Status of the muskellunge population at Lake Webster, Indiana - 2006 through 2009 -

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EXECUTIVE SUMMARY

Lake Webster is one of the Midwest's premier muskie fisheries and serves as brood stock for Indiana's muskie hatchery production. The population is based on annual fingerling stockings at 5/acre – higher than stocking rates in other states - prompting concerns that the rate may be too high to sustain good growth even though anglers have expressed interest in a higher size limit (40 inches) to improve quality. Since 2007, muskie fingerlings stocked in Webster have been fed live minnows for 30 days prior to release, down from 90 days prior to 2007. Therefore, long-term abundance, growth, and survival, as well as how the recent diet change might affect the muskie population are being monitored.

Altogether, 640 muskies (including recaptures) were caught during brood stock operations from 2006 through 2009 at the rate of 3.7/day/trap. During that time, the catch rate declined 48%. Individual muskies ranged in length from 16 to 47 inches, but size distributions shifted toward larger fish through 2008 before declining in 2009.

Annual survival of age-4 and older muskies was 78% and annual mortality was 22%. Annual mortality was 40% among age-5 and older muskies but 78% among age-8 and older muskies. Seber-Jolly estimates of muskie numbers varied from 1,461 in 2007 (1.9/ac) to 2,761 in 2006 (3.6/ac). The average annual estimate was 1,925 (2.5/ac).

Length distributions, mean length at age at time of capture, and growth increments differed between male and female muskies. Overall, males increased 4.2 inches from age-5 to age-8, whereas females increased 8.0 inches. Based on PIT-tag data, male muskies grew only 1-2 inches per year after 30 inches, while female muskies grew 1-2 inches per year after 36 inches.

Lake Webster continues to support a high-density population of adult muskies that may be near its carrying capacity. Increasing the size limit may only slow growth further, given the high density, current growth rate, and low exploitation of the population. A larger size limit might be useful if the stocking rate is reduced, but a lower density could result in a shortage of brood stock. Reducing the stocking rate at this time, however, would confound results of a study to examine the diet change and pose a risk to the fishery and brood stock capability.

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INTRODUCTION

Over the past three decades, Lake Webster in northeastern Indiana has developed into one of the Midwest's premier muskie fisheries. Success and maintenance of the fishery, however, is based on annual stockings of muskie fingerlings. Since 1981 over 70,000 fingerlings that typically ranged from 8.0 to 11.5 inches long have been stocked in the lake (Table 1). Fingerlings in the early years came from a variety of sources. In recent years, sexually-mature muskies captured at Webster during April served as brood fish for fingerling production within Indiana hatcheries. Approximately 20,000 fingerlings are now reared each year instate for stocking various waters, including Webster. The fingerlings are fed a dry-pellet diet while held in hatchery raceways but then fed live minnows for 30 days prior to release in the fall. Until 2007 fingerlings for Webster were held in earthen ponds for 90 days prior to release and fed live minnows. Due to costs and contamination of a hatchery by zebra mussels, fingerlings released in Webster since 2007 were switched to the 30-day diet of live fish prior to stocking. Although the change in diet is recent, how it might affect the long-term status of the muskie population at Webster, muskie fishery, and source for brood fish is being monitored.

Since 1998, hatchery production has been relatively stable, resulting in a typical stocking rate of five fingerlings per acre per year at Webster and at most other Indiana muskie lakes. The goal is to establish one adult (≥30-in) per acre. Other states generally stock fingerlings in the fall at lower rates (Esocid Technical Committee 2007). For example, Michigan stocks 11-inch fingerlings at less than 3/acre every two or three years. In Missouri, the largest fingerlings that can be produced in one season are stocked at 1/acre. In Wisconsin, stocking rates up to 2/acre are allowed but most are 0.5-1.0/acre. Ohio stocks muskie fingerlings at 1/acre. In light of these differences, there is concern that the stocking rate at Lake Webster may be too high. If true, over-stocking could lead to declines in muskie growth and shift size structure to smaller fish as the population reaches carrying capacity. A shift toward smaller fish may increase angler dissatisfaction since muskies are normally prized for their size. Likewise, over-stocking could result in an unnecessary loss of muskie fingerlings to cannibalism, greater oscillations in size structure, and excessive predation on other species.

Angler interest in muskie fishing at Lake Webster has increased considerably through time. Only 6-7% of Webster anglers targeted muskies in 1987 and 1990. By 1998 the percentage increased to 23%. In 2005 anglers who fished solely for muskies accounted for 54% of all Webster anglers. Another 6% fished for muskies in combination with other species (Pearson 2005). Muskie anglers made 6,400 fishing trips to Webster in 2005 and caught 2,215 muskies, nearly all of which were subsequently released. Although these figures indicate muskie fishing interest is high, there is little available information on the size of muskies in the lake. Some anglers have expressed concern that muskie size is declining. It is unclear if the decline is real or, if real, whether the decline is due to slow growth or higher mortality due to fishing as some anglers suggest.

To more fully examine possible changes underway within the muskie population at Lake Webster, the Division of Fish and Wildlife also increased the amount of data recorded from muskies captured during brood stock operations, including use of Passive Integrated Transponder (PIT) tags. Because retention is so high, PIT-tags are often used for long-term mark-recapture studies to evaluate mortality and growth (Nielsen, 1992). The purpose of this report, therefore, is to summarize the additional data obtained on muskie size, population density, age composition, growth, and mortality at Lake Webster from 2006 through 2009.

LAKE WEBSTER

Lake Webster, including the Backwater Area, is a mesotrophic 774-acre lake located at North Webster, Indiana, about equal distance from Fort Wayne and South Bend. The lake consists of five small natural basins that were impounded in the mid-1800s. Public access is available at a state-owned site along CR 550N. The lake lies in the Tippecanoe River watershed and drains 31,488 acres, 92% of which enters the Backwater. The outlet leaves the west side over a concrete structure and flows to James Lake. Maximum depth is 52 feet and average depth is 12 feet. A large percentage of the lake is less than 6 feet deep. Estimates of hydraulic retention time range from 49-82 days. Water clarity in recent years has averaged 10 feet in the spring and 7 feet in summer. During summer oxygen is present for fish in the top 10 to 15 feet of water. Dominant fish species in the lake include bluegill, yellow perch, gizzard shad, and largemouth bass.

METHODS

Three large trap nets were set in early spring from 2006 through 2009 primarily at three locations (Table 2, Figure 1). The number of trap-days ranged from 10 in 2006 to 23 in 2007 and averaged 15. Mean water temperatures varied from 45-48F per year. Each trap was usually fished every day and usually checked each day, although some were occasionally left for 2-3 days depending on weather, work schedules, and catch success. When catches declined at Site #1 in 2008 and 2009, the trap was moved elsewhere.

