STUDY PERFORMANCE REPORT

State: Michigan

Project No.: F-53-R-15

Study No.: 482

Title: Investigations into causes of, and solutions for, variable survival of chinook salmon stocked into Lake Huron

Period Covered: April 1, 1998 to September 30, 1999

Study Objective: (1) To develop methods for documenting the lacustrine early life history of stocked salmonids, with emphasis upon an understanding of factors influencing mortality of chinook salmon in Lake Huron during their first year at large. (2) To identify the cause of low returns of chinook salmon stocked into the AuSable River. (3) To determine if there is a significant difference in return rates for chinook salmon stocked in three different regions of Lake Huron: North, Central, and South. (4) To determine the relative contributions of wild and hatchery-produced chinook salmon to Lake Huron's fisheries.

Summary: Since 1993, a salmon harvest raceway on the AuSable River near Oscoda has been used as a rearing pen for chinook salmon parr. In 1995 the raceway was divided to permit the rearing of two test lots of chinook salmon. From 1993-1998, study fish were marked, reared, and stocked at Oscoda, Swan River, and Harbor Beach as planned. Two roving "head hunters" were employed in all study years on Lake Huron to collect snouts with coded-wire tags from angler–caught chinook salmon. Angler awareness was heightened by signing at access sites and by networking with fishing groups. Sportfishing groups also sponsored reward programs to stimulate returns. Coded-wire tags from chinook salmon were processed and the data entered into computer database. Tag recovery rates from the sportfishery suggested survival of penned groups from Oscoda was more than twice that of conventionally planted fish. Weir collections and fall electrofishing were used to assess homing to stocking site for mature fish. In the AuSable River, test (penned) fish were observed more than 5 times as frequently as the control (conventionally stocked) groups in the spawning runs, suggesting pen culture there enhanced both survival and homing. Return rates from a net pen at Harbor Beach were not different from conventional stockings. The pen at Harbor Beach is in a power plant discharge and the heated water may have compromised the quality of its fish. Wild age-0 chinook salmon were observed in seine samples taken near the AuSable River in earlier segments of this study, but there was no evidence that natural reproduction was contributing to the spawning run based on examination of oxytetracycline marks in returning spawners. Pelagic sampling with suspended gill nets was conducted from 1997-1999 to measure catch rates, distribution, and diet of offshore predators, including chinook salmon. The diet of chinook salmon was composed principally of alewives, but in 1997 and 1998 over half the stomachs were void, suggesting prey availability was low in 1997 and 1998. Biological data for the Swan and AuSable river spawning runs were summarized. Growth was significantly slower at both sites in 1997 and 1998 than in 1996. The 1995 year class from Swan River appeared to be unusually weak. Archived fall salmon netting data from the 1973-1981 period were entered and compared with 1996-1998 data. Results of this analysis also indicated growth and condition of chinook salmon has declined significantly in recent years. All data processing and reporting requirements for this study were met. Diet information from offshore netting, and trends in growth and condition from fall sampling were

used to analyze stocking rates, which resulted in an interjurisdictional agreement to reduce chinook salmon stocking by 20 percent. Results of this study and Study 451 were used to build a Lake Huron pelagic prey consumption model, in conjunction with the Lake Huron Technical Committee and Michigan State University.

Job 1. Title: Mark, imprint, and evaluate quality of the stocked fish.

Findings: Fish marking and handling, quality control, feed, transport, and advice to the pen-culture cooperators were supplied by DNR personnel.

The stocking phase of the Oscoda study was completed in 1997. Pen rearing at Harbor Beach in 1998 was uneventful and the fish were released from the pens without loss. The Harbor Beach pen is in a power plant thermal discharge. The warm pen temperatures there caused the penned fish to be larger at stocking than fish in the conventional plant.

Job 3. Title: Evaluate predator distribution at time of stocking, and evaluate relative abundance and returns of test fish following stocking.

Findings: *Relative abundance, diet, and pelagic distribution of chinook salmon:* In 1997-1999, graded-mesh gill nets were built and deployed to sample for all ages of chinook salmon. The purposes of this sampling effort were to: 1) further document catch rates, distribution, and seasonal prey of chinook salmon and other pelagic predators, and 2) to provide diet and tissue samples for bioenergitics modeling being conducted by Michigan State University at the request of the Lake Huron Committee. The first year of work (1997) was designed as a “shakedown” of the technique and to determine the feasibility of setting such gear with the Alpena Station’s vessel as presently equipped.

