John M. Burr, Alaska Department of Fish and Game, Division of Sport Fish,
1300 College Road, Fairbanks, Alaska 99701

Maturity of Lake Trout from Eleven Lakes in Alaska

Abstract

This study was undertaken to estimate the length and age at which lake trout *Salvelinus namaycush* become sexually mature in a variety of lakes in Alaska. Probit analysis was used to estimate length and age at first, median, and complete maturity for lake trout from 11 populations. Ages at which lake trout matured among the populations were quite variable. Ages at 50% maturity for females ranged from 4.9 to 14.3 years. Males generally matured at a younger age than did females. The estimates of age at maturity were within the range of estimates reported from other areas. Estimates of length at maturity were less variable among the populations studied. Lengths at 50 percent maturity for females ranged from 348 to 481 mm FL and have a positive correlation to lake surface area. The estimates of length at maturity for lake trout from these Alaskan lakes were generally less than those reported from other areas. The effects of latitude, altitude, lake size and available forage on the sexual maturity of lake trout are examined. Length limit regulations applied to lake trout populations in lakes of greatly different surface area sizes, even within a small geographical area, are unlikely to be effective at providing adequate protection for lake trout from harvest through at least one spawning.

Introduction

The length and age at which lake trout *Salvelinus namaycush* become sexually mature are indicative of growth rates, productivity, and food habits of a population (Martin 1952), which in turn affects the reproductive potential and sustainable yield. In addition, populations composed of small, rapidly maturing lake trout may provide greater yield in numbers than do populations of later maturing larger fish (Martin 1966). Consequently, fishery management regulations designed to protect immature and first spawning fish in a population of lake trout through minimum length limits or the spawning stock with a slot limit must address differences in size at maturity. Information about maturity of lake trout and the criteria for classifying a fish as mature or immature is often not well defined (Healey 1978). Other than those fish which are in spawning condition, designating a fish as mature or immature in the field can be subjective and relies heavily on the experience of the examiner, particularly for younger and smaller fish (Martin and Olver 1980).

The age and length at sexual maturity is variable among populations of lake trout. Slow growing populations may not mature until ages 13-17 (Miller and Kennedy 1948). In most naturally reproducing populations, maturity does not occur until age 5 for males and ages 6-8 for females (Martin and Olver 1980). Females reared in experimental ponds (Surber 1933) or stocked (Hanson and Wickwire 1967, Olver and Lewis 1977) have occasionally been reported to spawn at age 4. Male lake trout from planktivorous populations were mature at age 4 with females mature at age 5 or older (Martin 1966, Donald and Alger 1986). Reported lengths at maturity vary from 180 mm for males and 200 mm for females in Sassenach Lake (Donald and Alger 1986) to lengths in excess of 600 mm (Seneca Lake, Royce 1943; Lake Superior, Eschmeyer 1955; and Lake Simcoe, MacCrimmon and Skobe 1970).

Little is known about the age and length at which lake trout mature in Alaska, the western extent of the native range of the species. Lake trout in Itkillik, Campsite, and Old John Lakes (68° latitude) mature between 10 and 14 years of age (otoliths) and between 340 and 430 mm FL (McCart *et al.* 1972; Craig and Wells 1975). Farther south (63° latitude), most lake trout in Paxson and Summit Lakes were mature at 7 to 10 years of age (scales), and at lengths of 450 to 490 mm FL (Van Wyhe and Peck 1968).

In 1987, harvest limits for lake trout were reduced in most areas of Alaska and a minimum length limit was adopted for some lake trout fisheries. The goal of the minimum length limit was to permit lake trout to spawn at least once prior to legal harvest. A single size limit (18 inches TL, 420 mm FL) was applied to roadside lakes ranging in size from 150 to more than 1,500 ha. This study was conducted to determine age and length at maturity for lake trout from a variety of lakes in Alaska and to evaluate if the length limit regulation provided adequate protection for lake trout from harvest through at least one spawning.

Methods

Data on length, age, and maturity were collected from lake trout in nine lakes in the Alaska Mountain Range in central Alaska and from two lakes in the Brooks Mountain Range of arctic Alaska (Figure 1). All lakes except Paxson Lake and Walker Lake are above tree line (Table 1). Lake trout were collected with small mesh, sinking, gill nets measuring 60 m X 3 m and with mesh size of 25 mm and 38 mm square measure. Samples were collected during mid June through September, 1987-1990. All fish were measured to the nearest mm fork length (FL) and were dissected to obtain otoliths (saggitae). Sex and state of maturity were determined by field inspection of gonads.

Females containing eggs with diameters greater than 1 mm and ovaries with stretched, fragmented mesovarium were considered mature (Martin and Olver 1980). The presence of retained eggs was used to identify females which had spawned previously. Females with tightly compacted and granular ovaries that contained eggs less than 1 mm in diameter were considered immature. Males with flattened testes with a maximum width of 3 mm or more were considered mature. Males with testes which were cylindrical in cross section and less than 3 mm in diameter were considered immature.

