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McDonald Lake Sockeye Salmon Stock Status and Escapement Goal Recommendations, 2008

by

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and

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

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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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ABSTRACT

McDonald Lake is one of the largest sockeye salmon (*Oncorhynchus nerka*) producing systems in southern Southeast Alaska. The stock assessment of McDonald Lake sockeye salmon was implemented to assess effects of large-scale lake fertilization project that occurred from 1982 to 2004. Escapements were enumerated with a counting weir in 1981, 1983–1984, and mark-recapture experiments from 2005 to 2007. Historical escapements were estimated from the peak foot survey counts, conducted annually since 1980, using a multiple regression calibration estimated from the paired peak foot survey counts –total escapements, and September precipitation. Total runs by age and brood tables were reconstructed based on estimated escapements, escapement age composition, terminal catch, and distant water fishery harvest rate (0.41) observed during years of coded wire tagging (CWT) to assess distant water catch. Based on a stock-recruit analysis of the 1980 to 2001 brood years, we recommend revising the sustainable escapement goal (SEG) for this system from the current SEG of 70,000 to 100,000 adult spawners to a new SEG of 55,000 to 120,000 adult spawners. We recommend that this goal be classified as a sustainable escapement goal, due to the uncertainty in future stock productivity because of discontinued lake fertilization. McDonald Lake escapements were relatively stable from 1980 to 1995, then declined later in the 1990s, and have remained at low levels since 2002. The stock is clearly in a period of persistent lowered recruitment. The recommended escapement goal has not been achieved in 4 of the last 5 years, and based on recent assessments of fall fry abundance, will likely be depressed for some time. Therefore McDonald Lake sockeye salmon meets the criteria of a stock of management concern, as defined in Alaska's Sustainable Salmon Fisheries Policy (5 AAC 39.222). We are recommending that a stock of management concern be established for this stock.

Key words: escapement, escapement goal, harvest, McDonald Lake, Oncorhynchus nerka, sockeye salmon, stock-recruit, stock status

INTRODUCTION

McDonald Lake is located in the Tongass National Forest, approximately 70 km north of Ketchikan, Southeast Alaska, on the Cleveland Peninsula (Figure 1; 55^o 58' N, 131^o 50' W, Orth 1967). The lake is situated within a heavily forested watershed of 118 km^2 (Olson 1989), and has a surface area of 420 ha, a mean depth of 45.6 m, and a maximum depth of 110 m (Zadina and Heinl 1999). The lake is organically stained with a volume of 197 x 10^6 m^3 and a residence time of approximately 0.67 years (Zadina and Heinl 1999, Olson 1989). The primary inlet stream and spawning grounds is Hatchery Creek (ADF&G stream number 101-80-10680-2030; also know as Walker Creek, Orth 1967). Movement of salmon upstream into Hatchery Creek is blocked by a barrier falls approximately 1.5 km upstream of the lake. The outlet stream, Wolverine Creek (ADF&G stream number 101-80-10680), flows south 2.4 km to Yes Bay, in West Behm Canal

Historically, McDonald Lake was considered the largest sockeye salmon producing system in southern Southeast Alaska (Geiger et al. 2004). Like most other major sockeye salmon systems in Southeast Alaska, the McDonald Lake run has a history of commercial exploitation and hatchery operation during the late 19th and early 20th centuries (Roppel 1982). Runs were thought to exceed 100,000 sockeye salmon in 1909 and 1911, and more than 200,000 in 1910 (Johnson et al. 2005). Fertilization of McDonald Lake was initiated by the Alaska Department of Fish and Game (ADF&G) in the late 1970s (Olson 1989), and continued annually from 1982 to 2004. Over most of the enhancement period, runs of sockeye salmon to McDonald Lake were strong, with estimated escapements averaging over 90,000 fish per year. The stock was actively managed during the 1990s, and fish that were expected to be in excess of the escapement goal were harvested in near terminal purse seine fisheries in upper west Behm Canal. Peak harvests were 150,000 sockeye salmon in 1993, worth an exvessel value of $0.75 million, and 250,000 sockeye salmon in 1996, worth an exvessel value of $1.5 million (catch numbers included all sockeye salmon harvested in Districts 101-80, -85, and -90). The McDonald Lake stock has supported the largest personal-use fishery in southern Southeast Alaska, with a maximum reported harvest of more than 10,000 fish in

1994. McDonald Lake sockeye salmon were also used as a brood source for stocking projects at a number of other sites in southern Southeast Alaska (Johnson et al. 2005). Over the past five years, however, the sockeye salmon run to McDonald Lake has declined, despite lake fertilization. Estimated escapements were below the lower bound of the current escapement goal (70,000 fish) in six of the last seven years, 2001–2007.

The first escapement goal (85,000 sockeye salmon) for McDonald Lake was established in 1989, based on the euphotic volume model (Koenings and Burkett 1987). In 1993, the escapement goal was changed from the point goal to a range of 65,000 to 85,000 sockeye salmon, based on an early undocumented Ricker stock recruit analysis (Geiger et al. 2004). The goal was updated to a sustainable escapement goal of 70,000 to 100,000 sockeye salmon in 2005, based on a brood-year yield analysis (Johnson et al. 2005). Accurate escapement estimates are important McDonald lake sockeye salmon stock assessment and management because catch and runs are estimated from the escapement magnitude. Johnson et al. (2005) recommend a more focused stock assessment effort to estimate escapement into the system.

The McDonald Lake sockeye salmon escapement has been estimated by various means since 1981, including weir counts from 1981 to 1984, scaled foot surveys from 1985 to 2007, and mark-recapture estimates from 2005 to 2007 (Heinl et al. 2008, Heinl et al. *in prep*.). From 1981 to 1984, the ADF&G operated an adult salmon weir at the outlet of the lake as part of joint U.S.-Canada studies (Hoffman et al. 1983 and 1984). The weir was expensive and difficult to operate (the 1982 weir count was considered unreliable (Johnson et al. 2005). In 1983 and 1984, ADF&G biologists conducted a series of seven foot surveys of spawning sockeye salmon in Hatchery Creek, and scaled the sum of the surveys to the final weir counts in those two years (Johnson et al. 2005). This scaled foot-survey method was similar to the area-under-the-curve approach (English et al. 1992, Bue et al. 1998), which was developed to estimate total escapement from a series of foot or aerial survey observations. The principal difference between the scaled foot-survey approach and the area-under-the-curve approach is that two key parameters, which vary annually (stream life and observer bias), were not known and were assumed to be constant in the scaled foot-survey approach. Previously published estimates of the escapement at McDonald Lake (e.g., Zadina and Heinl 1999, Geiger et al. 2004, Geiger et al. 2005, Johnson et al. 2005, and Heinl et al. 2008) have all been based on the scaled foot-survey method.

ADF&G conducted three seasons of mark-recapture work at McDonald Lake in 2005–2007. Subsequently, a comparison was made between the escapement estimates based on the historical scaled foot-survey method to six years of total escapement estimates from weir counts (1981, 1983, and 1984) and mark-recapture studies (2005–2007; Heinl et al. 2008, Heinl et al. *in prep*.). The historical method produced escapement estimates that were generally biased low (e.g., accounted for only 82% of the escapement, on average) and highly variable when compared to estimates of escapement derived from weir counts and mark-recapture studies. The historical method was based on only two years of comparisons between foot surveys and weir counts (1983 and 1984), and it is unlikely that two years of comparisons were enough to capture the variation that probably exists in observer estimates over varying run-sizes and environmental conditions at McDonald Lake.

The best predictor of the McDonald Lake sockeye salmon escapement was a multiple-regression model that compared the peak annual foot survey estimate to the total escapement, and incorporated an index of annual September precipitation (Heinl et al. *in prep*.). Hind-cast escapement estimates based on that model accounted for an average of 100% of the total escapement, and were much less variable; e.g., estimates were within 20% of the observed escapement in all six years (CV = 13%).

Expanded peak survey counts have been used extensively to estimate Chinook salmon escapements in Southeast Alaska (McPherson et al. 2003, Pahlke 2007). In addition, multiple expansion factors were used for the Little Tahltan River (Bernard et al. 2000) and the Blossom River (Weller et al. 2007), to account for environmental conditions: a larger expansion factor was used when survey conditions (based on stream flow and water clarity) were “normal” or “poor,” and a smaller expansion factor was used when conditions were “excellent.” Rainfall, and the accompanying rise in water levels and decreased water clarity, not only affects the ability of observers to accurately estimate the numbers of fish in a stream, the amount of rainfall over the spawning period can affect the run-timing of fish; greater water flow would cause the run to be less protracted with a more pronounced peak, and relatively more fish would be present in the stream exactly when survey conditions are less than optimal. Observers tend to estimate a smaller portion of the fish actually present as the number of fish increases (Jones et al. 1998). The same phenomena likely affect visual estimates of sockeye salmon at McDonald Lake.

Heinl et al. (*in prep*.) recommended recasting the escapement series for McDonald Lake, using the peak survey model to estimate escapements. Our intention here is to use these improved estimates of escapement to recommend an updated escapement goal for this system. Our second goal is to comment on the performance of the stock and report on this stock’s status as a fishery resource, as required under Alaska’s Sustainable Salmon Fisheries Policy (5 AAC 39.222).

STOCK ASSESSMENT INFORMATION

ESCAPEMENT ESTIMATES

The McDonald Lake escapement was estimated using a peak survey, multiple-regression model that incorporated an index of annual September precipitation (from Appendix D of Heinl et al. *in prep*.):

$$\hat{Y} = (-33283) + (4.8)(E) + (2375)(T) + \sigma, \qquad (1)$$

where $\hat{Y}$ is the estimated total escapement, E is the annual peak foot-survey estimate, T is the index of precipitation during September, and σ is standard deviation. This model was based on regression of six years of total observed escapement (weir counts in 1981, 1983, and 1984; mark-recapture estimates 2005–2007) on the annual peak foot survey and total September precipitation at the Ketchikan airport NOAA recording station. September precipitation was not available for 1980 and 1987–1988. Therefore, we calculated a regression between precipitation at the Ketchikan airport and precipitation recorded at the nearby Beaver Falls NOAA station, and used that relationship to impute precipitation values for those years (1980, 1987, and 1988). Escapements averaged 109,000 fish from 1980 to 2000, but declined thereafter to an average of only 50,000 fish since 2001, including escapements less than 30,000 in 2004 and 2007 (Table 1; Figure 2). The revised escapement estimates were 34% larger, on average, than the historical escapement estimates (Figure 2).

