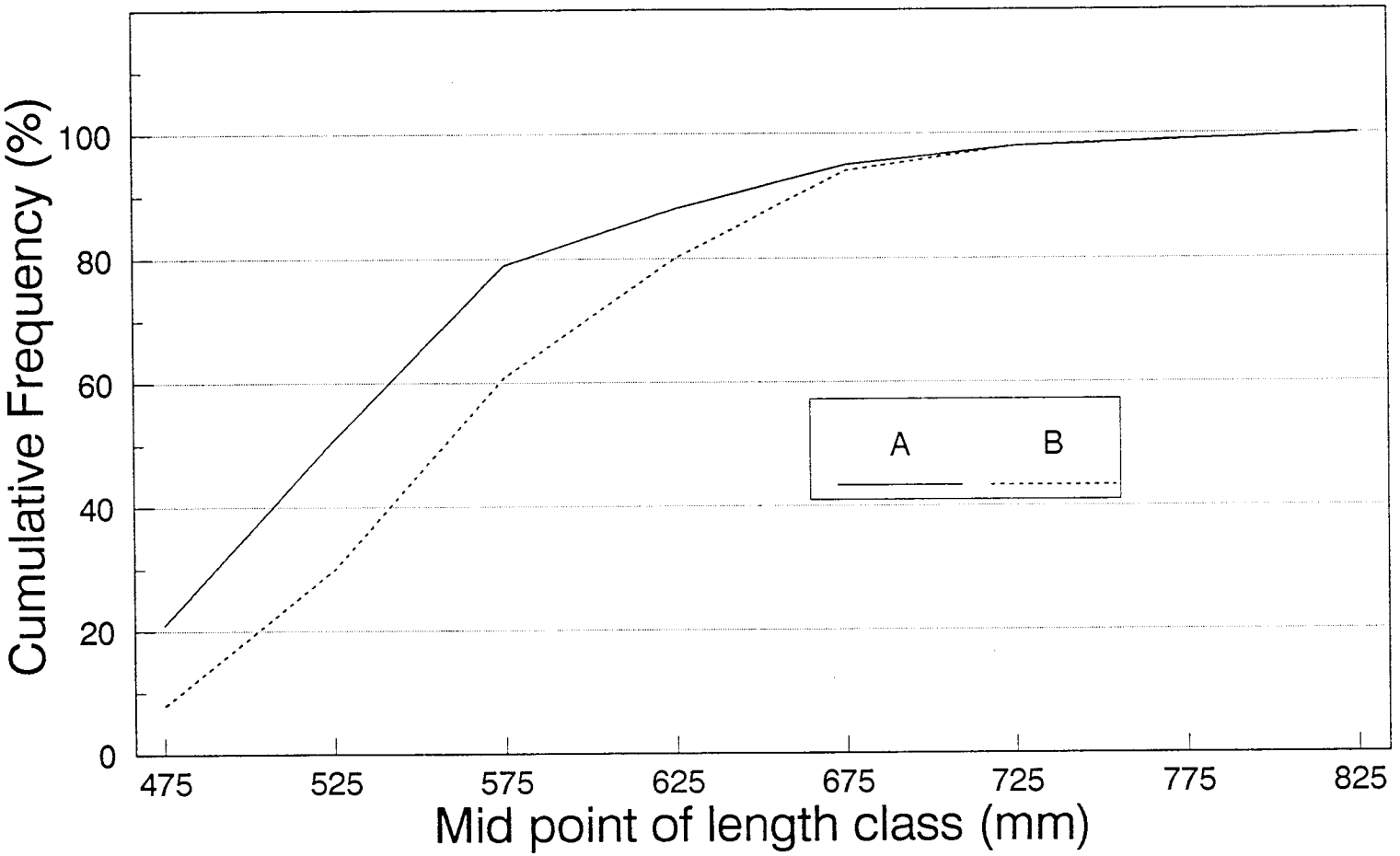

Figure 4. Cumulative frequency (%) for northern pike 449 mm marked and released in event one (A) and northern pike captured in event two (B).

Table 2. The number of marked and unmarked northern pike > 449 mm captured during the second sampling event by sampling location.

Northern Pike Category	Sampling Location I	II	III	Total
Marked	20	24	5	49
Unmarked	57	56	22	135
Total collected	77	80	27	184
Recovery rate	(0.35)	(0.42)	(0.23)	(0.36)

Table 3. Relative Stock Density (RSD) estimates of northern pike > 449 mm in Harding Lake during May 1990.