Ages were determined from otoliths. Whole otoliths were cleared in a solution of glycerine, ethyl alcohol, and water and viewed with a dissecting microscope with moderate power (12x-50x) under reflected light (Sharp and Bernard 1988). The hyaline or translucent bands were used as annuli and the annuli were counted from the nucleus outward (Nordeng 1961). When necessary, a portion of the lateral surface was removed by hand grinding on a carborundum stone. Some of the oldest samples (age 15 or greater) required additional preparation. The outer annuli in these samples were very closely spaced and were indistinct when the whole otolith was viewed laterally (sagital plane). In these cases, the otoliths were sectioned through the nucleus with the aid of a Dremel tool, and the otoliths were viewed in cross section. The nucleus of the otolith was clearly visible and the outer annuli were distinct.

The proportion of mature and immature lake trout of each sex from each population was determined for each age class and for 25 mm length categories. More than one age or length category generally contained mature and immature fish. Probit analysis was used to estimate the median age (AM_{50}) and length (LM_{50}) at maturity (Finney 1971; Tripple and Harvey 1991). The same samples were used for analysis of maturity at both age and length. The midpoints of the 25 mm fork length intervals were used for computations of maturity at length. Estimates of 5% and 95% maturity from the probit analysis were used for first and complete maturity. The numbers of lake trout of each sex sampled from each population are given in Figure 2.

Comparison of 95% fiducial limits from the probit analysis was used to determine if estimates of maturity were different between sexes and between populations. Estimates were considered different when there was no overlap in the fiducial limits.

Results

Estimates of age at which 50% of female lake trout matured (AM_{50}) in the eleven populations sampled ranged from 4.9 to 14.3 years (Figure 2). Males generally matured at younger ages than did females. However, because of overlap in the fiducial limits around estimates of AM_{50} for males and females, only males and females from Paxson Lake were considered statistically different. The estimated age at first maturity (AM_5) for females varied from 4.9 years in Paxson Lake to 11.0 years in Walker Lake (Figure 2). Estimates of first maturity for males were generally about one year earlier than for females but as with most of the estimates of AM_{50}, were not considered statistically different. Estimates of the age of complete maturity for females (AM_{95}) ranged from 7.7 years to 21.1 years. Complete maturity for males ranged from 7.5 to 20.1 years. Ages at which males and females were all mature were similar for each population except for Twobit Lake where males matured at a younger age.

Estimates of the length at which 50% of the female lake trout from these populations matured (LM_{50}) varied from 348 to 481 mm. The range of values for LM_{50} were relatively less than for AM_{50} (Figure 3). The coefficient of variation between the estimates of LM_{50} was 10.8 percent (sd, 44.1) compared with 29.5% (sd, 2.6) for estimates of AM_{50}. In general, the estimates of LM_{50} for females were not different between the populations studied. Lack of overlap in the 95% fiducial limits for the estimates indicates the LM_{50} for females from four of the largest lakes (Walker Lake, Fielding, Summit,

