Fishery Management Report No. 06-52

AYK Lake Trout Management Plan

by

John Burr

October 2006

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

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

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

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

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
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
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
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	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
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.
minute (angular)	'
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
variance	
population	Var
sample	var

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The Division of Sport Fish Fishery Management Reports series was established in 1989 for the publication of an overview of Division of Sport Fish management activities and goals in a specific geographic area. Since 2004, the Division of Commercial Fisheries has also used the Fishery Management Report series. Fishery Management Reports are intended for fishery and other technical professionals, as well as lay persons. Fishery Management Reports are available through the Alaska State Library and on the Internet: http://www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm. This publication has undergone regional peer review.

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ABSTRACT

Wild lake trout *Salvelinus namaycush* distribution in the Arctic Yukon Kuskokwim management area is described. As a background for this management plan, sport and subsistence fisheries that target the lake trout in this geographic area are characterized along with the known growth and population characteristics of the species. Management options are presented that would maintain harvests below maximum sustained yield levels (MSY), including harvest restrictions and special management waters.

Key words: Wild lake trout *Salvelinus namaycush,* Arctic Yukon Kuskokwim, sport catch and harvest, management plan, special management waters.

INTRODUCTION

The purpose of this document is to establish a plan for the management of sport fisheries on wild lake trout *Salvelinus namaycush* stocks in the Arctic, Yukon, Kuskokwim, and Upper Copper/Upper Susitna management areas of Alaska (Region III; Figure 1). This plan was adopted for the Upper Copper, Upper Susitna area by the Alaska Board of Fisheries (BOF) in December 2005. The document begins with a brief description of the Region's lake trout fisheries including current levels of participation and patterns of use. Next a brief review of the biology of the species is given to highlight the unique life history traits and constraints on the viability of the species. Management options are considered with the view of providing sustained yield from these stocks within the biological constraints of the species. Finally, a management scheme is provided with the goal of managing this species in an effective and uniform way across Alaska.

The objective of the management plan is to maintain harvests below maximum sustained yield levels (MSY). A general bag and possession limit of two lake trout is applied to all waters. As increasing harvests approach MSY, the plan outlines a prescription for increasingly restrictive regulations. The plan also provides for special management waters such as catch-and–release only or trophy fish management. The establishment of special management waters requires broad public support since some level of fishing opportunity will likely be sacrificed in order to provide the desired outcome.

DESCRIPTION OF THE FISHERY

The distribution of lake trout in Alaska represents the edge of the geographic range of the species and includes areas of very slow growth and low productivity. Lake trout are found throughout the high elevation lakes of the Brooks Range, the Arctic coastal plain, the Upper Tanana, Susitna and Copper River drainages, Bristol Bay and the Kenai Peninsula (Figure 1). The species is most frequently associated with deep, oligotrophic lakes in the mountains and is rarely found in lower elevations (Morrow 1980; McPhail and Lindsey 1970). The habitats occupied by the species have experienced little impact from land use or from industrial contaminants and are mostly still in pristine condition.

The fisheries for lake trout are primarily on wild stocks. In the limited instances where lake trout have been stocked, the purpose was to introduce the species to a new water body rather than to enhance or rehabilitate a wild stock. There are currently no lake trout in Alaska hatcheries. The fisheries for lake trout include subsistence and sport uses; there are no commercial fisheries for lake trout.

SUBSISTENCE FISHERIES

In Alaska, the subsistence use of lake trout is limited to stocks inhabiting waters situated near rural communities (Andersen et al. 2004; Gustafson 2004). Examples include harvest of lake trout from Chandler Lake by residents of Anaktuvuk Pass and from Old John Lake by residents of Arctic Village. While no quantitative measure of the annual subsistence harvest from these and similarly situated waters is available, the effect of these fisheries on lake trout stocks is believed to be minimal (Pedersen and Hugo 2005). In most cases the relatively small human populations target other fish species for subsistence; species that can be harvested with higher efficiency and in greater numbers (e.g., whitefish species, Pacific salmon). At present there is no regulation or limit on the subsistence harvest of lake trout from these remote water bodies.

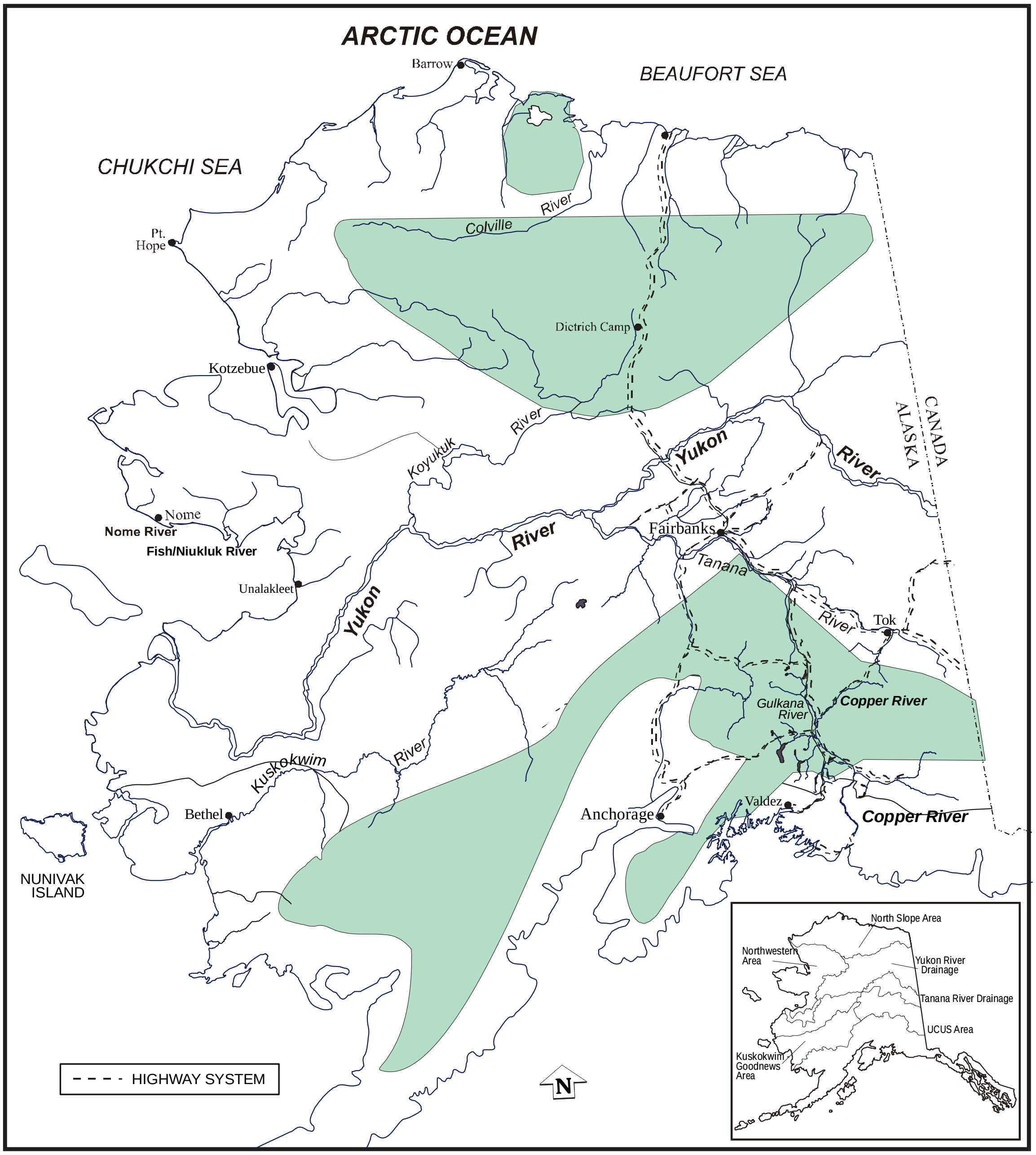

Figure 1.–Distribution of lake trout (Salvelinus namaycush) in Alaska indicated by shading.

SPORT FISHERIES

Lake trout support important recreational fisheries in Alaska. In nearly all areas the greatest amount of fishing effort directed at lake trout stocks is by sport fisheries. Sport fishing for lake trout in Alaska is popular throughout the year. Annual sport catch and harvest of lake trout is estimated by the Alaska Statewide Harvest Survey (SWHS), a mail survey of licensed anglers (Mills 1979-1994; Howe et al. 1995, 1996, 2001a-d; Jennings et al. 2004, 2006a-b, *In prep a-b;* Walker et al. 2003). The SWHS also estimates total fishing effort for all fish species for fishing sites but fishing effort directed at individual species is not generally available. The utility of the estimates is strongly dependant on the number of responses for a fishing site.

The sport harvest of lake trout in Alaska statewide has decreased during the last two decades while catch has remained relatively stable. Between 1986 and 1995 harvest averaged about 14,300 lake trout per year compared with about 7,400 per year in the recent 10 year period (Table 1). Estimates of total catch did not become available until 1990. Average catch for the most recent period (2001-2005) was 38,300 compared with 33,300 in 1996-2000 and 41,200 during 1991-1995. These results suggest that although the total catch of lake trout in Alaska has not changed substantially, the portion of the catch that is released has increased. Since 1993 the portion of the catch and harvest taken by Alaska residents vs. non-residents has been estimated. These results show that the lake trout fishery is primarily conducted by Alaska residents (Appendix A1). Residents account for approximately 80% of the harvest and 60% of the total catch.

Sport Fish Division's Region III includes the North Slope, the Yukon River drainage including the Tanana drainage, Northwest Alaska, the Kuskokwim drainages and the upper Copper and Upper Susitna drainages. The lake trout fishery within this region accounts for approximately half of the catch and harvest of the species in Alaska. Between 2001 and 2005, approximately 2,800 lake trout were harvested annually while the total catch averaged 16,600 (Table 2). Within the region most catch and harvest of lake trout comes from lakes in the Glennallen area (upper Copper and Upper Susitna drainages; Figure 2). In the last 5-year period, 61% of the total catch and 57% of the harvest came from this area. The Tanana River portion of the Yukon drainage accounts for the other large portion of the use of lake trout in the region; 27% of the harvest and 21% of the total catch of lake trout is on average from the Tanana area. Harvest and catch estimates for all survey areas in Region III are provided in Appendices A2-A7.

