Fishery Data Series No. 95-7

Abundance and Composition of Northern Pike in Volkmar and Deadman Lakes, 1994

by

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and

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July 1995

Alaska Department of Fish and Game

Division of Sport Fish

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd

Spell out acre and ton.

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s

Spell out year, month, and week.

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

FISHERY DATA SERIES NO. 95-7

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by

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ABSTRACT

Populations of northern pike *Esox lucius* in Volkmar and Deadman lakes in interior Alaska were studied during spawning in the spring of 1994. Multiple capture-recapture events were used to estimate the abundance of northern pike ≥ 300 millimeters fork length. Abundance was estimated to have been 2,810 northern pike in Volkmar Lake in 1994 (SE = 302; 10.3 per hectare). Abundance of northern pike in Deadman Lake in 1994 was estimated at 1,999 fish (SE = 191; 9.4 fish per hectare). The population of northern pike in Volkmar Lake was composed primarily of the Relative Stock Density category of "stock"-sized fish (300-524 millimeters). The population in Deadman Lake was composed primarily of the Relative Stock Density category of "quality"-sized fish (525-654 millimeters). Age 5 northern pike were most abundant in Volkmar Lake and age 4 northern pike were the most abundant in Deadman Lake. The sustainable population of northern pike in Volkmar Lake is approximately 2,000 spawners. The population appears unable to maintain itself above this level, possibly due to cannibalism when the spawning population is high and resources are limited. The 1994 recruitment from the 1989 spawning population (1,081 fish) did not appear to have suffered from cannibalism. Data collected since the inception of northern pike research in Volkmar Lake is summarized.

Key words: Northern pike, *Esox lucius*, Volkmar Lake, Deadman Lake, abundance, mark-recapture, length/age composition.

INTRODUCTION

BACKGROUND

Northern pike *Esox lucius* are popular with sport anglers in Alaska. An estimated 121,717 northern pike were caught statewide during 1993, of which 19,366 (16%) were harvested (kept) according to Mills (1994). Excluding anadromous and saltwater species, northern pike ranked third in preference (following rainbow trout *Oncorhynchus mykiss* and Arctic grayling *Thymallus arcticus*) of freshwater fish both caught and harvested statewide during 1993. In the Arctic-Yukon-Kuskokwim region (AYK), where the highest percentage (63%) of the statewide harvest of northern pike occurred, northern pike ranked fourth among all species harvested in recreational fisheries, and second for those non-anadromous species considered indigenous to the region. The estimated harvests of northern pike in the AYK region have averaged 14,934 fish between 1977 and 1993, with a harvest range from 11,302 to 20,771.

Within AYK, harvest of northern pike from waters of the Tanana River drainage comprised 63% (7,712 fish) of the regional total for the species during 1993. George, Harding, Volkmar, East Twin, and Deadman lakes, in that order, were the sites of the most popular fisheries for northern pike in lakes in the Tanana River drainage during 1993, accounting for 12% (1,505 fish) of the total harvest.

Concern over the level of harvest of northern pike throughout AYK prompted the Alaska Department of Fish and Game (ADF&G) to initiate studies of northern pike stocks in the major fisheries of the Tanana River drainage in 1985. The overall goals have been to estimate population abundance and composition over several years, which along with estimates of sport harvest, recruitment, mortality, and sustainable yield will provide much of the information needed to balance recreational demands with surplus production in populations of Alaskan northern pike. Significant results to date include estimates of northern pike abundance, size and age composition, mortality, recruitment, movements, and sustainable yield in selected lakes in the Tanana River drainage. Estimates of the above have depended upon the establishment of a long term data-series for the lakes studied.

As a result of the above investigations, the ADF&G responded to stock declines due to overfishing by recommending bag and length limit reductions for all waters in the AYK Region, and a winter fishing closure for Minto Flats. These recommendations were adopted by the Alaska Board of Fisheries in December 1987. The daily bag and possession limit for northern pike in the Tanana River drainage (and Yukon River drainage near the Haul Road Bridge) was reduced from 10 northern pike, plus two over 30 inches (762 mm) total length, to five northern pike only one of which can be over 30 inches. In the rest of the AYK Region, a 10-fish bag limit without size restrictions was adopted. Previously, no bag limit existed for the AYK Region outside of the Tanana River drainage. In 1990, restrictions that included gear limitations (no spears or bows and arrows), a minimum size limit (26 in total length [TL] or 660 mm), and spawning closure (April 1 to May 31) were placed on the Harding Lake sport fishery. In February 1992, the Board of Fisheries adopted sport fishing regulations pertaining to the Tanana Area which limited the sport harvest of northern pike to the period from June 1 through March 31. This was done to provide additional protection prior to and during spawning when northern pike actively feed or are concentrated.

STUDY AREA DESCRIPTIONS

Volkmar Lake

Volkmar Lake (64°07'N, 145°11'W) is a remote 273 ha (675 ac) lake located approximately 25 km northeast of the town of Delta Junction (Figure 1). The lake is accessible during the open water season by float-equipped aircraft. Snow machines and ski-equipped aircraft provide access during the winter. Volkmar Lake lies at an elevation of 326 m and has a maximum depth of 12.8 m. The lake has two small inlets and an ill-defined outlet that drains westerly through wetlands toward the Goodpaster River. Near shore waters are shallow with beds of aquatic vegetation providing spawning and rearing substrate for northern pike. Volkmar Lake is typically ice-free from mid-May to early October, and spawning activity of northern pike generally coincides with the beginning of the ice-free period and continues for up to two weeks, into early June. Other fish species present include humpback whitefish *Coregonus pidschian*, least cisco *Coregonus sardinella*, and slimy sculpin *Cottus cognatus*.

The popularity of Volkmar Lake as a recreational area continues to grow. For the period 1981 through 1993, estimated annual fishing effort averaged 501 angler days (range 129 to 1,052; Mills 1994; Appendix A) and an estimated average fishing pressure of 1.8 ad/ha. The estimated harvest for northern pike averaged 408, ranging from 84 (1990) to a high of 777 (1982), with an average harvest of 0.9 northern pike per angler-day. In 1993, 77% of the catch was harvested. The average annual harvest per hectare is 1.8 northern pike. In 1993, of 302 northern pike under 30 in TL (720 mm fork length [FL]) caught in Volkmar Lake, 207 (69%) were retained (Mills 1994). Almost all northern pike over 30 in caught were kept (113 of 130). The component 30 in and longer comprised 30% of the total catch (130 of 302), and 35% of the harvest (113 of 320). Recreational fishing occurs year-round.

The research program on northern pike in Volkmar Lake began in 1985. Results of subsequent investigations have been reported upon by Clark and Gregory (1988); Timmons and Pearse (1989); Pearse (1990, 1991); Pearse and Clark (1992); Pearse and Burkholder (1993); and, Pearse and Hansen (1993).