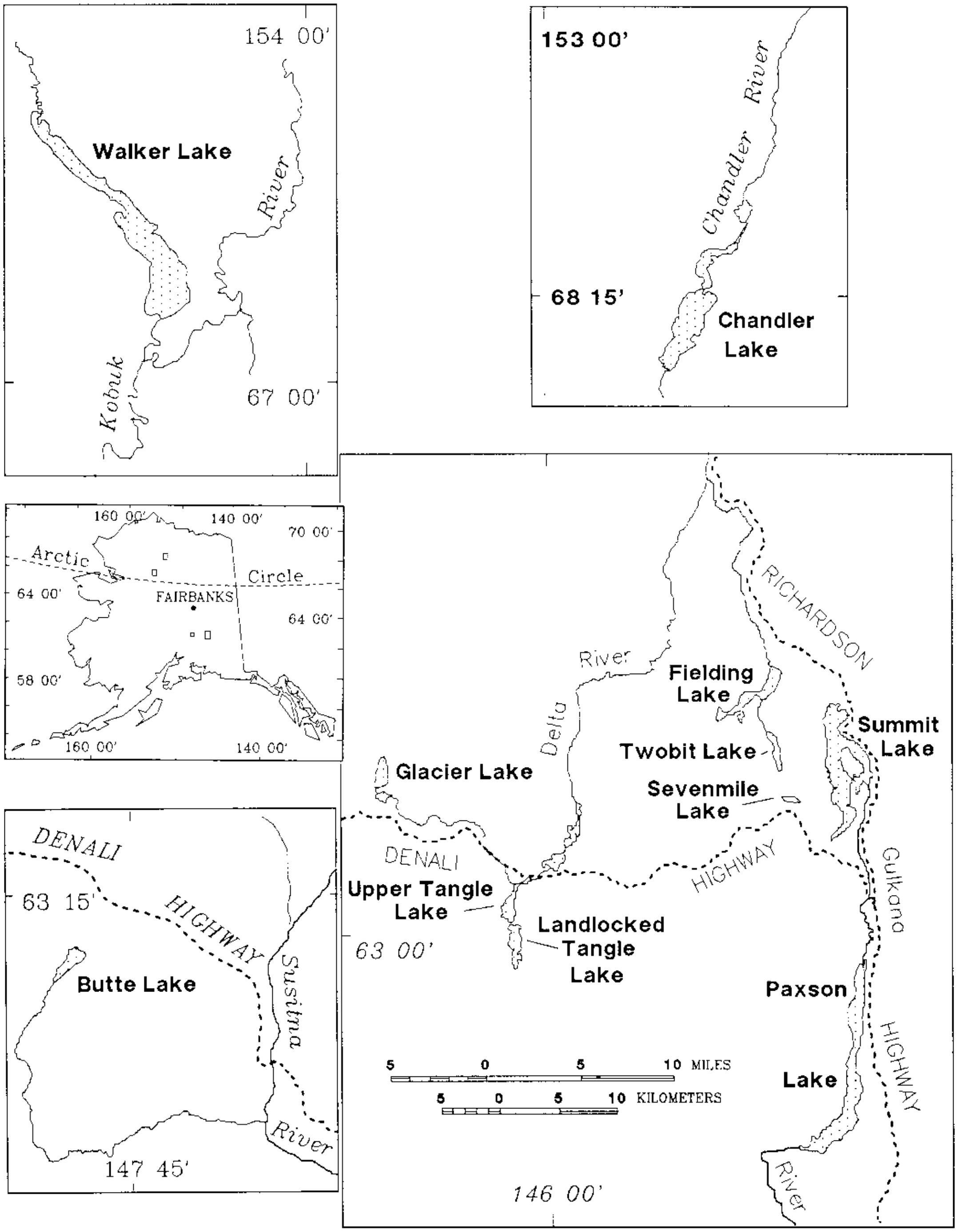

Figure 1. Study lakes in Alaska Mountain Range and in the Brooks Mountain Range.

TABLE 1. Location, elevation, surface area, maximum depth and fish species in the 11 study lakes.[1]

Lake	Location	Elevation (m)	Area (ha)	Maximum Depth (m)	Fish Species[2] Present
Sevenmile	63° 06′ N 145° 37′ W	925	33	12	BB,SC,LT
Paxson	62° 55′ N 145° 33′ W	778	1,575	26	BB,GR,HW,RW,SC,SS,LT
Summit	63° 08′ N 145° 33′ W	978	1,650	70	BB,GR,RW,SC,SS,LT
Fielding	63° 10′ N 145° 40′ W	906	538	24	BB,GR,RW,SC,LT
Upper Tangle	63° 02′ N 146° 03′ W	868	150	27	BB,GR,LS,RW,SC,LT
Butte	63° 10′ N 147° 50′ W	1,022	318	24	GR,RW,SC,LT
Glacier	63° 07′ N 146° 15′ W	1,124	177	27	BB,GR,RW,SC,LT
Landlocked Tangle	63° 00′ N 146° 06′ W	872	241	37	BB,GR,RW,SC,LT
Twobit	63° 08′ N 145° 38′ W	1,006	109	24	SC,LT
Chandler	68° 14′ N 152° 44′ W	914	1,300	22	AC,BB,GR,RW,SC,LT
Walker	67° 08′ N 154° 20′ W	206	3,800	122	AC,BB,CS,GR,LC,NP,LT,RW,SC

[1]Lakes ordered by increasing mean age to 50% maturity (AM_{50}) of lake trout.

[2]AC-*Salvelinus alpinus*, BB-*Lota lota*, CS-*Oncorhynchus keta*, GR-*Thymallus arcticus*, LC-*Coregonus sardenella*, LT-*Salvelinus namaycush*, LS-*Catasomus catasomus*, NP-*Esox lucius*, RW-*Prosopium cylindraceum*, SC-*Cotus cognatus*, SS-*Oncorhynchus nerka*.

Paxson) are larger than from most of the smaller lakes (Landlocked Tangle, Twobit, Glacier) but not all (Sevenmile, Butte). In most of the populations, male lake trout appear to mature at a smaller size (335-460 mm) than females. However, differences between males and females were seen only in the samples from Paxson, Summit, and Fielding lakes. The length at first maturity estimated by LM_5 for female lake trout ranged from 266 mm in Twobit Lake to 428 mm in Fielding Lake. No females encountered from any of the lakes were mature at fork lengths less than 290 mm. In most populations, the estimated length of first maturity for males appears to be less than for females but differences in the fiducial intervals were seen only for Paxson and Summit Lakes. Estimates of LM_{95} for females ranged from 420 mm to 600 mm and for males from 389 mm to 678 mm (Figure 3).