LAKE TROUT BIOLOGY

Lake trout in Alaska spawn during mid to late September. The fish are broadcast spawners and preferred spawning locations are along wave washed rocky shorelines often in less than 2 m of water. The age at which lake trout mature is variable; the age of maturity for females ($AM_{50,}$ age at which at least 50% are mature) estimated from 11 Alaskan lakes ranged from 5 to 14 years (Burr 1993). Faster growing populations in small lakes generally spawn at younger age than do fish in larger lakes or in lakes situated at higher latitude. Lengths of maturity ($LM_{50,}$ length at which at least 50% are mature) for the Alaska populations were less variable were ages, ranging from 16 to 20 inches (360-480 mm FL; Burr 1993). Once mature, lake trout in productive lakes may spawn annually or once every 2 or more years in more severe habitats (Burr 1991).

Table 1.–Alaska statewide freshwater sport fishing effort (all species) and total catch and harvest of lake trout.

	Effort - All Species		Lake Trout	
Year	Trips	Days Fished	Harvest	Catch
1977	0	828,153	17,469	
1978	0	897,485	12,010	
1979	0	946,858	15,477	
1980	0	1,052,787	18,041	
1981	0	952,941	18,316	
1982	0	1,123,756	20,550	
1983	0	1,146,817	20,304	
1984	1,014,635	1,256,092	16,925	
1985	1,034,656	1,326,070	18,473	
1986	1,150,519	1,433,618	21,463	
1987	1,156,481	1,453,529	15,209	
1988	1,316,125	1,588,940	17,193	
1989	1,190,877	1,522,273	17,070	
1990	1,211,471	1,586,903	12,602	42,443
1991	1,108,061	1,587,057	13,772	35,670
1992	1,183,360	1,626,916	12,525	43,295
1993	1,175,985	1,641,741	13,094	53,578
1994	1,187,084	1,673,268	11,374	45,107
1995	1,195,759	1,714,767	8,412	28,262
1996	883,061	1,262,580	9,772	34,781
1997	853,766	1,263,675	7,486	30,701
1998	761,062	1,153,277	5,985	22,807
1999	910,036	1,574,744	9,948	45,910
2000	993,448	1,649,833	6,292	32,176
2001	815,500	1,373,018	4,995	26,040
2002	821,324	1,403,777	7,109	43,218
2003	814,095	1,351,490	7,084	37,434
2004	856,236	1,466,586	7,934	44,051
2005	878,750	1,409,627	7,312	40,714
Ten-Year Average, 1996-2005	858,572	1,390,861	7,392	38,291
Five-Year Average, 2001-2005	837,181	1,400,900	6,887	38,291

Table 2.–Estimated freshwater sport fishing effort and total catch and harvest of lake trout from Region III.

	Effort - All Species[a]		Lake Trout[a]	
Year	Trips	Days Fished	Harvest	Catch
1977		174,646	9,968	
1978		190,058	6,533	
1979		183,362	8,872	
1980		210,784	10,356	
1981		202,385	11,158	
1982		253,744	13,826	
1983		245,089	11,309	
1984	191,189	238,176	9,935	
1985	179,024	232,505	14,040	
1986	172,122	243,871	10,029	
1987	204,127	265,964	7,834	
1988	216,477	277,454	9,007	
1989	204,377	288,357	10,752	
1990	194,092	292,690	7,246	24,223
1991	188,480	280,131	7,897	17,800
1992	166,521	249,547	6,442	21,343
1993	208,969	298,842	7,167	27,511
1994	198,284	291,415	5,889	20,405
1995	249,810	369,273	4,266	16,320
1996	178,924	262,749	3,838	18,486
1997	151,890	236,316	3,289	16,737
1998	140,288	224,092	2,657	13,348
1999	156,749	302,137	4,131	22,251
2000	132,313	235,917	3,174	15,229
2001	102,197	191,998	1,903	10,890
2002	115,330	217,753	3,362	21,198
2003	111,142	203,242	3,101	20,926
2004	113,662	215,863	2,244	15,029
2005	103,448	181,448	2,740	15,015
Ten-Year Average, 1996-2005	130,594	227,152	3,044	16,912
Five-Year Average, 2001-2005	109,156	202,061	2,670	16,613

[a] Region III estimates are the sum of estimates from the Glennallen, Tanana, Yukon, Kuskokwim, North West Alaska, and North Slope survey areas.

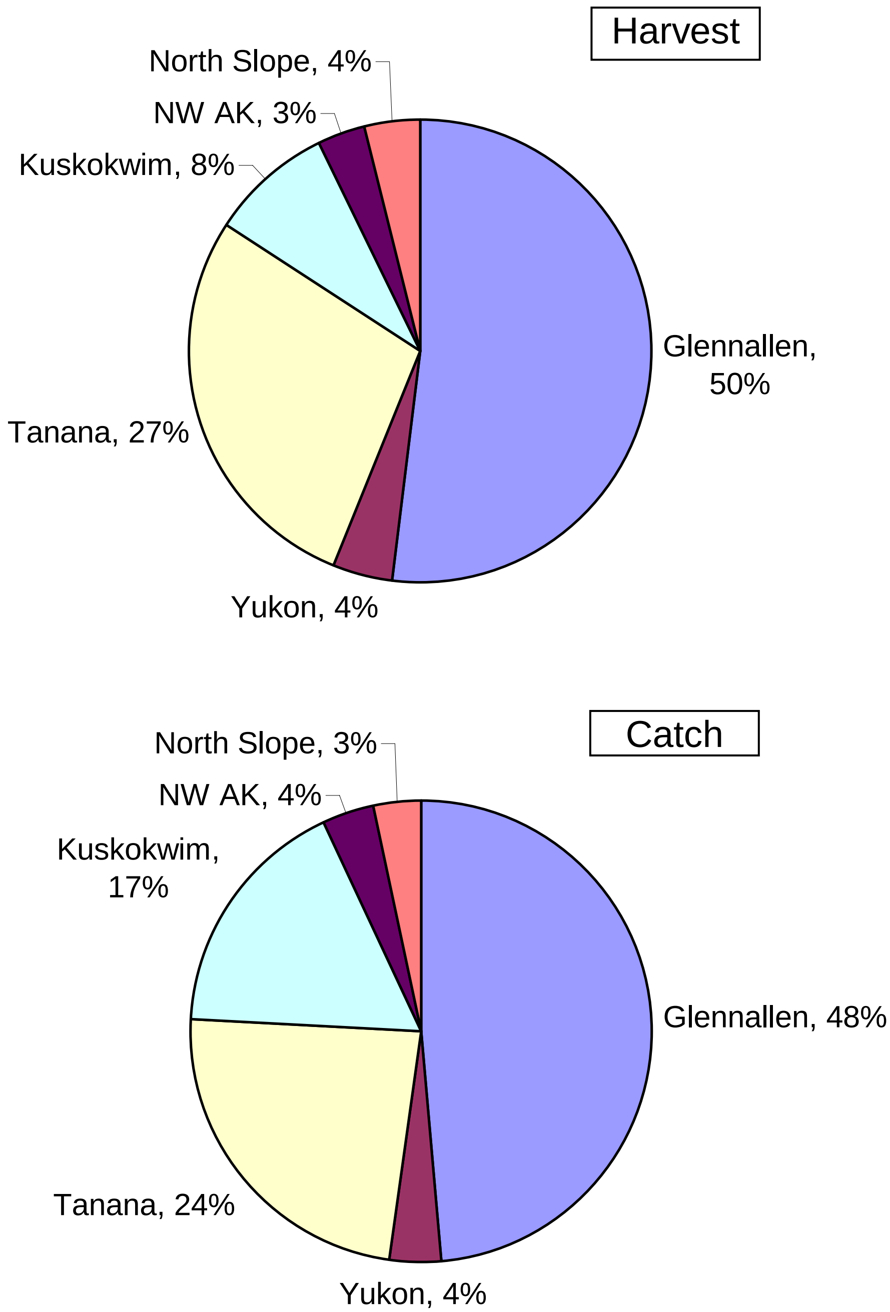

Figure 2.–Average harvest and total catch of lake trout from Region III, 2001-2005.

Growth of lake trout is generally slow. In most Alaska lakes studied, lake trout required on average more than 10 years to reach 18 inches (400 mm FL; Burr 1997). In other lakes, growth was markedly faster with most fish reaching 18 inches in approximately 5 years. Lake trout can attain old age and very large size. Maximum ages of lake trout sampled from lightly exploited populations in Alaska exceed 40 years and ages in excess of 30 years are common (Burr 1987). The presence of fish in old age classes indicates low annual natural mortality (Burr 1993). Large lake trout are present in most lakes and a number of trophy size lake trout (> 20 lbs) are taken in sport fisheries each year. The current Alaska record is 46 inches and 47 lbs. The maximum length that lake trout attain is positively correlated with length at maturity and with lake surface area (Burr 1997).

Estimates of abundance and density from populations in Alaska show that lake trout populations are sparse (Burr 1992, 1997). Density of lake trout of mature size varied from 0.6 fish/ha (1.2 kg/ha) to 32.8 fish/ha (33.5kg/ha). The seven lakes in the data set ranged in size from 33 to 1,600 ha and a significant inverse relationship between lake surface area and adult lake trout density was observed (Burr 1997).

The results from lake trout studies in Alaska including maturity schedules, growth rates and population densities summarized above are within ranges reported for the species from other North American locations (Burr 1993, 1997). Consequently, the wealth of information gained from long term, detailed studies of lake trout population dynamics from other areas is generally applicable to lake trout management in Alaska. Carl et al. (1990) reported that mean size, maximum size, and size and age at maturity of lake trout increase with lake size along with the number of predators and competitors. As described in a following section on estimating annual yield, the influence of lake surface area on the growth, mortality, and productivity of lake trout populations can be used in estimating annual yield expectations.

The biological characteristics of lake trout (slow growth, late maturity, low reproductive potential, long life expectancy, and low replacement rates) reflect adaptation to the cold infertile (oligotrophic) lakes that this species inhabits (Olver et al. 1991). The species has also proven to be extremely susceptible to seemingly minor changes in habitat (Martin and Olver 1980). The life history traits and the low productivity of the habitats that the species inhabits combine to make lake trout very susceptible to over-exploitation.