All trapped muskies were removed from the trap and taken to shore for processing where they were measured (total length), examined for sexual maturity, and scanned near the base of the dorsal fin for presence of a tag. PIT-tags had been placed in 844 muskies in 2005 (Pearson 2005) and were added to newly captured muskies each year thereafter. Dates and capture locations of each muskie were recorded. Tag numbers of all recaptured muskies were noted and each newly-captured fish was subsequently tagged before release. The anterior left pectoral fin ray was also removed from previously-unmarked fish for age and growth determinations. To prevent the possible spread of VHS to Indiana hatcheries, sexually ripe muskies were spawned on location at a facility outfitted for egg-taking and fertilization. "Green" muskies, those not ripe, and surplus males were released immediately after tagging. Fish used for spawning were released after egg or milt collection. Some muskies "gill-netted" within the lead died during the trapping operation and were noted accordingly.

To estimate the number of adult muskies in Webster each year from 2006 through 2008, the Seber-Jolly formula that accounts for tagged ratios through multiple years was used (Ricker 1975) where:

$$N_t = \frac{M_t}{\alpha_t} \qquad \alpha_t = \frac{m_t + 1}{n_{t+1}} \qquad M_t = \frac{(s_t + 1)z_t}{R_t + 1} + m_t$$

N_t = Number of muskies in the population at sample t

α_t = Proportion of muskies marked during sample t

M_t = Marked muskies in the population at sample t

m_t = Marked muskies caught in sample t

u_t = Unmarked muskies caught in sample t

n_t = Total muskies caught in sample t; $m_t + u_t$

s_t = Muskies released after sample t (n_t – no. of accidental deaths)

R_t = number of the s_t individuals released at sample t and caught again in a later sample

z_t = number of individuals marked before sample t, not caught in sample t, but caught in some sample after t.

To determine muskie age and growth, the pectoral fin rays were dried and cut into 0.06-inch sections using a Buehler® Isomet low-speed diamond blade saw. Sections were observed under a stereomicroscope and digitized using a Paxcam® digital microscope camera (MIS, Inc., 2007). After identifying the central lumen of the fin ray, annuli measurements were made using SigmaScan 5.0 (Systat software, 2007) perpendicular to the central lumen and extending edge-ward. Annuli measurements were then used to estimate back-calculated lengths at each age.

A variety of muskie catch statistics and trends in population characteristics were analyzed. To examine annual changes in muskie size, length-frequency histograms were constructed in 1-inch increments (x.0-x.9 where x = inch integer). Age-frequency distributions were also constructed and used to estimate total annual mortality of age-4 and older muskies (Robson and Chapman 1961). Differences in length-frequency distributions and mean length at each age at the time of capture between male and female muskies were also plotted, as were male and female differences in one-year growth increments among recaptured PIT-tagged fish.

RESULTS

The number of muskies trapped from 2006 through 2009 varied from 81 to 185 and averaged 140 (Table 2). Site #2 (Figure 1) provided the greatest total number of muskies (270) and the highest overall catch rate (4.4/day). Site #3 provided 249 muskies at an overall catch rate of 4.1/day. Site #1 provided fewer total fish and a lower catch rate (2.5/lift). Few muskies were caught at Site #4 and Site #5, although sampling at these two locations took place mainly at the end of the brood stock collection period. Altogether, 640 muskies (including recaptures) were caught over the four-year period at the rate of 3.7/day/trap. Peak catches generally occurred early during the trapping period at each of the three primary sites with the steepest decline at Site #2 (Figure 2). Muskie catch rates

at Sites #1, #2, and #3 were variable over the four-year period, although higher catch rates occurred at each site in 2006 and lower catch rates occurred at each site in 2007 (Figure 3). The overall trend in catch rate, standardized to include only the period beginning with the first trapping day through April 13 of each year, declined 48% from 2006 through 2009 (Figure 4).

Individual muskies trapped during 2006 from 2009, excluding fish recaptured within the same year, ranged in total length from 16 to 47 inches, although most were 28 inches or larger (Figure 5). Their minimum length was smaller than muskies caught in 1998 (Pearson 1999) or 2005 (Pearson 2005) and their maximum length was also smaller than those caught in 2005. Length-frequency distributions shifted toward larger fish during 2005 through 2008 as mean length increased from 33 to 36 inches and modal length increased from 30 to 34 inches. Mean length was 35 inches in 2009 and identical to mean length in 1998, although there were two modal peaks of 29 and 35 inches in 2009, compared to 37 inches in 1998 and only one modal peak in other years.

Although mean length of the muskie population increased, age composition appeared to shift toward younger fish, seemingly based on alternating years of weak and strong year classes (Figure 6). Age-6 muskies (2000 year class) dominated the catch in 2006, followed by age-5 muskies in 2007 (2002 year class), and age-4 muskies in 2008 (2004 year class). These peaks, however, were not sustained in subsequent years. For example, the strong 2000 year class present in 2006 (age-6) was not evident again in 2007 (age-7), nor was the strong 2002 year class present in 2007 (age-5) evident again in 2008 (age-6). No particular age group dominated the 2009 catch.

Based on the age composition of the catch each year, annual survival of age-4 and older muskies was estimated to be 78% and total annual mortality was 22% (Figure 7). Estimates of mortality, however, increased with age. Although not depicted in Figure 5, total annual mortality was 40% among age-5 and older muskies, 47% among age-6 and older muskies, 47% among age-7 and older muskies, and 78% among age-8 and older muskies.

Annual Seber-Jolly estimates of the number of muskies in Lake Webster (Table 3) varied from 1,461 in 2007 (1.9/ac) to 2,761 in 2006 (3.6/ac). The number present in 2008 was estimated to be 1,554 (2.0/ac). The average annual population estimate was 1,925

(2.5/ac). Beginning in 2006, when 20% of the catch included muskies previously tagged only in 2005, the proportion of previously tagged muskies in the catch since then has varied from 36% to 43%. Recaptured fish marked in the previous year only accounted for 7% to 11% in 2007 through 2009. Over all four years, recaptured muskies marked the previous year averaged 12% of the total catch per year. Numbers of muskies that were marked in 2005 and caught in subsequent years from 2006 through 2009 were relatively constant and made up 20%, 26%, 20%, and 22% of the annual catch, respectively.

