STUDY PERFORMANCE REPORT

State: Michigan

Project No.: F-80-R-2

Study No.: 482

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

Period Covered: October 1, 2000 to September 30, 2001

Summary: 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. Coded-wire tags from chinook salmon were processed and the data entered. Tag recovery rates from the sportfishery suggested survival of pen-reared groups from Oscoda was more than twice that of conventionally-planted fish. Weir collections and fall electrofishing were used to assess return to the stocking site for mature fish. In the Au Sable 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 netpen at Harbor Beach were not consistently different from conventional stockings. Wild age-0 chinook salmon were observed in seine samples taken near the Au Sable River in earlier segments of this study, but there was no evidence that natural reproduction was contributing to the spawning run there, based on examination of oxytetracycline marks in returning spawners. Biological data for the Swan and Au Sable river spawning runs were summarized. Growth was significantly slower at both sites in 1997 and 1998 than in 1996 or 1999-2000. The 1995 year class from Swan River was unusually weak but was exceptionally strong in the Au Sable River. The 1997 year class appeared to be weak across all experimental stocking sites. Archived fall salmon netting data collected from the Au Sable River during 1973-1981 were compared with the 1996-2000 data. Results of this analysis indicated growth and condition of chinook salmon declined significantly after 1981 and were particularly low in 1997 and 1998. 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. A lake-wide interjurisdictional study of the contribution of wild chinook salmon to recruitment in Lake Huron was designed and implemented. Results were presented in the Lake Huron State of Lake Report and other forums.

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

Findings: *Beach Seining:* Night beach seining was completed during 1992-95. During this period all stocked chinook were marked with tetracycline and the number of wild (unmarked) fish was estimated from the seine catch. The use of tetracycline ceased in 1996. Objectives of the beach seining have been met; thus, there was no beach seining scheduled for 1996-2001.

Predators of age-0 chinook salmon: From 1995-97, predator fish abundance was indexed and diets were recorded at Oscoda, Harbor Beach, and Swan Bay. These collections suggested that where alewives were abundant there was less consumption of stocked salmonids. For example, salmonids were more important to the diet of walleye collected from the Au Sable River, where alewives were scarce, than for walleye from the lake, where alewives and smelt appeared to be more abundant (see 1997 performance report). This element of Study 482 was completed in 1997. There was no further activity in 1999-2001.

Small-mesh gill netting to index age-0 chinook: Relative abundance of age-0 chinook was measured in July and August, 1994-96, fishing 38-mm and 51-mm mesh 4.6-m deep gillnets in the littoral zone. A total of 1,077 age-0 chinook was sampled during the three years. The purpose of the survey was to estimate relative first-summer survival of each of the study groups and contribution of wild, unmarked chinook to Michigan's chinook fishery. However, in 1996 marking with oxytetracycline ceased, which brought an end to this study element. An analysis of origin of the age-0 catch will be provided in the final report.

Relative abundance, diet, and pelagic distribution of chinook salmon: In 1997-99, graded-mesh gillnets were built and deployed to sample for all ages of chinook. 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 bioenergetics modeling being conducted by Michigan State University at the request of the Lake Huron Committee.

Chief pelagic predators were chinook salmon, walleye, and lake trout. The majority of prey consumed by chinook salmon was alewives. However, 50% of stomachs examined were void suggesting prey availability was occasionally low. The PERM Research 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 alewives, smelt, and bloater chubs as the prey base. For 1998-2001, 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; consequently, a decision was made to reduce stocking by 20% lake-wide (Ontario and Michigan waters) beginning in 1999. The model was used in 2000-2001 to produce estimates of prey consumption for the State of Lake Report prepared by the Lake Huron Technical Committee.

The pelagic netting conducted in 1999 completed work required to meet this study objective. Therefore, no pelagic netting was conducted in 2000-2001.

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 and solicited cooperation of bait and tackle vendors. Creel survey clerks (Study 427) were also instructed to collect snouts from all study fish encountered. Signs were posted at all fish cleaning stations and public launch ramps to notify anglers of the study and instruct them on how to identify study fish and how to remove and return snouts to the DNR. Local interest groups sponsored a reward program for return of coded-wire-tags. Rewards ranged from free fishing lures to drawings for cash and other prizes. Coded-wire tags were taken from survey and weir catches at the Au Sable River and Swan weir.

Tag recovery rates in the recreational fishery for each of the study lots stocked since 1993 are summarized in Table 1. Pen-reared cohorts stocked in the Au Sable River in 1993 and 1994 returned at 1.9 and 2.8 times the rate of control (conventionally stocked) cohorts, respectively. Both study groups were pen reared from 1995-1997, but the test group was transported by truck from the pen to the river mouth and the control group was transported to Whirlpool access site, approximately 6 stream miles above the river mouth. Whirlpool is where most stocking of anadromous salmonids has occurred in the Au Sable River in recent years. Earlier segments demonstrated walleyes and smallmouth bass were relatively abundant in the Au Sable River and that they frequently ate recently stocked chinook salmon and steelhead. However, salmon transported to the river mouth did not survive better than those taken to Whirlpool (Table 1), suggesting predation rates in the Au Sable River were not significantly affecting return to creel.