REVIEW OF LAKE TROUT MANAGEMENT IN ALASKA AND IN OTHER JURISDICTIONS

Sustainable yields for lake trout are low. In cases where the stock has been depressed recovery is very slow (Christie 1978; Martin and Olver 1980). Several studies have shown that a small amount of residual fishing pressure may be enough to prevent recovery of the stock (Olver et al. 2004). Because of this, the most effective management strategy of lake trout populations must seek to maintain harvests well within sustainable limits. A key part of effective lake trout management is to manage expectations of anglers.

ESTIMATING ANNUAL SUSTAINABLE YIELD

Lake trout occur in low densities inhabiting deep water and frequently in remote areas. Stock assessment research on these populations is inherently difficult and costly and the resulting estimates are frequently imprecise. In some cases research activities may have a larger impact on the population than do current levels of fishing activities. In lieu of direct stock assessments, researchers and managers are increasingly using models to estimate annual yield potential (YP) of lake trout based upon environmental variables. These models are based on the concept that the potential yield of lake trout is limited by available habitat and can be estimated from a quantitative measure of that habitat (Christie and Regier 1988; Evans et al. 1991; Marshall 1996). In Alaska two models, lake surface area (LA) and thermal habitat volume (THV) have been used to estimate annual yield (Szarzi and Bernard 1997).

Christie and Regier (1988) developed the thermal habitat volume (THV) model for estimating harvest potential of lake trout in large lakes (18,900–8,200 ha). THV was defined as the volume of water bounded by the 8^{o}C and 12^{o}C temperature isotherms averaged over the summer (June – September) period. Optimal levels of dissolved oxygen for lake trout occur in this temperature range. The model was adapted for smaller lakes (100–4,000 ha) by Payne et al. (1991) using temperature data from July only. These authors stressed that caution was needed when applying the THV model to waters outside of the set of relatively "good" lake trout lakes in Ontario. In smaller lakes and in those situated in more severe environments, critical elements of habitat other than the temperature regime will likely become limiting. Szarzi and Bernard (1997) applied the THV model to lake trout in Paxson Lake and Lake Louise in Alaska, but found that measurements of THV could vary by up to a factor of three from one year to the next, generating wide fluctuations in available habitat and consequentially potential yield estimates. Because of this variability and because many Alaska lakes do not thermally stratify, this model has not been adopted for managing Alaskan lakes.

Payne et al. 1991 and Evans et al. 1991 developed models that describe the relationship between lake area and observed annual yields of lake trout in Ontario. These lake area models use surface area as a measure of available preferred habitat (Marshall 1996). Lake surface area has a strong association with the growth, mortality, and productivity of lake trout populations (Carl et al. 1990; Payne et al. 1991). Mean size, maximum size, and size and age at maturity of lake trout increase with lake size along with the number of predators and competitors. As a result, lake surface area provides a surrogate factor representing a wide range of environmental and biological factors affecting lake trout populations. These authors demonstrate that lake trout yield varies inversely with lake area. On a per unit area basis, small lakes produce greater yields than large lakes although total harvests from small lakes are much smaller and small lakes are more vulnerable to overexploitation. The model given by Evans et al. (1991) is based on a larger and more diverse lake data set and is recommended (Olver et al. 1991):

$$\mathrm{Log}_{10}\, H = 0.60 + 0.72\, \mathrm{Log}_{10}\, A$$

where H = annual harvest in kilograms (kg) and,

A = lake surface area in hectares (ha)

The lake area (LA) model described above is currently used to set target harvest levels for Interior Alaska lake trout lakes. This model provides an excellent general guideline but, because the model is based on a large range of lakes and their observed sustainable yields, the predicted annual yields are inherently imprecise. The potential yield given by the LA model is treated as a threshold that should not be exceeded rather than a target level of exploitation.

Estimating Annual Harvest and Yield

The estimates of harvests of lake trout from the SWHS provide an estimate of annual yield of lake trout for each water body. These harvest estimates are compared to the yield potential predicted by the lake area model. Because harvest is estimated as number of fish and the yield from the lake area model is in terms of biomass (kg), the harvest estimate must be converted to biomass (kg) of lake trout. For Alaska lake trout stocks that have been directly studied, information on the size composition of fish present in the stock is used for this conversion. In cases where a minimum length limit regulation is in place, the conversion is based on harvest of legal sized fish only. For lake trout stocks that have not been directly studied, the size of fish harvested is estimated from information from other similarly sized lakes. Appendix B provides figures for converting annual harvest in terms of number of fish to biomass (kg) of fish for lakes of a range of surface areas under a range of minimum length limits.

Because of the inherent imprecision (variability) in the yield potential (YP) from the lake area model and the variability in and generally poor precision for lake specific estimates of harvest from the SWHS, it is important to emphasize the limitations of this monitoring scheme. Annual harvests that exceed the estimated annual YP should be used primarily as an indication that the stock may be in danger of excessive exploitation. For high use fisheries where harvest estimates are generally more precise, annual harvest in excess of the LA model target will likely trigger assessment of the population and/or a change in the fishing regulation. For remote, low use fisheries, two or more consecutive years of “excessive” harvest estimates would be needed to trigger research/management actions. Implementing drastic regulatory changes to curtail fishing opportunity based only on the model’s YP threshold target and results from the mail survey is inappropriate.

Methods of Controlling Exploitation Within Estimated Levels of Yield

The goal of fishery management is to ensure the perpetuation of fish stocks by controlling human induced mortality of fish. In sport fishery management the intent is to provide continuing fishing opportunity and to distribute the allowable catch/harvest fairly among participants.

Traditional harvest control measures include daily catch (bag) limits, size based regulations, gear restrictions and seasons. These measures are effective until they are undermined by large increases in the demand for recreational fishing. Several studies have shown that increases in fishing effort translate roughly into increased fishing mortality (harvest plus unintentional mortality; Goddard et al. 1987; Carl et al. 1990). The management challenge is to balance the desire for increased fishing opportunity with finite annual production. Because of our open access, common property system of resource management, it is very difficult to control high levels of angling effort short of closing lakes to fishing (Christie 1978). Balancing increasing demand with a clearly finite supply is particularly challenging with lake trout. As stated previously, it is critical to manage the expectations of anglers.

In Alaska, current levels of angling effort on lake trout stocks are generally moderate and the traditional harvest control measures are expected to effectively regulate harvest. The application of each of these measures to the management of lake trout in general is summarized below along with the current application of the techniques in Alaska waters.

Daily Harvest Limits

This is the most common form of regulation that applies to the efforts of individual anglers. While often used as a harvest control measure, the effect of daily harvest limits is to apportion the total harvest among anglers. Because most anglers do not fish each day during the open season, the harvest is distributed throughout the season and among anglers by limiting the harvest of the more skillful anglers. If the daily harvest limit is small and the number of participants is moderate, the total annual harvest will, in theory, remain within allowable annual yield.

In lake trout fisheries, daily bag limits typically range from 1 to 4 fish per day with most daily limits of either 2 or 3 lake trout (McKee and Thompson 2004). These limits are often combined with either a minimum or maximum length limit. For lake trout populations in Interior Alaska the daily catch limit is currently 2 per day in most areas.

Size-Based Regulations

Size limit regulations exert biological control of the harvest by determining or manipulating the size (and age) of recruitment and the entry of year classes into the fishery. This type of regulation has also been used in an attempt to attain certain social goals such as apportioning the catch of large fish among participants.

Hooking Mortality

Size based regulations infer the release of live fish. The use of this type of regulation to achieve either a social or biological goal is based on the assumption that the survival rate of released fish is sufficient to ensure the sustainability of wild fish. Therefore, the use of size-based regulations requires considering the unintentional mortality of released fish.

Numerous studies have attempted to estimate hooking mortality of lake trout. In all of these studies mortality was evaluated by holding the fish in net pens or tanks for a period of 24 hrs or longer (e.g., Falk et al. 1974; Loftus 1988; Dextrase and Ball 1991; Persons and Hirsch 1994). Studies in large lakes during spring and summer have shown hooking mortality rates for lake trout in the range of 7% (Great Bear and Great Slave lakes, Northwest Territories; Falk et. al 1974) to 14.9% (Lakes Huron, Michigan, and Superior; Loftus 1988). Most studies conducted during winter reported higher levels of mortality partly due to the more prevalent use of live and dead fish bait. Persons and Hirsch (1994) examined hooking mortality of lake trout angled through the ice and reported that lake trout caught with dead bait and then released had a mortality rate of 32% after 6 days, whereas lake trout caught on artificial lures (jigs) and then released had a mortality of 9%. Seventy percent of the lake trout caught by dead bait were hooked in the gills or gut, compared to 9% of the lake trout caught by jigging. In a mortality study using minnows as bait on still lines through the ice, Dextrase and Ball (1991) reported an overall hooking mortality of 10%. In this study, all lake trout that died after release were hooked deep in critical areas and showed signs of bleeding. While none of these studies provide universally applicable estimates of hooking induced mortality, it is evident that fish caught with bait are more often critically hooked and therefore are less likely to survive.

Maximum Size Limits

Maximum size limits require that all fish larger than a designated size be released. This type of size limit can protect native brood stock or counter a decline in the size and age of the spawning stock if the designated size is sufficiently small. This form of regulation has been successfully used to rebuild the age composition for other species (e.g., cutthroat trout *Oncorhynchus clarki*; Greswell 1980). The concept is that the fish are vulnerable to harvest for a short period before reaching maturity and fishing mortality is focused on a life stage that may be better adapted to withstand high levels of exploitation. This type of maximum size limit has not been widely used for lake trout. The slow growth of lake trout makes them vulnerable for a relatively longer time than faster growing species. Also the large size potentially attained by lake trout attracts many anglers. Eliminating all opportunity for harvesting larger fish would likely be resisted by the fishing public.