In Sevenmile Lake, all age 4 fish were immature and all age 6 fish were mature. Estimates for maturity were not obtained from the probit procedure due to the "knife-edged" maturity of lake trout in this population. Other methods are recommended for populations with this type of maturation (Trippel and Harvey 1991). First and complete maturity could not be estimated with the probit procedure from samples of either sex from Upper Tangle Lake and for females from Chandler Lakes. The 95% fiducial limit around the estimate of LM_{50} for males from Walker Lake ranged from 0 to 540 mm and is not shown in Figure 3. Small sample sizes were likely responsible for the failure of probit analysis to accurately predict the length and age of first and complete maturity for these populations (Figure 2, 3).

Discussion

The estimates of first and complete maturity from probit analysis were generally not different from values observed in the samples. The minimum observed values for age and length of first maturity fell within the 95 percent fiducial interval for 5 percent maturity most of the time (87% of the time for age, 88% for length). Similarly, values for complete maturity from the samples were generally within the 95 percent limits of AM_{95} and LM_{95} (ages 87.5%, lengths 95%). The point estimates for age and length at first maturity were often less than the youngest or smallest mature fish encountered in the samples. However, actual differences were observed only for males from Paxson and Chandler Lakes. The source of this potential bias is unknown but may be due either to errors in age determination or to incorrectly assigning mature status to immature fish. Similarly, estimates for the age and length at complete maturity predicted with probit analysis were often older and larger than encountered in the samples. Differences between estimated and observed age at complete maturity

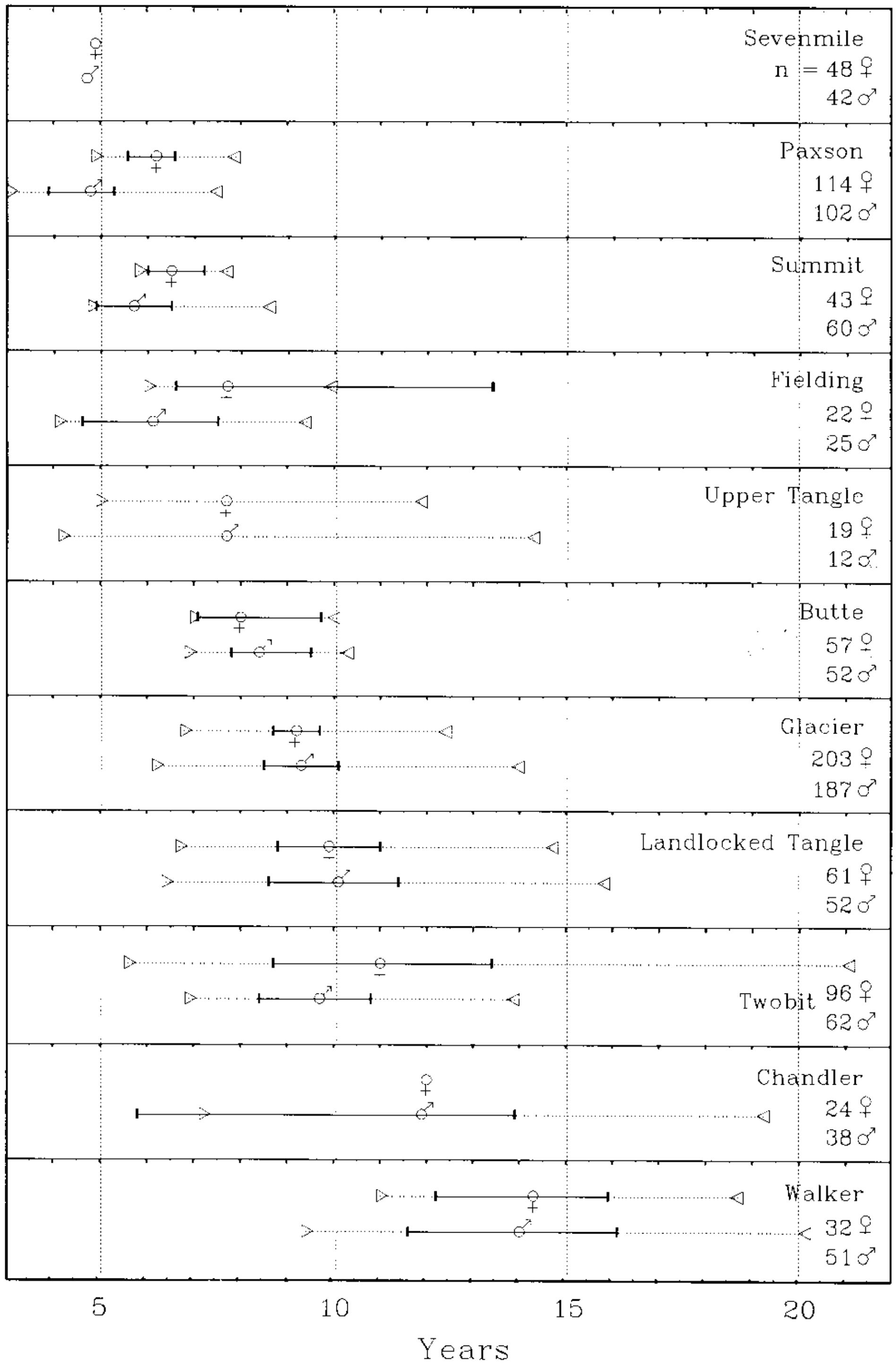

Figure 2. Age at maturity for 11 lake trout populations from Alaska. Age at 50% maturity is shown by sex symbol, fiducial limits around estimate are shown by solid bar. Ages at first and complete maturity are shown by open triangles and connected by broken line.