All effort set was “jugged” to fish 3- to 10-m below the surface or “legged” up to sample the layer 4 to 20 m above the bottom. Each net was 244 m long and 6.1 m deep (from float to lead line) when deployed. Mesh sizes ranged from 76 to 152 mm in 17.7-mm increments plus one panel of 178-mm mesh. These nets were deployed from May through early September.

A summary of the 1997 and 1998 catch is given in Table 2. Chief pelagic predators were chinook salmon, walleye, and lake trout. The catch was measured on board and stomachs were removed and shipped to the lab in Alpena for analysis of diet. A summary of diet composition from the suspended nets is given in Table 3. The majority of prey consumed by chinook salmon during 1997 and 1998 was alewives. However, 56% of stomachs examined were void suggesting prey availability was low. Spiny water fleas (Bythotrephes cederstroemi) were observed in the diet (Table 3) but were abundant in only two chinook salmon stomachs; the total volume of prey contributed by this nonnative plankter was nearly insignificant, owing to their small body size. The PERM Unit at Michigan State University used these catch and consumption data, similar types of data from Alpena’s Study 451, and data contributed by other agencies on Lake Huron to produce a bioenergetics model of Lake Huron. The model is based upon chinook salmon, lake trout, burbot, and walleye as the principal predators and alewife, smelt, and bloater chub as the prey base. The model is being used to evaluate stocking and management strategies to optimize use of the lake’s prey base. In 1998 and 1999, the model was used to estimate prey consumption by pelagic predators, compare consumption with historical (pre-sea lamprey) consumption levels, and evaluate consumption rates under various stocking scenarios. This exercise suggested that current prey consumption is exceeding historic levels and resulted in a decision to reduce stocking by 20% lake-wide (Ontario and Michigan waters) beginning in 1999.

Pelagic netting was conducted as planned in the summer of 1999. The data from the 1999 field season will be entered and analyzed this winter.

Return to creel: Ultimately, return to creel is the most important measure of performance of the experimental groups. Coded-wire tags were collected using two summer fisheries assistants who examined angler catches, worked with agency project cooperators, and solicited cooperation of bait and tackle vendors. Signs were posted at all fish cleaning stations and public launch ramps notifying anglers of the study and instructing them on how to identify study fish and how to remove and return snouts to the DNR. Local interest groups have sponsored a reward program for return of coded-wire-tags. Rewards range from free fishing lures to drawings for cash and other prizes. Creel survey clerks (Study 427) were also instructed to collect snouts from all study fish encountered. In addition, other coded-wire tags were taken from survey and weir catches at the AuSable River and Swan weir. Tags from 1998 and 1999 are still being received from anglers, cooperating agencies, and vendors. Most of the tags received have been processed.

Tag recovery rates in the recreational fishery for each of the study lots stocked since 1993 are summarized in Table 4. For each cohort stocked in the AuSable River, test groups have returned at higher rates than control groups. For 1993 and 1994, when the control groups were conventionally (direct from hatchery) planted fish, the respective penned fish have returned 1.9 and 3.4 times better than control lots to date. For 1995-1997, penned fish were used for both the upriver (control) and the beach (test) plant. In this case, the 1995 test (beach stocked) group has thus far returned 1.4 times better than the control. Returns for the 1996 beach plant were only slightly higher than the upriver plant in the Oscoda study (Table 4). The first year of the Harbor Beach comparison (1995), the penned fish were exposed to water temperatures that exceeded 21 C and significant mortality resulted. Because of that mishap, it was decided to extend the stocking period at Harbor Beach to 1998. The 1998 rearing effort went well and there were no significant losses. To date, conventionally stocked fish from the 1995 Harbor Beach comparison have slightly outperformed the pen-reared (temperature stressed) fish, but pen-cultured fish composed the majority of first- and second-year returns of the more successful 1996 rearing effort. Surprisingly, returns to creel from Harbor Beach seem to have doubled after 1994. Conventionally planted fish stocked in 1993 and 1994 (not as part of this study) returned at much lower rates than either the control or penned groups stocked in 1995 and 1996 (Table 4). Return rates in the recreational fishery for chinook salmon stocked at Swan River in 1995 were less than half the rate of previous years.

Coded-wire tag returns from the 1999 fishing season were still being received at the time of this report. A summary of 1999 returns will be produced in March of next year.

Measurement of biological parameters and composition of spawning escapement: During September and October, 1996-1999, the AuSable River was electrofished weekly to determine relative contributions of study fish to the spawning run. The hypothesis was that pen culture would better imprint the fish and thus enhance returns to the AuSable River. For the combined 1993 and 1994 year classes, test (pen cultured) groups were observed in the spawning runs 6.3 times more frequently than control lots (Table 5), which is much higher than the rate expected based upon returns to creel (Table 4). Thus, the test groups appeared to benefit from a combination of improved post-stocking survival (Table 4) and enhanced imprinting (Table 5). For the 1995 and 1996 year classes, combined, penned fish transported to the beach were sampled 3.0 times the rate of pen-cultured fish transported upriver for stocking (Table 5).