Category	Gabelhouse[a] Minimun Length (mm)	RSD[a]	Standard Error	Number of Fish	
				Estimated Abundance	Standard Error
Stock	300	18	3	230	45
Quality	525	64	4	816	102
Preferred	655	18	3	237	45
Memorable	855				
Trophy	1,080				
Totals		100		1,283	

[a] Relative Stock Density expressed as a percentage; categories taken from Gabelhouse (1984).

Sex

Sex was determined for only 21 northern pike (all males) during the second sampling event. This was because the timing of sampling was past the time of peak spawning, and extrusion of sex products in fish sampled was very limited.

Age

The age 6 cohort was the most abundant (419 fish) and probably the first fully recruited age class into the population estimate of northern pike > 449 mm (Table 4). Because mean length-at-age minus two standard deviations for age 4 and age 5 northern pike (Table 5) was < 450 mm, the estimated abundance of age 4 and age 5 northern pike (Table 4) represents only those in their respective cohorts above 449 mm. Estimated abundance of northern pike by cohort decreased from age 6 through age 10 (Table 4).

Mean length-at-age for northern pike in Harding Lake has varied between 1969 and 1990 (Table 5 and Appendix A2 through A14). Half of the mean-lengths-at-age for northern pike sampled during the 1990 mark-recapture experiment fell within the range of means observed for other years. Whereas almost all the mean lengths-at-age for northern pike sampled during the 1990 Harding Lake test fishing (Appendix A14) were within the means observed for other years (Appendix A2 through A13). Historical test fishing for northern pike in Harding Lake has occurred throughout the entire open water season. The mark-recapture experiment occurred in the spring. Therefore smaller mean length-at-age estimates would be expected for fish sampled in the mark-recapture experiment than for fish sampled in test netting because northern pike sampled during test netting were captured later in the season and had more time to grow.

DISCUSSION

While northern pike of lengths < 447 mm were tagged in the first sampling event, and sampled during the recapture event, no tagged fish < 449 mm were recaptured. At this time any explanation would be mere speculation. The lack of recapture of small northern pike is not unique to this experiment, however. Clark (1988) reported similar results in a mark-recapture experiment for northern pike in T Lake.

Estimated density of northern pike > 449 mm in Harding Lake during 1990 (1.3 per hectare) was in the low end of the range reported for other northern pike populations in Alaska. The density of northern pike > 449 mm in Volkmar Lake in both 1985 and 1986 was estimated to be 14.7 fish per hectare (Peckham 1986; Peckham and Bernard 1987). The density of northern pike > 449 mm in George Lake was estimated to be 4.66 fish per hectare (Clark et al. 1988). The density of northern pike > 449 mm in T Lake was estimated to be 2.80 and 3.19 fish per hectare in 1986 and 1987, respectively (Peckham and Bernard 1987; Clark 1988).

Estimated density of northern pike in Harding Lake was also at the low end of the range of densities reported for various non-Alaskan populations. Average

Table 4. Estimates of the age class proportions and abundances of northern pike > 499 mm in Harding Lake during May 1990.

Age Class	Sample Size	Estimated Proportion	Standard Error of Proportion	Estimated Abundance	Standard Error of Abundance
4	2	0.01	0.01	17	12
5	20	0.13	0.03	171	40
6	49	0.33	0.04	419	68
7	46	0.31	0.04	393	65
8	21	0.14	0.03	180	41
9	11	0.07	0.02	94	29
10	1	0.01	0.01	9	9
Total	150	1.00		1,283	

Table 5. Mean length-at-age for northern pike sampled from Harding Lake during May 1990.

Age	Sample Size	Average Length (mm)	Standard Error (mm)
1	3	137	6
2	5	217	25
3	23	312	7
4	48	407	6
5	100	484	4
6	165	535	3
7	119	593	3
8	46	667	6
9	19	701	13
10	4	831	9