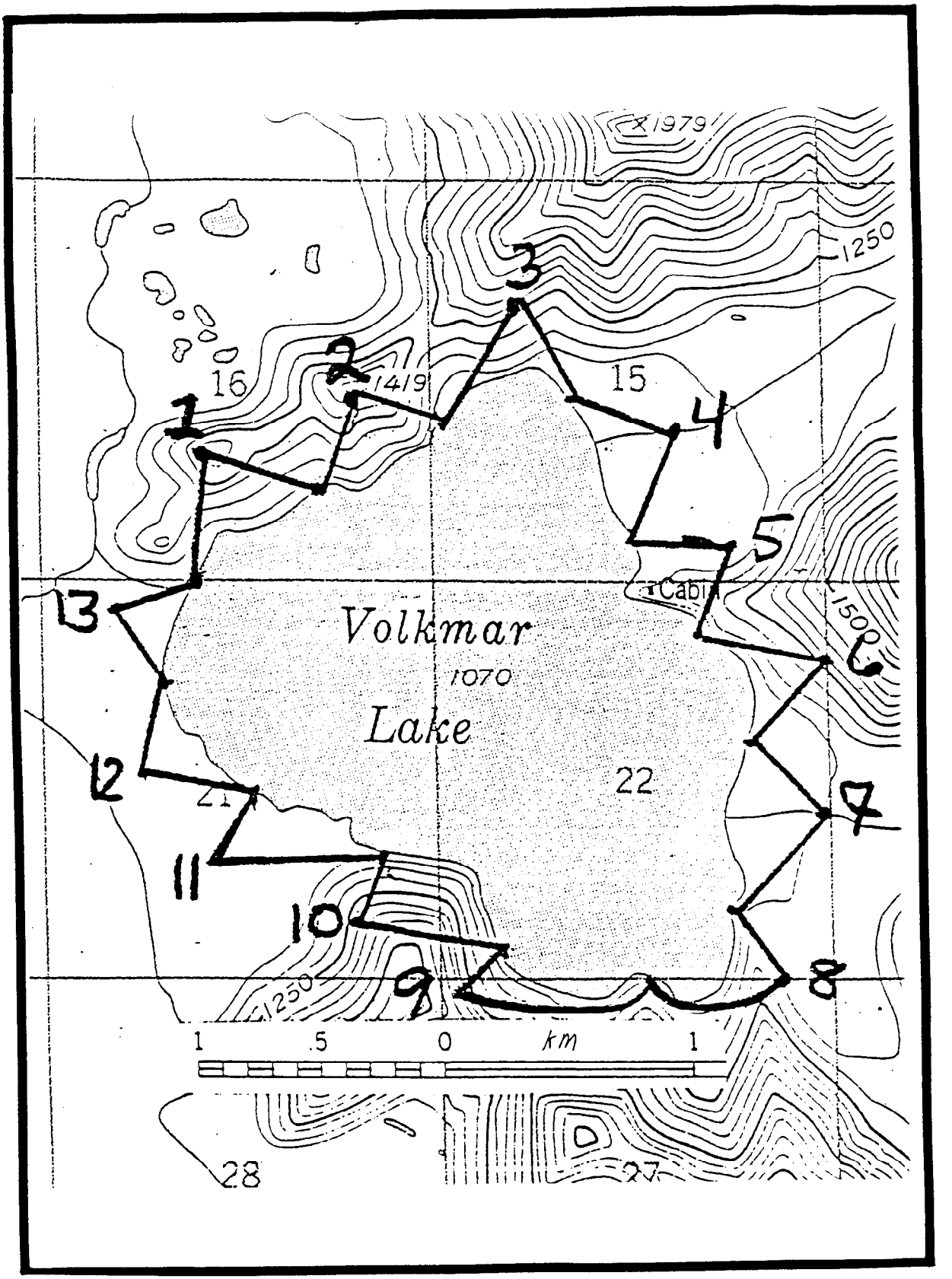

Figure 1.-Volkmar Lake study area.

Deadman Lake

Deadman Lake (64°51′ N, 149°58′ W) is a remote fly-in lake located approximately 100 km southwest of Fairbanks in rising terrain along the western edge of Minto Flats (Figure 2). The 213 ha lake lies at an elevation of 137 m, has a maximum depth of 21 m, and a shoreline circumference of 6.3 km. The lake has one small inlet and an outlet that flows from the northwest corner into the Tanana River approximately 10 km to the west. Nearshore waters are shallow with beds of aquatic vegetation providing spawning and rearing substrate for northern pike. Deadman Lake is believed to be typically ice-free from mid-May to early October, and spawning of northern pike likely coincides with the beginning of the ice-free period, continuing for up to two weeks into late May as in other Tanana drainage lakes. Other known fish species in the lake include burbot *Lota lota*, and humpback whitefish.

Recreational harvest for northern pike is low compared with other drainage waters, and therefore has not been regularly reported in Statewide Harvest surveys. However, estimated harvest in 1988 was 182 northern pike (in 36 angler-days), 119 fish taken in 1991 (53 angler-days), and 415 northern pike in 1992 taken during 213 angler-days (Mills 1994, pers comm.; Appendix A). In 1993, 303 angler-days produced a catch and harvest of 397 and 68 (17%) northern pike, respectively, all of which were under 30 in TL. Previous investigations of the northern pike population in this lake have been limited to those dedicated to preliminary lake inventory and sampling of the resident fish populations (Kramer 1979).

Study Goals and Objectives

The long-term goal of the northern pike research program is to accurately and precisely describe the stock status of selected northern pike populations on a regular basis, and to use the data to estimate sustainable yield. The specific objectives sought in 1994 were to:

1. estimate the population abundance of northern pike (300 mm FL and longer) in Volkmar and Deadman lakes;
2. estimate the length composition of the northern pike populations (300 mm FL and longer) in Volkmar and Deadman lakes; and,
3. test the hypothesis that cannibalism is an important factor in the productivity of northern pike in Volkmar Lake.

METHODS

Study Design

Prior experience indicated that population studies of northern pike in interior Alaskan lakes are best conducted during and immediately after the spawning period, which coincides with spring ice melt during mid to late May. Northern pike concentrate and move in near-shore waters at this time to spawn and feed, making them more available to the sampling gear, and low water temperatures minimize temperature-sensitive handling injuries (Peckham and Bernard 1987). Daily peaks in activity, as reflected by both observation of fish activity and catch of ripe or feeding fish in gill nets and seines, normally occurs during mid-day, generally between 1000 and 2000 hours. Sampling efforts were therefore focused to include this peak period of daily near-shore activity (within 100 m of the shoreline).

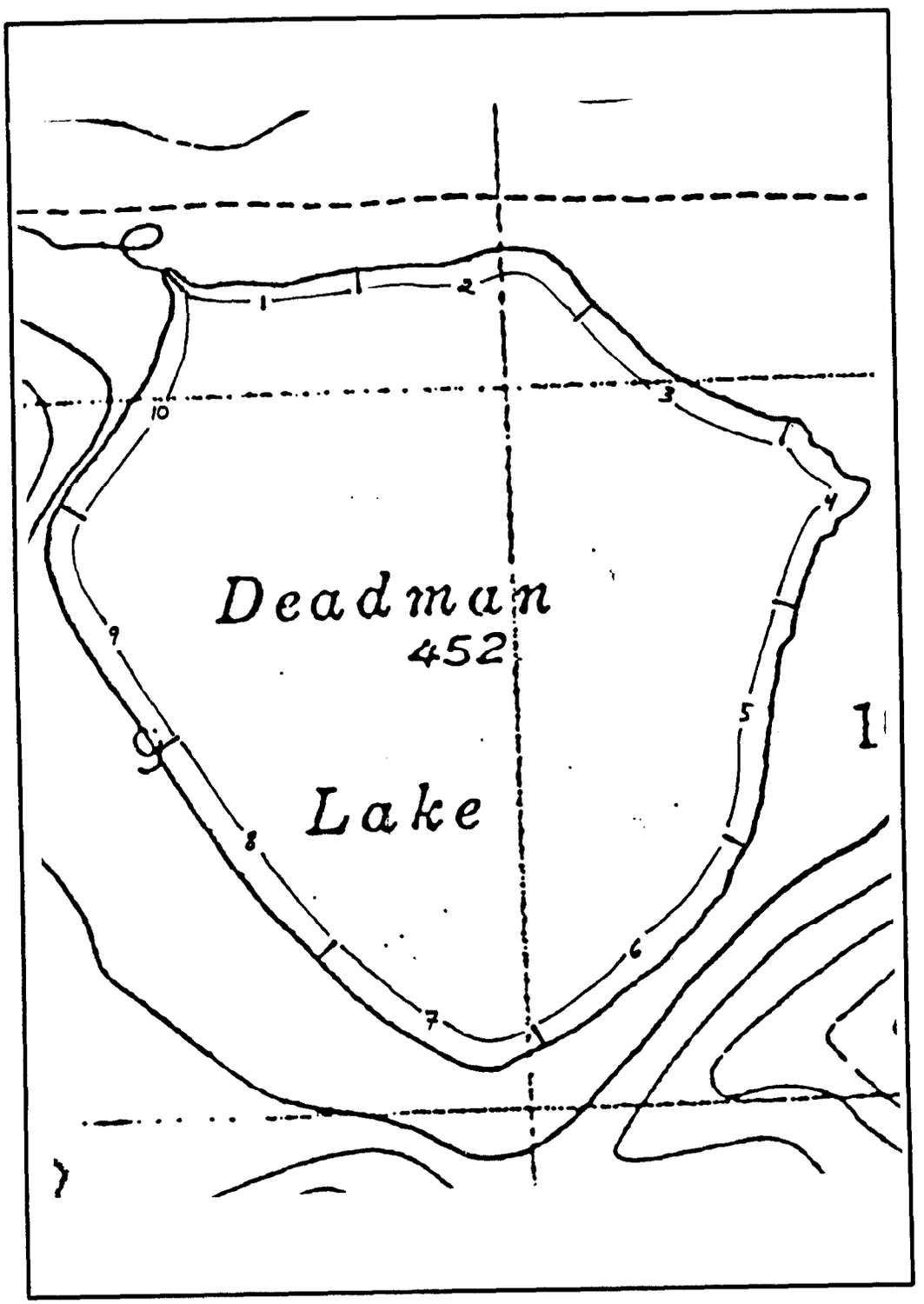

Figure 2.-Deadman Lake study area.