Modified maximum size limits where anglers are permitted to harvest only one fish over the designated size are more common in lake trout management. This modification provides some protection for mature brood stock, maintains angling opportunity and the opportunity to harvest a limited number of larger fish. This type of regulation is often part of a protected slot limit where no fish may be retained. The Yukon Territories have designated a protective slot limit including a large modified maximum size limit (2 fish total, release all fish 26-39 inches, only one over 39 inches) for their "high quality" waters. The goal is to preserve fishery quality and to maintain the presence of very large (and presumably old) lake trout. This regulation seeks to highlight the importance of large lake trout as a "keystone predator" and their effect on the fish community (Toews et al. 2004). The use of modified maximum size limits may be a useful regulatory strategy where anglers target large lake trout or where establishing a trophy fishery is a management objective. This type of regulation has generally received public support in jurisdictions where it has been used. However the long term effect of this type of regulation has not been well studied.

Minimum Size Limits

Minimum size limits, requiring the release of all fish less than a designated size, are commonly used to regulate harvest in fish populations. For lake trout, the purpose is generally to permit fish to mature and spawn at least once before becoming susceptible to harvest. The release of fish of sub-legal size will in theory increase the recruitment of young (small) fish into older (larger) age groups and increase the standing stock of spawning fish. Angling opportunities are maintained with this type of regulation although anglers desiring to keep and eat small pan-sized lake trout are prohibited from doing so.

Minimum length limits have often not been effective in controlling lake trout harvest because the length limit adopted was too small to effectively protect immature and first time spawning fish (Olver 1988). When minimum length limits are sufficiently large, reduced levels of harvest have been observed particularly where the limit served to protect fish through at least two spawnings (Barnhart and Engstrom-Heg 1984; Smith et al. 1988).

Potential negative effects from the use of minimum length limits have been observed. This regulation focuses most fishing mortality on fish in older age and size classes. The result may be that fish less than the legal size limit will become proportionally more abundant ("stockpiling"). In wild lake trout populations, large fish represent many year classes. If harvest on large fish is excessive, there is the potential for eliminating the built-in resiliency of the population to environmentally caused recruitment failures. The repeat spawning of individual fish over their lifetime serves to average out mortality during early life stages (Giesel 1976). If large fish disappear due to angling, any favorable increase in growth, or survival of younger age classes would be unlikely to offset the loss of old large fish.

The use of length limit regulations for lake trout in Alaska was reviewed by Burr (1991). Currently in Alaska the use of minimum length limits for lake trout is constrained to a few medium to large sized lakes (200 – 6,500 ha) located along the road system (Appendix C). Minimum length restrictions have generally been structured to allow fish to spawn at least once prior to being harvested. The goal of the minimum length limits has been to reduce harvest by delaying the entry of year classes into the fishery rather than to manipulate the size composition of the standing stock. Given this goal, the implementation of a length limit regulation should generally be coupled with the prohibition of the use of bait.

Seasons

The use of a fishing season with fixed open and closed dates serves to limit fishing opportunity. For lake trout, closed seasons have been used to protect fish during spawning (fall closures), or during other periods when fish are especially vulnerable. Examples include closures during spring break-up or during the winter ice covered season for smaller lakes located near large human population centers (Olver et al. 2004).

The length of the open season is in general inversely related to the intensity of management needed. In Saskatchewan and Manitoba open seasons are typically long with only brief closed periods in April/May. In Ontario, long open seasons are also common but portions of the winter season are closed. In most of New York, Minnesota and Quebec winter fishing is not permitted.

Winter fishing is a contentious issue in lake trout management. Studies have found substantially increased fishing effort, catchability and harvest in winter fisheries. Lake trout populations in small lakes (composed of smaller sized individuals maturing younger and at smaller size) are particularly vulnerable to winter fishing. Ryder and Johnson (1972) suggest that this is because anglers can locate and decimate the concentrated schools lake trout tend to form in winter. Also, anglers in winter tend to catch a higher proportion of small fish (both immature and mature) than in open water fisheries (Martin 1954; Schumacher 1961). The increased harvest of sub-adult fish can have a large impact on recruitment. In one extreme example, Ryder and Johnson (1972) estimated that 2-4 years of annual production was removed by ice fishermen in one day.

In Alaska, lake trout fishing is open year round in nearly all locations. One exception is Fielding Lake where lake trout fishing is closed during the spawning season (September). For lakes where exploitation becomes excessive, curtailing the winter fishery in some manner may be an effective harvest control mechanism and should be considered. Winter season closures are justified because of the potential biological impact on lake trout stocks.

Gear Restrictions

The intent of regulations that limit the type of legal fishing gear is to control harvest by reducing angler efficiency, to affect the size of fish caught or to reduce the mortality of released fish. Gear restrictions intended to reduce angler efficiency include, reducing the number of lines or hooks, regulations on the use of “high tech” devices such as fish finders, down riggers and trolling speed indicators, and reducing or eliminating the use of bait particularly with unattended set lines. Regulations for the purpose of controlling the size of fish caught include restrictions on lure/hook size, and the size of fish baits that are permitted. Regulations that seek to reduce unintended mortality of fish include restrictions on the type of hooks used (gorge hooks, barbed/barbless), and the use of bait.

Most jurisdictions allow the use of two lines (hooks) while fishing through the ice but only one line during open water periods (Olver et al. 2004). The effect on catch of using two lines instead of one is variable but significant. Lester et al. (1991) reported increased catch rates 0.5 to 2.0 times higher with two lines and Evans et al. 1991 found greater effect in smaller lakes (<1000 ha). In Alaska, the use of two rods while ice fishing is widely permitted.

Several studies have reported increased catch rates with the use of "high tech" devices (see Olver 2004 for a review). To date, regulations controlling the use of "high tech" gear do not appear to be in place in any jurisdictions including the state of Alaska.

The use of live fish bait is prohibited in the state of Alaska primarily to maintain the integrity of native fish fauna. Hence, all regulations concerning the use of bait refer to the use of dead fish. Although restrictions on the use of bait undoubtedly have the effect of reducing angler efficiency, most regulations concerning bait use are in place to reduce the unintended mortality of fish. This is because of the higher incidence of fish being hooked in critical areas (gills, deep mouth, and stomach) associated with the use of bait (see Hooking Mortality). Very high mortality rates have been reported for fish caught on set lines (still fishing) because bait and hooks are generally deeply ingested. The use of this fishing method is no longer allowed in many Canadian and Northeastern US jurisdictions (Olver 2004). While the use of set lines in lake trout lakes is not considered appropriate; the practice is still permitted in many lakes in Alaska.

Circle hooks may offer a method for reducing mortality of fish caught using bait. It appears that fish caught with bait on circle hooks are more likely to be hooked in the mouth than are fish caught on bait with standard "J" hooks. Jenkins (2003) reported that less than 10% of all rainbow trout caught on baited circle hooks were killed. In addition, 77% of all trout hooked with this gear type were hooked in the mouth and the hook was extracted safely. Jenkins (2003) further suggested that if the fishing line was cut when hooks were deeply imbedded rather than attempting to extract these hooks, the release mortality rate would be less than 3% (97% survival). Additional studies are needed to better understand the potential benefits of this gear type.

Barbless hooks are required through out Manitoba and on catch-and-release waters in Saskachewan. The use of barbless hooks is believed to facilitate release of fish. To date, no studies clearly demonstrate a significant difference between mortality of fish caught and released with barbless verses barbed hooks. Never-the-less, many anglers are proponents of the use of barbless hooks when they seek to release fish. The use of barbed hooks is not currently restricted in lake trout fisheries in Alaska.

Catch-And-Release

The use of catch-and-release only regulations for lake trout is generally limited to high use fisheries where continued fishing opportunity is desired but where low annual yields will not support intentional harvest. A careful analysis of the expected level of hooking mortality associated with the fishery (summer/winter, size of fish present) must be undertaken to ensure that expected annual yields are not likely to be exceeded. In Alaska a catch-and-release only regulation is in place for the small number lakes supporting lake trout within the Dalton

Highway corridor (North Slope haul road). In the 5 year period prior to implementation of this regulation (1990-1995) between 50 and 100% of the harvest of lake trout from the entire North Slope area came from these few small lakes. Assessment of selected lakes in the area found sparse populations with individuals in numerous old age categories (Burr 1995; Taube et al. 1998).

REHABILITATION/STOCKING

Attempts at enhancing or rehabilitating wild lake trout stocks have generally not been successful, are very expensive and have resulted in numerous unintended negative consequences. Evans et al. (1991) make a strong case against stocking lake trout for purposes other than for establishing new populations or for re-establishing stocks that have become extinct.

In Alaska lake trout have been stocked as adults, juveniles, and as eyed eggs in a few lakes that did not previously contain lake trout (Burr 1987, 1994). One of the larger lakes is Harding Lake (1,000 ha) near Fairbanks. This lake currently provides a popular fishery targeting large lake trout. There are no plans for enhancing existing wild lake trout stocks in Alaska.

In recent years Paxson Lake (1987 – 1990, 1,575 ha, Copper River drainage) and (Sevenmile Lake 1991-1998, 33 ha) have been used as sources of fertilized lake trout eggs for the AYK stocking program. The egg take from Paxson Lake ended in 1990 because of concerns over disease (IHN virus from sockeye salmon) and genetics (Paxson Lake is not within the Tanana/Yukon drainage). The Sevenmile Lake stock was used only on alternate years because of the small population size (approximately 1,000 adults) and provided about 100,000 eggs each event. Additional sites for obtaining fertilized eggs will be needed if and when lake trout again become part of the stocking program. There are currently no lake trout in any state hatcheries.

HISTORY OF SPORT FISHERY REGULATION AND MANAGEMENT

The daily bag and possession limit for lake trout in most of Alaska until mid 1980s was 10 per day, with only two lake trout larger than 20 inches. Set lines (unattended, baited trot lines) were permitted and the season was open all year. Under these regulations, stocks located in areas near the road system experienced loss of large fish through high harvest rates particularly by the indiscriminate set line fishery (targeting both lake trout and burbot, *Lota lota*).

In 1988, the regulation for most of Region III was changed to four per day without size limit (Appendix C). In less remote areas (Tanana management area) the general regulation was reduced to two per day with no size limit. Minimum size limits and or reduced daily bag limits were applied to certain high use areas. Within the Dalton Highway corridor of the North Slope, a no harvest regulation (catch-and–release only) was instituted in 1995. This regulation was in response to very high harvest rates in the lakes adjacent to the road system.