Length distributions, mean length at age at time of capture, and annual growth increments differed between male and female muskies. Muskies larger than 36 inches were more likely to be females, while muskies less than 36 inches were more likely to be males (Figure 8). Only one muskie larger than 40 inches was a male. Length differences between the sexes were evident at age-5 and increased as fish got older (Figure 9). At age-5, males averaged 33.5 inches and females averaged 34.1 inches. By age-6, the difference was 2.2 inches with males averaging 34.6 inches and females averaging 36.8 inches. Males didn't reach legal-size (36 in) until some time during age-7. Overall, males increased an average of only 4.2 inches from age-5 to age-8, whereas females increased an average of 8.0 inches. The strongest evidence that demonstrated males did not grow as well as females came from one-year length increments based on PIT-tag data (Figure 10). For example, a 30-inch male muskie was likely to grow only 1-2 inches larger during the year, but a female muskie was likely to grow 4-5 inches. Male muskies typically grew only 1-2 inches per year after reaching 30 inches, while female muskies typically grew 1-2 inches per year after reaching 36 inches. Although sample size of muskies caught more than one year after tagging was small, four males tagged at 34 inches grew an average of only 0.5 inches over two years and four males tagged at 35 to 36.5 inches grew an average of only 0.5 inches over three years. In contrast, three females ranging from 43.5 to 44.0 inches when tagged grew an average of 1.2 inches over a four-year period. Excluding differences between the sexes, mean annual lengths at the time of capture for age-4 through age-8 muskies during 2006 through 2009 were 31, 34, 36, 38, and 42 inches, respectively. In comparison, mean lengths reported in 2005 were 29, 33, 36, 40, and 45 inches, respectively (Pearson 2005).

DISCUSSION

Based on data obtained from 2006 through 2009, Lake Webster continues to support a high-density population of adult muskies. Annual densities ranged from 1.9 to 3.6/acre, exceeded the original goal of 1/acre, and were above those of nearby states. For example, most Wisconsin muskie lakes contain less than one adult per acre (Simonson 2003) and 0.5/acre is considered average (Hanson 1986). Margenau (1999) described a Wisconsin population consisting of one adult (≥30 in) per acre as a high density population. In Bone Lake, Michigan a density of 0.8/acre was characterized as high (Siler and Beyerle 1986). In Michigan, the stocking goal is to establish an adult muskie density of one per 3 acres (Thomas et. al. unpublished). In Spirit Lake, Iowa, the goal is to provide only one adult per 7 to 10 acres (Larscheid et. al. 1999). Compared to these figures, Lake Webster may contain one of the densest populations of muskies in the Midwest.

Although density in Webster is above average, overall trap net catch rates declined by 47% since 2006. Likewise, the Jolly-Seber estimate in 2006 (3.6/ac) was 49% lower than a Schnabel estimate (6.9/ac) reported in 2005 (Pearson 2005). The estimate declined another 47% in 2007 (1.9/ac) before stabilizing in 2008 (2.0/ac). While these estimates indicate muskie numbers are lower than 2005, it is important to consider some assumptions of vulnerability. Each fish within a population being estimated must be equally vulnerable to the sampling gear. However, trap nets set from 2006 through 2009 were placed in the same locations each year and at fewer sites than 2005. This may have excluded a segment of the population not present at the trapping sites. Based on a study at Webster in 1998 and 1999, muskies tagged with ultrasonic transmitters generally demonstrated site fidelity during the spawning season (Pearson 2000). Catches also declined through the sampling period at each site and may indicate less willingness by muskies to enter the trap after it accumulated other fish and became coated with filamentous algae. Prior capture experience, i.e. "trap shyness", might also reduce the immediate likelihood of recapturing fish, although not necessarily in subsequent years as indicated by recapture rates that exceeded 20%. And lastly, differences in vulnerability based on gender can also bias population estimates. Although the overall sex ratio of males to females from 2006 through 2009, including recaptured fish, was fairly even at 198:186, males made up a much larger percentage of the catch (71%) in 2009.

Population estimates, coupled with information on growth obtained from recaptured PIT-tagged fish, indicate muskies may be near the carrying capacity of the lake. Annual growth increments of only 1-2 inches for males after reaching 30 inches and females after reaching 36 inches, although not unusually small, were less than expected given the lake's latitude, productivity and abundance of forage fish. In Michigan, annual growth increments after muskies reach 30 inches average 2-3 inches, although differences based on sex were not reported (Schneider and Merna 2000). Even so, muskies in Webster grew faster than muskies in Wisconsin, averaging 36 inches long within 6 years compared to 7-8 years in Wisconsin (Simonson 2003). Apparently enough forage is available to support the current number of muskies (>2/ac), despite concerns that high densities may lead to excessive predatory demand (Wahl 1999) or population imbalances (Margenau 1999).

Muskie anglers at Lake Webster have expressed interest in increasing the minimum size limit to 40 inches in hopes of shifting the size distribution to larger fish, despite data that indicate fishing mortality due to harvest is very low. In 2005, estimates were that anglers kept only 14 muskies from April through November but caught and released 2,201 muskies, including 816 that were larger 36 inches or larger (Pearson 2005). Only 27 muskies were removed in 1998 (Pearson 1999). Therefore, given the high density, current growth rate, and low exploitation, a larger size limit may only slow growth further and increase competition for forage. Larger size limits are most beneficial where densities are low and exploitation is high. Although some angler-released muskies may die due to stress and handling, a larger size limit would not prevent a fish from being caught and would have no impact on delayed mortality and no effect on total mortality. In contrast, a larger size limit might actually draw more anglers to the lake that are under the impression that their chance of catching a larger muskie is greater (Cornelius and Margenau 1999), which in turn could increase the number of muskies that are caught and die after release.

Even though increasing the minimum size limit at Webster would have little biological effect on muskie density and size structure, a larger size limit could be useful if the stocking rate is reduced. By reducing the number of muskies stocked each year, density would presumably decline, growth might increase, and size structure could shift toward larger fish, thus benefiting muskie anglers who want to catch larger fish. The

trade-off, however, would be fewer muskies to catch and might not be popular among muskie anglers who want to catch more fish. Nevertheless, fishing regulations are not based solely on biological justifications, but may be based on optimizing angler satisfaction (Jacobsen 1996). In a statewide review of Indiana fishing regulations in 2009, the Natural Resources Commission received 46 comments regarding muskie regulations, of which 28 (61%) indicated support for a larger limit (Indiana NRC, unpublished data). How strong or persistent that support would be if linked to a reduced stocking rate is not known. In time, however, opposition to reducing the stocking rate of 5/acre at Webster might be offset by increasing the number and geographical distribution of sites where muskies could be stocked without increasing hatchery production and its associated costs.