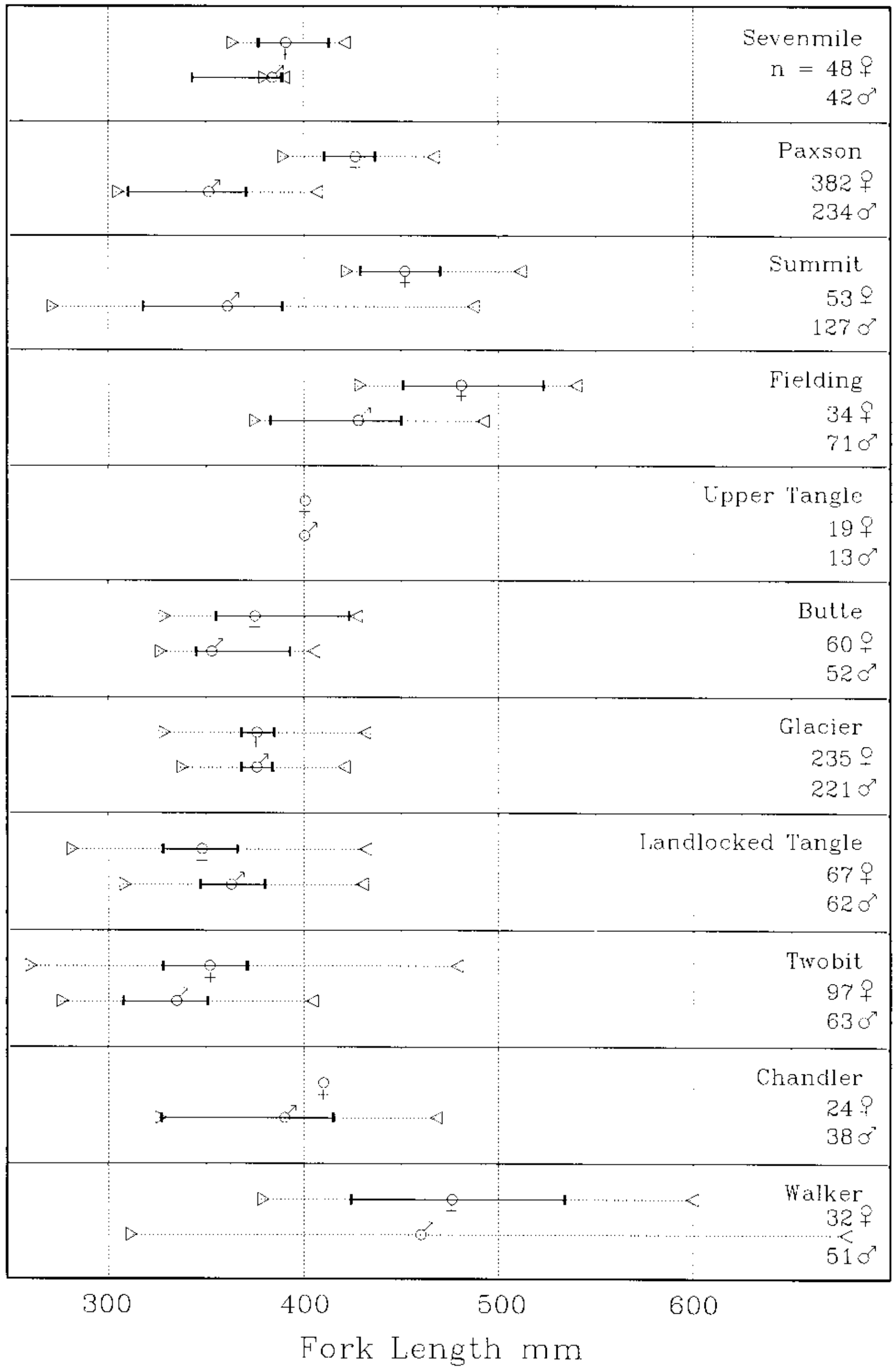

Figure 3. Length at maturity for 11 lake trout populations from Alaska. Length at 50% maturity is shown by sex symbol, fiducial limits around estimate are shown by solid bar. Lengths at first and complete maturity are shown by open triangles and connected by broken line.

were detected only for males from Chandler and Walker Lakes and for length at complete maturity only for males from Walker Lake. Failure to recognize as mature males that would not have spawned in the year of capture but that had spawned previously may be one source of this potential bias. Nonconsecutive spawning is common in northern populations (Martin and Olver 1980).