In 2004, the general regulation for lake trout in Region III was reduced to two per day without size limit. The reason for this change was to provide a uniform regulation throughout the region that was generally consistent with expected annual yields from most lakes. Except for the Tanana and Glennallen management areas the new regulation combines the daily bag limit for lake trout with the existing two fish limit for lake resident Arctic char *Salvelinus alpinus*. These closely related species coexist in several lakes in the Yukon and North Slope of the Brooks Range. These species have very similar life history traits and potential yields.

PLAN FOR THE MANAGEMENT OF WILD LAKE TROUT STOCKS IN ALASKA

In this section, a plan for the management of sport fisheries on wild lake trout stocks in the Arctic, Yukon, Kuskokwim, and Upper Copper/Upper Susitna management areas of Alaska is proposed. **The overall objective of the plan is to maintain harvests of lake trout below defined MSY thresholds**. Annual harvest levels are estimated from the annual SWHS, and compared to predicted annual yields based on site specific studies or on the lake area model. In addition to maintaining harvests below expected maximum yields, this plan seeks, where practical, to promote simplicity and uniformity of regulation. This is in response to public concerns regarding a trend in increasingly complex regulations. Broad based (uniform) regulations are also preferred because this approach reduces the problem of displacement or shifting of angling effort. Restrictive site-specific regulations often have the effect of simply pushing angler effort and harvest to other nearby waters that are often equally vulnerable to increased harvest.

DESCRIPTION OF MANAGEMENT PLAN

The **general regulation** will provide a **daily bag and possession limit of two lake trout per day without size limit.** This bag limit was selected because it is likely to provide sustainable levels of harvest across a wide range of populations under moderate levels of angling effort. At this level of regulation, bait is permitted although set lines (unattended trot lines) are not.

When harvest levels increase such that control is needed, regulations will be applied in the following (increasingly restrictive) fashion.

First, the **bag limit** will be **reduced from two to one fish**. A reduction in bag limit prior to introducing other regulatory controls is preferred for at least two reasons. First the unintentional mortality associated with the mandatory release of certain size fish is avoided. Secondly a reduction in harvest is obtained without unnecessarily reducing the diversity of fishing opportunity (e.g., use of bait, type of lure/hook, reduction in length of season).

Next if an additional reduction in fishing mortality is needed, the following regulatory actions may be taken alone or in combination: 1) application of a length limit; 2) gear restrictions; and or, 3) seasonal closures.

The use of a **minimum length limit** is recommended when size limits are contemplated. The goal of this type of length limit is to reduce harvest by delaying the entry of year classes into the fishery rather than to manipulate the size composition of the adult standing stock. Given this goal, the use of a length limit regulation should generally be coupled with the elimination of the use of bait (to reduce the incidental mortality of released fish).

Minimum length restrictions should be structured to allow fish to spawn twice prior to recruitment to the fishery. For most lakes larger than 250 acres (100 ha) in interior Alaska, 24 inches (total length) will provide the needed protection (Burr 1991, 1993). For consistency of regulation, the 24 inch minimum length limit should be used unless compelling, site specific data indicate that an alternate minimum size limit is needed. The use of length limits is not recommended for lakes smaller than 250 acres. The lake trout populations in these small lakes are typically composed of small individuals and there is little difference between length of maturity and the maximum size of fish present.

Gear Restrictions intended to reduce fishing mortality include elimination of bait and the mandatory use of single hook, artificial lures. Circle hooks also appear to offer a benefit in reduced mortality of released fish and their use may be considered. The use of barbless hooks is widely believed by anglers to facilitate release of fish. However, because there are at present no compelling studies that demonstrate a measurable benefit, it is difficult to justify mandating the use of barbless hooks.

Reducing Open Season. Closing the fishery during periods when the fish are particularly vulnerable to harvest has been shown to be effective at reducing total annual harvest. Seasonal closures that should be considered include spawning closures, closures during spring break-up or closures during the ice covered season. Winter season closures may be especially effective for small lakes located near large communities.

If implementing these regulatory actions fails to control harvests within sustainable levels, a **catch-and-release only regulation** will be implemented. Just as with size-based regulations, catch-and-release regulations require that we consider the unintentional mortality of released fish. To estimate the fishing mortality resulting from catch-and–release fisheries, we will assume that 10% of all released lake trout are killed (harvested).

Finally, if these measures are insufficient to curtail fishing mortality within clearly identified limits, the lake trout fishery will be **completely closed** until assessment of the population indicates that it has recovered to an abundance level that can sustain a harvestable surplus that is sufficiently large to effectively manage. The recovery period is likely to last a decade or more due to the low productivity of the species.

Special Management Waters. In waters where harvests are within biologically sustainable levels, secondary management objectives seeking to achieve publicly supported alternative management goals may be implemented. An example of special management may include shortened open seasons and or catch-and-release only fishing to maintain a higher stock abundance and presumably to provide higher catch rates. An alternative length limits could be used with the goal of maintaining a higher proportion of fish in large size categories. Because special management regulations generally result in less overall fishing opportunity, broad-based public support is emphasized for this type of regulation. The proposed inclusion of lakes/stocks into this category of management will generally originate with either the public or the Board of Fisheries.

ADOPTION OF MANAGEMENT PLAN FOR UPPER COPPER / UPPER SUSITNA AREA LAKE TROUT FISHERIES.

The Alaska Board of Fisheries considered and adopted this management scheme for the Upper Copper / Upper Susitna management area during the December 2005 meeting. The regulatory language by which the plan was codified in the Alaska Administrative Code (AAC) is reprinted below. The majority of the plan is found under 5AAC 52.060. The general regulation (two fish per day) is listed as 5AAC 52.022(a)(9) and the restriction on the use of setlines in lakes in the management area is found as 5AAC 52.022(a)(14).

Wild Lake Trout Management Plan

5 AAC 52.060. Wild Lake Trout Management Plan. (a) Notwithstanding the other provisions in this chapter regarding lake trout, the department shall manage wild lake trout populations in the Upper Copper River and Upper Susitna River Area by employing a conservative harvest regime and by maintaining harvests below maximum sustained yield levels. Following sustained yield principles, the department may manage wild lake trout fisheries to provide or maintain fishery qualities that are desired by sport anglers.

(b) In a sport fishery covered by this management plan, the commissioner, by emergency order, may take one or more of the management actions specified in this subsection if there is a conservation or biological concern for the sustainability of the fishery or for a stock harvested by that fishery or for a stock harvested by that fishery. The concern must arise from harvest, effort, or catch data for that fishery which has been derived from statewide harvest survey data, on-site creel survey data, stock status data, stock exploitation rates, or from inferential comparisons with other fisheries. The management actions are as follows:

(1) reduce the bag and possession limits;
(2) reduce fishing time;
(3) allow only a catch-and-release fishery; and,
(4) modify methods and means of harvest.

(c) If the harvest level in the Upper Copper River and Upper Susitna River Area exceeds sustained yield for a two-year time period, the commissioner by emergency order, may close the fishery and immediately reopen a fishery during which one or more of the following restrictions apply:

(1) bag and possession limit of one lake trout;
(2) a minimum size limit applies, the size limit shall be established based on the following considerations:

(A) length of maturity, with two years of protection from harvest for spawning fish before recruitment to the fishery;
(B) lake size, with no size limits for a trout population in a lake with a surface area less than 247 acres;
(C) uniformity of size limits, with the minimum size limit of 24 inches unless the department determines that there is a biological justification for an alternate size limit;

(3) if the reduced bag limit or size limits do not keep harvest below maximum sustained yield levels the commissioner may further restrict harvest opportunity, through:

(A) seasonal closures;
(B) spawning closures, winter closures, or both;
(C) allowing single-hook, artificial lures only or no bait, or both;
(D) allowing catch-and-release fishing only; and,
(E) a complete closure of the fishery.

- continued -

(d) Special management waters are waters designated by regulation of the Board of Fisheries, where harvests are within sustained yield levels and where the management objectives include higher stock abundance or a need for a higher percentage of trophy-sized fish. Within special management areas, if the department determines that management objectives will not be met under existing regulatory provisions, the commissioner may, by emergency order, close the fishery and immediately reopen a fishery during which one or more of the following management measures apply:

(1) reduced fishing season;
(2) special gear restrictions;
(3) alternative size limits; and,
(4) catch-and-release fishing only.

(e) The department shall minimize potential conflicts with a subsistence fishery, or other fisheries that overlap the sport fishery, that harvest other fish within the same body of water.

5 AAC 52.022(a)(9). Lake trout: may be taken from January 1 **–** December 31: bag and possession limit of two fish: no size limit.

5 AAC 52.022(a)(14). The use of set lines is prohibited.

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APPENDIX A

Appendix A1.–Alaska statewide sport fishing effort, total catch, and harvest of lake trout by resident and non-resident anglers.

	Effort - All Species							
	Trips		Days Fished		Harvest		Catch	
Year	Residents	Non Resident	Residents	Non Resident	Residents	Non Resident	Residents	Non Resident
				Totals				
1993	873,480	302,505	1,170,877	470,864	10,624	2,470	39,876	13,702
1994	874,031	313,053	1,158,211	515,057	8,222	3,152	25,448	19,659
1995	860,480	335,279	1,167,864	546,903	6,357	2,055	19,340	8,922
1996	657,614	225,447	877,825	384,755	8,171	1,601	26,425	8,356
1997	599,496	254,270	833,546	430,129	5,597	1,889	21,341	9,360
1998	564,393	196,669	791,055	362,222	5,250	735	16,625	6,182
1999	654,730	255,306	1,104,119	470,625	8,751	1,197	37,940	7,970
2000	699,629	293,819	1,117,715	532,118	5,233	1,059	22,147	10,029
2001	538,921	276,579	864,245	508,773	3,979	1,016	17,983	8,057
2002	557,946	263,378	928,527	475,250	5,576	1,533	31,662	11,556
2003	540,993	273,102	866,108	485,382	5,770	1,314	25,694	11,740
2004	555,456	300,780	917,851	548,735	5,907	2,027	21,559	22,492
2005	507,740	371,010	805,331	604,296	5,615	1,697	21,437	19,277
Average 2001-2005	540,211	296,970	876, 412	524,487	5,369	1,517	23,667	14,624

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	Effort - All Species							
	Trips		Days Fished		Harvest		Catch	
Year	Residents	Non Resident	Residents	Non Resident	Residents	Non Resident	Residents	Non Resident
				Percent				
1993	74%	26%	71%	29%	81%	19%	74%	26%
1994	74%	26%	69%	31%	72%	28%	56%	44%
1995	72%	28%	68%	32%	76%	24%	68%	32%
1996	74%	26%	70%	30%	84%	16%	76%	24%
1997	70%	30%	66%	34%	75%	25%	70%	30%
1998	74%	26%	69%	31%	88%	12%	73%	27%
1999	72%	28%	70%	30%	88%	12%	83%	17%
2000	70%	30%	68%	32%	83%	17%	69%	31%
2001	66%	34%	63%	37%	80%	20%	69%	31%
2002	68%	32%	66%	34%	78%	22%	73%	27%
2003	66%	34%	64%	36%	81%	19%	69%	31%
2004	65%	35%	63%	37%	74%	26%	49%	51%
2005	58%	42%	57%	43%	77%	23%	53%	47%
Average 2001-2005	65%	35%	63%	37%	78%	22%	62%	38%

Appendix A2.–Estimated total catch and harvest of lake trout from the Glennallen survey area.