While there may be some advantages to a lower stocking rate at Webster, two additional factors should be considered before implementing a reduction: brood fish needs and the recent change in muskie diet. Ideally, a dense population of readily-available, older, sexually-mature muskies is preferred for brood stock. A lower density could result in a shortage of brood stock. At current population levels in Webster, the number of trapping days needed to capture sufficient brood stock varied from 10-23 and averaged 15. Presumably, more days, and therefore higher costs, would be required if density was lower. Perhaps the same number or fewer days might be needed to catch enough fish if more traps were used, but the possibility of trapping more days over a longer period is not an option since muskies are sexually-ripe for a relatively short time. More importantly, the recent reduction in the number of days that muskie fingerlings are fed live minnows prior to release from 90 days to 30 days could impact their survival and result in lower density at the current stocking rate. Although there has not be a meaningful study comparing survival rates of fingerlings fed minnows for 90 days versus 30 days (Pearson 2006), this opportunity now exists at Webster. Therefore, reducing the stocking rate at this time would confound the results of a study to examine the diet change and could pose a risk to the quality of the fishery and the lake's brood stock capability. Since it would probably take 10 years or more to adequately assess the long-term impacts of the diet change, no short-term change in stocking rate is warranted.

RECOMMENDATIONS

Adult muskies captured for brood stock provide a simple, cost-effective way to monitor muskie abundance and size structure, and should be sufficient to monitor the possible long-term effect of the 2007 shift in diet of stocked fingerlings. Therefore, biologists and hatchery personnel involved with annual muskie brood stock collections and stocking program at Webster should continue do the following:

1. Investigate the use of lighter, less-cumbersome traps that can be readily set in more locations while maintaining the catch efficiency of the current traps and trapping sites.

2. Continue to record data on date and trap location of each captured muskie, as well as data on fish length, sexual condition, brood stock utility, and fate.

3. Continue to scan muskies for the presence of a PIT-tag to obtain additional data on density and growth.

4. Continue to place additional PIT-tags in newly-captured muskies and collect fin-ray samples for age analysis.

5. Examine in closer detail the original and subsequent trap locations of recaptured tagged muskies during brood stock collection to document movement and site fidelity.

6. Continue to stock muskie fingerlings fed a 30-day diet of minnows prior to release at the rate of 5/acre each fall.

7. Postpone increasing the minimum size limit until the impact of the change in muskie fingerling diet is adequately assessed.

8. Consider repeating a more-intensive study of the muskie population and fishery on a periodic basis similar to studies done in 1998 and 2005.

LITERATURE CITED

Cornelius, R.R. and T.L. Margenau. 1999. Effects of length limits on muskellunge in Bone lake, Wisconsin. North American Journal of Fisheries Management 19:300-308.

Esocid Technical Committee, 2007. Introductory, maintenance, and restoration stocking of esocids. Second Edition. North Central Division, American Fisheries Society.

Hanson, D.A. 1986. Population characteristics and angler use of muskellunge in eight northern Wisconsin lakes. Pages 238-248 in G. Hall, editor. Managing muskies: a treatise on the biology and propagation of muskellunge in North America. American Fisheries Society Special Publication 15. Bethesda, Maryland.

Jacobson, P.C. 1996. Trophy and consumptive value-per-recruit analysis for a walleye fishery. North American Journal of Fisheries management 16:75-80.

Larscheid, J., J. Christianson, T. Gengerke, and W. Jorgensen, 1999. Survival, growth, and abundance of pellet-reared and minnow-reared muskellunge stocked in northwestern Iowa. North American Journal of Fisheries Management 19:223-229.

Margenau, T.L. 1999. Muskellunge stocking strategies in Wisconsin: the first century and beyond. North American Journal of Fisheries management 19:230-237.

Pearson, J. 1999. Muskellunge population characteristics at Lake Webster, Indiana. Indiana Division of Fish and Wildlife, Indianapolis, Indiana.

Pearson, J. 2000. Seasonal movements of radio-tagged muskellunge in Lake Webster, Indiana. Indiana Division of Fish and Wildlife, Indianapolis, Indiana.

Pearson, J. 2005. Current status of the fish community and quality of fishing at Lake Webster, Indiana. Indiana Division of Fish and Wildlife, Indianapolis, Indiana.

Pearson, J. 2006. Juvenile muskellunge electrofishing assessment. Indiana Division of Fish and Wildlife, Indianapolis, Indiana.

Robson, D.S. and D.G. Chapman. 1961. Catch curves and mortality rates. Transactions of the American Fisheries Society 90(2):181-191.

Schneider, J.C. and J.W. Merna. 2000. Manual of fisheries survey methods II: with periodic updates. Michigan Department of Natural Resources, Fisheries Special Report 25, Ann Arbor, Michigan.

Siler, D.H. and G.B. Beyerle. 1986. Introduction and management of northern muskie in Iron Lake. Pages 257-262 in G. Hall, editor. Managing muskies: a treatise on the biology and propagation of muskellunge in North America. American Fisheries Society Special Publication 15. Bethesda, Maryland.

Simonson, T. 2003. Muskellunge management update. Wisconsin Department of Natural Resources. Madison, Wisconsin.

Thomas, M.V., J.S. Diana, and K. Smith. Unpublished. Management plan for muskellunge in Michigan. Michgan Department of natural Resources, Lansing, Michigan.

Wahl, D.H. 1999. An ecological context for evaluating the factors that influence muskellunge stocking success. North American Journal of Fisheries Management 19:238-248.

Table 1. Number, minimum and maximum total length (inches), and source of muskies stocked in Lake Webster from 1978 through 2009.

Year	Number	TL (min)	TL (max)	Source	Diet
1978	48483	fry		Pennsylvania	Pellet
1981	350	10	12	Minnesota	Fish
1982	1622	8	17	Mixed	90d-fish
1983	300	10	12	Minnesota	Fish
1984	3240	6	11	DFW ponds	90d-fish
1985	350	10	12	Minnesota	Fish
1986	860	7	13	DFW ponds	90d-fish
1987	0				
1988	3294	5	8	DFW mixed	90d-fish
1989	1760	7	9	Fawn River	90d-fish
1990	1702	9	12	Fawn River	90d-fish
1991	3144	9	12	Fawn River	90d-fish
1992	1386	8	11	Fawn River	90d-fish
1993	1009	8	10	Fawn River	90d-fish
1994	836	7	11	Fawn River	90d-fish
1995	2370	8	10	Fawn River	90d-fish
1996	0				
1997	2746	7	10	Fawn River	90d-fish
1998	3870	9	12	Fawn River	90d-fish
1999	3870	10	12	Fawn River	90d-fish
2000	3870	10	13	Fawn River	Pellet
2001	3870	8	13	Fawn River	90d-fish
2002	3870	8	12	Fawn River	90d-fish
2003	3870	7	11	Fawn River	90d-fish
2004	3994	8	12	Fawn River	90d-fish
2005	3876	7	12	Fawn River	90d-fish
2006	3893	8	12	Fawn River	90d-fish
2007	3000	7	10	Fawn River	30d-fish
2008	3888	8	12	Fawn River	30d-fish
2009	3870	8	11	Fawn River	30d-fish

Table 2. Date, water temperature F, number, and locations (see Figure 1) of muskies captured at Lake Webster from 2006 through 2009, including recaptured muskies.