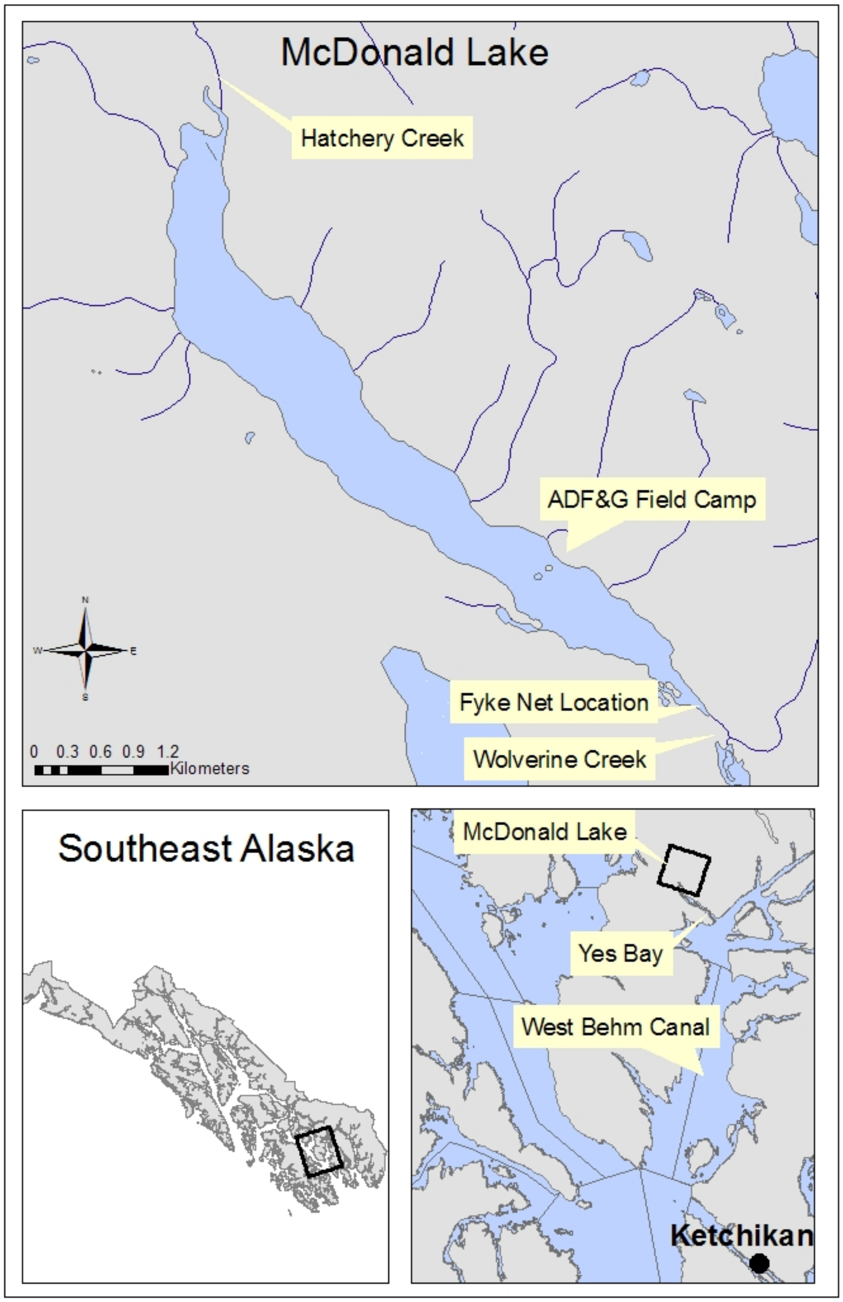

Figure 1.–Map of McDonald Lake and its location with respect to Ketchikan and Southeast Alaska.

Table 1.–Annual peak live counts of sockeye salmon at McDonald Lake, precipitation indices, and estimated annual escapements of sockeye salmon (1980–2008), compared to the observed escapements from weir counts (1981, 1983, and 1984) and mark-recapture studies, 2005 to 2007 (from Appendix D in Heinl et al. *in prep)*.

Year	Peak Live Count	September Precipitation[a]	Estimated Escapement	80% Confidence Interval Lower Bound	80% Confidence Interval Upper Bound	Observed Escapement[b]
1980	19,500	**10.8**	86,285	71,746	103,770	
1981	23,050	21.8	129,129	107,371	155,296	129,653
1982	13,200	8.6	50,942	42,358	61,264	
1983	15,000	10.9	65,089	54,122	78,279	56,142
1984	27,100	9.7	119,783	99,600	144,056	121,224
1985	27,300	9.3	119,667	99,503	143,916	
1986	25,400	11.0	114,660	95,341	137,895	
1987	**23,635**[c]	22.3	133,116	110,687	160,091	
1988	25,000	12.3	115,891	96,364	139,375	
1989	24,000	6.5	97,358	80,954	117,087	
1990	33,600	6.5	143,050	118,947	172,038	
1991	34,300	6.0	145,147	120,691	174,560	
1992	28,300	23.3	157,624	131,065	189,565	
1993	37,000	2.8	150,542	125,176	181,048	
1994	32,700	18.2	166,527	138,468	200,272	
1995	16,130	4.5	55,103	45,819	66,270	
1996	16,865	13.7	80,449	66,893	96,751	
1997	13,900	**19.5**	80,160	66,653	96,403	
1998	12,793	**9.6**	51,447	42,778	61,872	
1999	22,540	20.1	122,729	102,049	147,598	
2000	25,605	17.3	130,763	108,730	157,260	
2001	11,656	21.8	74,938	62,312	90,124	
2002	8,000	15.3	42,102	35,008	50,633	
2003	20,353	19.4	110,633	91,992	133,052	
2004	5,920	13.8	28,759	23,913	34,586	
2005	10,375	15.3	53,477	44,467	64,314	61,043
2006	5,153	18.4	35,842	29,802	43,105	31,357
2007	7,100	10.0	25,185	20,941	30,289	29,086
2008	5,430	5.4	20,738	17,243	24,940	

[a] September precipitation recorded at the Ketchikan airport NOAA recording station. Precipitation records were not available for 1980, 1997, and 1998; missing values were imputed.

[b] Observed escapements were from weir counts in 1981, 1983, and 1984, and from mark-recapture studies in 2005–2007.

[c] The peak survey for 1987 was imputed, because no peak foot survey was conducted at McDonald Lake in 1987; the missing value was imputed based on other surveys conducted that year.

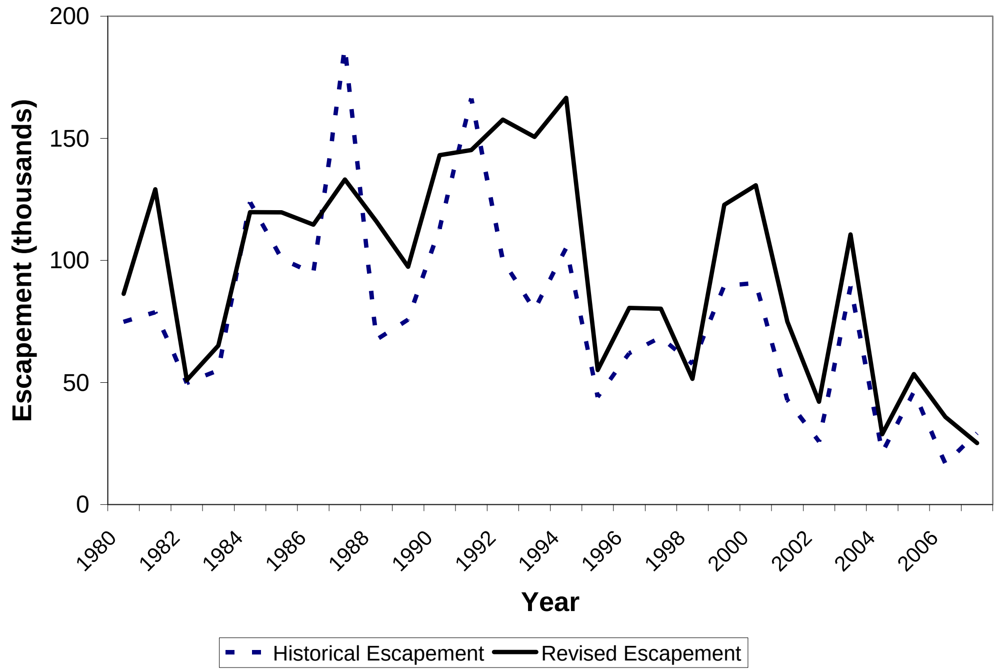

Figure 2.–Comparison of historical escapement estimates (from Johnson et al. 2005) with revised escapement estimates based on calibrated peak foot survey counts, 1980–2007.

HARVEST ESTIMATES

Information about the harvest of McDonald Lake sockeye salmon was summarized by Johnson et al. (2005). Because much of the commercial harvest of the McDonald Lake stock takes place in distant, mixed-stock fisheries, the ADF&G does not have the same kind of comprehensive commercial harvest information for this stock that is available for some other sockeye stocks in the state. Some information regarding the distribution of McDonald Lake sockeye salmon in U.S.-Canada boundary area fisheries was provided by joint U.S.-Canada mark-recapture studies conducted in 1982 (Hoffman et al. 1983) and 1983 (Hoffman et al. 1984). Those studies showed that a small portion of the McDonald Lake run was harvested in Canadian fishing waters in boundary Areas 1 and 3 (Geiger et al. 2004). The best information is from limited adult returns from coded-wire tagging studies conducted by ADF&G in the 1980s through early 1990s. Unfortunately, commercial fisheries in British Columbia were not sampled for coded-wire tagged sockeye salmon; thus, the contributions of McDonald Lake sockeye salmon to Canadian fisheries are not available from the coded-wire tagging studies. McDonald Lake sockeye salmon have also been harvested in directed purse seine fisheries in upper west Behm Canal, ADF&G test fisheries in west Behm Canal, and a personal-use fishery in Yes Bay.

Terminal Harvest

In the mid-1990s, runs to McDonald Lake were projected to be well above escapement needs, and beginning in 1993, sockeye salmon that had bypassed traditional fisheries, and were projected to be in excess of escapement needs, were harvested near McDonald Lake in a terminal purse seine fishery at Yes Bay, in upper west Behm Canal (District 101-80). ADF&G test fisheries were conducted to determine run-strength prior to commercial fishery openings. Maximum harvests occurred in 1993 (142,000 sockeye) and 1996 (210,000 sockeye), and harvests averaged 30,000 sockeye salmon a year from 1997 to 2001 (Figure 3).