	Effort - All Species		Lake Trout	
Year	Trips	Days Fished	Harvest	Catch
1977		51,485	7,699	
1978		44,566	5,433	
1979		57,266	7,271	
1980		50,518	8,067	
1981		53,499	8,337	
1982		54,953	8,699	
1983		51,512	7,246	
1984	38,709	51,964	6,311	
1985	35,338	48,707	8,686	
1986	35,907	51,563	6,779	
1987	35,351	52,324	6,721	
1988	34,071	45,867	6,277	
1989	36,765	52,262	7,147	
1990	32,760	50,791	5,503	15,335
1991	39,559	64,207	4,864	10,444
1992	39,600	72,052	4,251	12,886
1993	47,561	77,870	4,569	17,728
1994	48,612	85,520	4,058	13,368
1995	56,001	102,951	2,934	10,937
1996	35,056	64,407	2,632	11,209
1997	30,951	56,257	1,923	9,101
1998	30,528	56,706	1,723	8,184
1999	36,780	77,619	2,135	14,184
2000	30,780	58,194	1,700	9,388
2001	25,432	48,879	1,185	6,913
2002	22,962	46,613	2,067	12,197
2003	25,707	52,051	1,831	12,425
2004	19,914	39,702	791	2,500
2005	19,274	37,188	1,077	6,167
		Average		
1996-2005	27,739	53,762	1,706	9,236
2001-2005	22,659	44,887	1,390	8,058

Appendix A3.–Lake trout sport fisheries in the Glennallen (Upper Copper/Upper Susitna) area.

	Crosswind			Louise			Susitna		
Year	Harvest	Catch	Effort	Harvest	Catch	Effort	Harvest	Catch	Effort
1977	252		1,852						
1978	714		2,800						
1979	609		802						
1980	895		1,885						
1981	540		769						
1982	734		2,423						
1983	388		1,113						
1984	188		252	2,018		10,644	650		2,707
1985	832		936	2,341		6,953	763		3,364
1986	137		337	2,227		10,586	1,114		3,746
1987	401		1,204	1,636		5,428	401		3,182
1988	382		1,128	1,801		7,185	418		1,583
1989	272		478	1,979		6,106	441		1,360
1990	306	1,307	989	1,036	2,971	5,506	187	1,019	2,154
1991	463	1,150	1,228	1,332	2,131	5,910	308	757	1,544
1992	378	1,411	1,504	1,033	3,108	6,765	324	1,010	2,358
1993	311	1,306	1,358	1,316	6,979	10,316	669	2,047	2,651
1994	429	2,044	1,649	1,463	5,087	9,976	426	1,308	3,510
1995	94	956	1,719	946	2,798	9,352	200	850	4,241
1996	339	1,230	1,323	662	3,021	5,436	381	2,103	2,267
1997	96	451	865	585	2,897	3,544	52	474	689
1998	238	1,540	966	625	2,516	3,490	131	383	1,052
1999	525	2,598	2,309	430	4,753	6,654	176	989	3,163
2000	297	910	1,111	563	3,103	5,671	131	970	2,400
2001	44	594	1,914	259	1,495	3,048	110	878	1,302
2002	262	879	986	412	2,676	3,408	131	725	1,300
2003	403	1,438	2,328	393	3,145	5,934	128	410	1,161
2004	105	861	1,401	770	3,985	4,653	30	794	1,236
2005	519	2,256	2,392	370	2,570	2,396	429	1,011	977
Averages									
1996-2005	283	1,276		507	3,016		170	874	
2001-2005	267	1,206		441	2,774		166	764	

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	Tyone			Paxson			Summit		
Year	Harvest	Catch	Effort	Harvest	Catch	Effort	Harvest	Catch	Effort
1977									
1978									
1979									
1980									
1981									
1982									
1983									
1984	0		1,720	787		3,946	581		2,156
1985	35		1,283	1,803		3,780	520		1,977
1986	161		1,978	944		2,549	428		1,538
1987	45		506	1,457		4,402	1,368		1,888
1988	55		709	1,310		4,038	528		2,001
1989	385		1,407	1,557		4,099	863		2,936
1990	17	34	330	2,139	4,466	3,890	968	2,513	2,132
1991	0	70	584	1,248	2,047	4,572	981	1,837	3,016
1992	62	278	800	1,118	2,383	4,247	524	1,134	2,219
1993	225	450	1,008	778	2,402	4,336	344	1,638	1,792
1994	110	228	2,062	262	1,221	4,103	353	1,020	2,923
1995	60	189	2,189	507	1,746	5,269	224	1,199	3,224
1996	22	131	480	297	1,928	3,107	120	757	1,378
1997	20	70	345	452	2,040	2,517	158	698	1,675
1998	15	37	56	205	1,738	2,372	59	384	1,069
1999	9	201	740	342	3,031	4,085	220	672	1,209
2000	0	0	632	228	2,067	2,352	79	346	732
2001	15	30	75	302	1,839	3,101	74	634	973
2002	0	0	100	327	3,757	3,961	66	372	592
2003				399	3,437	2,442	102	644	1,214
2004	0	0	72	46	182	1,080	107	279	392
2005									
Average									
1996-2005	9	52		265	2,138		102	548	
2001-2005	4	8		225	2,116		76	524	

Appendix A4.–Estimated total catch and harvest of lake trout from the Tanana survey area.

	Effort - All Species		Lake Trout	
Year	Trips	Days Fished	Harvest	Catch
1977		99,919	1,471	
1978		119,364	603	
1979		98,514	946	
1980		131,494	1,264	
1981		115,099	1,721	
1982		150,530	3,104	
1983		144,981	2,749	
1984	124,355	145,142	2,000	
1985	116,580	135,745	2,984	
1986	113,536	144,814	713	
1987	141,436	155,346	652	
1988	150,869	173,706	2,221	
1989	135,400	185,715	1,650	
1990	131,831	184,887	896	2,433
1991	113,247	155,662	1,978	4,162
1992	94,265	120,848	993	4,656
1993	126,733	160,117	1,939	7,414
1994	118,052	148,633	1,582	4,415
1995	154,458	201,389	887	3,314
1996	117,911	150,227	877	5,199
1997	91,122	119,699	832	5,161
1998	81,335	112,025	524	2,736
1999	94,996	160,427	1,145	4,480
2000	76,787	121,785	1,133	4,012
2001	57,697	91,135	445	2,304
2002	62,945	108,462	709	4,816
2003	64,418	99,934	860	3,595
2004	68,584	116,486	646	3,816
	57,846	93,398	1,082	5,164
		Average		
1996-2005	77,364	117,358	825	4,128
2001-2005	62,298	101,883	748	3,939

Appendix A5.–Lake trout sport fisheries in the Tanana River drainage.

	Harding		Fielding		Tangle[a]	
Year	Harvest	Total Catch	Harvest	Total Catch	Harvest	Total Catch
1994	66	280				
1995	177	258	44		246	
1996	121	556	42		235	
1997	90	462	55		240	
1998	44	311	19	302	290	1,222
1999	89	807	43	279	484	2,034
2000	18	258	18	221	376	1,626
2001	44	453	12	106	112	591
2002	48	597	0	137	414	2,464
2003	41	518	83	423	505	1,631
2004	72	479	101	520	270	976
2005	48	707	112	862	224	2,327
1996-2005	62	515	49	356	315	1,609
2001-2005	51	551	62	410	305	1,598

[a] Includes the connected Tangle Lakes, Landlocked Tangle, Glacier and Landmark Gap lakes.

Appendix A6.–Estimated total catch and harvest of lake trout from the Yukon survey area.

	Effort - All Species		Lake Trout	
Year	Trips	Days Fished	Harvest	Catch
1977		4,729	308	
1978		6,314	262	
1979		7,714	173	
1980		6,849	293	
1981		6,679	302	
1982		11,034	720	
1983		11,070	305	
1984	4,591	6,358	143	
1985	6,122	8,670	485	
1986	3,987	9,381	508	
1987	7,083	7,017	0	
1988	6,596	8,261	0	
1989	7,640	10,712	272	
1990	9,487	15,539	220	914
1991	6,314	10,699	434	757
1992	7,529	12,767	193	741
1993	7,911	14,011	101	196
1994	6,755	12,803	59	177
1995	10,927	18,663	66	155
1996	4,756	10,536	9	60
1997	6,028	12,725	0	70
1998	5,114	10,127	27	74
1999	5,370	12,761	545	1,330
2000	5,291	11,201	55	166
2001	3,912	10,517	56	56
2002	8,198	14,955	147	1,596
2003	4,089	9,100	57	296
2004	5,027	13,092	98	553
2005	4,721	8,965	171	540
		Average		
1996-2005	5,251	11,398	117	474
2001-2005	5,189	11,326	106	608

Appendix A7.–Estimated total catch and harvest of lake trout from the Kuskokwim survey area.