2006

Date	Site 1	Site 2	Site 3	Site 4	Site 5	Total	Temp F
4/4/06	0	16	8			24	43
4/5/06	12	2	10			12	45
4/6/06	13	13	3			16	51
4/7/06	3	9	10			19	44
4/8/06	7	6	13			19	46
4/9/06	2	10	8			18	45
4/10/06	4	8	3			11	46
4/11/06	3	13	6			19	47
4/12/06	2	12	11			23	48
4/13/06	3	5	3			8	57
Total	49	94	75			169	
Days	10	10	10			**Mean F**	47

2007

Date	Site 1	Site 2	Site 3	Site 4	Site 5	Total	Temp F
4/3/07	9	17	8			25	54
4/4/07	0	0	7			7	49
4/6/07	2	2	0			2	38
4/9/07	0	14	5			19	37
4/10/07	0	3	0			3	
4/13/07	1	0	3			3	38
4/16/07	1	1	3			4	40
4/18/07	10	0	4			4	43
4/19/07	5	0	0			0	44
4/22/07	1	5	3			8	56
4/24/07	1	1	1			2	55
4/25/07	0	0	4			4	54
Total	30	43	38			81	
Days	23	23	23			**Mean F**	45

2008

Date	Site 1	Site 2	Site 3	Site 4	Site 5	Total	Temp F
4/3/08	10	8	12			30	42
4/4/08	9	10	21			40	44
4/6/08	3	9	8			20	48
4/7/08	0	7	7			14	48
4/8/08	3	0	7			10	54
4/9/08	5	3	4			12	51
4/10/08	3	1	4			8	49
4/11/08	1	4	5			10	46
4/12/08	0	7	8			15	48
4/13/08		2	4	2		8	42
4/16/08		9	8	1		18	49
Total	34	60	88	3		185	
Days	10	14	14	4		**Mean F**	48

2009

Date	Site 1	Site 2	Site 3	Site 4	Site 5	Total	Temp F
3/31/09	2	19	8			29	49
4/1/09	2	6	1			9	49
4/3/09	0	9	12			21	46
4/4/09	0	8	3			11	46
4/6/09		13	9		1	23	45
4/7/09		9	6		0	15	45
4/8/09		2	3			5	44
4/9/09		3	1			4	42
4/10/09		3	0			3	46
4/13/09		1	5			6	45
Total	4	73	48		1	126	
Days	4	14	14		2	**Mean F**	46
Overall total	117	270	249	3	1		
Total days	47	61	61	4	2		
Number/day	2.5	4.4	4.1	0.8	0.5		

Table 3. Seber-Jolly population estimates of muskies in Lake Webster from 2006 through 2009, based on PIT-tagged recaptured fish (r) from specific years (t). Population estimates (N_t) were obtained by dividing the proportion of marked muskies (a_t) by the size of the marked population (M_t).

	Number of recaptures per year (r_t)				
	2005	**2006**	**2007**	**2008**	**2009**
Year of marking					
2005		44	29	37	28
2006			11	18	7
2007				13	6
2008					14
2009					
Total marked (m_t)	0	44	40	68	55
Total unmarked (u_t)	844	176	70	117	72
Total caught ($n_t = m_t + u_t$)	844	220	110	185	127
Total released (s_t)	844	203	97	180	121
Proportion marked (a_t)	0.000	0.204	0.369	0.371	0.438
Marked population size (M_t)	0	562	540	576	
Population estimate (N_t)		2761	1461	1554	

Figure 1. Location of muskie trapping sites at Lake Webster from 2006 through 2009. See Table 2 for site-specific catch data.

Figure 2. Number of muskies caught in trap nets (y-axis) at three locations in Lake Webster in relation to number of trapping days (x-axis) from 2006 through 2009.