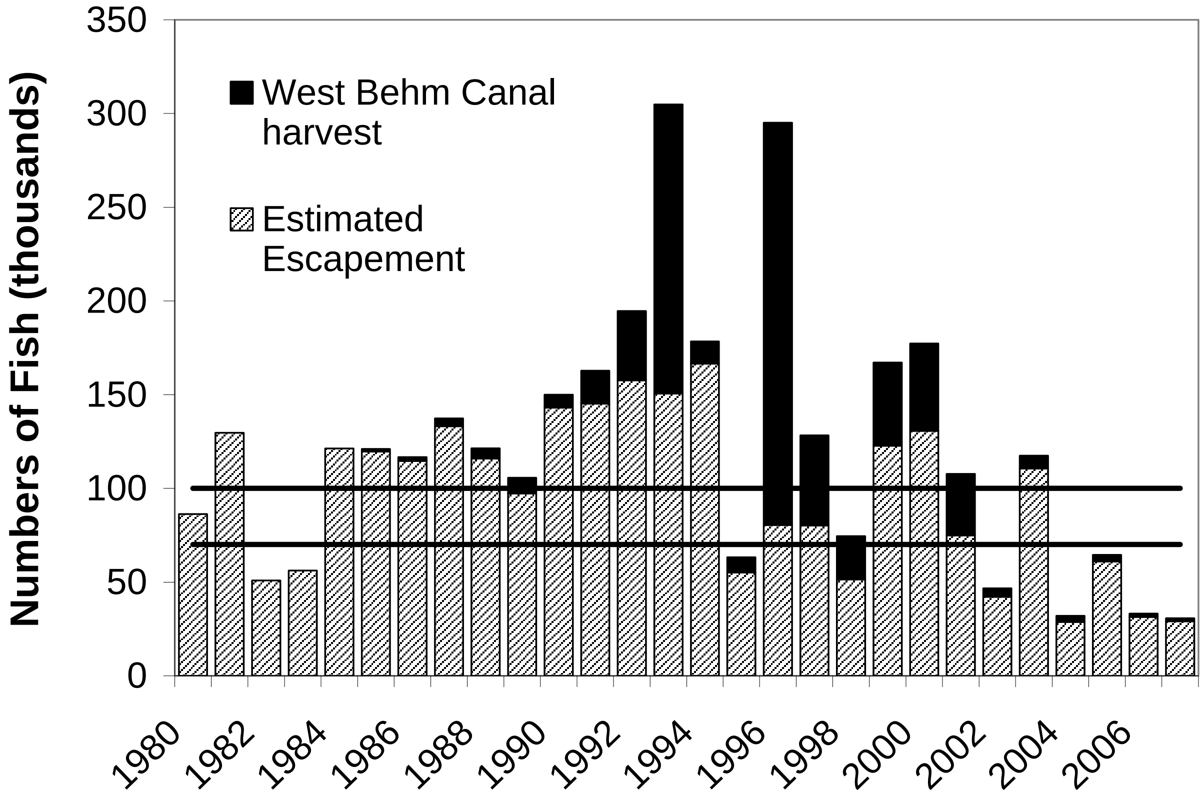

Figure 3.–Estimated escapement of McDonald Lake sockeye salmon, and estimated terminal harvest in west Behm Canal, 1980–2007. Note that escapements from 1980 to 1984 were not the influenced by lake fertilization, while escapements from 1985 to 2007 were all influenced by lake fertilization.

There is no careful accounting of the personal-use take, although fishers have been required to return permits together with a record of their catch. Since about 2000, fishers have been required to report their catch from the previous year before they can be issued a new permit. Even if the recorded harvest represents a substantial undercount, the personal-use harvest must typically represent less than 10% of the entire run. We simply assumed that the sum of reported catch on the returned harvest permits was adequate for our purposes. The accounted for personal-use catches averaged about 5,700 fish from 1985 to 2004, with a range of about 1,100 fish in 1985 to 10,000 fish in 1994 (Figure 3). The bag limits were gradually reduced from a daily limit of 50 fish per day prior to 2005, down to a seasonal limit of 20 fish per person since 2007. As a result, personal use harvest has averaged only about 2,000 fish per year since 2005. The sport fish harvest was assumed to be around 200 fish annually (Geiger et al. 2004), and likely accounted for a very small fraction of the total annual run.

Distant, Traditional Mixed-Stock Commercial Fisheries

Most of the information on the contribution and distribution of the McDonald Lake stock of sockeye salmon in the Alaska traditional commercial harvest comes from coded-wire tag studies conducted by ADF&G in 1982–1985, and 1986–1991. Useful information provided by these studies is limited to only three years of adult returns: 1985, 1989, and 1990. Tag return estimates in 1991 were badly biased by very low initial rates of tagging and recovery (Johnson et al. 2005). Fewer than 6,000 smolts were tagged, 51% of which were tagged during the last three days of the six-week tagging period, and only 112 tagged adults were recovered in the commercial fisheries. As already mentioned, commercial fisheries in British Columbia were not sampled for coded-wire tagged sockeye salmon at all; thus, the contribution of McDonald Lake sockeye salmon to Canadian fisheries are not available from the coded-wire tagging studies.

Tag recoveries were expanded to estimate harvest using standard methods (Bernard and Clark 1996). These methods were outlined in detail in Appendix 2 of Heinl et al. (2000, p. 41–50). The harvest rate on McDonald Lake sockeye salmon was calculated by first estimating the total harvest by statistically expanding sampled commercial fishery recoveries of coded-wire tags for the fraction of the return not tagged, based on the observed tag ratio in the escapement. Johnson et al. (2005) reported the average harvest rate to be 47% of the total annual run, over the three years of coded-wire tag recoveries, 1985, 1989 and 1990. Those estimates were based on estimates of escapement that were assumed to be approximately known; however, as they pointed out, those estimates of escapement were in need of recalibration. We recalculated those harvest rate estimates for the three years of coded-wire tag recoveries using the recently recast escapement estimates. The result was a slightly lower average exploitation rate of 41%: 32% in 1985, 48% in 1989, and 41% in 1991.

RUN-RECONSTRUCTION

Johnson et al. (2005) examined three approaches to estimate historical harvests and the total annual run of McDonald Lake sockeye salmon. Here, we use their "Case 2" reconstruction, which was based simply on a constant harvest rate of 41% as estimated from three years of coded-wire tag recoveries in 1985, 1989, and 1990. Total brood-year returns were developed using the age-class distribution from samples of the escapement (Appendix A). Though drift gillnet fisheries may have been size and age selective (i.e., the age distribution in the escapement could be different than the distribution in the catch), we assumed this would be a reasonable approximation.

We estimated the total annual run in two steps. First, we estimated the number of McDonald Lake sockeye salmon that escaped the traditional commercial fisheries. In addition to the estimated escapement, this total included the number of sockeye salmon harvested in terminal fisheries at Yes Bay and at McDonald Lake, including the terminal purse seine fishery at Yes Bay (District 101-80), ADF&G test fisheries conducted at Yes Bay, personal-use fisheries in Yes Bay, and sport fisheries at McDonald Lake. We also added the number of fish killed for brood stock for enhancement programs by ADF&G or Southern Southeast Regional Aquaculture Association (SSRAA). Second, we divided that total by 59% to expand for distant harvest; i.e., the catch in mixed-stock fisheries outside of District 101-80. Thus, the total annual run was estimated as the escapement, plus the terminal harvest, plus the estimated harvest in distant mixed-stock fisheries (Table 2). Again, Canadian harvests of McDonald Lake sockeye salmon were not represented in this run reconstruction; therefore, the harvest estimates are biased low to some unknown (but probably small) degree. Estimates of complete brood-year returns were available for the 1980–2001 brood years (Table 3).

Table 2.–Estimated harvest and total run (in thousands) of McDonald Lake sockeye salmon, 1982–2007. The distant, traditional commercial harvest in Alaska fisheries (i.e., the catch in mixed-stock fisheries outside of west Behm Canal) was estimated by assuming a 41% harvest rate. Canadian harvests are assumed zero.

		Terminal Harvest							
Year	Estimated Escapement	Yes Bay Purse Seine[a]	Yes Bay Test Fish	Yes Bay Personal Use[b]	Assumed Sport Fish	Brood Stock	Estimated Traditional Commercial Harvest	Total Estimated Harvest	Estimated Total Run
1982	50.9	0.0	0.0	0.0	0.0	0.0	35.4	35.4	86.3
1983	56.1	0.0	0.0	0.0	0.0	0.0	39.0	39.0	95.2
1984	121.2	0.0	0.0	0.0	0.0	0.0	84.2	84.2	205.5
1985	119.7	0.0	0.0	1.2	0.2	0.0	84.1	85.5	205.2
1986	114.7	0.0	0.0	1.8	0.2	0.0	81.1	83.1	197.7
1987	133.1	0.0	0.0	4.0	0.2	0.0	95.4	99.6	232.7
1988	115.9	0.0	0.0	2.3	0.2	2.9	84.4	89.8	205.7
1989	97.4	0.0	0.7	3.4	0.2	4.0	73.4	81.7	179.1
1990	143.1	0.0	0.4	5.7	0.2	0.6	104.3	111.2	254.3
1991	145.1	6.2	1.8	8.2	0.2	1.3	113.1	130.7	275.9
1992	157.6	23.0	1.9	9.9	0.2	2.0	135.3	172.4	330.0
1993	150.5	141.6	0.7	9.9	0.2	1.9	211.8	366.1	516.6
1994	166.5	0.0	0.1	10.2	0.2	1.4	124.0	136.0	302.5
1995	55.1	0.0	0.4	6.7	0.2	0.8	43.9	52.0	107.1
1996	80.4	210.1	0.0	4.4	0.2	0.0	205.1	419.9	500.3
1997	80.2	38.2	2.3	7.3	0.2	0.0	89.1	137.1	217.3
1998	51.4	16.0	0.6	6.1	0.2	0.0	51.7	74.7	126.2
1999	122.7	35.2	2.4	6.5	0.2	0.0	116.1	160.5	283.2
2000	130.8	35.8	2.7	7.6	0.2	0.3	123.2	169.8	300.5
2001	74.9	25.0	0.9	6.4	0.2	0.3	74.9	107.7	182.6
2002	42.1	0.0	0.5	3.7	0.2	0.2	32.4	37.0	79.1
2003	110.6	0.0	0.9	5.3	0.2	0.4	81.6	88.4	199.0
2004	28.8	0.0	0.1	3.0	0.2	0.0	22.2	25.5	54.2
2005	61.0	0.0	0.0	3.3	0.2	0.0	44.9	48.4	109.4
2006	31.4	0.0	0.0	1.6	0.2	0.0	23.1	24.9	56.2
2007	29.1	0.0	0.0	1.1	0.2	0.2	21.3	22.9	51.9

[a] Yes Bay purse seine catches include only those sockeye salmon harvested in District 101-80.

[b] Estimates of the personal-use catch for Yes Bay are not available prior to 1985.

Table 3.–Reconstructed brood-year returns and yields (in thousands) resulting from each brood-year escapement (in thousands), 1980–2001.

Brood Year	Escapement	Total Brood-Year Return	Brood-Year Yield
1980	86.3	251.5	165.3
1981	129.7	196.0	66.3
1982	50.9	189.4	138.5
1983	56.1	176.2	120.0
1984	121.2	270.1	148.9
1985	119.7	165.1	45.4
1986	114.7	292.7	178.0
1987	133.1	548.7	415.6
1988	115.9	293.3	177.4
1989[a]	97.4	314.4	217.0
1990[a]	143.1	108.8	-34.2
1991	145.1	498.8	353.6
1992	157.6	217.4	59.8
1993	150.5	148.2	-2.3
1994	166.5	294.8	128.3
1995	55.1	262.9	207.8
1996	80.4	193.8	113.4
1997	80.2	48.8	-31.4
1998	51.4	222.9	171.4
1999	122.7	52.5	-70.2
2000	130.8	103.6	-27.2
2001	74.9	74.2	-0.7

[a] McDonald Lake sockeye salmon fry were hatchery-reared and back-planted into the lake in 1989 (3.5 million) and 1990 (0.99 million).

JUVENILE FRY ABUNDANCE

Rearing sockeye salmon fry populations were estimated annually, from 1983 to 2007, using hydroacoustic gear to estimate abundance and mid-water trawl gear to estimate species and age composition. The methods and equipment used to conduct the sampling changed several times over the 22-year period, but the sampling methods generally followed those briefly described by Zadina and Heinl (1999) and Piston (2004). For this analysis we looked only at population estimates of age-0 sockeye salmon fry from sampling conducted in the fall. Fall surveys were conducted nearly annually, and provided us with the longest data series.