Estimates of the median age at maturity from the 11 Alaskan lake trout populations in the study (5-14 years) are within the range reported for the species (Healey 1978, Martin and Olver 1980, Donald and Alger 1986, Table 2). Length at maturity for lake trout populations in Alaska (335-481 mm) are generally less than those observed for populations farther south, but are within the range reported (Table 2). Differences in the rate of maturation in lake trout have been related to a number of environmental and biological factors such as latitude, altitude, growth, lake size, and available forage. Maturity is often related to the attainment of a given size and age such that fast growing lake trout may mature at an earlier age and the largest members of an age group are the first to mature (Martin and Olver 1980). For lake trout, the lower limit of age of maturity appears to be 4 years and at a length of approximately 200 mm (Table 2).

Maturity is expected to be slower in populations in high latitude and altitude lakes due to low available solar energy (Henderson *et al.* 1973) and slow growth (Healey 1978). In this study, estimates of median age at maturity were highest (12 and 14 years) for the two populations north of 67° latitude (Walker and Chandler Lakes). Reports of median age at maturity from high latitude populations in Alaska (Itkillik, Campsite, and Old John Lakes) and from northern Canada (e.g., Great Bear Lake, and Kaminuriak Lake, Table 2) are similar to results found at Walker and Chandler Lakes. In contrast, estimates of age at maturity from the nine lake trout populations investigated farther south (62° 55′ to 63° 10′ N) are consistently younger (AM_{50} 5.4-10.4 yrs) than estimates from populations residing in lakes at higher latitudes. The age at maturity for lake trout in these lower latitude Alaskan lakes are similar to results from Lake Tahoe in California and more temperate areas in Canada (Table 2). An increase in age of maturity with increase in latitude was reported by Falk *et al.* (1973) and Healey (1978). Length at maturity may also decrease with increasing latitude (Healey 1978). In this study, latitude is not inversely related to LM_{50}. The effect of elevation on length or age at maturity was not evident in the Alaskan lakes, but the range of elevation in this study was quite limited (Table 1).

Differences in age at maturity among populations have been attributed to differences in growth rates such that age and size of maturity are inversely related (Alm 1959, Hanson and Wickwire 1967, Paterson 1968). In contrast, Healey (1978) found that size and age at maturity were not correlated. In some populations (primarily planktivorous) small fish mature at young age (Martin 1966, Donald and Alger 1986). An inverse relationship between age and length at maturity between populations was not observed in the results from the 11 Alaskan populations (Figures 2, 3).

Lake size may also affect the length at which lake trout mature. Lake area is highly correlated with measures of community structure, catch and harvest, and numerous abiotic factors (Goddard *et al.* 1987). A significant correlation between lake area and LM_{50} for lake trout, and a positive relation between area and $L_{infinity}$ is reported by Payne *et al.* (1990). This means larger lakes contain populations with larger lake trout and correspondingly greater LM_{50}. In Alaska, length at 50% maturity for females was generally larger in the larger lakes; all estimates greater than 400 mm were from lakes larger than 500 ha. The overall smaller size at maturity for lake trout from lakes in the Alaska Range is likely a result of the small surface area of these lakes. Most lakes that have been studied in areas outside Alaska are relatively larger; Sassenach Lake, Alberta is smaller (8.1 ha), length at maturity is less (Donald and Alger 1986).

The effect that lake surface area has on the size at maturity for lake trout is significant in consideration of length limit regulations. The median lengths at maturity estimated as LM_{50} for the lakes in Alaska, indicate that the 420 mm FL length limit adopted in Alaska is unlikely to provide protection for first spawning lake trout in lakes larger than 500 ha (Figure 2). For lakes 320 ha and smaller in this study, the estimated median length at maturity was less than the length limit, and protection for lake trout through first spawning can be expected.

Available forage and diet may also affect the age and size of maturity for lake trout. Small lakes in Alaska are inhabited by few fish species (Table 1). In other studies, slow-growing lake trout which feed on plankton matured earlier than fast-growing

TABLE 2. Maturity schedules for lake trout from selected North American populations[1]