	Effort - All Species		Lake Trout	
Year	Trips	Days Fished	Harvest	Catch
1977		4,475	124	
1978		4,801	172	
1979		6,999	218	
1980		7,757	267	
1981		8,344	117	
1982		12,244	464	
1983		12,429	419	
1984	6,115	13,848	662	
1985	4,411	11,254	34	
1986	4,881	11,288	1,110	
1987	6,957	17,476	28	
1988	5,540	22,923	181	
1989	7,737	16,044	1,086	
1990	4,823	15,513	72	1,091
1991	6,473	12,799	272	1,019
1992	5,941	14,219	356	1,426
1993	6,046	14,505	218	1,314
1994	6,663	17,828	40	1,861
1995	6,882	15,777	215	540
1996	6,082	15,903	135	1,094
1997	10,238	26,977	404	1,167
1998	12,857	26,944	131	951
1999	6,925	26,325	128	1,089
2000	6,360	19,990	152	1,076
2001	4,851	20,673	63	242
2002	6,866	20,645	134	1,629
2003	7,950	24,278	244	3,435
2004	9,137	25,391	497	6,941
2005	7,758	19,410	233	1,951
		Average		
1996-2005	7,902	22,654	212	1,958
2001-2005	7,312	22,079	234	2,840

Appendix A8.–Estimated total catch and harvest of lake trout from the Northwest Alaska survey area.

	Effort - All Species		Lake Trout	
Year	Trips	Days Fished	Harvest	Catch
1977		3,776	278	
1978		5,212	54	
1979		2,593	0	
1980		4,042	86	
1981		5,284	227	
1982		6,906	210	
1983		7,963	223	
1984	3,673	5,710	338	
1985	3,316	6,389	144	
1986	2,671	5,744	504	
1987	3,179	9,288	159	
1988	3,682	5,248	255	
1989	1,636	4,453	115	
1990	1,363	3,682	387	2,722
1991	2,967	8,109	173	486
1992	2,938	5,757	270	747
1993	3,279	7,809	234	593
1994	3,279	7,809	77	257
1995	2,826	5,587	126	1,004
1996	4,814	7,810	166	626
1997	2,268	5,291	73	455
1998	1,761	3,609	31	111
1999	1,614	3,637	101	255
2000	2,271	6,588	116	130
2001	2,889	5,167	117	1,109
2002	1,835	5,494	88	550
2003	2,759	6,285	11	11
2004	1,452	4,408	137	599
2005	2,274	5,355	81	760
		Average		
1996-2005	2,054	4,890	92	461
2001-2005	1,948	4,921	87	606

Appendix A9.–Estimated total catch and harvest of lake trout from the North Slope survey area.

	Effort - All Species		Lake Trout	
Year	Trips	Days Fished	Harvest	Catch
1977		2,434	88	
1978		1,422	9	
1979		1,551	264	
1980		2,156	379	
1981		2,601	454	
1982		4,879	629	
1983		4,456	367	
1984	2,601	2,596	481	
1985	4,235	3,599	1,707	
1986	2,880	3,824	415	
1987	2,855	4,132	274	
1988	2,291	1,993	73	
1989	2,845	3,728	482	
1990	2,201	3,445	168	1,728
1991	3,484	6,537	176	932
1992	3,385	4,553	379	887
1993	3,395	5,600	106	266
1994	4,308	5,407	73	327
1995	3,549	5,644	38	370
1996	3,000	4,487	19	298
1997	3,032	4,586	57	783
1998	2,068	3,653	221	1,292
1999	3,344	5,230	77	913
2000	2,232	4,739	18	457
2001	3,817	6,032	37	266
2002	3,262	4,770	217	410
2003	1,756	2,710	98	1,164
2004	1,970	3,310	75	540
2005	2,685	4,352	96	433
		Average		
1996-2005	2413	4051	92	656
2001-2005	2346	3961	105	563

APPENDIX B

Appendix B1.–Converting estimates of the number of lake trout harvested to biomass.

The following figures are offered to facilitate converting the estimated number of lake trout harvested into the total biomass (weight) of the harvest. This conversion is needed because the potential annual yield predicted by the lake area model (Evans et al. 1991) is in terms of biomass:

$$\text{Log}_{10}\ H = 0.60 + 0.72\ \text{Log}_{10}\ A$$

where H = annual harvest in kilograms (kg) and,

A = lake surface area in hectares (ha).

The calculations are based on a number untested assumptions and should be viewed accordingly. First the distribution of lengths used is assumed to be representative of either the size of fish harvested in the creel and/or the size distribution extant in the stock. Where data from stock assessments were used, we assume that anglers harvest fish in proportion to the size distribution of fish present. We also assume that the behavior of the anglers and the distribution of fish present do not change significantly in the short term. Finally we assume that the length/weight relationship is representative.

Figures are provided for lakes ranging from 100 ha (250 acres) to 5,000 ha (12,350 acres) and for a selected set of lakes for which site specific information was available either from direct assessment studies or from creel sampling. For lakes 100 ha and larger, figures are listed for harvests under regulations with and without minimum length limits. The use of minimum length limits affects the size of fish harvested and the resulting estimated total biomass of fish removed.

The mean weight W of fish harvested was calculated for each lake from length frequency distributions as:

W = Sum over all categories [p_i * w_i]

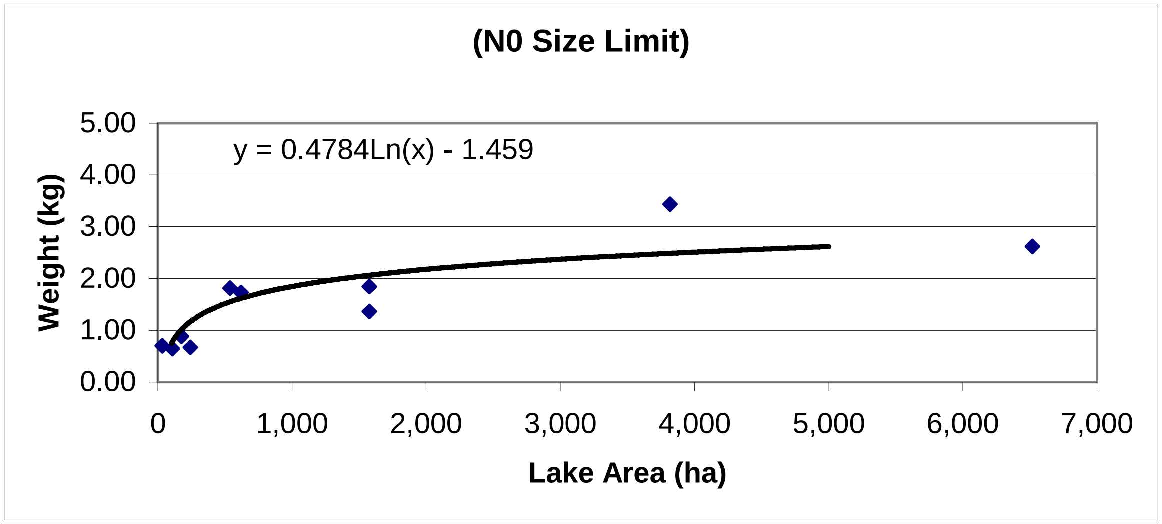
where

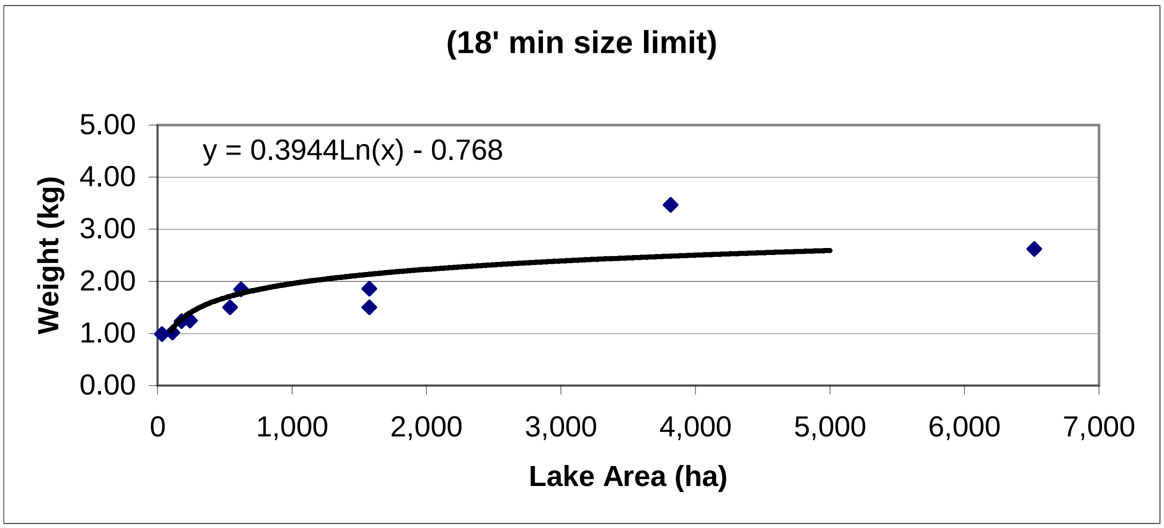
p_i = the proportion of fish in length category i (one inch length categories), and

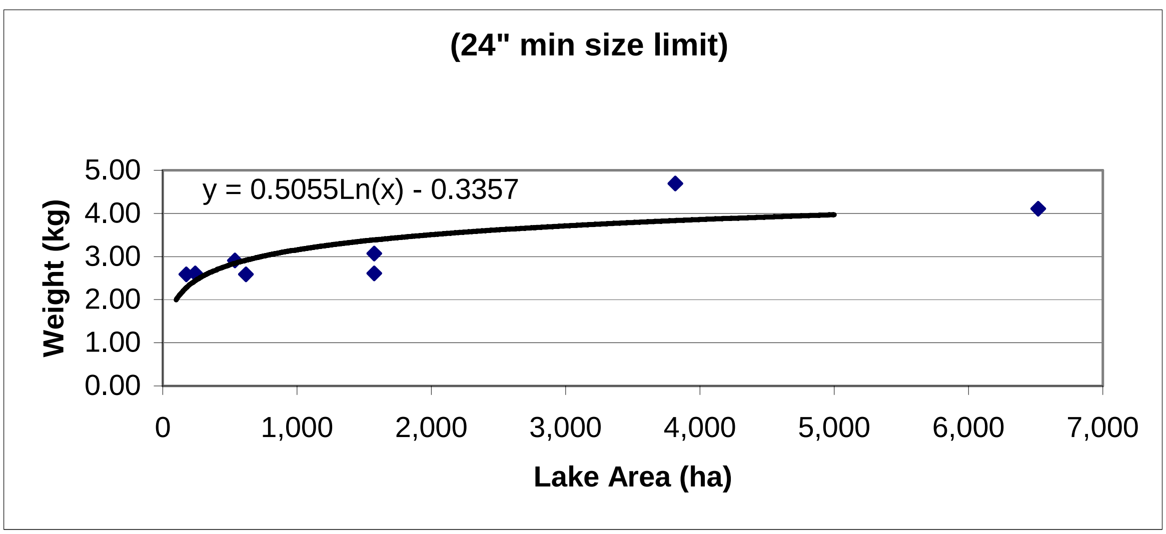
w_i = median weight of fish in length category i.