The age-0 sockeye salmon fry population averaged 1.4 million fry during the period 1982–1986, increased to an average of 3.1 million fry during the period 1987–1994, but then dropped back to an average of only 1.2 million fry from 1995 to 2007 (Table 4; Figure 4). Although the estimates of rearing fry populations are rough, they do appear to track the parent escapement to the extent that we can see that escapements and fry populations were higher in the mid-1980s than they have been since the mid-1990s (Figure 4), and fall fry abundance is also correlated ($\rho = 0.66$) with parent escapement (Figure 5). Fall fry abundance is highly variable; however abundance decreased in 2005 and has been at low levels since (Figure 4).

Table 4.–Estimated sockeye salmon brood-year escapements at McDonald Lake, 1982–2003, and subsequent age-0 sockeye salmon fry population estimated one year later.

Brood Year	Estimated Brood-Year Escapement (in Thousands)	Survey Year	Survey Date	Estimated Age-0 Sockeye Fry Population (in Millions)	Age 1.3 Adult Return Year
1982	51	1983	7-Nov	1.5	1987
1983	56	1984	18-Sep	1.7	1988
1984	121	1985	18-Sep	1.2	1989
1985	120	1986	15-Sep	1.5	1990
1986	115	1987	1-Sep	1.2	1991
1987	133	1988	21-Sep	3.7	1992
1988	116	1989	25-Sep	2.9	1993
1989	97	1990	26-Sep	2.9	1994
1990	143	1991	21-Oct	1.1	1995
1991	145	1992	8-Nov	4.6	1996
1992	158	1993	14-Sep	4.0	1997
1993	151	1994	6-Oct	2.3	1998
1994	80	1995	No survey		1999
1995	80	1996	No survey		2000
1996	51	1997	10-Oct	2.0	2001
1997	123	1998	12-Oct	0.7	2002
1998	131	1999	21-Dec	1.3	2003
1999	75	2000	28-Oct	1.4	2004
2000	42	2001	Oct	1.9	2005
2001	111	2002	23-Oct	1.1	2006
2002	29	2003	8-Dec	0.5	2007
2003	61	2004	22-Oct	1.8	2008
2004	31	2005	5-Oct	0.4	2009
2005	51	2006	10 Oct	0.4	2010
2006	56	2007	20 Sep	0.5	2011

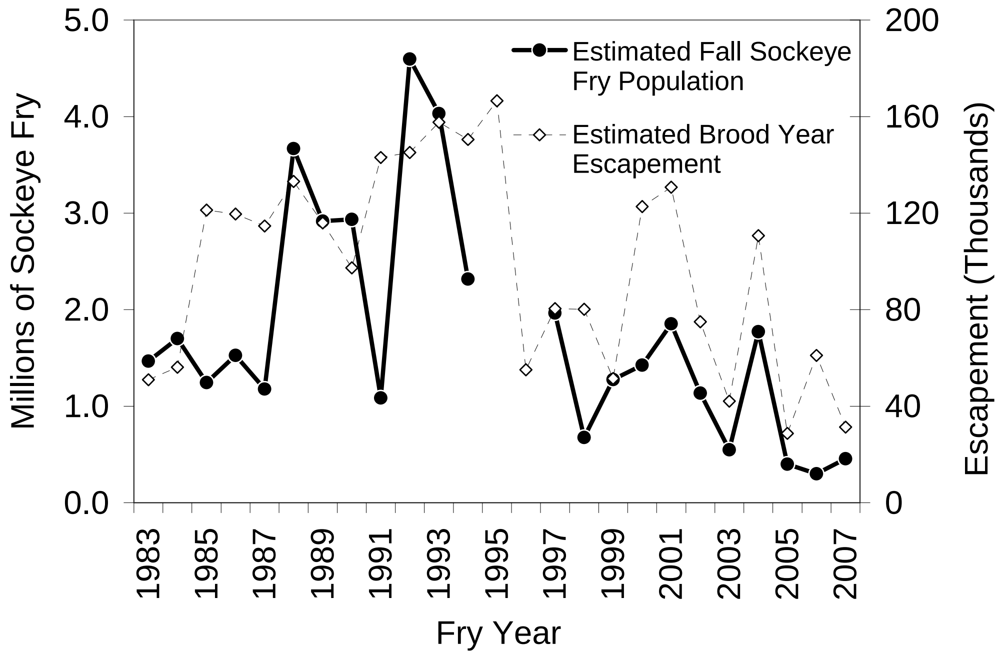

Figure 4.–Estimates of age-0 sockeye salmon fry abundance in McDonald Lake, 1983–2007, compared to the estimated brood-year escapements of adult sockeye salmon one year prior. Note that McDonald Lake sockeye salmon fry were hatchery-reared and back-planted into the lake in 1989 (3.5 million fry) and 1990 (1.0 million fry).

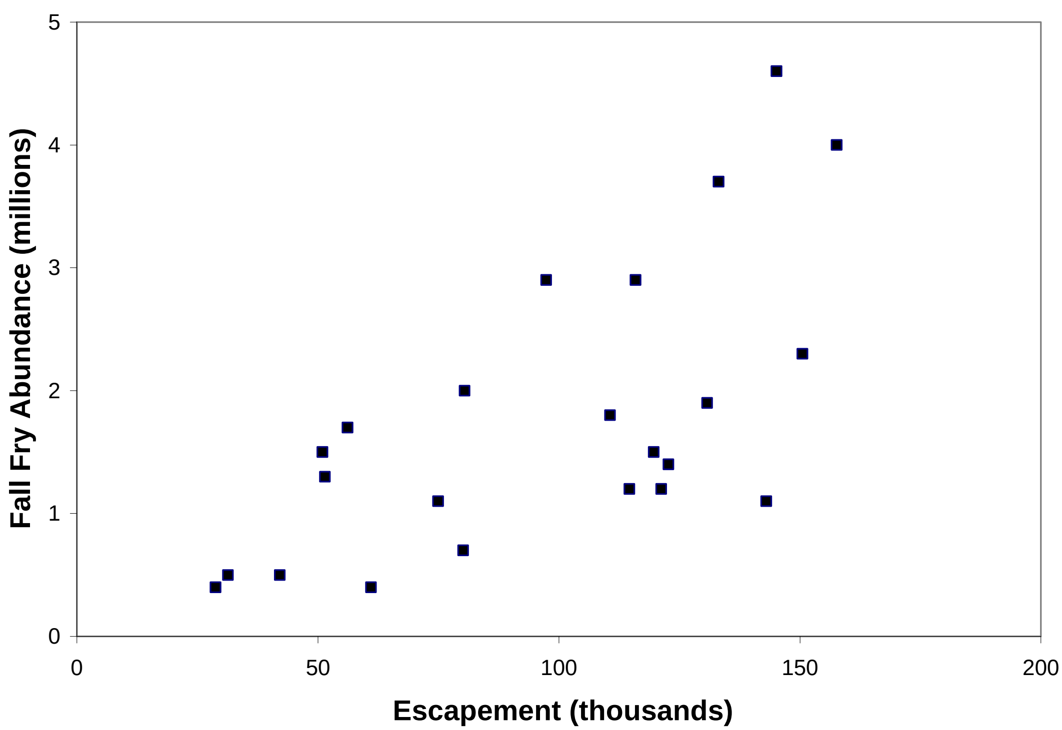

Figure 5.–Fall abundance of sockeye salmon fry (estimated through hydroacoustic surveys) versus parent escapement (i.e., the escapement in the year prior to the survey.

LAKE FERTILIZATION

ADF&G began to focus attention on McDonald Lake starting in the late 1970s, as part of a region-wide program to rehabilitate sockeye salmon runs in Southeast Alaska through lake fertilization and fry stocking (Burkett et al. 1989). Over a 23-year period, the McDonald Lake system was enhanced through a lake fertilization program (Figure 6). Lake fertilization is an attempt to increase the primary production of a sockeye salmon nursery lake through the application of essential nutrients (nitrogen and phosphorous), and in turn increase the production at higher trophic levels. The desired product is healthier (larger) sockeye salmon smolt, increased fry-rearing capacity, higher survival rates, and increased adult returns (Smith 1969; LeBrasseur et al. 1978; Barraclough and Robinson 1972; Stockner and MacIsaac 1996).

Preliminary limnological data were collected at McDonald Lake in 1979–1981, and the lake was fertilized from 1982 to 2004. McDonald Lake sockeye salmon fry were also back-planted into the lake in 1989 (3.5 million fry) and 1990 (1.0 million fry). The enhancement program was assessed through annual monitoring of the zooplankton and chemical properties of the lake, and through estimates of fall fry abundance.

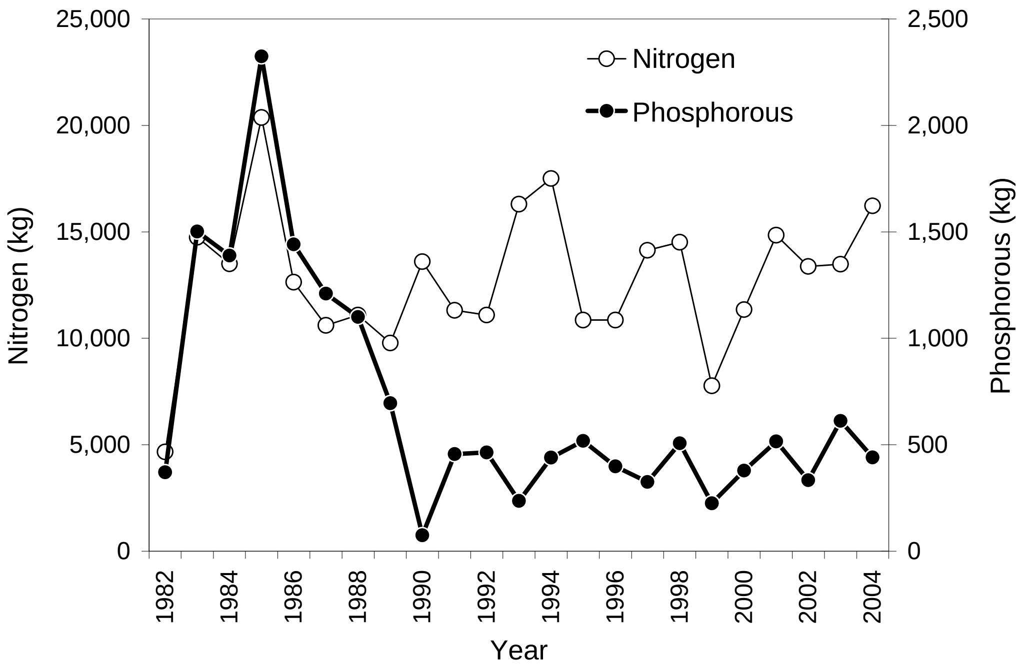

Figure 6.–Annual nitrogen and phosphorous loads applied to McDonald Lake in the form of liquid fertilizer, 1982–2004.

Limnological observations (total nitrogen, total phosphorus, chlorophyll *a*, zooplankton density, and zooplankton biomass) were first collected at McDonald Lake in May, June and December of 1979. Limnological data were collected monthly from May to September during nearly all years, 1980 to 2005, with sampling being conducted from seven or more months in 1980 to 1992. Thus, although we have 26 years of limnological data, we have only two years of comprehensive pre-fertilization data (1980–1981) to compare to data from years when the lake was fertilized. The methods used for limnological samples are described in Johnson et al. (2005).