Both lakes were divided into uniform sampling zones (by lakeshore distance) to evenly apportion sampling effort, and to allow for later testing of movement of marked fish between areas of release and recapture. The rationale behind establishing the size of the individual sampling zones was derived from the results of data collected in the Volkmar Lake telemetry study conducted during a similar time frame in 1991 (Pearse and Clark 1992). The median distance moved during a single nightly period for the radio-tagged northern pike (642 m; Pearse and Clark 1992) was divided into the circumference of each lake which resulted in 13 uniform sampling zones in Volkmar Lake and 10 sampling areas in Deadman Lake.

In Volkmar Lake, a beach seine, 100 by 10 m with 25 mm square mesh and with an attached bag, was used to capture northern pike. Seines were normally set in water less than 3 m deep usually within 100 m of the shore. The seines were drawn to the shore around the northern pike, which were transferred to holding containers for sampling. The method of sampling in Deadman Lake was the same as Volkmar Lake, with the exception that daily sampling effort involved a crew of four setting gillnets in each of the 10 sampling areas. In both lakes the sampled northern pike were released near shore at the middle of the respective sampling zone. Sampling effort was equally divided among the sampling areas in each lake, and all areas were systematically sampled on a daily basis. Seine hauls and gillnet sets were numbered sequentially through the experiment, regardless of success of capture. Location of each haul or set was recorded on lake maps with a separate map used each sampling day.

Each captured northern pike was examined for tags and secondary marks and measured to the nearest 1 millimeter FL. A minimum of three scales were taken from the preferred zone[1] of each newly captured northern pike and mounted on gummed cards. Northern pike ≥ 300 mm FL were marked with a Floy FD-68B internal anchor tag inserted posteriorly at the left base of the dorsal fin. The tip of the upper caudal fin was punched to identify marked fish in case the numbered tag was shed (Appendix B). If any captured northern pike exhibited signs of injury or imminent mortality it was not tagged.

Scale impressions were made on 20 mil acetate sheets using a Carver press at 137,895 kPa (20,000 psi) heated to 93°C for one minute. Scales were read on a microfiche reader (32x) and ages estimated in accordance with age identification criteria established by Williams (1955) and Casselman (1967). The formation of scale annuli in Alaskan stocks of northern pike generally coincides with the sampling period in late May. Therefore, estimated ages corresponded to counts of annuli.

ESTIMATION OF ABUNDANCE

Multiple-sample population estimates were performed in each lake. Volkmar Lake was sampled for seven consecutive days between May 17 and 23, 1994. Deadman Lake was sampled for five consecutive days between May 18 and 22, 1994. Captures histories from each lake were used as input to program CAPTURE (Rexstad and Burnham 1992, Appendix C). Program CAPTURE was used to perform a rigorous examination of assumptions necessary for multiple-sample abundance estimators. The underlying logic and statistical process of program CAPTURE is described in Otis et al. (1978) and, White et al. (1978, 1982). The assumptions necessary for accurate estimation of abundance in a closed population are (from Seber 1982):

---

[1] The preferred zone for northern pike is adjacent to but not on the lateral line above the pelvic fins as described by Williams (1955).

1. the population is closed (no changes in the number of northern pike during the experiment);
2. all northern pike have the same probability of capture in the first sample ***or*** in all subsequent samples ***or*** marked and unmarked northern pike mix randomly between sampling events;
3. marking of northern pike does not affect their probability of capture in subsequent samples;
4. northern pike do not lose their mark between sampling events; and,
5. all marked northern pike are reported when recovered in subsequent samples.

Assumption 1 could not be tested directly, but was implicitly assumed because of the short duration of the experiment. Assumptions 2 and 3 were tested with statistical procedures within program CAPTURE. Assumption 4 was assured of validity by double marking of northern pike. Assumption 5 was assumed to be valid because we carefully examined all northern pike captured for tags and secondary marks.

The various models developed for which abundance estimators are available in CAPTURE (January 8, 1993 version) are as follows:

1. Model M_o: This is the most restrictive model and assumes capture probabilities to be constant through all sampling events, but does not allow capture probabilities to vary by individual (heterogeneity), or provide for individual behavior (trap happy or shy). Also called Estimator Null.
2. Model M_b: Allows capture probabilities to vary due to behavioral response, but not due to heterogeneity or temporal variation (by sampling event). It assumes every unmarked fish in the population has the same probability of capture during each event, and every marked fish has the same probability of recapture for all events subsequent to marking. Also called Estimator Zippin.
3. Model M_t: The original M_t. Allows capture probabilities to vary only by time or sampling event, but does not allow heterogeneity of individual capture probabilities or behavioral response. Also called Estimator Darroch.
4. Model Chao M_t: This is the updated estimator for M_t, which assumes capture probabilities vary with time. This modification (Chao 1989) reportedly performs well when probabilities of capture are small.
5. Model M_h: The original M_h. Allows heterogeneity but not behavioral response, and assumes each fish has its own unique capture probability which remains constant over all sampling events. Calculating population estimates by size, sex or age can apparently minimize heterogeneity of capture probabilities, if detected. Also called Estimator Jacknife.
6. Model Chao M_h: An updated estimator for M_h. Similar to M_h, this modified estimator (Chao 1988) is reportedly less biased when probabilities of capture are small.
7. Model Chao M_{th}: This model assumes capture probabilities vary with time and individual.

8. Model Burnham M_{tb}: This estimator assumes capture probabilities vary with time and behavioral effects (trap-happy or shy).
9. Model M_{bh}: Allows for both heterogeneity and trap response, and assumes each fish has its own unique pair of potential capture probabilities, referring to whether the fish is marked or unmarked, which remain constant over all sampling events.

To choose the most appropriate model, assumptions about capture probabilities were tested by comparing the absolute and relative fit of the data to the various models and then selecting the simplest, best fitting model. A total of seven tests were performed. Tests 1, 2, and 3 compared models to detect the presence of heterogeneity, behavior and time responses respectively. Tests 4, 5, and 6 test the goodness of fit of the data to models M_h, M_b, M_t respectively. Test 7 compared models M_b and M_{bh} to detect behavioral responses in the presence of heterogeneity. All seven tests have a Chi-square distribution under the null hypothesis. Program CAPTURE has a model selection procedure which uses the results from the seven tests to determine the most appropriate model. However, the model selection procedure in CAPTURE can be unreliable when capture probabilities are small (Otis et al. 1978), therefore, results from the seven tests and knowledge of northern pike behavior were used to select the most appropriate model.

Cumulative distribution functions (CDF) of daily lengths of captured northern pike were examined to determine if the abundance estimates needed to be stratified by length. The proportion of recaptured northern pike in the daily sample versus the number of northern pike that were marked prior to the daily sampling was also examined to detect changes in capture probability (Seber 1982). The proportion of recaptured fish is expected to increase linearly as the number of marked fish increases, providing mixing of marked and unmarked fish occurs, or capture probabilities of all fish are uniform.

COMPOSITION ESTIMATION

Estimates of abundance were used to apportion northern pike populations into the following sets of categories:

1. "Small" (300-449 mm), "Medium" (450-749 mm), "Large" (750 mm and larger), and "All northern pike greater than 300 mm, and "All northern pike greater than 449 mm". This was done to facilitate annual comparisons among and between all lakes studied;
2. Relative Stock Densities (RSD; Gabelhouse 1984) in "stock" (300-524 mm), "quality" (525-654 mm), "preferred" (655-859 mm), "memorable" (860-1,079 mm), and "trophy" (> 1,079 mm) FL classes;
3. abundance by age; and,
4. mean length-at-age.

Composition estimates were calculated as follows:

$$\hat{p}_j = \frac{n_j}{n} \qquad (1)$$

where:

n = the number of fish sampled for information on age or length composition;

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

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

The variance of the proportion was estimated as:

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

The estimated number of northern pike by length group was calculated as:

$$\hat{N}_j = \hat{p}_j \hat{N} \tag{3}$$

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

$$\hat{V}\left[\hat{N}_j\right] = \hat{V}\left[\hat{p}_j\right]\hat{N}^2 + \hat{V}\left[\hat{N}\right]\hat{p}_j^2 - \hat{V}\left[\hat{p}_j\right]\hat{V}\left[\hat{N}\right] \tag{4}$$

Mean length-at-age was calculated as the arithmetic mean length for each age class.