To simulate the effect of minimum length regulations, the distributions were truncated to exclude lengths less than the minimum length limit.

Results from the individual lakes were plotted for each length limit scenario and the resulting relationships were used to estimate weight of fish for lakes of various sizes (Appendix B2).







Appendix B2–Weighted average of median weights of fish harvested varying with lake surface area and length limit regulation.

Appendix B3.–Annual yield of lake trout predicted from lake surface area.

Lake	Area (ha)	Length Limit	Mean Size (kg)	Yield kg/yr	Yield kg/ha/yr	Yield Number
Default values based on lake area.	5,000	None	2.6	1833	0.37	**701**
		18	2.8	1833	0.37	**708**
		24	4.0	1833	0.37	**462**
	3,000	None	2.4	1269	0.42	**535**
		18	2.5	1269	0.42	**531**
		24	3.7	1269	0.42	**342**
	1,500	None	2.0	771	0.51	**378**
		18	2.2	771	0.51	**364**
		24	3.4	771	0.51	**229**
	1,000	None	1.8	575	0.58	**312**
		18	2.0	575	0.58	**294**
		24	3.2	575	0.58	**182**
	500	None	1.5	349	0.70	**231**
		18	1.6	349	0.70	**208**
		24	2.9	349	0.70	**125**
	200	none	1.0	181	0.90	**168**
		18	1.2	181	0.90	**137**
		24	2.4	181	0.90	**77**
	100	none	0.7	110	1.10	**147**

Appendix B4.–Annual yield of lake trout predicted from lake area for selected lakes.

Lake	Area (ha)	Length Limit	Mean Size (kg)	Yield kg/yr	Yield kg/ha/yr	Yield Number
Louise[a]	6,519	none	**2.6**	2219	0.34	**848**
		24	**4.1**	2219	0.34	**540**
Susitna[a]	3,816	none	**3.4**	1509	0.40	**439**
		24	**4.7**	1509	0.40	**321**
Paxson[b]	1,575	none	**1.8**	798	0.51	**585**
		24	**3.1**	798	0.51	**306**
Fielding[b]	538	none	**1.8**	368	0.68	**203**
		24	**4.1**	368	0.68	**90**
		26	**4.7**	368	0.68	**78**
Tangle (connected)[b]	620	none	**1.7**	408	0.66	**235**
		18	**1.8**	408	0.66	**221**
		24	**2.6**	408	0.66	**158**
Landlocked Tangle[b]	241	none	**0.7**	207	0.86	**309**
		18	**1.2**	207	0.86	**168**
		24	**2.9**	207	0.86	**71**
Glacier[b]	177	none	**0.9**	165	0.93	**187**
		18	**1.2**	165	0.93	**132**
		24	**3.2**	165	0.93	**51**
Twobit[b]	109	none	**0.6**	117	1.07	**181**
		18	**1.0**	117	1.07	**118**
7 Mile[b]	33	none	**0.7**	49	1.50	**71**

[a] 1991-1993 Creel.

[b] Stock assessments various years.

APPENDIX C

Appendix C1.–Current sport fishery regulations for lake trout in Region III Alaska.

Drainage	Area	Bag	Open Season	Length Limit	Bait	Gear Restrictions	
Tanana	General	2	All Year	None	Allowed	None	
	Tangle Lks System	1	All Year	18" min	Allowed	No Set Lines	
	Fielding Lake	1	Oct 1 through Aug 31	26" min	Required	No Set Lines	Only one single hook with bait may be used.
	Harding Lake	1	All Year	26" min	Allowed	No Set Lines	
Yukon	General	2	All Year	None	Allowed	None	
	Dalton Highway Corridor	0[a]	All Year	None	Allowed	None	
North Slope	General	2	All Year	None	Allowed	None	
	Dalton Hwy Corridor	0[a]	All Year	None	Allowed	None	
Kuskokwim	General	2	All Year	None	Allowed	None	
NW Alaska	General	2	All Year	None	Allowed	None	
Upper Copper - Upper Susitna	General	2	All Year	None	Allowed	No Set Lines[b]	
	Lake Louise	1	All Year	24" min	Allowed	No Set Lines[b]	
	Susitna Lake	1	All Year	24" min	Allowed	No Set Lines[b]	
	Tyone Lake	1	All Year	24" min	Allowed	No Set Lines[b]	
	Summit Lake	1	All Year	None	Allowed[c]	No Set Lines[b]	Only unbaited single hook artificial lures may be used [d]
	Paxson Lake	1	All Year	None	Allowed[c]	No Set Lines[b]	Only unbaited single hook artificial lures may be used [d]
	Crosswind Lake	1	All Year	24" min	Allowed	No Set Lines[b]	

[a] Catch-and-release only.

[b] Lake burbot management plan.

[c] November 1-April 15: bait may be used , single hooks only.

[d] April 16-October 31.

Appendix C2.–Chronology of sport fishing regulations for lake trout in the Glennallen (Upper Copper/ Upper Susitna management area.

Location/Date		Bag Limit	Open Season	Length Limit	Bait	Gear Restrictions	
Upper Copper- Upper Susitna Management Area							
General							
Before 1987		*2*	*All Year*	*>20"*	*Allowed*	*None*	
		10	*All Year*	*<20"*	*Allowed*	*None*	
	1988	2	All Year	None	Allowed	None	
	1991	2	All Year	None	Allowed	No Set Lines[a]	
Lake Louise							
	1988	2	All Year	18" min	Allowed	None	
	1991	2	All Year	18" min	Allowed	No Set Lines[a]	
	1994	1	All Year	24" min	Allowed	No Set Lines[a]	
Susitna Lake							
	1988	2	All Year	18" min	Allowed	None	
	1991	2	All Year	18" min	Allowed	No Set Lines[a]	
	1994	1	All Year	24" min	Allowed	No Set Lines[a]	
Tyone Lake							
	1988	2	All Year	18" min	Allowed	None	
	1991	2	All Year	18" min	Allowed	No Set Lines[a]	
	1994	1	All Year	24" min	Allowed	No Set Lines[a]	
Summit Lake							
	1988	2	All Year	18" min	Allowed	None	
	1991	2	All Year	18" min	Allowed	No Set Lines[a]	
	1994	2	All Year	24" min	Allowed	No Set Lines[a]	
	2000	2	All Year	24" min	No	No Set Lines[a]	
	2006	1	All Year	24" min	Allowed[b]	No Set Lines[a]	Only unbaited single hook artificial lures may be used[c]
Paxson Lake							
	1988	2	All Year	18" min	Allowed	None	
	1991	2	All Year	18" min	Allowed	No Set Lines[a]	
	1994	2	All Year	24" min	Allowed	No Set Lines[a]	
	2000	2	All Year	24" min	No	No Set Lines[a]	
	2006	1	All Year	24" min	Allowed[b]	No Set Lines[a]	Only unbaited single hook artificial lures may be used[c]
Crosswind Lake							
	1988	2	All Year	None	Allowed	None	
	1991	2	All Year	18" min	Allowed	No Set Lines[a]	
	1994	1	All Year	24" min	Allowed	No Set Lines[a]	

[a] Lake Burbot Management Plan.

[b] November 1-April 15: bait may be used, single hooks only.

[c] April 16-October 31.

Appendix C3.–Chronology of sport fishing regulations for lake trout in the Tanana management area.

Location/Date	Bag Limit	Open Season	Length Limit	Bait	Gear Restrictions	
Tanana Management Area						
General						
Before 1987	*2*	*All Year*	*>20"*	*Allowed*	*None*	
	10	*All Year*	*<20"*	*Allowed*	*None*	
1987	2	All Year	None	Allowed	None	
Tangle Lakes[a]						
1987	1	All Year	18" min	Allowed	No Set Lines	
Fielding Lake						
1987	2	All Year	18" min	Allowed	No Set Lines	
1988	2	All Year	18" min	Allowed	No Set Lines	
1993	1	All Year	22" min	Allowed	No Set Lines	
2001	1	Oct 1-Aug 31	26" min	Required	No Set Lines	Only one single hook with bait may be used
Harding Lake						
1987	2	All Year	None	Allowed	None	
1993	2	All Year	18" min	Allowed	No Set Lines	
2001	1	All Year	26" min	Allowed	No Set Lines	

[a] Tangle lakes include the connected Tangle lakes, Landlocked Tangle Lake, Glacier Lake and Landmark Gap Lake.

Appendix C4.–Chronology of sport fishing regulations for lake trout in the Arctic, Yukon, Kuskokwim and Northwest Alaska management areas.

Location/Date	Bag Limit	Open Season	Length Limit	Bait	Gear Restrictions
Arctic/Yukon Management Area					
General					
Before 1987	*2*	*All Year*	*>20"*	*Allowed*	*None*
	10	*All Year*	*<20"*	*Allowed*	*None*
1987	4	All Year	None	Allowed	None
2004	2	All Year	None	Allowed	None
Dalton Highway Corridor					
1987	4	All Year	None	Allowed	None
1995	0[a]	All Year	None	Allowed	None
2004	0[a]	All Year	None	Allowed	None
Kuskokwim Management Area					
General					
Before 1987	*2*	*All Year*	*>20"*	*Allowed*	*None*
	10	*All Year*	*<20"*	*Allowed*	*None*
1987	4	All Year	None	Allowed	None
2004	2	All Year	None	Allowed	None
Northwest Management Area					
General					
Before 1987	*2*	*All Year*	*>20"*	*Allowed*	*None*
	10	*All Year*	*<20"*	*Allowed*	*None*
1987	4	All Year	None	Allowed	None
2004	2	All Year	None	Allowed	None

[a] Catch-and-release only.