McDonald Lake was enriched with combinations of liquid fertilizer having a nitrogen to phosphorous atomic ratio of 27:7 and 32:0 (Johnson et al. 2005). During most of the enhancement project, the quantity of fertilizer applied to the lake each year was equal to 90% of the critical phosphorus load, as calculated after Vollenweider (1976), and determined from annual late fall or early spring phosphorus concentrations in McDonald Lake (see Appendix B Johnson et al. 2005, for specific annual fertilizer applications). Fertilizer was applied weekly to the upper half of the lake. The prescription for phosphorous was much higher from 1983 to 1989, than it was in later years (Figure 7). From 1982 to 1985, however, up to 25% of the fertilizer remained in the fertilizer storage barrels in the form of a crystalline precipitate, and it was determined that up to 50% of the phosphorous may not have been added to the lake in those years.

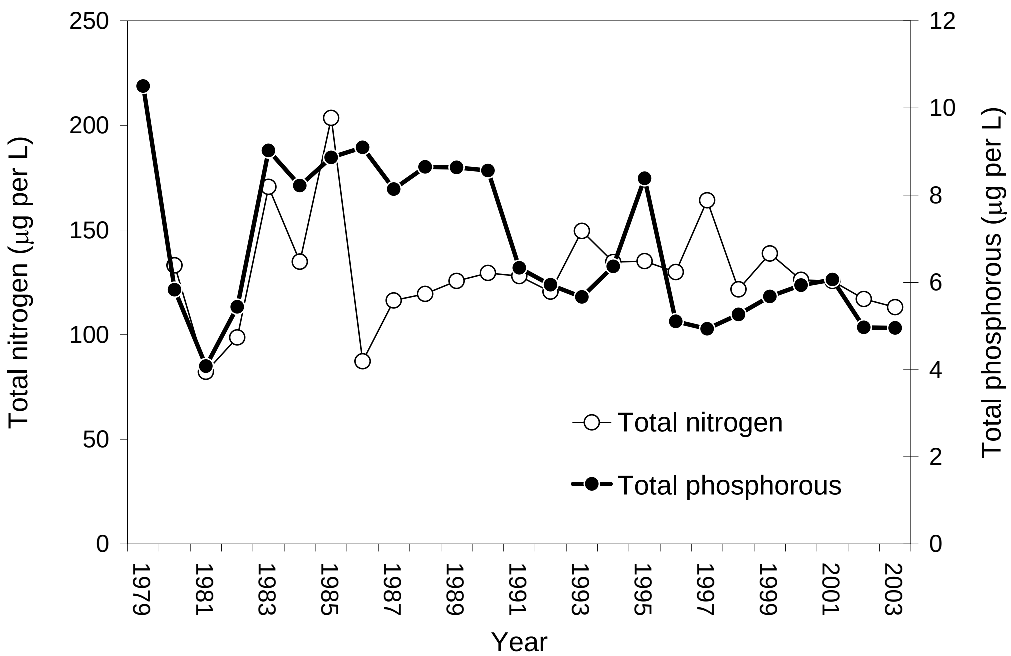

Figure 7.–Mean annual concentrations of total nitrogen and total phosphorous in McDonald Lake during May–September, 1979–2003.

The amount of nitrogen and phosphorus that was annually applied to McDonald Lake was on the same order of magnitude as the total P and total N that was naturally provided by carcasses from the annual sockeye salmon escapement. The range of measured total N concentrations was 75 to 200 µg/L which is equivalent to a standing stock of 14,000 to 38,000 kg of N in McDonald Lake. The range of measured total P concentrations was 4 to 10 µg/L which is equivalent to a standing stock of 770 to 1,900 kg of P in McDonald Lake. Note that in the McDonald Lake fertilization, the annual loadings of total P ranged from 75 to 2,224 kg or 17.9 to 550 mg/m^2; the annual loading of total N ranged from 4,700 to 17,500 kg or 1,100 to 4,200 mg/m^2. The annual loadings of fertilizer are on the order of the level of nutrients contained in the annual salmon escapement. Using the average carcass weights and concentrations of N and P in salmon carcasses provided in Barto (2005) and the range of historical escapements (29 to 167 thousand), the level of P in McDonald Lake salmon escapements ranged from 383 to 2,493 kg and the level of N in McDonald Lake salmon escapements ranged from 2,500 to 14,400 kg.

The average summer (May–September) concentration of total nitrogen in the lake was relatively stable compared to the average concentration of total phosphorous (Figure 5). The total P concentration averaged 8.6 µg/L from 1983 to 1990, but declined thereafter, and averaged 5.8 µg/L from 1991 to 2003. Note that the highest total P concentration during the study period was 10.5 µg/L recorded in 1979, prior to enrichment of the lake.

Limnological monitoring at McDonald Lake (from 1980 to 1986) following the initial application of fertilizers to McDonald Lake (Burkett et al. 1989).indicated increases in nutrient concentration (Figure 7), algal biomass (Figure 8), zooplankton biomass (Figure 9), and zooplankton density (Figure 10) coincident with lake fertilization. Since 1986, however, summer production of Chlorophyll *a* has been variable, and appears to have trended downward (Figure 8). Over that same time period, a similar downward trend was exhibited by the total zooplankton density and total weighted biomass of zooplankton in the lake (Figures 9 and 10). Zooplankton in the order Cladocera are the preferred prey of sockeye salmon fry (Koenings and Burkett 1987). Trends in the mean density and weighted biomass of Cladocera closely followed trends shown by the total zooplankton population (Figures 9 and 10). In 2003, the total zooplankton density jumped to the highest level recorded (Figure 10). This recent increase in zooplankton population coincided with the decrease in the escapement level, suggesting a possible predator or top down control of the zooplankton. Fall fry abundance also tracked zooplankton abundance during the period, 1983 to 2000. However, zooplankton increased (Figure 9 and 10) after 2000, while fall fry abundance decreased (Figure 4).

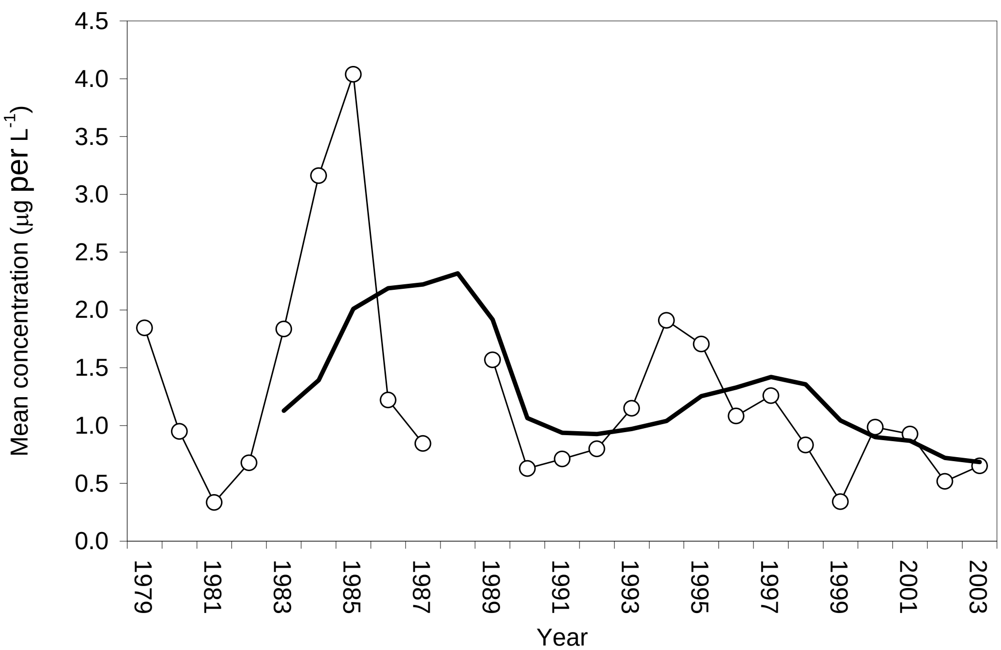

Figure 8.–Mean annual concentration of Chlorophyll a in McDonald Lake during May–September. The heavy black line shows the 5-year moving average concentration.

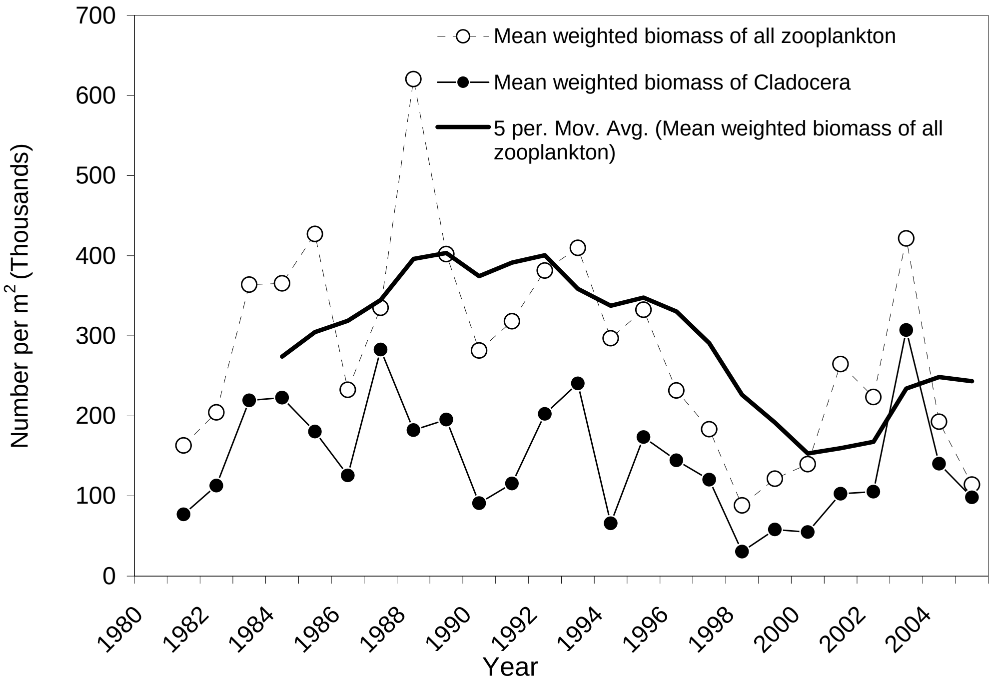

Figure 9.–Mean annual weighted biomass of total zooplankton and mean annual weighted biomass of Cladocera, 1980–2005. The biomass is a function of zooplankton density and zooplankton size. The heavy black line shows the 5-year moving average biomass of all zooplankton species.