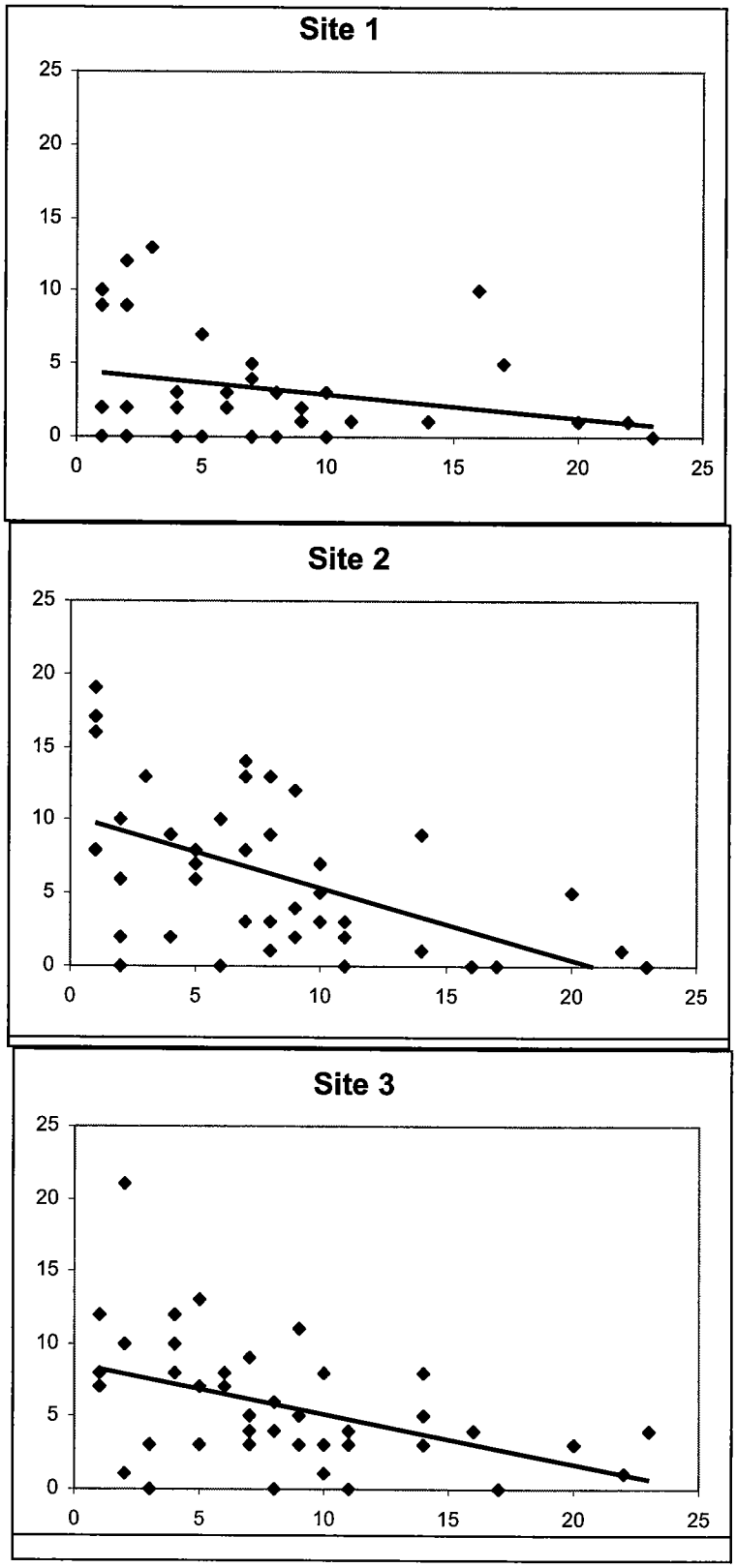

Figure 3. Number of muskies caught per day per year in trap nets at three locations in Lake Webster during 2006 through 2009.

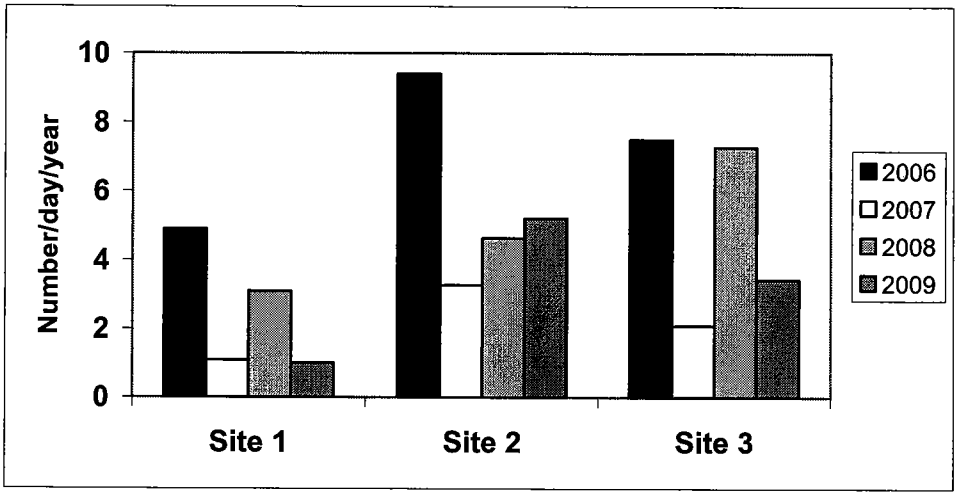

Figure 4. Overall trend in the number of muskies caught per day in trap nets at three locations in Lake Webster from 2006 through 2009. Catch rates were standardized for the period beginning with the first day of trapping through April 13 each year.

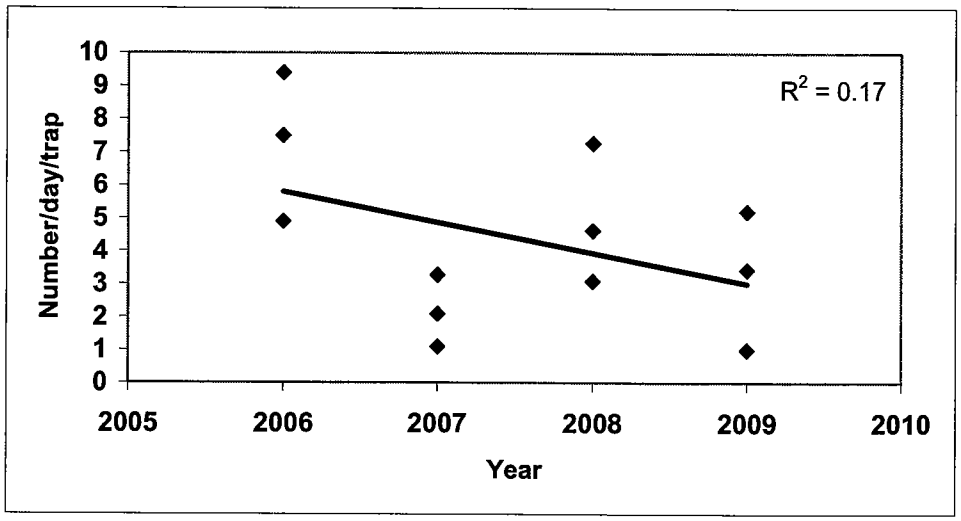

Figure 5. Frequency distribution (percentage) of muskies per inch captured at Lake Webster in 1998, 2005, and 2006 through 2009 (Pearson 1999 and 2005). Distributions do not include muskies recaptured in the same year.