CANNIBALISM

Cannibalism has been postulated as an important factor affecting the relationship between stock size and recruitment for other populations of northern pike (i.e., Kipling and Frost 1970; Craig and Kipling 1983; Giles et al. 1986; Grimm 1981a, 1981b, 1983; Le Cren 1987). Abundance of fully recruited northern pike (age 5 and older) and recruitment have been estimated each year for the population of northern pike in Volkmar Lake since 1985. There has been a negative relationship between abundance of fully recruited northern pike and recruitment five years later in Volkmar Lake (Figure 3), which is consistent with cannibalism being an important factor in determining the productivity of this population. However, 1994 data should provide a good test of this hypothesis since the lowest estimated abundance in the series (1,081) occurred five years ago. If recruitment in 1994 is the highest since 1987, this would indicate that cannibalism may be a factor even at low abundance; if not, this would indicate that other factors controlling recruitment such as fecundity and natural mortality may play a greater role.

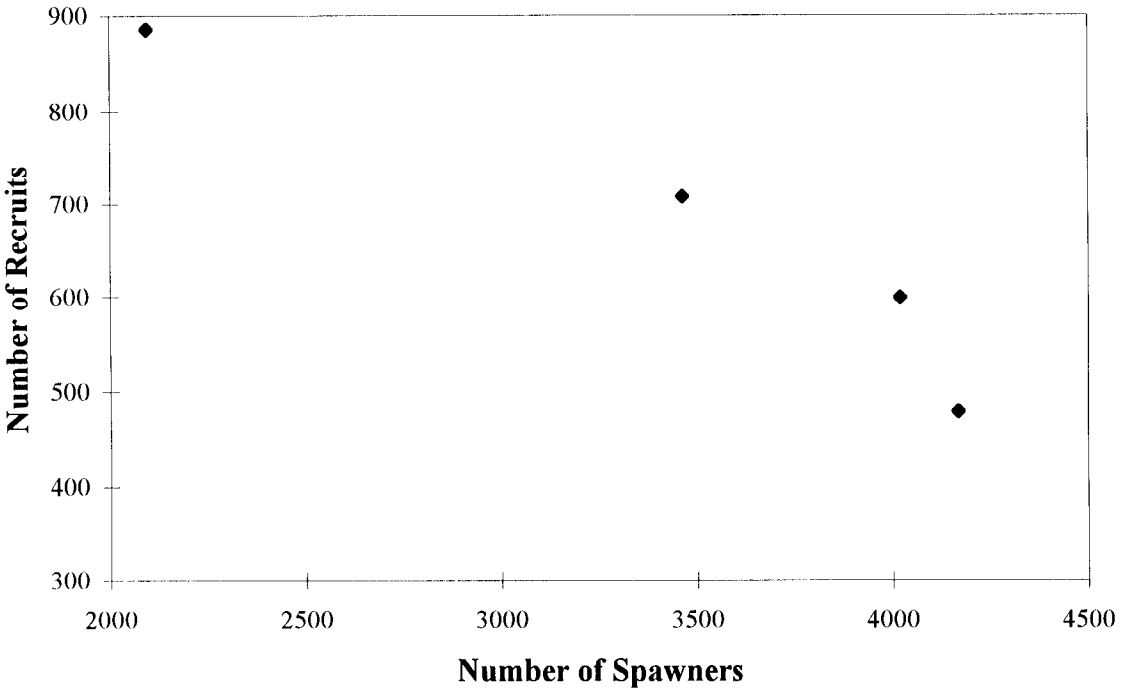

Figure 3.-Relationship between the number of spawning northern pike (1985-1988) and the resultant number of recruits (1990-1993) in Volkmar Lake.

RESULTS

VOLKMAR LAKE

Abundance Estimation

The estimated abundance of northern pike (≥ 300 mm FL) during mid-May was 2,810 fish (SE = 302, RP = 21%). Density was estimated to have been 10.3 northern pike per ha (Appendix D). The estimated abundance of northern pike ≥ 450 mm was 2,318 fish (SE = 236, RP = 20%).

The statistical tests indicated effects of behavior and time responses but no effect of heterogeneity (Appendix E). Since beach seines were used to capture the fish, it would be very unlikely that fish could become trap happy or trap shy. Therefore, the model selected was M_t.

Inspection of the length CDF plots indicated no problems with size-selectivity among sampling events (Figure 4). There was a positive linear correlation between the number of marked fish at large and the proportion of recaptured northern pike in the sample (Figure 5). No evidence of tag loss was observed during the sampling events.

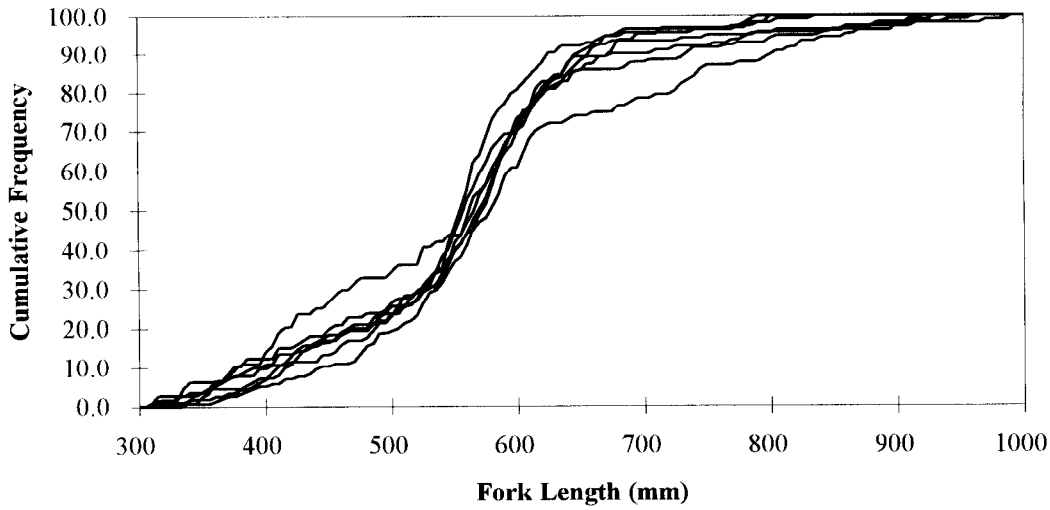

Figure 4.-Daily cumulative length distribution frequencies of northern pike captured in Volkmar Lake, 1994.

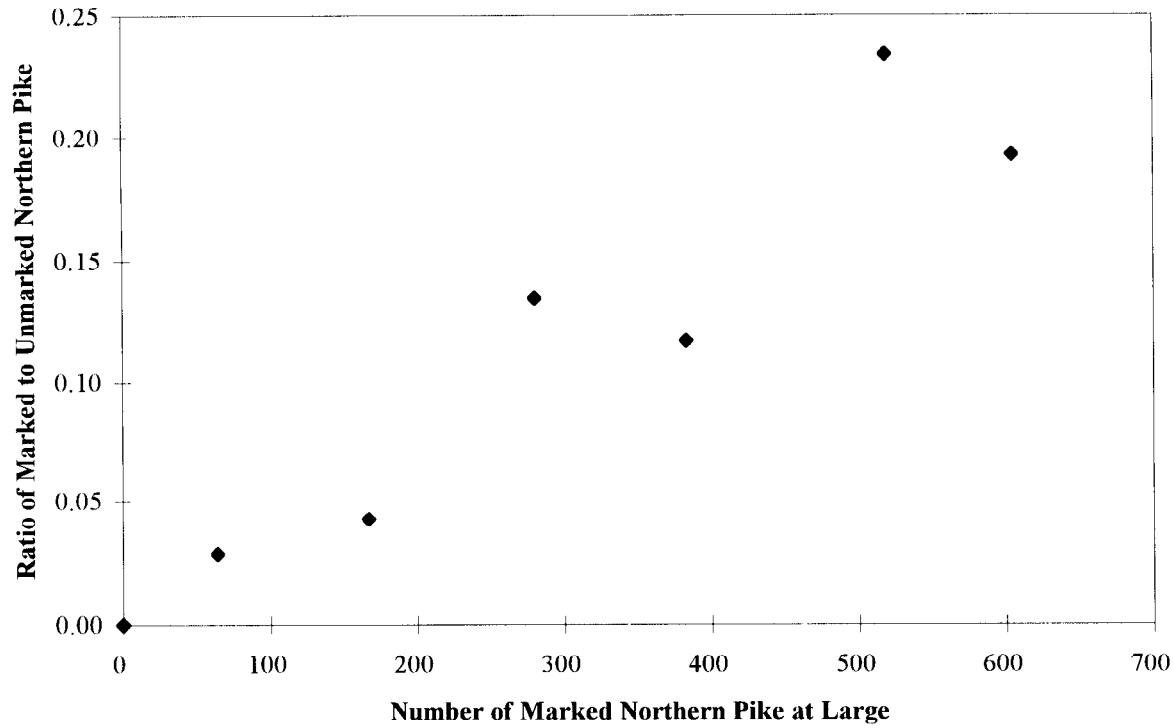

Figure 5.-Ratio of marked to unmarked northern pike captured in Volkmar Lake, 1994.