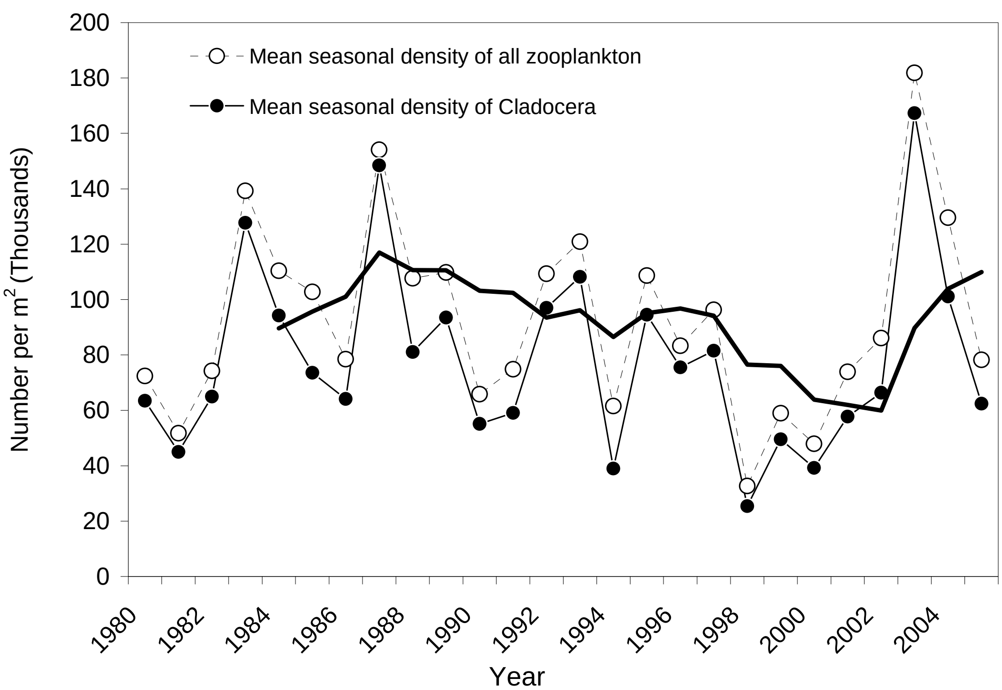

Figure 10.–Mean seasonal density of total zooplankton and mean seasonal density of Cladocera, 1980–2005. The heavy black line shows the 5-year moving average density of all zooplankton species.

It is impossible to directly evaluate the effects of the McDonald Lake fertilization project due to the lack of pre-fertilization monitoring of the juvenile sockeye salmon population. McDonald Lake is a highly oligotrophic lake in a coastal rainforest, and, consequently, retention of nutrients is low, because of the high flushing rate (mean residence time 0.67 years) caused by heavy rain in the fall–winter period when the lake is un-stratified. McDonald Lake has a hydrologic productivity regime that is characteristic of the coastal British Columbia lakes selected for the whole-lake fertilization experiments described by Stockner and Shortreed (1985), Hyatt and Stockner (1985), and Hyatt et al. (2004). These lakes are phosphorous limited and, in spite of the regime of low hydrologic nutrient retention, primary production (Stockner and Shortreed 1985) and secondary production (Hyatt and Stockner 1985) were observed to increase linearly with phosphorous loadings. These increases resulted in increased juvenile growth rate, increased smolt size, and increased productivity of sockeye salmon populations utilizing these lakes as nursery areas (Hyatt and Stockner 1985, Hyatt et al. 2004).

Primary productivity in McDonald Lake is undoubtedly phosphorus limited based on the very low baseline, observed total P concentrations, and the observed correlation of total P to cholorophyll *a* concentration (c.f. Figure 5 and 6). As such, the lake fertilization project should be viewed as having enhanced primary and secondary productivity at McDonald Lake.

ESCAPEMENT GOAL ANALYSIS

METHODS OF STOCK RECRUIT ANALYSIS

The following hierarchal set of models was fit to the McDonald Lake stock-recruit data for the 1980–2001 brood years. The stock-recruit models are Ricker-type (Ricker 1975), and the hierarchal terms included; parental escapement abundance, number of fry stocked, and a first order autoregressive term. Five models were constructed: Model 1, linear, no density dependence from parental escapement; Model 2, straight Ricker, parental escapement density dependence; Model 3, Ricker with fry plants, escapement density dependence and fry plants (this model used in Hilborn and Eggers 2000); Model 4, autoregressive Ricker, density dependence with first order autoregressive term; and Model 5, autoregressive Ricker with fry plants and the highest order model escapement density dependence. Models were constructed as follows:

Model 1: Linear

$$R_i = S_i \exp\left(\alpha\right)\exp(\varepsilon_i)\,, \tag{2}$$

Model 2: Straight Ricker

$$R_i = S_i \exp\left(\alpha\left(1-{S_i}/{\beta}\right)\right)\exp(\varepsilon_i)\,, \tag{3}$$

Model 3: Ricker with fry plants

$$R_i = S_i \exp\left(\alpha\left(1-{S_i}/{\beta}-\gamma F_{i+1}\right)\right)\exp(\varepsilon_i)\,, \tag{4}$$

Model 4: Autoregressive Ricker

$$R_i = S_i \exp\left(\alpha\left(1-{S_i}/{\beta}\right)\right)\exp(\phi\varepsilon_{i-1})\text{, and} \tag{5}$$

Model 5: Autoregressive Ricker with fry plants

$$R_i = S_i \exp\left(\alpha\left(1 - {S_i}/{\beta} - \gamma F_{i+1}\right)\right)\exp(\phi\varepsilon_{i-1}), \quad (6)$$

where α, β, γ, ϕ are model parameters, and the data are total recruits from brood year i escapement (R_i), escapement in brood year i (S_i), and fry plants from brood year i in year i + 1 (F_{i+1}). Finally, ε_i is the process error, where ln(ε_i) ~ normal(0,σ). The significance of the relative fit of the alternative models was evaluated using a likelihood ratio test (Hilborn and Mangel 1997). Note that the Ricker model with fry plants was used in Hilborn and Eggers (2000) to evaluate effects of hatchery releases. Each of these models was fit to the stock-recruit data from McDonald Lake sockeye salmon using the method of maximum likelihood. Parameters were selected to maximize likelihood (L). The log normal error structure was used to derive the likelihood function (L).

$$L(\alpha,\beta,\gamma,\delta\,|data) = \prod\left[\left(\frac{1}{\sigma\sqrt{2\pi}}\right)\exp -\left(\frac{\ln\left(\frac{R_i}{\hat{R}_i}\right)}{2\sigma^2}\right)\right] \quad (7)$$

The parameters (α, β, γ, ϕ, and σ) of the respective models were estimated using EXCEL. The models were fit to the data using the solver routine to search over the parameter space to minimize the – ln(L) which is equivalent to maximizing L. The (α, β) parameters of the stock recruit models were bias corrected using procedures in Hilborn and Walters (1992). Appropriate reference points were calculated using the bias corrected parameters (α' and β'**),**

$$\alpha' = \alpha + {\sigma^2}/{2}, \quad (8)$$

$$\beta' = \frac{\alpha'}{\alpha}\beta, \quad (9)$$

and

$$\sigma^2 = \frac{\sum \ln\left(\frac{\hat{R}_i}{S_i}\right)^2}{n-p}. \quad (10)$$

For the autoregressive model the bias correction is:

$$\alpha' = \alpha + {\sigma^2}/{2(1-\phi^2)}. \quad (11)$$

For each model applied to the stock-recruit data set, we calculated the maximum sustained yield (MSY) escapement goals, the range of escapements predicted to produce 90% of MSY, and MSY harvest rates. In addition, the likelihood profiles for the MSY escapement goals and the

MSY harvest rates were calculated. The likelihood profiles were estimated using a numerical method described in Hilborn and Mangel (1997) and were used to evaluate the uncertainty in these reference points.

RESULTS OF STOCK-RECRUIT ANALYSIS

The hierarchal set of stock-recruit models was fit to the McDonald Lake recruits from parent escapements, 1980–2001 (Table 4). There was significant density dependence in the stock-recruit data, with the models with the escapement term (Model 2 and Model 4) having a significant improvement in fit (likelihood ratio test p = 0.04) over the linear model (Model 1; Table 5). There was no significant autocorrelation in the Model 2 residuals, and Model 4 (i.e, with the autoregressive term, ϕ = 0.08, which corrects for time-series bias) provided no significant improvement in fit (likelihood ratio test, p = 0.77). The models with the fry plant terms (Model 3 and 5) showed improved fit relative to the lower-order Model 2 (Table 5); however, the improvement in fit was not significant (likelihood ratio test, p = 0.42). Note that because of the lack of improvement in fit exhibited by Model 4, the autoregressive model with the fry plant term (Model 5) was not considered.

We chose Model 3 as the best model. The 90% MSY escapement goal range was 55,000 to 120,000 sockeye salmon (numbers rounded up). The fit of Model 3 was reasonable (Figure 11), and there was no autocorrelation or trend in the Model 3 residuals (Figure 12), although the production from four of the most recent five broods was the lowest in the series. This model produced good definition of the MSY escapement level (Figure 13).

Table 5.–Results of model fits to the escapement-recruit data, 1980–2001 brood years. Estimated parameters, and reference points (MSY escapements, 90% MSY escapement goal ranges, MSY harvest rates), measures of fit (-log L, AIC), and p-values for likelihood ratio tests for significance of straight Ricker relative to linear, Ricker with fry plants relative to straight Ricker, autoregressive Ricker relative to straight Ricker, and autoregressive Ricker with fry plants relative to autoregressive Ricker, respectively.

Model	**Parameters**				**MSY Escape-Ment**	**90% MSY Escapement Goal Range**		**MSY Harvest Rate**	**Fit Criteria**		**Number of Parameters**	***p*-value**
	α	β	ϕ	γ		**Lower**	**Upper**		**-log L**	**AIC**		
1: Linear	0.62								28.41	30.41	1	
2: Straight Ricker	1.66	218			84	54	119	0.639	20.79	24.79	2	0.042
3: Ricker with fry plant	1.42	186		-0.099	82	53	116	0.633	20.47	26.47	3	0.423
4: Autoregressive Ricker	1.51	183	0.077		80	44	113	0.659	20.74	26.74	3	0.765

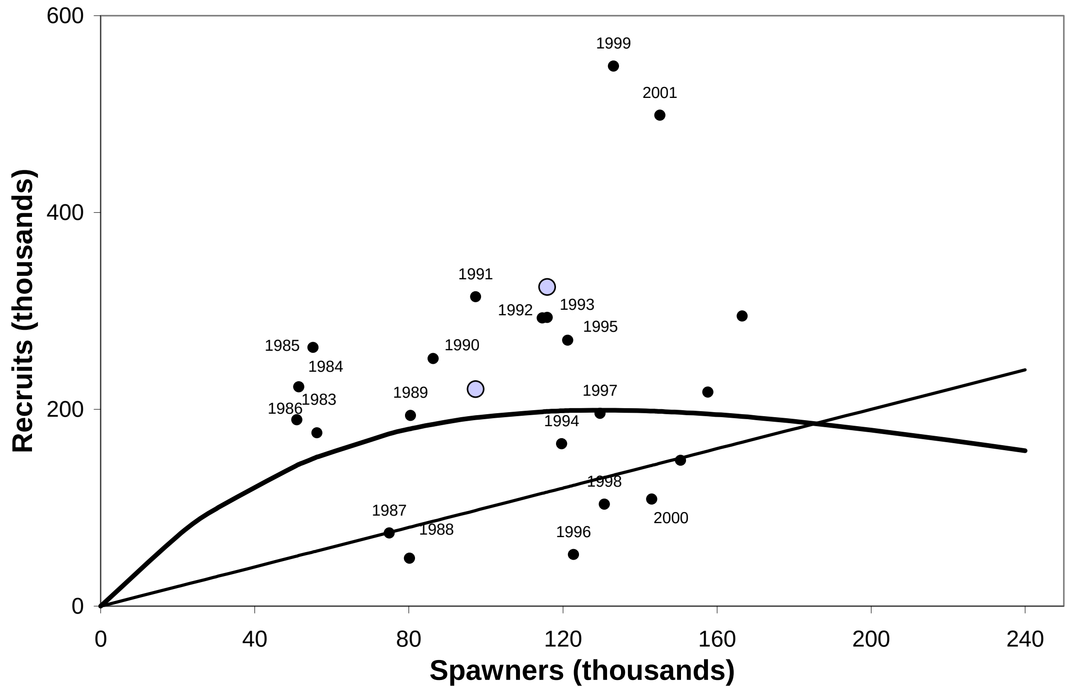

Figure 11.–Stock-recruitment relationship for McDonald Lake sockeye salmon, brood years 1980-2001. Solid circles are observed recruits from parental escapements, open circles and the curved line are Model 4 predictions, and the straight black line is the replacement line.