Because both groups were imprinted in the pen, the difference in returns for the 1995 and 1996 year classes could represent survival costs during the smolt stage river migration in the upstream stocking group. Differences in the 1995 and 1996 study groups' lake catch in the 1997 and 1998 recreational fishery were much less pronounced (Table 4), than in fall escapement, which is not consistent with the imprinting hypothesis, however (both test groups having been reared in pens). Sample sizes for recent age groups in the recreational fishery are sparse, but will become more robust with subsequent years of sampling. Returns (at age 1) in 1998 for all study groups stocked in 1997 were much lower than usual (Tables 4 and 5).

From 1996-1999, chinook salmon were sampled from the spawning run at Swan Weir during October. Because the Swan run is thought to be almost entirely supported by stocking, we used this run as a "benchmark" with which to evaluate the contribution of wild fish in the AuSable River's run. All chinook salmon stocked in 1992-1995 were marked with oxytetracycline; thus a significantly higher rate of unmarked fish in the AuSable River than at Swan would indicate reproduction was contributing to the AuSable's spawning population. The catch was aged using vertebrae. In both locations, the 1992 through 1995 year classes were composed almost entirely of fish with oxytetracycline and/or fin clips (Table 6). The percentage of unmarked fish was not significantly different between the Swan and AuSable runs in any year, suggesting reproduction contributed little to the AuSable River spawning population.

Sea lamprey wounding rates on chinook salmon longer than 700 mm declined each year from 6.4 type A1-A3 wounds per 100 salmon in 1996 to 2.1 per 100 in 1998 (Table 7).

At both Swan and the AuSable, weight and length of most age groups declined significantly from 1996 to 1997 fall sampling periods (Table 8). Overall condition factor also was significantly lower in 1997 ($p<0.05$). The change in growth was most pronounced in older age groups. Weight of age-4 salmon from the AuSable River, for example, declined 1.7 kg between 1996 and 1997. Mean weight, length, and condition of chinook salmon older than age-1 remained relatively low in 1998 (Table 8).

During 1973-1981, chinook salmon were sampled from the mouth of the AuSable River in late August and early September. Scales were taken from the caudal peduncle region of the fish for age determination. These samples were taken early enough in the spawning run that scale degeneration was not advanced and ages could be determined from the scale samples. We entered these old data during 1998 and compared them with recent collections (Table 9). Chinook salmon from the earlier period were significantly larger and more robust than those from the 1996 to 1998 collections ($p<0.05$). These data were used in the analysis of stocking and prey consumption rates that led to stocking reductions in 1999.

Typically, mature salmon cannot be aged with scales or otoliths due to erosion and opaqueness, respectively, of these bony structures. Vertebrae aging has proved to be a viable alternative. Collection of biological data and vertebrae from approximately 100 salmon per week from each major spawning run appears to be sufficient to describe age-specific biological parameters of annual chinook salmon escapement.

Sampling of the fall, 1999, spawning runs was being conducted at the time of this report. A summary of the 1999 data will be presented in next year's performance report.

Job 4. Title: Read coded-wire tags and tetracycline marks, enter and analyze data, and prepare annual reports and publications

Findings: Data entry for all 1998 collections is complete; 1999 data entry will be completed this winter on schedule. Oxytetracycline and coded-wire tag processing is continuous and on schedule. The 1998-99 annual performance report was prepared. Data from this study were used by the Lake Huron Technical Committee in the development of the Lake Huron bioenergetics model. Trends in growth of chinook salmon were presented to the Lake Huron Committee, the Lake Huron Citizen Advisory Committee, Fisheries Division internal committees, and to approximately 15 different meetings and interest groups in support of a stocking reduction proposal, which became effective in spring 1999.

Job 5. Title: Collaborate with other research projects on stocking of anadromous salmonids to compare results and coordinate planning and design of future studies

Findings: We began work on experimental design of a study to determine contribution of hatchery origin and wild chinook salmon to the Lake Huron salmon population. Through the Lake Huron Technical Committee, we reached a consensus among of the fishery management agencies on Lake Huron that the study should be implemented in year 2000. We negotiated marking strategies for each agency and coordinated marking with other ongoing chinook studies so as to maximize information gained and prevent duplication of efforts. Personnel from Michigan State University were recruited to assist in experimental design. The results of this study will be used to improve estimates of chinook recruitment for the Lake Huron Technical Committee's Pelagic Prey Consumption Model.