Lake	Fork Length at maturity			Age at maturity			Reference
	1st mature	50% mature	All mature	1st mature	50% mature	All mature	
Tahoe, Calif-Nev	335 m[2]	505 m	610 m	4 m	7 m	10 m	Hanson & Wickwire 1967
	422 f	531 f	620 f	4 f	8 f	11 f	
Louisa, Ontario	330 f	355 f	400 f	6 f	7 f	8 f	Martin 1951, 1956
Algonquin Park, Ont	250 m			4 m	6 b		Martin 1957, 1966
	330 f			5 f			
Opeongo, Ontario	380 f	457-500 f	480-580 f				Martin & Fry 1973
Squeers, Ontario		310 m	395 m	5 m	7 m	9-11 m	Ball 1988
	280 f	366 f	415 f	7 f	8 f	9-11 f	
Mistassini, Quebec				7 m		9 m	Dubois & Lageux 1968
	483 f	511 f		9 f	11 f		
Swan, Alberta				5 m			Paterson 1968
	479 f	479 f	525 f	6 f	6 f	7 f	
Sassenach, Alberta	180 m	180 m	200 m	4 m	4 m	5 m	Donald & Alger 1986
	200 f	220 f		6 f	7 f		
la Ronge, Sask	500 f	560 f	612 f	5 f	7 f	8 f	Rawson 1961
Great Slave, N.W.T.	484 b			8-9 f	8-10 f	14-19 f	Falk *et al.* 1974
Paxson, Alaska			450 b			7-9 b	Van Whye & Peck 1968
Paxson	304 m	351 m	405 m	3 m	5 m	8 m	This study
	388 f	426 f	467 f	5 f	6 f	8 f	
Kaminuriak, N.W.T.				13 m			Bond 1975
	545 f	610 f		19 f	27 f		
Hottah, N.W.T.	465 f	465 f	526 f	5 b	5 b	7 f	Wong & Whillans 1973
Landlocked Tangle	308 m	363 m	429 m	6 m	10 m	16 m	This study
	281 f	348 f	431 f	7 f	10 f	15 f	
Upper Tangle		400 m		4 m	8 m	14 m	This study
		400 f		5 f	8 f	12 f	
Sevenmile	379 m	348 m	389 m		5 m		This study
	363 f	391 f	420 f		5 f		
Glacier	337 m	376 m	421 m	6 m	9 m	14 m	This study
	328 f	376 f	432 f	7 f	9 f	12 f	
Twobit	315 m	335 m	405 m	7 m	10 m	14 m	This study
	327 f	352 f	479 f	7 f	11 f	22 f	
Summit, Alaska			500 b			8-10 b	Van Whye & Peck 1968
Summit	271 m	361 m	487 m	4 m	6 m	9 m	This study
	421 f	452 f	511 f	6 f	7 f	8 f	
Butte	326 m	353 m	405 m	7 m	8 m	10 m	This study
	328 f	375 f	427 f	f	8 f	f	
Fielding	374 m	428 m	491 m	4 m	6 m	9 m	This study
	428 f	481 f	540 f	6 f	8 f	10 f	
Keller, N.W.T.	500 b			11 f			Johnson 1972
Great Bear, N.W.T.	448 b				14 m		Falk *et al.* 1974
				10-11 f	14-15 f	15-20 f	
Walker	311 m	460 m	678 m	9 m	14 m	20 m	This study
	378 f	476 f	600 f	11 f	14 f	19 f	
Old John, Alaska	350 b		450 b	10 b		15 b	Craig & Bain 1975
Chandler	326 m	390 m	468 m	7 m	12 m	19 m	This study
	410 f		425 f		12 f		
Itkillik, Alaska	400 m		450 m	11 m	11-15 m	17 m	McCart *et al.* 1972
	450 f			14 f	15-17 f	20 f	
Campsite, Alaska		350 m			11 m		McCart *et al.* 1972
		350-400 f			13 f		

[1]Lakes ordered by increasing latitude.

[2]m—males, f—females, b—both sexes

piscivorous lake trout, and a change in diet from plankton to fish resulted in an increase in size and age of maturity (Martin 1966). The absence or unavailability of suitable-sized forage fish for lake trout resulted in a diet of benthic invertebrates, smaller fish (including lake trout), and plankton in many northern populations (Falk *et al.* 1973, Ball 1989). Such populations may become dominated by small, slow-growing or "stunted" individuals (Donald and Alger 1986, Carl *et al.* 1990). In contrast to the slow growing, early maturing, planktivorous lake trout described by Martin (1966), lake trout in Alaskan lakes with limited forage mature at small size and old age. Twobit Lake in Alaska has the lowest fish species diversity in the data set, and estimates of AM_{50} (11 yrs) and LM_{50} (352 mm) for female lake trout from Twobit Lake are older and smaller than for other populations in the Alaska Mountain Range. Alaskan lake trout populations in smaller lakes are generally benthivorous/planktivorous and species diversity and piscivory increases with lake size.

Acknowledgments

Funding for this study was provided by Federal Aid in Fish Restoration. I am grateful to David R. Bernard and Saree Timmons for assistance with the analysis and to John H. Clark and Margaret Merritt for support. Thanks to the U.S. Fish and Wildlife Service and Jeffery Adams for data from Chandler and Walker lakes. Special thanks for field assistance to Daniel Sharp, David Doudna, Tom Yeager, and Vera Kinzer.

Literature Cited

Alm, G. 1959. Connection between maturity, size, and age in fishes. Inst. Freshwat. Res. Drottningholm 40:123-137.

Carl, L., M.-F. Bernier, W. Christie, L. Deacon, P. Hulsman, D. Loftus, D. Maraldo, T. Marshall, and P. Ryan. 1990. Fish community and environmental effects on lake trout. Lake trout synthesis, Ontario. Min. Nat. Resour., Toronto. 47 p.