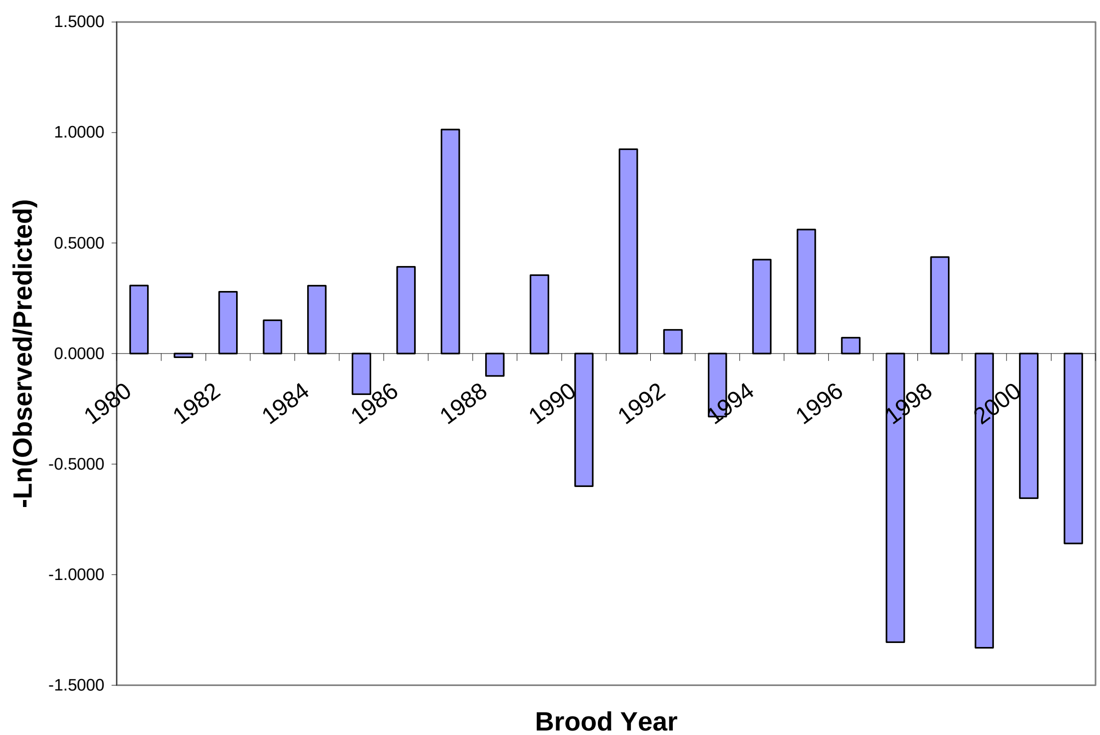

Figure 12.–Residual plots for the Model 4 stock-recruit relationship fit to the 1980–2001 brood years for McDonald Lake sockeye salmon.

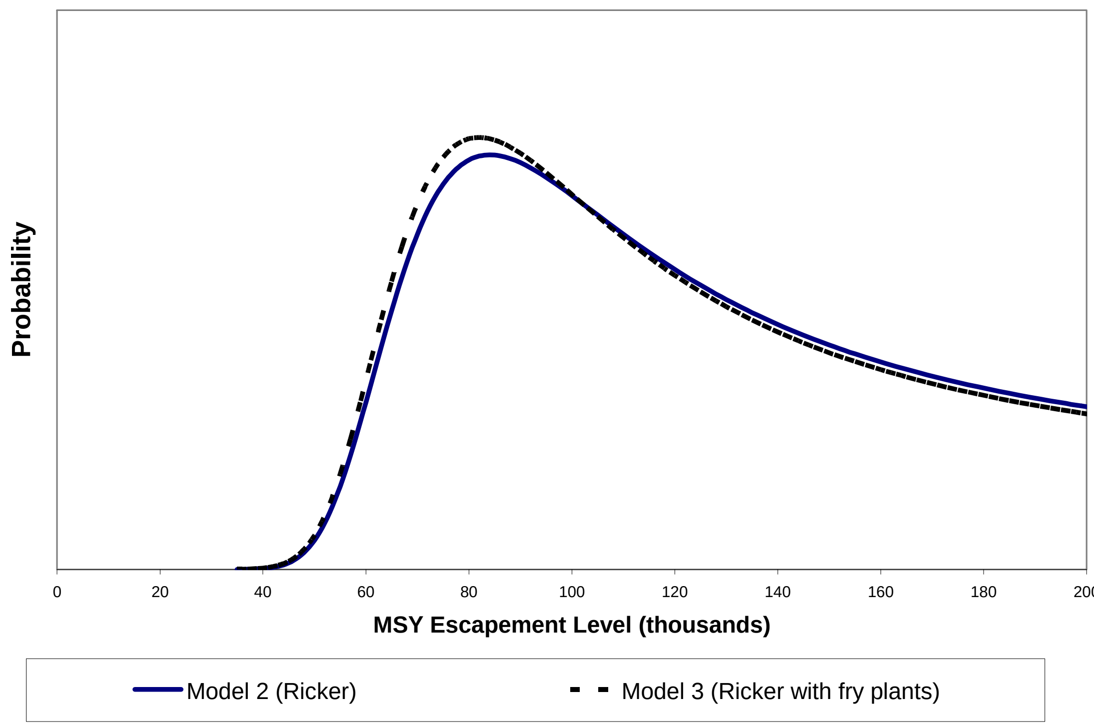

Figure 13.–Likelihood profiles for MSY escapement levels for Model 2 and Model 4 fits to stock-recruit data for McDonald Lake sockeye salmon, 1980–2001 brood years.

STOCK STATUS AND ESCAPEMENT GOAL RECOMMENDATION

ESCAPEMENT GOAL RECOMMENDATION

Our recommendation is to establish a *sustainable escapement goal* of 55,000 to 120,000 spawners per year for McDonald Lake sockeye salmon, as estimated from the annual, calibrated, peak, foot-survey count. This goal is based on the approximate escapement range that produced 90% of MSY as determined by the Model 3 (Autoregressive Ricker with fry plants) fit to the brood year 1980–2001 stock-recruit data set. While this model was not the most parsimonious (i.e., minimum AIC), it was selected because it accounted for the bias in our assessment of the wild stock production due to the stocking of fry that occurred in 1989 and 1990; therefore, it was deemed the most meaningful biological model. Note that the recommended escapement goal range differs from the prior SEG of 70,000 to 100,000 spawners (Johnson et al. 2006).

It is difficult to directly evaluate or demonstrate fertilization enhancement of lake productivity due to lack of pre-fertilization baseline data. The escapement levels were within escapement goal ranges prior to lake fertilization. Olson (1989) attempted to measure the effect of lake fertilization on growth of rearing fry at the lake and failed to demonstrate any effect because the fertilization was likely masked by the between-year differences in other growth-influencing environmental variables. Escapements and stock productivity were at high levels during the initial decade of fertilization. However, escapements and productivity declined in the mid 1990s and the low productivity persisted in the face of continued fertilization. Lake fertilization was discontinued after 2004 due to low escapements and belief that continued fertilization was unnecessary due to low fry abundance. This belief was consistent with the observed increasing zooplankton abundance in response to low sockeye fall fry abundance during recent years. This indicates that prey resources are not limiting during periods of low escapements and low sockeye fry populations.

Alternatively, inflation of stock productivity due to lake fertilization is possible and certainly cannot be ruled out. Primary production in McDonald Lake is clearly phosphorous limited. The magnitude of fertilizer loadings were substantial and likely enhanced the primary and secondary productivity in McDonald Lake, consistent with well documented responses of lakes with similar characteristics to fertilization (c.f. Hyatt and Stockner 1985, Hyatt et al. 2004).

The recommended escapement goal should be considered a sustainable escapement goal, because of the uncertainty of the effect of lake fertilization that occurred from 1982 to 2004 on the stock productivity. The productivity estimates on which the escapement goal recommendation is based may not reflect the future productivity of an unfertilized lake. Essentially all returns in the stock-recruit time series used to estimate the recommended escapement goal had a lacustrine residence affected by lake fertilization.

STOCK OF CONCERN RECOMMENDATION

The McDonald Lake sockeye salmon stock has recently undergone a reduction in recruitment. The recommended escapement goal was not achieved in six of the last seven years (2002 - 2008), and escapements have been below the escapement goal for four of the last five years. In addition fall fry abundance, 2005–2007 have been the lowest observed, has been the lowest observed in the history of fall fry assessments. This indicates McDonald Lake runs will be depressed for some time. Therefore, this stock meets the criteria for a stock of management concern as defined under the Sustainable Salmon Fishery Policy. We recommend that a stock of management concern be established for McDonald Lake sockeye salmon.

Coded-wire tagging studies in the 1980s showed that this stock was harvested primarily in the District 6 drift gillnet fishery, with the next largest portions of the run harvested in the District 1, 2, and 4 purse seine fisheries. The ADF&G has implemented a multi-year, genetic stock identification project to help identify areas of potential catch of McDonald Lake sockeye salmon in 2007 and 2008. Weekly samples were collected from the District 6 drift gillnet fishery and from the District 1 purse seine fishery. These data, once analyzed, will be used to update the coded-wire tagging studies and provide improved information about the time and area distribution of McDonald Lake sockeye salmon in those fisheries.

The ADF&G has already implemented a series of management actions designed to allow more McDonald Lake sockeye salmon to escape to McDonald Lake. In 2007 and 2008, the District 6 drift gillnet fishery was restricted to two-day openings for three weeks from mid-July to early August; in addition, the western portion of Sumner Strait was closed to fishing during the middle week of that conservation period in 2007. In 2007 and 2008, the District 1 purse seine fishery along the Gravina Island shoreline (north of the latitude of Cone Point) was closed to fishing from mid-July to early August. In addition to these measures for sockeye salmon conservation, overall purse seine fishing time in Southern Southeast was very limited during the 2006 and 2008 seasons due to poor runs of pink salmon. The Yes Bay terminal purse seine fishery has not been conducted since 2001. Finally, the bag limits in the McDonald Lake Personal Use fishery have been stepped down from a daily bag limit of 50 fish per person, to an annual limit of 20 fish per person.