Composition Estimation

All unique fish examined in 1994 were used for composition estimates because size-selectivity was not detected. The Small size category was mainly comprised of partially recruited northern pike, and contributed an estimated 18% of the population's makeup in 1994. Fish in the Medium size range predominated with an estimated 76% of the population in 1994. Fish over 749 mm contributed an estimated 7% of the population (Appendix D). Medium and Large sized northern pike consisted primarily of fish fully recruited to the spawning population.

Estimated RSDs (Appendix F) indicated the stock and quality categories predominated (an estimated 31% and 56%, respectively), with few captured in the preferred and memorable size groups (estimated 10% and 3%, respectively). No northern pike were captured in the trophy size category.

The recruitment, measured as the abundance of age 5 northern pike, was estimated to be 767 northern pike (SE = 96). The age 5 cohort made up an estimated 27% of the population and had the highest abundance of any cohort in 1994 (Appendix G).

The mean length-at-age data (Appendix H) indicated increasing length with increasing age, as indicated in prior samples. The mean length of age 5 northern pike was 543 mm (SE = 4).

No northern pike died as a result of sampling in Volkmar Lake and no incidence of unhealthy northern pike was observed.

DEADMAN LAKE

Abundance Estimation

The estimated abundance of northern pike (≥ 300 mm FL) during mid-May was 1,999 fish (SE = 191, RP = 19%). Density was estimated to have been 9.4 northern pike per ha. The estimated abundance of northern pike ≥ 450 mm was 1,428 fish (SE = 139, RP = 19%).

No effect of heterogeneity was detected but the statistical tests indicated effects of behavior and time responses (Appendix I). Since gillnets were used to capture the fish, it would be very unlikely that fish could become trap happy or trap shy. Therefore, the model selected was M_t.

Inspection of the length CDF plots indicated no problems with size-selectivity among sampling events (Figure 6). There was a positive linear correlation between the number of marked fish at large and the proportion of recaptured northern pike in the sample (Figure 7). No evidence of tag loss was observed during the sampling events.

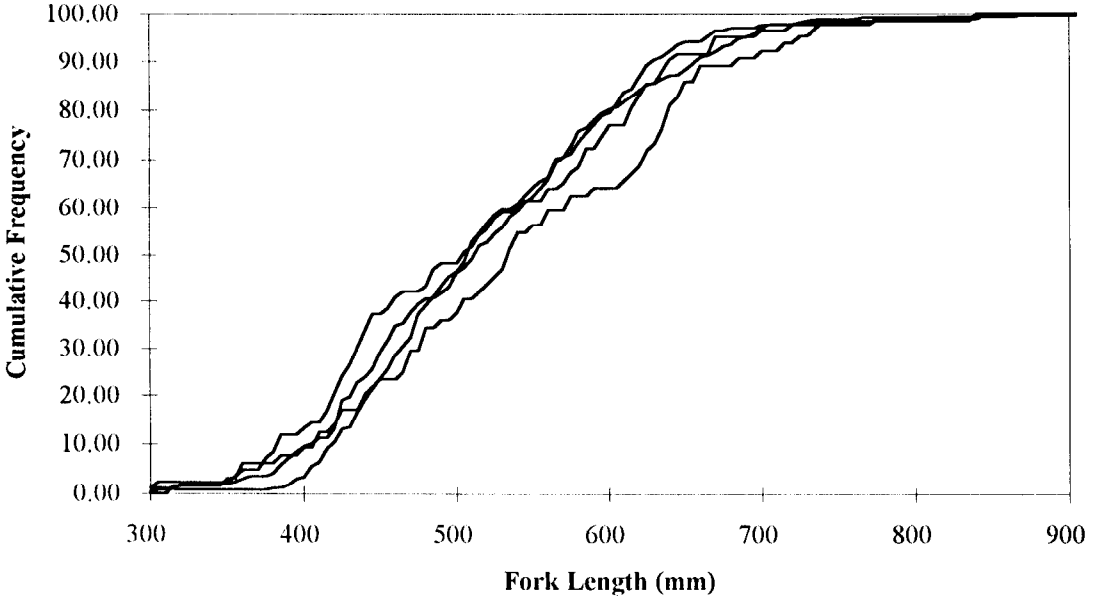

Figure 6.-Daily cumulative length distribution frequencies of northern pike captured in Deadman Lake, 1994.

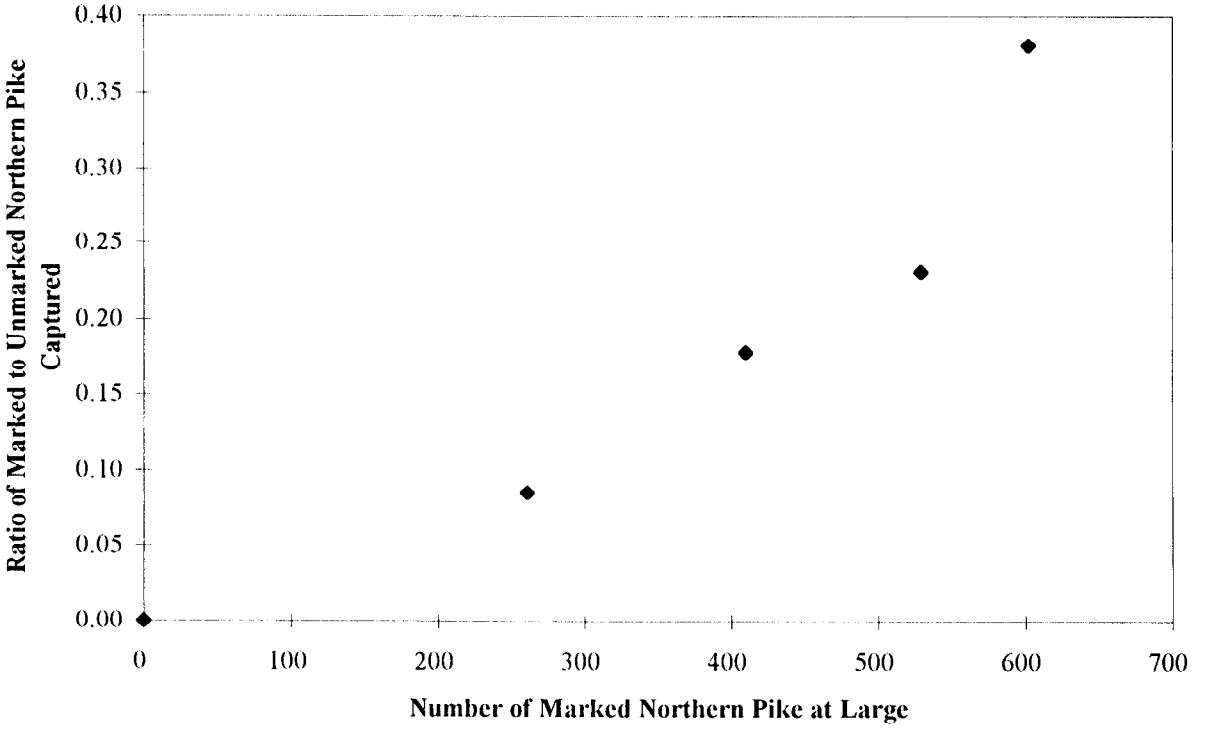

Figure 7.-Ratio of marked to unmarked northern pike captured in Deadman Lake 1994.

Composition Estimation

The source for the 1994 estimates of composition was all unique fish examined in 1994. An estimated 70% of the northern pike population were in the Medium category (1,397, SE = 138). The Small category (300 to 449 mm) is mainly comprised of partially recruited northern pike and accounted for an estimated 29% of the population. Fish over 749 mm (Large category) contributed 2% of the overall estimate.

Recruitment in Deadman Lake (defined as the abundance of age 5 fish) was estimated to be 408 northern pike (SE =61), comprising 20% of the estimated population (Table 1). Age-5 was not the most abundant cohort. Length at age 5 was similar to Volkmar Lake (Appendix H). Age 5 fish have been identified as the age at which full recruitment for both sexes of fish occur in Volkmar Lake, but has not necessarily been the most abundant cohort sampled during annual events (Appendix G).