Craig, P. C., and J. Wells. 1975. Fisheries investigations in the Chandalar River region, northeast Alaska. Canadian Arctic Gas Study Limited (Calgary, Alberta), Biological Report Series. 105 p.

Donald, D. B., and D. J. Alger. 1986. Stunted lake trout from the Rocky Mountains. Can. J. Fish. Aquat. Sci. 43:608-612.

Eschmeyer, P. H. 1955. The reproduction of lake trout in southern Lake Superior. Trans. Amer. Fish. Soc. 84:47-74.

Falk, M. R., D. V. Gilman, and L. W. Dahle. 1973. The 1972 sports fisheries of Great Bear and Great Slave lakes, Northwest Territories. Fish. Mar. Serv. Rep. Ser. CEN/T-73-8: 100 p.

Finney, D. J. 1971. Statistical methods in biological analysis. 2nd ed. Charles Griffin & Company, Ltd., London. 668 p.

Goddard, C. I., D. H. Loftus, J. A. MacLean, C. H. Olver, and B. J. Shuter. 1987. Evaluation of the effects of fish community structure on observed yields of lake trout (*Salvelinus namaycush*). Can. J. Fish. Aquat. Sci. 44 (Suppl. 2):239-248.

Hanson, J. A., and R. H. Wickwire. 1967. Fecundity and age at maturity of lake trout, *Salvelinus namaycush*, in Lake Tahoe. Calif. Fish Game 53:154-164.

Healey, M. C. 1978. Dynamics of exploited lake trout populations and implications for management. J. Wildlife Mgmt. 42:307-328.

Henderson, H. F., R. A. Ryder, and A. W. Kudhongnia. 1973. Assessing fishery potential of lakes and reservoirs. J. Fish. Res. Bd. Can. 30(12/2):2000-2009.

MacCrimmon, H. R., and E. Skobe. 1970. The fisheries of Lake Simcoe. Ont. Dep. Lands and Forests, Fish Wildlife Branch, Toronto. 140 p.

Martin, N. V. 1952. A study of the lake trout, *Salvelinus namaycush*, in two Algonquin Park lakes. Trans. Amer. Fish. Soc. 81:111-137.

________. 1966. The significance of food habits in the biology, exploitation, and management of Algonquin Park, Ontario, lake trout. Trans. Amer. Fish. Soc. 95:415-422.

Martin, N. V. and C. H. Olver. 1980. The lake charr, *Salvelinus namaycush*. *In* E. K. Balon, ed. "Charrs: Salmonid fishes of the genus *Salvelinus*. D. W. Junk, Publishers. The Hague, Netherlands. 925 p.

Miller, R. B., and W. A. Kennedy. 1948. Observations on the lake trout of Great Bear Lake. J. Fish. Res. Board Can. 7:176-189.

McCart, P., P. Craig, and H. Bain. 1972. Report on fisheries investigations in the Sagavanirktok River and neighboring drainages. Report to Alyeska Pipeline Service Company, Bellevue, Wash. 170 p.

Nordeng, H. 1961. On the biology of char (*Salmo alpinus L.*) in Salangen, north Norway. I. Age and spawning frequency determined from scales and otoliths. Nytt. Mag. Zool. 10:67-123.

Paterson, R. J. 1968. The lake trout (*Salvelinus namaycush*) of Swan Lake, Alberta. Alberta Department of Land Forests. Fish and Wildlife Division of Research Report 2:1-149.

Payne, N. R., R. M. Korver, D. S. MacLennan, S. J. Nepszy, B. J. Shuter, T. J. Stewart, and E. R. Thomas. 1990. The harvest potential and dynamics of lake trout populations in Ontario. Lake trout synthesis. Ont. Min. Nat. Resour. Toronto. 72 p.

Olver, C. H., and C. A. Lewis. 1977. Reproduction of planted lake trout, *Salvelinus namaycush*, in Gamitagama, a small Precambrian lake in Ontario. J. Fish. Res. Board Can. 34:1419-1422.

Royce, W. F. 1943. The reproduction and studies on the life history of the lake trout, *Cristivomer namaycush* (Walbaum). Ph.D. Thesis, Cornell Univ., Ithaca, N.Y. 136 p.

Sharp, D., and D. R. Bernard. 1988. Precision of estimated ages of lake trout (*Salvelinus namaycush*) from five structures. N. Amer. J. Fish. Mgmt. 8:367-372.

Surber, T. 1933. Rearing lake trout to maturity. Trans. Amer. Fish. Soc. 63:64-68.

Received 5 April 1991
Accepted for publication 6 August 1992

Trippel, E. A., and H. H. Harvey. 1991. Comparison of methods used to estimate age and length of fishes at sexual maturity using populations of white sucker (*Catostomus commersoni*). Can. J. Fish. Aquat. Sci. 48:1446-1459.

Van Whye, G. L., and J. W. Peck. 1968. A limnological survey of Paxson and Summit lakes in interior Alaska. Alaska Dept. Fish & Game Inf. Leafl. 124:1-39.