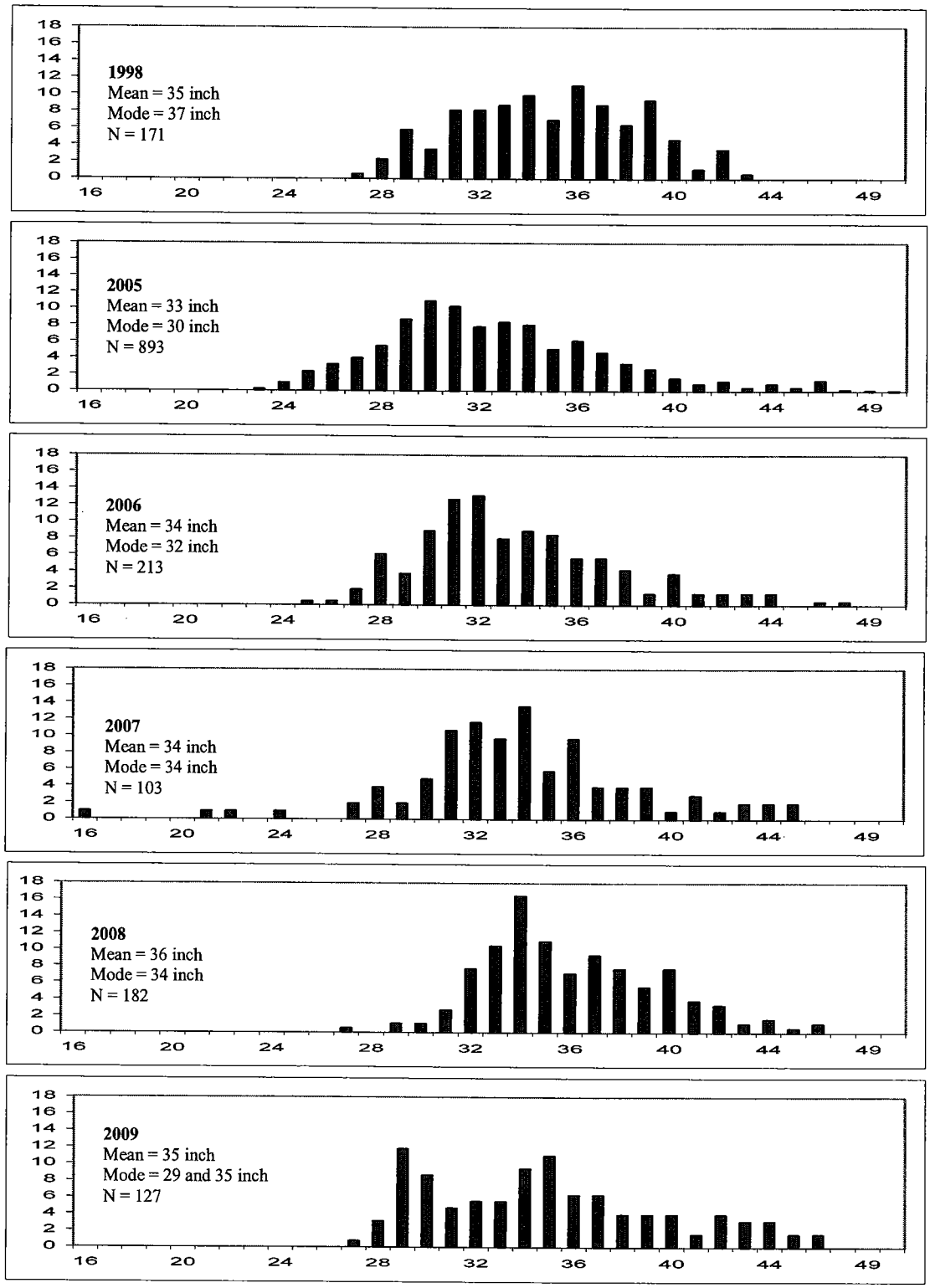

Figure 6. Age composition (percentages) of muskies captured at Lake Webster from 2006 through 2009.

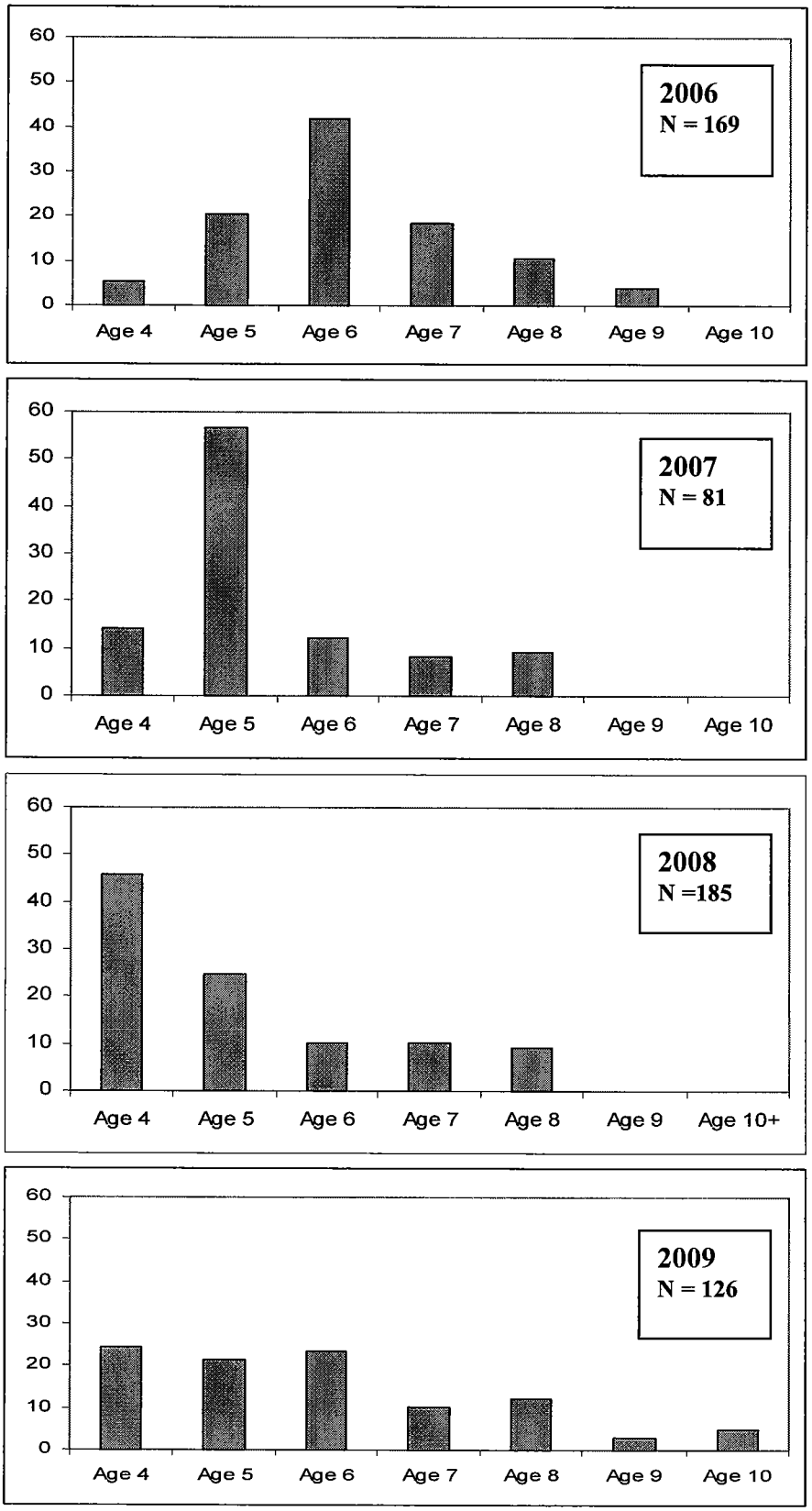

Figure 7. Age composition (percentages) and survival rate of age-4 and older muskies captured at Lake Webster from 2006 through 2009. Z = instantaneous rate of mortality, S = survival, M = mortality.