During the first year of the Harbor Beach comparison (1995), the pen-reared fish were exposed to water temperatures that exceeded 21 ºC and significant mortality resulted. Because of that mishap, it was decided to extend the study period at Harbor Beach to 1998. As expected, conventionally stocked fish from the 1995 Harbor Beach comparison outperformed the pen-reared (temperature stressed) fish. Pen-cultured fish composed the majority of returns from the 1996 rearing effort but not from 1997. To date, the 1998 penned group has returned at about twice the rate of the control group (Table 1).

Return rates to the recreational fishery for chinook salmon stocked at Swan River in 1995 were about half those of other years, while the 1995 cohorts stocked at the other study sites returned exceptionally well. Returns from the 1997 year class have been weak from all stocking locations and test groups. This pattern of inconsistent return rates suggests there is considerable annual variation in conditions of the receiving waters and, perhaps, quality of fish at stocking.

Coded-wire tag returns from the 2001 fishing season were still being received at the time of this report. A summary of 2001 returns will be produced in next year's report.

Measurement of biological parameters and composition of spawning escapement: During September and October, 1996-2000, the Au Sable 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 Au Sable River. For the combined 1993 and 1994 year classes, 6.5 times more test (pen cultured) group fish were observed in the spawning population than control lot fish (Table 2), which is much higher than the expected difference based upon returns to lake creel (Table 1). Thus, the test groups appeared to benefit from a combination of improved post-stocking survival and enhanced imprinting. For the 1995 and 1996 year classes combined, pen-reared fish transported to the beach were sampled at 2.3 times the rate of pen-cultured fish transported upriver for stocking (Table 3). The differences between the 1995 and 1996 test and control groups was much less pronounced in returns to the recreational fishery, however (Table 1). Returns to date for both Au Sable River study groups stocked in 1997 were much lower than for previous years (Tables 1 and 2).

From 1996-2000, chinook salmon were sampled from the spawning run at Swan Weir during October. We used this run as a "benchmark" with which to evaluate the contribution of wild fish in the Au Sable River's run, because the Swan River run is thought to be almost entirely supported by stocking. All chinook salmon stocked in 1992-95 were marked with oxytetracycline; thus a significantly higher rate of unmarked fish in the Au Sable River than at Swan would indicate reproduction was contributing to the Au Sable's spawning population. The catch was aged by counting annuli on vertebrae under ultraviolet light. In both locations, the 1992 through 1995 year classes were composed almost entirely of fish with hatchery marks

(Table 3). The percentage of unmarked fish was not different between the two runs in any year, suggesting reproduction contributed little to the Au Sable River spawning population. Wild smolts were sampled during earlier segments of this study by seining beaches near the Au Sable River. Although wild smolts were abundant, sometimes composing near 50% of the age-0 chinook catch, they were significantly smaller than stocked smolts and did not leave the beach zone until late June. This slower development may have exposed the wild recruits to higher predation levels and warmer water temperatures than those the larger, stocked fish experienced.

Sea lamprey wounding rates on chinook salmon longer than 700 mm ranged from 8.0 to 2.4 type A1-A3 (fresh to not completely healed) wounds per 100 salmon from 1996-2000 (Table 4).

At both Swan and Au Sable rivers, weight and length of most age groups declined during 1996-98, then recovered in 1999 and 2000. All age groups except age-4 were larger in 2000 than during any of the previous 4 years (Table 5). Overall condition factor was significantly lower in 1997 than in 1996 but recovered significantly between 1998 and 2000 (t tests, $p<0.001$). The changes in growth were most pronounced in older age groups. Weight of age-3 salmon from the Au Sable River, for example, declined 1.8 kg between 1996 and 1998 but increased 2 kg between 1998 and 2000 (Table 6).

During 1973-81, chinook salmon were sampled from the mouth of the Au Sable 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 compared age-3 chinook salmon from the earlier collections with those from 1996-99 (Table 6). Condition factors for chinook salmon from the earlier period were significantly higher than those from the 1996 to 2000 collections (t tests, $p<0.001$). Mean lengths and weights were lowest in 1997 and 1998, which was when numbers of adult alewives were exceptionally low in United States Geological Survey prey assessments of Lake Huron. These size-at-age data were used in the analysis of stocking and prey consumption rates that led to stocking reductions in 1999. These data were also presented in the State of Lake report and at the Upper Lakes meetings of the Great Lakes Fishery Commission in March of 2000.

Typically, mature salmon cannot be aged with scales or otoliths due to erosion and opaqueness, respectively, of these bony structures. Vertebrae aging, using ultra-violet light, 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 escapement.

Sampling of the fall, 2001, spawning runs was being conducted at the time of this report. A summary of the 2001 data will be presented in next year's performance report.