We also began work, in collaboration with DNR Management Units, on design and marking requests for studies of site-specific post-stocking survival. There is circumstantial evidence that some chinook salmon stocking sites on Lake Huron are contributing poorly to the fishery. The objective of this work will be to identify those sites that require corrective action and improve recruitment estimates for the Lake Huron Pelagic Prey Consumption Model.

A preproposal was prepared in collaboration with the Great Lakes Science Center, USGS, to seek funding for research into the thermal environment of chinook salmon. This study would involve implantation of chinook salmon with archival, recording thermal tags which would document thermal environments of chinook salmon over the course of up to two years. Again, this information is vital to the calibration of the Lake Huron Pelagic Prey Consumption Model.

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Table 1.–Number of fish stocked with recoverable (adjusted for fin clip quality & cwt retention) coded wire tags, Lake Huron.

	Swan River	AuSable River[1]		Harbor Beach	
Year	direct plant	direct plant	netpen	direct plant	Netpen
1991	202,742	105,542	107,542	---	---
1992	186,813	96,287	47,627	---	---
1993	188,803	97,641	93,139	87,742	---
1994	185,557	85,648	92,594	90,983	---
	Swan	AuSable R. netpen[1]		Harbor Beach	
	Swan River	River plant	Shore plant	direct plant	Net pen
1995	92,021	84,574	84,574	95,734	90,139
1996	86,034	90,404	83,257	87,663	93,863
1997	90,587	86,947	80,105	98,084	92,680
1998	86,048	---	---	81,749	78,673

[1] All study fish raised in net pen from 1995-1998; pen production was divided between river plant and shore plant.

Table 2.–Catch per 1,000 feet of pelagic gill nets, by species and month, Lake Huron, 1997-1998.

	Effort (feet)	Chinook catch	Chinook CPE	Lake trout catch	Lake trout CPE	Walleye catch	Walleye CPE
1997							
May	4,000	17	4.25	3	0.75	4	1.00
June	7,200	17	2.36	25	3.47	1	0.14
July	16,000	22	1.38	7	0.44	15	0.94
August	16,000	16	1.00	1	0.06	35	2.19
1998							
June	10,400	16	1.54	30	2.88	0	0.00
July	3,200	5	1.56	0	0.00	6	1.88
August	7,200	31	4.31	94	13.06	18	2.50

Table 3.–Diet composition of chinook salmon sampled with suspended, pelagic gill nets, 1997 and 1998.

Prey	Total	Average weight (g)
Smelt	18	4.9
Alewife	71	13.9
Whitefish	4	34.9
Unidentifiable fish	31	na
Spiny water flea	107	na
Total number of chinook caught	124	
Number stomachs not examined	14	
Number stomachs examined in field	12 (7 void)	
Number stomachs examined in lab	98 (54 void)	
Total void stomachs	61	
Percent void stomachs	55.5	

Table 4.–Number of sport-caught coded-wire tagged chinook salmon returns at age per 100,000 planted, Lake Huron stocking method studies, 1993-1998.

		AuSable River		Harbor Beach		
Year Class	Age	Test(Released at pen or beach)	Control (Whirlpool)	Study (pen)	Control (conv. Truck)	Swan (benchmark)
1993[1]	1	59.1	29.7		10.3	38.6
	2	124.6	63.5		26.2	77.3
	3	93.4	53.3		34.2	56.1
	4	16.1	6.1		9.1	33.4
Total		293.1	154.7		80.1	205.5
1994[2]	1	73.4	23.4		12.1	38.8
	2	95.0	30.4		22.0	83.5
	3	157.7	50.0		66.0	129.9
	4	5.4	1.2		14.3	38.3
Total		332.6	98.3		114.3	290.5
1995[3]	1	78.0	52.0	32.2	33.4	18.5
	2	115.9	87.5	106.5	94.0	45.6
	3	136.0	93.4	75.4	111.8	30.4
Total		329.9	232.9	215.2	239.2	95.6
1996						
	1	42.0	42.0	38.6	19.4	15.1
	2	94.9	79.6	105.5	86.7	91.8
Totals		136.9	121.7	143.8	106.9	106.9
1997	1	2.5	9.2	7.5	8.2	8.8

[1] Pen fish released directly from pen vs. conventional truck plant in 1993.
[2] Pen fish trucked to beach vs. conventional truck plant in 1994.
[3] Pen fish trucked to beach vs. pen fish trucked up river in 1995, 1996 and 1997.