Poor escapements at McDonald Lake since 2004 have resulted in very low fall fry abundance, with the estimated fall fry abundances 2005 the lowest in the history of the McDonald Lake fall fry assessments. Based on the dominant age at return for McDonald Lake sockeye salmon (age 5), these fish will return in 2009–2012. Therefore, it is likely that depressed runs of McDonald Lake sockeye salmon will continue for some time.

The Southern Southeast Regional Aquaulture Association (SSRAA) was recently permitted by ADF&G to conduct a lake stocking program at McDonald Lake. SSRAA was permitted to take up to 450,000 eggs annually from the McDonald Lake sockeye salmon run for three years, 2007–2009. These fish will be reared at SSRAA's Burnette Inlet Hatchery and up to 400,000 full-term smolt will be returned to McDonald Lake in the springs of 2009–2011. The full-term smolt will be put into net pens located at the mouth of Hatchery Creek to imprint. After release from net pens, they are expected to immediately smolt. All of these fish will be thermally marked, allowing them to be tracked through the fisheries when they return as adults in 2011–2014. These fish will presumably exhibit the same migratory behavior as wild McDonald Lake sockeye salmon, and it is thought that this project may also provide a measure of restoration, should the adults return to the lake and spawn with the wild population as intended.

It is recommended that a full stock assessment program be implemented in 2011. The stock assessment should include a mark-recapture/radio-telemetry study to estimate the total escapement, as well appropriate sampling for thermal marks within the spawning escapement, both at the lake outlet and on the spawning grounds, to assess the returns of wild and hatchery fish and the whether the hatchery fish spawn as anticipated. We also recommended that the genetic stock identification program for sockeye catches in the District 6 drift gillnet fishery and from the District 1 purse seine fishery be continued.

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APPENDIX

Appendix A.–Age compositions of the McDonald Lake sockeye salmon escapements, 1981–2007.

	Sample		Age Class									
Year	**Size**		**1.1**	**1.2**	**2.1**	**1.3**	**2.2**	**1.4**	**2.3**	**3.2**	**2.4**	**3.3**
1981	745	Number	3	25	0	557	17	0	143	0	0	0
		Proportion	0.4%	3.4%	0.0%	74.8%	2.3%	0.0%	19.2%	0.0%	0.0%	0.0%
		SE	0.2%	0.7%	0.0%	1.6%	0.5%	0.0%	1.4%	0.0%	0.0%	0.0%
1982	629	Number	2	30	2	462	54	1	78	0	0	
		Proportion	0.3%	4.8%	0.3%	73.4%	8.6%	0.2%	12.4%	0.0%	0.0%	0.0%
		SE	0.2%	0.9%	0.2%	1.8%	1.1%	0.2%	1.3%	0.0%	0.0%	0.0%
1983	1,363	Number	0	498	1	253	47	0	564	0	0	0
		Proportion	0.0%	36.5%	0.1%	18.6%	3.4%	0.0%	41.4%	0.0%	0.0%	0.0%
		SE	0.0%	1.3%	0.1%	1.1%	0.5%	0.0%	1.3%	0.0%	0.0%	0.0%
1984	928	Number	1	136	0	630	59	0	102	0	0	0
		Proportion	0.1%	14.7%	0.0%	67.9%	6.4%	0.0%	11.0%	0.0%	0.0%	0.0%
		SE	0.1%	1.2%	0.0%	1.5%	0.8%	0.0%	1.0%	0.0%	0.0%	0.0%
1985	537	Number	0	25	0	388	47	0	76	0	0	1
		Proportion	0.0%	4.7%	0.0%	72.3%	8.8%	0.0%	14.2%	0.0%	0.0%	0.2%
		SE	0.0%	0.9%	0.0%	1.9%	1.2%	0.0%	1.5%	0.0%	0.0%	0.2%
1986	555	Number	0	65	3	312	20	0	155	0	0	0
		Proportion	0.0%	11.7%	0.5%	56.2%	3.6%	0.0%	27.9%	0.0%	0.0%	0.0%
		SE	0.0%	1.4%	0.3%	2.1%	0.8%	0.0%	1.9%	0.0%	0.0%	0.0%
1987	833	Number	3	64	7	497	18	0	243	1	0	0
		Proportion	0.4%	7.7%	0.8%	59.7%	2.2%	0.0%	29.2%	0.1%	0.0%	0.0%
		SE	0.2%	0.9%	0.3%	1.7%	0.5%	0.0%	1.6%	0.1%	0.0%	0.0%
1988	1,063	Number	3	208	0	680	62	1	109	0	0	0
		Proportion	0.3%	19.6%	0.0%	64.0%	5.8%	0.1%	10.3%	0.0%	0.0%	0.0%
		SE	0.2%	1.2%	0.0%	1.5%	0.7%	0.1%	0.9%	0.0%	0.0%	0.0%
1989	530	Number	2	23	0	456	18	0	31	0	0	0
		Proportion	0.4%	4.3%	0.0%	86.0%	3.4%	0.0%	5.8%	0.0%	0.0%	0.0%
		SE	0.3%	0.9%	0.0%	1.5%	0.8%	0.0%	1.0%	0.0%	0.0%	0.0%
1990	794	Number	0	111	0	421	40	1	214	0	0	7
		Proportion	0.0%	14.0%	0.0%	53.0%	5.0%	0.1%	27.0%	0.0%	0.0%	0.9%
		SE	0.0%	1.2%	0.0%	1.8%	0.8%	0.1%	1.6%	0.0%	0.0%	0.3%

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Year	Sample Size		Age Class 1.1	1.2	2.1	1.3	2.2	1.4	2.3	3.2	2.4	3.3
1991	791	Number	3	51	0	703	8	0	26	0	0	0
		Proportion	0.4%	6.4%	0.0%	88.9%	1.0%	0.0%	3.3%	0.0%	0.0%	0.0%
		SE	0.2%	0.9%	0.0%	1.1%	0.4%	0.0%	0.6%	0.0%	0.0%	0.0%
1992	739	Number	0	10	0	709	1	0	19	0	0	0
		Proportion	0.0%	1.4%	0.0%	95.9%	0.1%	0.0%	2.6%	0.0%	0.0%	0.0%
		SE	0.0%	0.4%	0.0%	0.7%	0.1%	0.0%	0.6%	0.0%	0.0%	0.0%
1993	628	Number	5	44	12	285	22	0	260	0	0	0
		Proportion	0.8%	7.0%	1.9%	45.4%	3.5%	0.0%	41.4%	0.0%	0.0%	0.0%
		SE	0.4%	1.0%	0.5%	2.0%	0.7%	0.0%	2.0%	0.0%	0.0%	0.0%
1994	670	Number	0	37	2	538	15	1	77	0	0	0
		Proportion	0.0%	5.5%	0.3%	80.3%	2.2%	0.1%	11.5%	0.0%	0.0%	0.0%
		SE	0.0%	0.9%	0.2%	1.5%	0.6%	0.1%	1.2%	0.0%	0.0%	0.0%
1995	904	Number	3	122	2	599	20	0	157	0	1	0
		Proportion	0.3%	13.5%	0.2%	66.3%	2.2%	0.0%	17.4%	0.0%	0.1%	0.0%
		SE	0.2%	1.1%	0.2%	1.6%	0.5%	0.0%	1.3%	0.0%	0.1%	0.0%
1996	618	Number	4	47	0	536	14	0	17	0	0	0
		Proportion	0.6%	7.6%	0.0%	86.7%	2.3%	0.0%	2.8%	0.0%	0.0%	0.0%
		SE	0.3%	1.1%	0.0%	1.4%	0.6%	0.0%	0.7%	0.0%	0.0%	0.0%
1997	812	Number	5	57	0	590	15	1	144	0	0	0
		Proportion	0.6%	7.0%	0.0%	72.7%	1.8%	0.1%	17.7%	0.0%	0.0%	0.0%
		SE	0.3%	0.9%	0.0%	1.6%	0.5%	0.1%	1.3%	0.0%	0.0%	0.0%
1998	753	Number	1	30	1	615	4	0	102	0	0	0
		Proportion	0.1%	4.0%	0.1%	81.7%	0.5%	0.0%	13.5%	0.0%	0.0%	0.0%
		SE	0.1%	0.7%	0.1%	1.4%	0.3%	0.0%	1.2%	0.0%	0.0%	0.0%
1999	839	Number	5	64	2	670	21	0	77	0	0	0
		Proportion	0.6%	7.6%	0.2%	79.9%	2.5%	0.0%	9.2%	0.0%	0.0%	0.0%
		SE	0.3%	0.9%	0.2%	1.4%	0.5%	0.0%	1.0%	0.0%	0.0%	0.0%
2000	825	Number	0	33	0	634	7	1	150	0	0	0
		Proportion	0.0%	4.0%	0.0%	76.8%	0.8%	0.1%	18.2%	0.0%	0.0%	0.0%
		SE	0.0%	0.7%	0.0%	1.5%	0.3%	0.1%	1.3%	0.0%	0.0%	0.0%

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Year	Sample Size		Age Class 1.1	1.2	2.1	1.3	2.2	1.4	2.3	3.2	2.4	3.3
2001	685	Number	1	1	0	656	1	0	26	0	0	0
		Proportion	0.1%	0.1%	0.0%	95.8%	0.1%	0.0%	3.8%	0.0%	0.0%	0.0%
		SE	0.1%	0.1%	0.0%	0.8%	0.1%	0.0%	0.7%	0.0%	0.0%	0.0%
2002	545	Number	5	222	0	258	26	0	34	0	0	0
		Proportion	0.9%	40.7%	0.0%	47.3%	4.8%	0.0%	6.2%	0.0%	0.0%	0.0%
		SE	0.4%	2.1%	0.0%	2.1%	0.9%	0.0%	1.0%	0.0%	0.0%	0.0%
2003	615	Number	1	21	1	560	9	0	23	0	0	0
		Proportion	0.2%	3.4%	0.2%	91.1%	1.5%	0.0%	3.7%	0.0%	0.0%	0.0%
		SE	0.2%	0.7%	0.2%	1.2%	0.5%	0.0%	0.8%	0.0%	0.0%	0.0%
2004	231	Number	0	73	0	112	20	1	25	0	0	0
		Proportion	0.0%	31.6%	0.0%	48.5%	8.7%	0.4%	10.8%	0.0%	0.0%	0.0%
		SE	0.0%	3.1%	0.0%	3.3%	1.9%	0.4%	2.0%	0.0%	0.0%	0.0%
2005	774	Number	32	53	39	536	17	1	96	0	0	0
		Proportion	4.1%	6.8%	5.0%	69.3%	2.2%	0.1%	12.4%	0.0%	0.0%	0.0%
		SE	0.7%	0.9%	0.8%	1.7%	0.5%	0.1%	1.2%	0.0%	0.0%	0.0%
2006	652	Number	8	175	6	210	162	2	89	0	0	0
		Proportion	1.2%	26.8%	0.9%	32.2%	24.8%	0.3%	13.7%	0.0%	0.0%	0.0%
		SE	0.4%	1.7%	0.4%	1.8%	1.7%	0.2%	1.3%	0.0%	0.0%	0.0%
2007	703	Number		20		278	9	1	394		1	0
		Proportion	0.0%	2.8%	0.0%	39.5%	1.3%	0.1%	56.0%	0.0%	0.1%	0.0%
		SE	0.0%	0.6%	0.0%	1.8%	0.4%	0.1%	1.9%	0.0%	0.1%	0.0%