The age composition of northern pike sampled during 1994 in Deadman Lake indicated fish between age 1 and age 12 were captured. Age 4 northern pike dominated the composition. The mean length of the age 4 fish was estimated to be 488 mm in 1994 (SE < 1). Twenty-nine percent of the northern pike were assigned an age of 3 or younger (Table 1).

Table 1.-Composition estimates of northern pike in Deadman Lake, 1994.

	Sample			Estimated		Mean	
Age	Size	Proportion	SE	Abundance	SE	Length (mm)	SE
1	4	0.01	<0.01	15	8	321	10
2	28	0.05	0.01	108	22	387	5
3	118	0.23	0.02	454	57	444	4
4	129	0.25	0.02	497	61	488	5
5	106	0.20	0.02	408	53	544	6
6	49	0.09	0.01	189	31	591	9
7	43	0.08	0.01	166	29	632	6
8	21	0.04	0.01	81	19	654	10
9	14	0.03	0.01	54	15	694	22
10	4	0.01	<0.01	15	8	747	48
11	2	<0.01	<0.01	8	5	870	31
12	1	<0.01	<0.01	4	4	945	--

An estimated 56% of the population fell within the stock category (300 to 525 mm), quality sized northern pike made up an estimated 34% of the population, preferred and memorable contributed an estimated 9% and 1%, respectively. No northern pike were captured in the trophy size category.

No northern pike died as a result of sampling and no incidence of unhealthy northern pike was observed.

CANNIBALISM

The estimated 1994 recruitment in Volkmar Lake was 767 northern pike (SE = 96) and was not the highest since 1987 (Figure 8).

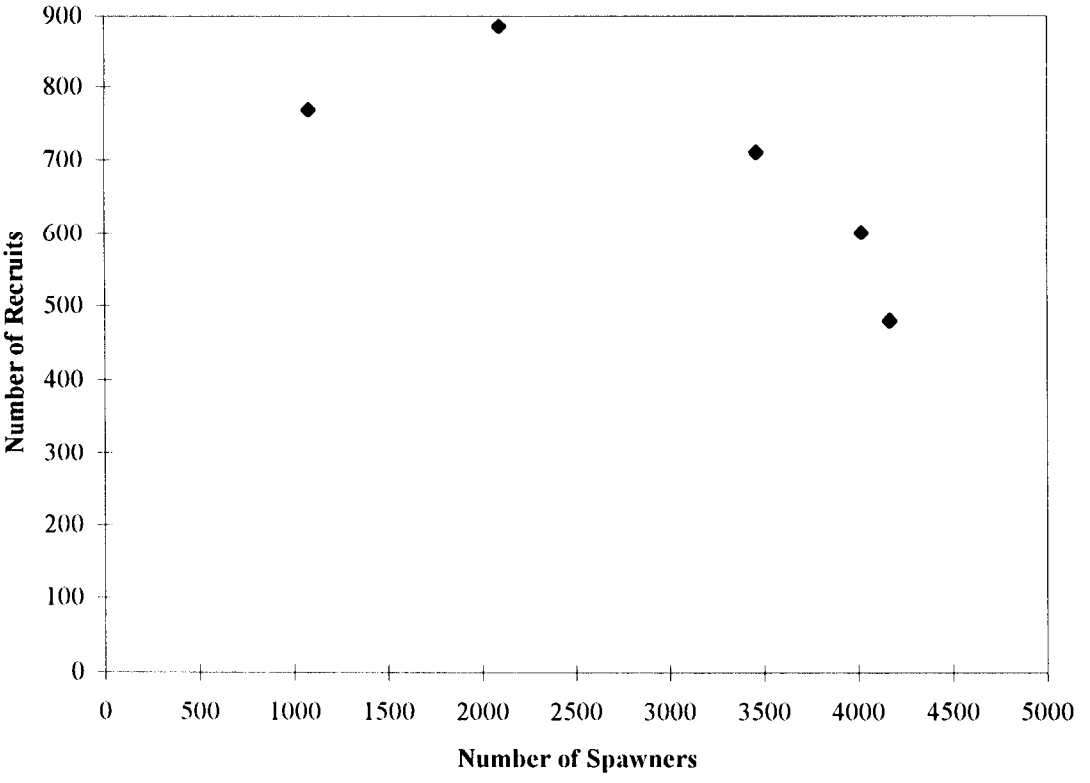

Figure 8.-Relationship between the number of spawning northern pike (1985-1989) and the resultant number of recruits (1990-1994) in Volkmar Lake.

DISCUSSION

VOLKMAR LAKE

We conclude that the sustainable population of northern pike in Volkmar Lake is approximately 2,000 spawners (about 3,000 northern pike ≥ 300 mm FL). During the past 10 years (1985-1994) annual estimates of abundance, harvest, recruitment and survival have been calculated (Pearse and Hansen 1993). Estimates of spawner abundance have been as high as 4,168 (1985) and as low as 1,081 (1989). There is a strong negative correlation between the number of spawners and the number of recruits when the spawner abundance is greater than 2,000. The population appears unable to maintain itself above this level. One of the reasons for this could be that cannibalism is a problem only when the spawning population is high and resources are limited. The 1994 recruitment from the spawning population in 1989 (1,081 fish) did not appear to have been affected as greatly by cannibalism and was probably limited more by fecundity and natural mortality. A spawning population of 2,000 northern pike could expect a natural mortality of about 30% and a recruitment of about 850 northern pike (Pearse and Hansen 1993, Figure 5). This would allow for a sustainable harvest of approximately 250 northern pike ≥ 500 mm. A creel survey conducted in George Lake (Hallberg and Bingham 1992) estimated that 85% of the

harvest of northern pike was ≥ 500 mm which, if applied to Volkmar Lake, would allow for a total sustainable harvest of just under 300 northern pike.

We recommend that the northern pike population in Volkmar Lake be monitored through the Statewide Harvest Survey. If there is a significant change in effort, catch-per-unit effort, or harvest levels then another estimate of abundance is advised.

The 1994 abundance estimate of 2,318 fully recruited northern pike is close to the maximum sustainable level and the estimated harvest from 1993 (320 northern pike) was only slightly over the optimal level. We conclude that the northern pike population is presently at a sustainable level.

DEADMAN LAKE

The recommended density of northern pike in Volkmar Lake was 7.3 spawners/ha. If that same guideline was applied to Deadman Lake we would conclude the sustainable population to be 1,560 fully recruited northern pike. Assuming similar rates of natural mortality and recruitment, a population of 1,560 spawners would produce about 660 recruits and would allow for a sustainable harvest of approximately 200 fully recruited northern pike (230 total).

The 1994 estimated abundance of 1,428 fully recruited northern pike is close to the recommended level. The average level harvest (239 northern pike) should be easily sustained.

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APPENDIX A

Appendix A.-Recreational fishing effort, harvest, and exploitation of northern pike in Volkmar and Deadman lakes, by year.

Lake		Angler Days[a]	Angler Days Per Ha	Harvest of Northern Pike	Harvest Per Angler Day	Estimated Abundance of Northern Pike ≥ 300 mm	Estimated Exploitation Rate if Harvested Fish were ≥ 300 mm	Estimated Abundance of Northern Pike ≥ 450 mm	Estimated Exploitation Rate if Harvested Fish were ≥ 450 mm
Volkmar									
	1981	458	1.7	648	1.4				
	1982	546	2.0	777	1.4				
	1983	270	1.0	430	1.6				
	1984	436	1.6	428	1.0				
	1985	711	2.6	503	0.7			4,020	0.13
	1986	596	2.2	657	1.1	8,056	0.08	4,028	0.16
	1987	472	1.7	224	0.5	6,932	0.03	4,230	0.05
	1988	186	0.7	255	1.4	2,766	0.09	2,196	0.12
	1989	466	1.7	180	0.4	1,330	0.14	1,115	0.16
	1990	129	0.5	84	0.7	4,038	0.02	2,019	0.04
	1991	1,052	3.9	565	0.5	4,510	0.13	2,509	0.23
	1992	608	2.2	231	0.4	3,888	0.06	2,542	0.09
	1993	579	2.1	320	0.6	4,160	0.08	3,097	0.10
	1994					2,810		2,318	
Mean		501	1.8	408	0.9	4,277	0.08	2,832	0.12
Deadman									
	1988	36	0.2	182	5.1				
	1989	100	0.5	160	1.6				
	1990	311	1.5	490	1.6				
	1991	53	0.2	119	2.2				
	1992	213	1.0	415	1.9				
	1993	303	1.4	68	0.2				
	1994								
Mean		169	0.8	239	2.1				

[a] Data source: Mills 1979-1993, Mills pers comm. 1992, 1994.

APPENDIX B

Appendix B.-Finclips and tags assigned to northern pike in Volkmar Lake, by year.