Table 5.–Return of study groups of chinook salmon to AuSable River at maturity, fall 1996-1998 electrofishing samples of approximately 500 fish per year. Total sample=1,420 fish; number with coded-wire tags = 356; 76% of sample was untagged (lacked fin clip or coded-wire tag).

Study group	CWT number	Site code	Clip adj factor	Tagging adj factor	Recoverable stocked	Number	Corrected number	Percent	Ratio test: control
AuSable study groups:									
1993 VanEtten Pen	594404	350001	0.993	0.917	93,139	54	58.0	84.99	5.66
1993 conventional	594413	350106	0.999	0.962	97,641	10	10.2	15.01	
1994 Pen, 3 Mile Park	594455	350004	0.997	0.920	92,594	74	79.9	87.25	6.84
1994 conventional	594456	350106	0.997	0.858	85,648	10	11.7	12.75	
1995 Pen, beach	594752	350004	0.955	0.868	84,574	72	85.1	72.00	2.57
1995 Pen, upstream	594750	350106	0.980	0.835	84,575	28	33.1	28.00	
1996 Pen, beach	594761	350004	0.990	0.820	83,375	22	26.4	77.48	3.44
1996 pen, upstream	594762	350106	0.980	0.890	91,250	7	7.7	22.52	
1997 Pen, beach	59-49-04	350004	0.904	0.875	80,105	0	0.0	0.00	0.00
1997 Pen, upstream	59-49-08	350106	0.950	0.890	86,947	2	2.3	100.00	
Other coded-wire tags:									
1993 Swan River						11			
1994 Swan River						52			
1995 Swan River						3			
1996 Swan River						3			
1997 Swan River						1			
1995 Harbor Beach						1			
1994 Strawberry R., WI						1			
1993 Grand R., L. Mich.						1			

Table 6.–Contribution of marked hatchery fish to the spawning runs of the AuSable and Swan Rivers, 1992-1995[1] year classes of chinook salmon, sampled in 1996-1998.

Sample year	Site	Sample size	% hatchery origin[2]
1996	Swan	100	100
	AuSable	426	100
1997	Swan	59	100
	AuSable	516	98.8
1998	Swan	141	96.5
	AuSable	344	97.4

[1] These year classes were marked with oxytetracycline.
[2] Fish with either a fin clip or oxytetracycline mark.

Table 7.–Number of A1-A3 (fresh) wounds per 100 chinook salmon > 700 mm total length, AuSable and Swan Rivers, combined, fall spawning runs.

Year	Wounds	Sample size
1996	6.4	535
1997	3.5	632
1998	2.1	662

Table 8.–Lengths (mm), weights (gm), and condition factor for chinook salmon spawning runs in AuSable River and Swan River, September-October, 1996-1998.

Site	Age group	Sample year	Length	Weight	Condition*	Sample size
Swan River	1	1996	569	1773	0.95	10
		1997	507	1372	1.05	6
		1998	509	1470	1.13	7
	2	1996	776	4414	0.93	52
		1997	840	4040	0.74	3
		1998	691	3150	0.95	61
	3	1996	852	5769	0.92	25
		1997	822	4973	0.89	40
		1998	846	5610	0.90	86
	4	1996	967	8886	0.97	13
		1997	860	5706	0.88	16
		1998	866	5860	0.88	56
AuSable River	1	1996	543	1727	1.05	126
		1997	528	1580	1.08	34
		1998	561	1970	1.06	11
	2	1996	766	4590	1.00	124
		1997	724	3730	0.97	190
		1998	710	3300	0.92	95
	3	1996	857	6246	0.98	149
		1997	827	5260	0.92	239
		1998	783	4490	0.92	310
	4	1996	911	7513	0.98	27
		1997	858	5830	0.91	92
		1998	825	4840	0.85	33

* Condition = $(Weight/Lenght^3)10^5$

Table 9.–Summary of lengths, weights, and condition of chinook salmon, AuSable River, 1973-1998.

	Length (mm)		Weight (kg)		Condition	
Year	Mean	StdDev	Mean	StdDev	Mean	StdDev
1973	795	94	6.64	2.05	1.29	.12
1974	821	127	7.28	2.67	1.26	.14
1975	815	64	6.89	1.53	1.26	.11
1976	841	82	7.36	1.94	1.21	.10
1977	856	74	7.59	1.76	1.19	.10
1978	836	86	7.30	1.93	1.23	.11
1979	721	140	5.32	2.78	1.30	.14
1980	775	93	5.72	1.60	1.20	.13
1981	815	73	6.68	1.49	1.22	.13
1996	743	146	4.53	2.31	1.01	.12
1997	777	101	4.59	1.59	0.94	.13
1998	766	82	4.21	1.33	0.92	.15