density of northern pike over 400 mm TL in Savanne Lake, Ontario, in 1973, 1977, and 1988 was estimated at 6.66 fish per hectare with a range of 5.91 to 7.19 fish per hectare (Mosindy and Momot 1987). Mann (1980) estimated average density of age 1 and older northern pike in Stour River, England, to be 61 fish per hectare over a five year period (range of 27 to 127 fish per hectare). Mann (1980) also reported a density range of 32 to 80 age 1 and older northern pike per hectare in the Frome River, England. Seaburg and Moyle (1964) estimated the density of northern pike over 250 mm TL in Grove Lake, Minnesota, at 7.6 fish per hectare and the density of northern pike over 355 TL in Maple Lake, Minnesota at 4.8 fish per hectare. Over a series of years, the density of northern pike over 356 mm TL in Murphy Flowage, Wisconsin, was estimated by Snow (1978) to range from 5.8 to 40.6 fish per hectare (mean = 20.8 fish per hectare). Kempinger and Carline (1978) estimated density of northern pike in Escanaba Lake, Wisconsin, over a series of years, and they reported a mean density of 6.9 fish per hectare for age 1 and older fish and a mean of 0.9 fish per hectare for fish over 560 mm TL.

The proportions of northern pike in RSD categories sampled from Harding Lake during 1990 cannot be compared to RSD proportions reported for other northern pike populations in Alaska because of size selection by category. Proportions of fish in RSD categories at T, George, and Volkmar lakes are based on population abundance estimates of northern pike > 299 mm, whereas proportions of fish in RSD categories at Harding Lake are based on population abundance estimates of northern pike > 449 mm in length. During 1986 through 1988, T, George, and Volkmar lakes contained northern pike in the memorable size category (Pearse 1990). In contrast, no northern pike sampled from Harding Lake in 1990 were in the memorable RSD category.

The objective of estimating sex composition was not met in this study. By the time sampling got underway spawning was nearly completed. Sex could not be reliably determined for northern pike that did not extrude sex products during handling. In order to meet this objective in the future, sampling of the population for peak time of spawning should occur prior to implementation of the mark and recapture experiment.

Mean lengths-at-age of northern pike in Harding Lake for ages 2 - 7 were below those reported for northern pike in George and Volkmar lakes (Pearse 1990). Mean lengths-at-age for northern pike ages 2 - 7 were similar between Harding and T lakes (Timmons and Pearse 1989). The oldest northern pike sampled in Harding Lake (age 10) in 1990 was younger than that reported for northern pike populations in Volkmar (age 12), George (age 14), and T (age 14) lakes (Pearse 1990; Timmons and Pearse 1990).

Statewide harvest surveys indicated an average annual removal of 1,900 northern pike from Harding Lake by sport fishermen from 1987-1989 (Mills 1988, 1989, and 1990). Fork length of northern pike sampled in the 1990 creel survey ranged from 455 mm to 643 mm. Studies conducted at Harding Lake during the spring of 1990 revealed that abundance of northern pike greater than 449 mm (about 17 in) was 1,283 northern pike. The estimated harvest of northern pike in Harding Lake was deemed in excess of the recommended limit for exploitation (15%) in interior Alaska lakes. Available harvest information and results of the mark-recapture experiment (Spring 1990) clearly

indicated that recent recreational harvests of northern pike in Harding Lake could not be sustained. Accordingly, in December 1990 emergency regulation changes were announced to prevent over-exploitation of northern pike in Harding lake and to allow for rebuilding of the population. The use of spears and bow and arrows for the taking of northern pike in Harding Lake was prohibited, and a spring closure was enacted (northern pike may only be taken from June 1 through March 31). A 26 in minimum legal size limit for northern pike was also announced. Continued research on the stock status of northern pike in Harding Lake will assess the effectiveness of these conservation measures in the rebuilding of the northern pike population.

ACKNOWLEDGEMENTS

The author thanks N. F. Hughes, Malcolm McEwen, Steve Bodine, Mike Doxey, Tim McKinley, John Clark, Robert Clark, and Margaret Merritt for assistance with 1990 field work. The author is grateful to John Clark, Dave Bernard and Margaret Merritt for help with various aspects of planning. John Clark reviewed early drafts of this report and these efforts are appreciated. Thanks to Sara Case for assisting with finalization of the manuscript.

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APPENDIX A

Appendix A1. Sources of historical test fishing data concerning northern pike in Harding Lake.