Year	Tag Series	Color	Finclips	Comments
1983	16189 - 16196	Red	None	
	174 - 214	Blue		
1984	16207 - 16347	Red	None	
1985	16431 - 17568	Red	None	
1986	3000, 4000	Yellow	016, 032	032=fish > 499 mm
	16000, 17000	Red	Many odd combos	mostly untagged fish during marking run; mostly tagged fish during recap run. 016=fish < 500 mm; most tagged. Odd 16000, 17000 series tags from previous years.
	20400 - 20454	White	Many odd combos	
1987	25000 - 26037	White	008	
			Many odd combos	
1988	98000 - 98355	Green	064	
			Many odd combos	
1989	21000 - 21383	Green	Option 5 = 2	Left opercle punch
1990	50000 - 50516	Blue	Option 5 = 1	Right opercle punch
1991	50517 - 50999	Blue	Option 5 = 4	Dorsal fin clip
	51000 - 51307	Blue	Same	
1992	03003 - 03442	Grey	Option 5 = 8	Anal fin clip
1993	03450 - 03924	Grey	Option 5 = 3	Dorsal punch
1994	03450 - 03924	Grey	Option 5 = 3	Caudal punch

APPENDIX C

Appendix C.-Number of northern pike marked and recaptured by event in Volkmar and Deadman lakes, 1994.

Volkmar Lake:

Event	Fish Caught (C)	Newly Caught	Tags at Start of Daily Event (M)	Recaptured[a] (R)	Recapture Rate % (R/M)	(R/C) %Ratio
1	64	64	0	0		
2	106	103	64	3	5	3
3	118	113	167	5	3	4
4	119	103	280	16	6	13
5	154	136	383	18	5	12
6	111	85	519	26	5	23
7	109	88	604	21	3	19
Total	781	692		89		

[a] Not necessarily unique fish.

Deadman Lake:

Event	Fish Caught (C)	Newly Caught	Tags at Start of Daily Event (M)	Recaptured[a] (R)	Recapture Rate % (R/M)	(R/C) %Ratio
1	261	261	0	0		
2	163	149	261	14	5	9
3	145	119	410	26	6	18
4	95	73	529	22	4	23
5	63	39	602	24	4	38
Total	727	641		86		

[a] Not necessarily unique fish.

APPENDIX D

Appendix D.-Abundance and density of various size groups of northern pike (≥ 300 mm FL) in Volkmar Lake, by year.

	Small (300-449 mm)				Medium (450-749 mm)				Large (Larger than 749 mm)				All (Larger than 300 mm)			All (Larger than 449 mm)				
Lake/	Abundance		Proportion		Abundance		Proportion		Abundance		Proportion		Abundance		Density	Abundance		Proportion		Density
Year	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Fish/Ha	Estimate	SE	Estimate	SE	Fish/Ha
1985	---	---	---	---	3,732	201	---	---	288	24	---	---	---	---	---	4,020	250	---	---	---
1986	4,028	2,266	0.5	0.006	3,891	584	0.48	0.006	137	65	0.02	0.001	8,056	2,915	21.6	4,028	587	0.50	0.006	10.8
1987	2,703	641	0.39	0.006	4,118	634	0.59	0.006	111	22	0.02	0.002	6,932	1,542	18.6	4,230	634	0.61	0.006	11.3
1988	570	64	0.21	0.008	2,135	147	0.77	0.008	61	19	0.02	0.003	2,766	177	7.4	2,196	148	0.79	0.008	5.9
1989	215	43	0.16	0.01	974	177	0.73	0.012	141	30	0.11	0.008	1,330	240	3.6	1,115	179	0.84	0.010	3.0
1990	2,019	372	0.5	0.026	1,866	346	0.46	0.026	153	48	0.04	0.010	4,038	714	10.8	2,019	349	0.50	0.028	5.4
1991	2,001	253	0.44	0.018	2,276	285	0.51	0.018	233	46	0.05	0.008	4,510	541	12.1	2,509	289	0.56	0.020	6.7
1992	1,346	212	0.35	0.02	2,450	368	0.63	0.020	92	28	0.02	0.006	3,888	572	10.4	2,542	369	0.65	0.021	6.8
1993	1,063	170	0.26	0.017	2,872	424	0.69	0.018	225	49	0.05	0.009	4,160	605	11.2	3,097	427	0.74	0.020	8.3
1994	492	67	0.18	0.014	2,131	234	0.76	0.016	187	33	0.07	0.009	2,810	302	10.3	2,318	236	0.83	0.022	8.5

APPENDIX E

Appendix E.-Model selection tests from program CAPTURE (Volkmar Lake 1994).

VOLKMAR LAKE 1994

Model Selection Tests from Program Capture

1. Test for heterogeneity of trapping probabilities in population.
Null hypothesis of model M(o) vs. alternate hypothesis of model M(h)

Chi-square value = 0.452 degrees of freedom = 1
Probability of larger value = 0.50120

2. Test for behavioral response after initial capture.
Null hypothesis of model M(o) vs. alternate hypothesis of model M(b)

Test failed. Failure criterion = -118

3. Test for time specific variation in trapping probabilities.
Null hypothesis of model M(o) vs. alternate hypothesis of model M(t)

Chi-square value = 47.138 degrees of freedom = 6
Probability of larger value = 0.00000

4. Goodness of fit test of model M(h)
Null hypothesis of model M(h) vs. alternate hypothesis of not model M(h)

Chi-square value = 39.266 degrees of freedom = 6
Probability of larger value = 0.00000

Test of model M(h) by frequency of capture
(frequencies less than 2t are not calculated.)

-continued-

Number of captures	Chi-square	d.f.	Probability
1	26.435	6	0.00018
2	18.097	6	0.00599

5. Goodness of fit test of model M(b)

Null hypothesis of model M(b) vs. alternate hypothesis of not model M(b)

Chi-square value = 3.701 degrees of freedom = 5

Probability of larger value = 0.59328

5a. Contribution of first capture homogeneity across time

Test failed. Failure criterion = -118

5b. Contribution of recapture homogeneity across time

Chi-square value = 3.701 degrees of freedom = 5

Probability of larger value = 0.59328

6. Goodness of fit test of model M(t)

Null hypothesis of model M(t) vs. alternate hypothesis of not model M(t)

Chi-square value = 407.390 degrees of freedom = 379

Probability of larger value = 0.15134

7. Test for behavioral response in presence of heterogeneity.

Null hypothesis of model M(h) vs. alternate hypothesis of model M(bh)

Chi-square value = 43.610 degrees of freedom = 12

Probability of larger value = 0.00002

APPENDIX F

Appendix F.-Percent RSDs and abundance of northern pike (≥ 300 mm FL) in Volkmar Lake by year.

	1986				1987				1988			
	RSD[a]	SE	N	SE	RSD[a]	SE	N	SE	RSD[a]	SE	N	SE
Stock	59	12.0	4,719	2,269	65	4.2	4,496	1,056	48	2.3	1,316	106
Quality	34	2.7	2,730	413	28	4.2	1,976	317	39	2.3	1,080	94
Preferred	7	0.8	562	91	6	0.9	412	64	12	1.6	352	49
Memorable	1	0.3	45	23	1	0.2	48	12	1	0.4	18	11
Trophy	0	---	---	---	0	---	---	---	0	---	---	---
Total	100		8,056		100		6,932		100		2,766	

	1989				1990				1991			
	RSD[a]	SE	N	SE	RSD[a]	SE	N	SE	RSD[a]	SE	N	SE
Stock	36	1.8	481	90	66	2.5	2,674	483	65	1.8	2,939	361
Quality	44	1.9	581	107	25	2.3	1,026	203	25	1.6	1,141	155
Preferred	19	1.5	247	49	8	1.4	327	81	8	1.0	350	61
Memorable	2	0.5	21	7	1	0.3	11	2	2	0.5	80	24
Trophy	0	---	---	---	0	---	---	---	0	---	---	---
Total	100		1,330		100		4,038		100		4,510	

	1992				1993				1994			
	RSD[a]	SE	N	SE	RSD[a]	SE	N	SE	RSD[a]	SE	N	SE
Stock	62	2.0	2,424	365	45	2.0	1,855	281	31	1.8	870	106
Quality	32	1.9	1,241	197	43	2.0	1,784	272	56	1.9	1,578	178
Preferred	5	0.9	197	45	10	1.2	450	83	10	1.2	293	45
Memorable	1	0.3	26	14	2	0.5	71	23	3	0.6	69	18
Trophy	0	---	---	---								
Total	100		3,888		100		4,160		100		2,810	

[a] "Stock" = 300-524 mm, "quality" = 525-654 mm, "preferred" = 655-899 mm, "memorable" = 860-1,079 mm, and "trophy" = 1,080 mm and larger (Clark and Gregory 1988).