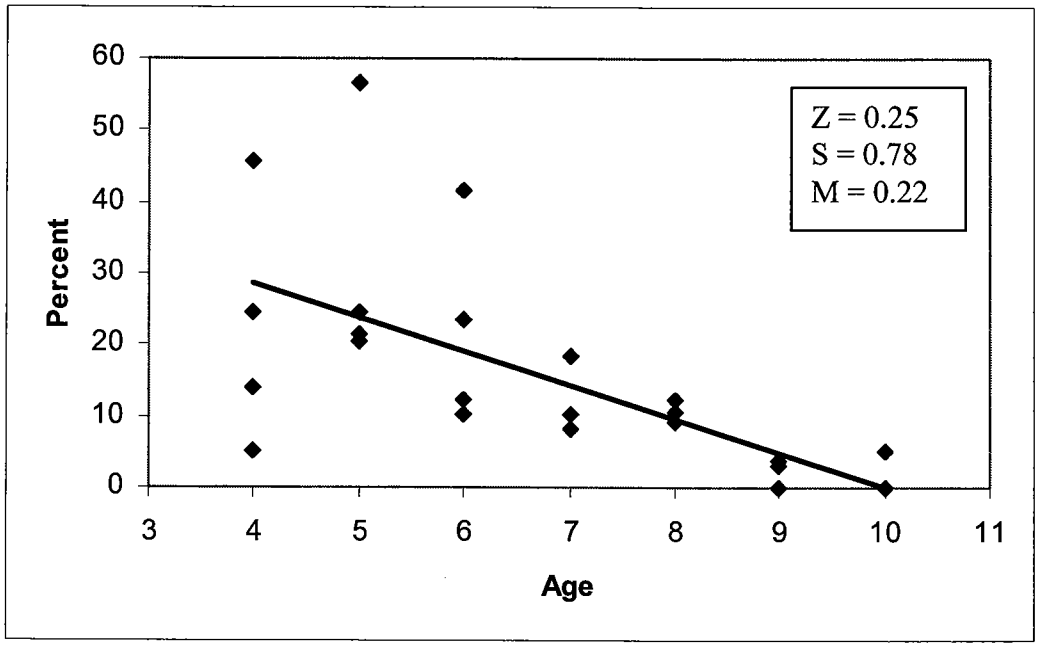

Figure 8. Length distribution of male muskies (dark columns) and female muskies (light columns) captured at Lake Webster from 2006 through 2009. Recaptured muskies were excluded.

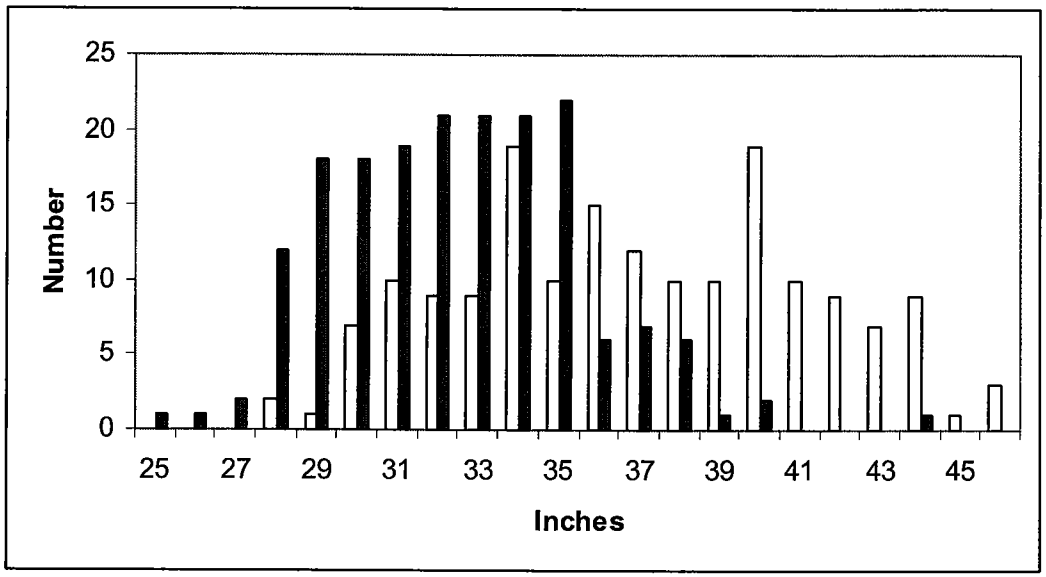

Figure 9. Average total length at time of capture of male muskies and female muskies at age-3 through age-9 at Lake Webster from 2006 through 2009. Recaptured muskies were excluded.

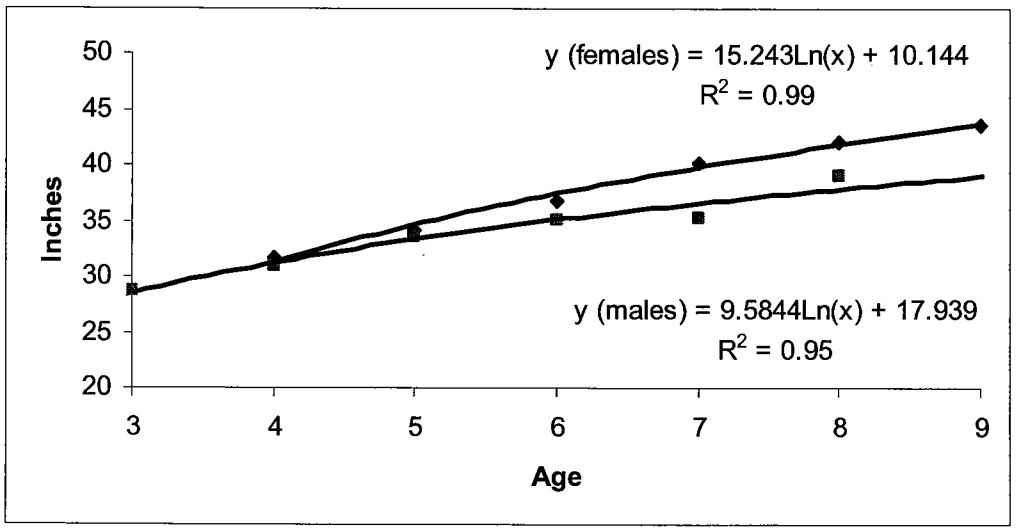

Figure 10. Growth increments in inches of male muskies (squares) and female muskies (triangles) within one year based on length at the time of PIT-tagging at Lake Webster from 2006 through 2009.