Year	Number Caught	Length (mm)		Source
		Mean	Range	
1961	24	508	—	McKirdy 1962
1962	2	544	503-584	Metsker 1963
1963	—	—	—	—
1964	14	500	356-838	Hechart 1965
1965	8	498	254-617	Hechart and Roguski 1966
1966	16	465	318-615	Roguski 1967
1967	—	—	—	—
1968	—	—	—	—
1969	23	524	371-715	Hallberg 1979
1970	12	591	485-690	Hallberg 1979
1971	1	675	675	Hallberg 1979
1972	42	562	173-707	Hallberg 1979
1973	148	516	255-830	Hallberg 1979
1974	52	423	140-635	Hallberg 1979
1975	11	498	365-585	Hallberg 1979
1976	—	—	—	Hallberg 1979
1977	85	516	120-880	Hallberg 1979
1978	85	500	125-838	Hallberg 1979
Total	523			

Appendix A2. Mean length-at-age of northern pike sampled from Harding Lake, 5 and 6 June, 1969.

Age	Sample Size	Mean Length	Standard Error
4	2	398	8
5	4	472	11
6	5	555	7
7	3	653	29
8	1	715	
Total	15		

Appendix A3. Mean length-at-age of northern pike sampled from Harding Lake, 25 - 27 August, 1970.

Age	Sample Size	Mean Length	Standard Error
5	3	519	10
7	4	654	15
Total	7		

Appendix A4. Mean length-at-age of northern pike sampled from Harding Lake, 9 June - 8 September, 1972.

Age	Sample Size	Mean Length	Standard Error
1	1	173	
3	5	406	16
4	5	483	7
5	11	579	7
6	15	620	10
7	1	635	
Total	38		

Appendix A5. Mean length-at-age of northern pike sampled from Harding Lake, 8 October 1976.

Age	Sample Size	Mean Length
15	1	1,117
Total	1	

Appendix A6. Mean length-at-age of northern pike sampled from Harding Lake, 25 May 1977.

Age	Sample Size	Mean Length	Standard Error
1	4	148	5
3	3	302	21
4	11	422	6
5	5	494	18
6	5	567	15
7	6	598	14
8	2	673	33
Total	36		

Appendix A7. Mean length-at-age of northern pike sampled from Harding Lake, 22 March - 19 September 1978.

Age	Sample Size	Mean Length	Standard Error
1	3	143	9
2	1	286	
3	9	352	13
4	16	432	9
5	24	490	9
6	8	556	14
7	9	631	13
8	5	708	15
9	2	808	30
10	1	813	
Total	78		

Appendix A8. Mean length-at-age of northern pike sampled from Harding Lake, 8 June - 14 October 1982.

Age	Sample Size	Mean Length	Standard Error
0	1	113	
1	2	173	12
2	4	291	11
3	2	376	10
4	2	461	21
5	2	542	9
6	4	563	10
7	2	618	18
8	2	738	38
Total	21		

Appendix A9. Mean length-at-age of northern pike sampled from Harding Lake, 12 June - 12 October 1984.

Age	Sample Size	Mean Length	Standard Error
1	1	156	
2	9	318	7
3	13	436	20
4	2	490	73
5	2	538	60
6	3	634	3
7	3	623	21
8	2	720	30
9	2	793	28
Total	37		

Appendix A10. Mean length-at-age of northern pike sampled from Harding Lake, October 1985.

Age	Sample Size	Mean Length	Standard Error
4	3	606	8
5	1	580	
Total	4		

Appendix A11. Mean length-at-age of northern pike sampled from Harding Lake, 14 October 1986.

Age	Sample Size	Mean Length	Standard Error
2	4	332	25
3	2	379	37
Total	6		

Appendix A12. Mean length-at-age of northern pike sampled from Harding Lake, 28 July - 14 October 1987.

Age	Sample Size	Mean Length	Standard Error
2	1	285	
3	2	362	18
4	1	346	
5	2	477	23
6	1	541	
Total	7		

Appendix A13. Mean length-at-age of northern pike sampled from Harding Lake, 21 July - 4 October 1988.

Age	Sample Size	Mean Length	Standard Error
2	2	303	1
3	5	351	16
4	3	438	28
5	1	470	
8	1	654	
Total	12		

Appendix A14. Mean length-at-age of northern pike sampled from Harding Lake, 28 June - 21 September 1990.

Age	Sample Size	Mean Length	Standard Error
0	25	112	4
1	5	187	5
2	4	288	25
3	3	365	22
4	11	438	13
5	26	501	5
6	9	575	12
7	1	660	
8	3	644	26
Total	87		

APPENDIX B

Appendix B. Statistical tests for analyzing data from a mark-recapture experiment for gear bias and evaluating the assumptions of two-event mark-recapture experiment.