APPENDIX G

Appendix G.-Estimated age composition and cohort abundance of the northern pike population (≥ 300 mm FL) in Volkmar Lake, 1985-1994.

	1985[a]				1986				1987			
	sample	Estimated			sample	Estimated			sample	Estimated		
Age	size	Proportion	Abundance	SE	size	Proportion	Abundance	SE	size	Proportion	Abundance	SE
2	0	0.00	0	0	2	0.04	384	307	45	0.04	319	87
3	0	0.00	0	0	11	0.26	2,110	1,244	213	0.22	1,500	359
4	0	0.00	0	0	11	0.17	1,394	738	242	0.24	1,648	374
5	90	0.31	1,238	137	23	0.16	1,262	316	278	0.23	1,611	284
6	59	0.21	840	112	19	0.11	924	231	215	0.15	1,021	152
7	49	0.17	677	99	14	0.10	824	267	95	0.06	439	73
8	42	0.13	525	86	11	0.07	535	169	47	0.03	176	33
9	47	0.09	377	65	5	0.03	243	111	35	0.02	115	24
10	36	0.05	179	35	7	0.04	282	107	17	0.01	51	14
11	26	0.03	120	27	1	0.01	49	49	16	0.01	42	12
≥12	14	0.02	64	11	1	0.01	49	49	9	0.01	10	5
Total	363	1.00	4,020	250	105	1.00	8,056	2,915	1,207	1.00	6,932	1,542

	1988				1989				1990			
	sample	Estimated			sample	Estimated			sample	Estimated		
Age	size	Proportion	Abundance	SE	size	Proportion	Abundance	SE	size	Proportion	Abundance	SE
2	2	0.01	13	9	25	0.04	51	14	35	0.10	411	97
3	27	0.06	175	34	28	0.04	58	15	99	0.29	1,162	227
4	75	0.18	486	60	68	0.11	140	30	51	0.15	599	130
5	124	0.29	804	80	128	0.20	263	52	51	0.15	599	130
6	118	0.28	764	77	172	0.27	354	68	53	0.15	622	135
7	50	0.11	324	48	108	0.17	222	44	31	0.09	364	89
8	18	0.04	117	28	64	0.10	132	28	15	0.04	176	54
9	5	0.01	32	15	25	0.04	51	14	6	0.02	70	31
10	7	0.02	45	17	12	0.02	25	8	2	0.01	23	17
11	0	0.00	0	0	5	0.01	10	5	1	<0.01	12	12
≥12	1	0.01	6	6	12	0.02	24	7	0	0.00	0	0
Total	427	1.00	2,766	177	647	1.00	1,330	240	344	1.00	4,038	354

	1991				1993				1994			
	sample	Estimated			sample	Estimated			sample	Estimated		
Age	size	Proportion	Abundance	SE	size	Proportion	Abundance	SE	size	Proportion	Abundance	SE
2	22	0.04	170	41	2	<0.01	16	12	13	0.02	55	16
3	185	0.32	1,428	192	72	0.14	585	106	67	0.10	282	45
4	130	0.22	1,003	143	82	0.16	666	118	70	0.11	295	46
5	62	0.10	479	81	109	0.21	886	149	182	0.27	767	96
6	80	0.14	618	98	95	0.19	772	133	134	0.20	565	75
7	48	0.08	371	68	42	0.08	341	70	83	0.12	350	52
8	34	0.06	263	54	50	0.10	406	80	56	0.08	236	39
9	14	0.02	108	31	30	0.06	244	56	27	0.04	114	25
10	5	0.01	39	18	15	0.03	122	35	14	0.02	59	17
11	4	0.01	31	16	7	0.01	57	23	10	0.02	42	14
≥12	0	0	0	0	8	0.02	65	23.9	11	<0.01	46	22
Total	584	1.00	4,510	541	584	1.00	4,160		667	1.00	2,810	

[a] Includes fish = 449 mm only.

APPENDIX H

Appendix H.-Estimated length-at-age of northern pike (≥ 300 mm FL) in Volkmar Lake, 1985-1994.

	1985			1986			1987		
	sample	Fork Length		sample	Fork Length		sample	Fork Length	
Age	size	Mean	SE	size	Mean	SE	size	Mean	SE
2	16	293	7	2	292	12	45	289	6
3	28	352	12	11	315	13	213	337	4
4	78	481	7	11	439	30	242	430	6
5	87	543	5	23	553	11	278	524	5
6	57	576	7	19	578	11	215	596	5
7	47	588	8	14	556	45	95	607	9
8	42	632	9	11	617	15	47	643	10
9	47	717	11	5	618	32	35	704	24
10	36	793	11	7	802	32	17	729	28
11	25	820	10	1	727	---	16	805	63
≥12	14	817	47	1	743	---	4	983	81
Total	477			105			1207		

	1988			1989			1990		
	sample	Fork Length		sample	Fork Length		sample	Fork Length	
Age	size	Mean	SE	size	Mean	SE	size	Mean	SE
2	2	318	13	79	318	2	19	315	2
3	27	362	12	232	362	3	105	355	3
4	75	443	8	185	417	5	64	405	5
5	124	512	8	207	511	5	28	497	8
6	118	565	8	256	559	5	30	552	8
7	50	619	13	157	602	7	17	600	13
8	18	642	23	84	682	11	5	646	21
9	5	627	25	35	723	19	4	643	34
10	7	737	38	15	786	23	1	743	72
11	---	---	---	6	767	48	---	---	---
≥12	1	972	---	15	838	13	3	870	14
Total	427			1,271			620		

	1991			1993			1994		
	sample	Fork Length		sample	Fork Length		sample	Fork Length	
Age	size	Mean	SE	size	Mean	SE	size	Mean	SE
2	39	325	3	202	310	2	13	355	10
3	281	369	3	897	356	2	67	397	6
4	194	434	5	849	432	3	70	461	8
5	89	491	8	836	517	3	181	543	4
6	102	565	7	797	572	3	134	589	4
7	71	611	10	451	603	4	83	602	6
8	51	643	14	258	652	5	56	625	10
9	26	721	23	157	708	9	27	675	19
10	13	808	24	96	778	9	14	780	26
11	7	814	65	55	807	21	10	836	22
>12	6	804	32	44	842	18	11	895	65
Total	879			4,642			666		

APPENDIX I

Appendix I.-Model selection tests from program CAPTURE (Deadman Lake, 1994).

DEADMAN LAKE 1994

Model Selection Tests from Program Capture

1. Test for heterogeneity of trapping probabilities in population.

Null hypothesis of model M(o) vs. alternate hypothesis of model M(h)

Chi-square value = 4.446 degrees of freedom = 1

Probability of larger value = 0.03498

2. Test for behavioral response after initial capture.

Null hypothesis of model M(o) vs. alternate hypothesis of model M(b)

Chi-square value = 219.264 degrees of freedom = 1

Probability of larger value = 0.00000

3. Test for time specific variation in trapping probabilities.

Null hypothesis of model M(o) vs. alternate hypothesis of model M(t)

Chi-square value = 163.021 degrees of freedom = 4

Probability of larger value = 0.00000

4. Goodness of fit test of model M(h)

Null hypothesis of model M(h) vs. alternate hypothesis of not model M(h)

Chi-square value = 168.275 degrees of freedom = 4

Probability of larger value = 0.00000

Test of model M(h) by frequency of capture

(frequencies less than 2t are not calculated.)

-continued-

Number of captures	Chi-square	d.f.	Probability
1	147.525	4	0.00000
2	24.651	4	0.00006

5. Goodness of fit test of model M(b)

Null hypothesis of model M(b) vs. alternate hypothesis of not model M(b)

Chi-square value = 7.736 degrees of freedom = 6

Probability of larger value = 0.25813

5a. Contribution of first capture homogeneity across time

Chi-square value = 4.058 degrees of freedom = 3

Probability of larger value = 0.25532

5b. Contribution of recapture homogeneity across time

Chi-square value = 3.678 degrees of freedom = 3

Probability of larger value = 0.29840

6. Goodness of fit test of model M(t)

Null hypothesis of model M(t) vs. alternate hypothesis of not model M(t)

Chi-square value = 368.823 degrees of freedom = 408

Probability of larger value = 0.91752

7. Test for behavioral response in presence of heterogeneity.

Null hypothesis of model M(h) vs. alternate hypothesis of model M(bh)

Chi-square value = 169.517 degrees of freedom = 7

Probability of larger value = 0.00000