The following statistical tests will be used to analyze the data for significant bias due to gear selectivity by sex and length:

1. A test for significant gear bias by sex will be based on a contingency table of the number of males and females that were recaptured and were not recaptured. The chi-square statistic will be used to evaluate the bias.

If Test 1 indicates a significant bias, the following tests will be done for males and females, separately. If Test 1 does not indicate a significant bias, males and females will be combined and the following tests will be done.

2. Tests for significant gear bias by size will be based on: (A) Kolmogorov-Smirnov goodness of fit test comparing the distributions of the lengths of all fish that were marked during the first event and all marked fish that were collected during the second event; and, (B) Kolmogorov-Smirnov two sample test comparing the distributions of the lengths of all fish that were captured during the first event and all fish that were collected during the second event. The null hypothesis is no difference between the distributions of lengths for Test A or for Test B.

For these two tests there are four possible outcomes:

Case I:

Accept H_o(A) Accept H_o(B)

There is no size-selectivity during the first sampling event or during the second sampling event.

Case II:

Accept H_o(A) Reject H_o(B)

There is no size-selectivity during the second sampling event but there is size-selectivity during the first sampling event.

Case III:

Reject H_o(A) Accept H_o(B)

There is size-selectivity during both sampling events.

Case IV:

Reject H_o(A) Reject H_o(B)

There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.

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Depending on the outcome of the tests, the following procedures will be used to estimate the abundance of the population:

Case I: Calculate one unstratified estimate of abundance, and pool lengths, sexes, and ages from both sampling events to improve precision of proportions in estimates of compositions.

Case II: Calculate one unstratified estimate of abundance, and only use lengths, sexes, and ages from the second sampling event to estimate proportions in compositions.

Case III: Completely stratify both sampling events, and estimate the abundance for each stratum. Add the estimates of abundance across strata to get a single estimate for the population. Pool lengths, ages, and sexes from both sampling events to improve precision of proportions in estimates of composition, and apply formulae to correct for size bias to the pooled data.

Case IV: Completely stratify both sampling events and estimate the abundance for each stratum. Add the estimates of abundance across strata to get a single estimate for the population. Also, calculate a single estimate of abundance without stratification.

Case IVa: If the stratified and unstratified estimates of abundance for the entire population are dissimilar, discard the unstratified estimate. Only use the lengths, ages, and sexes from the second sampling event to estimate proportions in composition, and apply formulae to correct for size bias (*See* Adjustments in Compositions for Gear Selectivity) to data from the second event.

Case IVb: If the stratified and unstratified estimates of abundance for the entire population are similar, discard the estimate with the larger variance. Only use the lengths, ages, and sexes from the first sampling event to estimate proportions in compositions, and do not apply formulae to correct for size bias.

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Closed Population

The following two assumptions must be fulfilled:

1. Catching and handling the fish does not affect the probability of recapture; and,

2. Marked fish do not lose their mark.

If the floy tag is lost, the fin clip given each fish will identify the lake section where it was marked.

Of the following assumptions, only one must be fulfilled:

3. Every fish has an equal probability of being marked and released during the first (mark) event;

4. Every fish has an equal probability of being collected during the second (recapture) event; or,

5. Marked fish mix completely with unmarked fish between first and second sampling events.

To evaluate assumptions 3 and 5, the chi-square statistic will be used to examine the following contingency table. The results will be used to determine the appropriate abundance estimator and if the estimate of abundance should be stratified by lake section or period:

1. Null hypothesis is that marked-to-unmarked ratio is the same at all sites. Columns 1, 2, and 3 in the table will be the corresponding lake area where the fish were recovered. Row 1 will be the number of marked fish collected during the second sampling event and row 2 will be the number of unmarked fish collected during the second sampling event. The column totals will be equal to the number of fish collected during the second sampling event.

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If the test statistic is not significant, then either every fish had an equal probability of being marked (caught in the first event) or marked fish mixed completely with unmarked fish between sampling events. In this case a Petersen estimate will be used to estimate abundance. If the test statistic is significant the following matrix will be created:

Lake Area of Release	Lake Area of Recapture		
	I	II	III
I			
II			
III			

If all the off-diagonal elements are zero, then a Petersen estimate will be calculated for each lake section. The sum of the three estimates will be the overall abundance estimate. If the off-diagonal estimates are not zero, then Darroch's (1961) method will be used to estimate abundance. With these tests it is unknown whether the second assumption was fulfilled. Darroch's method will be used to insure an unbiased estimate.