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

Findings: Data entry for all 2000 collections is complete; 2001 data entry will be completed this winter on schedule. Oxytetracycline and coded-wire tag processing is continuous and on schedule. The 2000-2001 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 Committee's State of Lake Huron Report, the Lake Huron Citizen

Advisory Committee, Fisheries Division internal committees, and to several meetings of interest groups. The paper "Trends in chinook salmon harvest, growth, and condition in Lake Huron: evidence of periodic episodes of prey limitation?" was presented at the 2001 International Association for Great Lakes Research at Green Bay, Wisconsin in June.

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

Findings: During 1999-2000, we completed work on experimental design of a study to determine relative recruitment rates of hatchery-origin and wild chinook salmon to Lake Huron. Accordingly, the 2000 year class of chinook salmon stocked in Michigan waters of the upper Great Lakes was marked with OTC in the hatcheries. Quality control samples were analyzed for OTC mark quality. The Ontario Ministry of Natural Resources fin clipped all chinook salmon stocked in 2000 and 2001 in Canadian waters of Lake Huron. The results of this study will be used to improve estimates of chinook salmon recruitment for the Lake Huron Technical Committee's Pelagic Prey Consumption Model.

We also continued work, in collaboration with DNR Management Units, on 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. The results of this work will also improve recruitment estimates for the Lake Huron Pelagic Prey Consumption Model.

A proposal 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 will involve implantation of chinook salmon with archival, recording depth and thermal tags, which would document thermal environments of chinook salmon over the course of up to two years. First-year funding for implanting approximately 35 chinook salmon with depth/thermal archival tags was received. This information is vital to the calibration of the Lake Huron Pelagic Prey Consumption Model.

Prepared by: James E. Johnson, Steven P. DeWitt and John Clevenger
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Table 1.–Number of sport-caught coded-wire-tagged chinook salmon returns at age per 100,000 planted, by stocking method and location, Lake Huron, 1993-2000.

		Au Sable River		Harbor Beach		Swan
Year Class	Age	Test (Released at pen or beach)	Control (Whirlpool)	Study (pen)	Control (conv. Truck)	(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
	5	0.0	2.1		1.1	2.7
	Total	293.1	154.7		80.9	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	56.0		66.0	129.9
	4	5.4	7.0		14.3	39.9
	5	0.0	0.0		6.6	4.3
	Total	332.6	116.8		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	140.7	98.1	75.4	111.8	30.4
	4	30.7	14.2	18.9	43.9	15.2
	Total	365.4	251.9	234.1	283.0	110.8
1996[3]	1	42.0	42.0	38.4	19.4	15.1
	2	96.1	81.9	104.4	86.7	93.0
	3	64.9	78.5	146.0	83.3	108.1
	4	8.4	5.5	21.3	8.0	22.1
	Total	211.4	208.0	310.0	197.4	238.2
1997[3]	1	2.5	9.2	7.6	8.2	8.8
	2	10.0	25.3	32.4	28.6	53.0
	3	13.7	19.6	18.3	25.5	51.9
	Total	26.2	54.1	58.3	62.2	113.7
1998	1	---	---	19.1	7.3	29.1
	2			21.6	9.8	36.0
	Total			40.7	17.1	65.1

[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 2.–Composition of mature chinook salmon in Au Sable River, fall 1996-2000 electrofishing samples of approximately 500 fish per year. Total sample=2,399 fish; number with coded-wire tags = 447; 78% 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 sampled	Corrected number	Percent	Ratio test: control
Au Sable 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	11	10.2	15.01	
1994 Pen, 3 Mile Park	594455	350004	0.997	0.920	92,594	82	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	85	99.3	73.68	2.80
1995 Pen, upstream	594750	350106	0.980	0.835	84,575	33	35.5	26.32	
1996 Pen, beach	594761	350004	0.990	0.820	83,375	54	62.4	68.64	2.19
1996 pen, upstream	594762	350106	0.980	0.890	91,250	27	28.5	31.36	
1997 Pen, beach	59-49-04	350004	0.904	0.875	80,105	5	1.2	21.34	0.27
1997 Pen, upstream	59-49-08	350106	0.950	0.890	86,947	4	4.6	78.66	
Other coded-wire tags:									
1992 Au Sable River (prior to this study)						3			
1992 Swan River						1			
1993 Swan River						11			
1994 Swan River						52			
1995 Swan River						3			
1996 Swan River						4			
1997 Swan River						2			
1994 Strawberry R., WI						1			
1997 Door Co., WI						1			
1995 Harbor Beach						1			
1997 Harbor Beach						1			
1998 Harbor Beach						1			
1993 Grand R., L. Mich.						1			

Table 3.–Contribution of marked hatchery fish to the spawning runs of the Au Sable and Swan Rivers, 1992-95[1] year classes of chinook salmon, sampled in 1996-99.

Sample year	Site	Sample size	% hatchery origin[2]
1996	Swan	100	100.0
	Au Sable	426	100.0
1997	Swan	59	100.0
	Au Sable	489	97.5
1998	Swan	141	96.5
	Au Sable	344	97.4
1999	Swan	10	80.0
	Au Sable	136	94.1

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

Table 4.–Number of A1-A3 (fresh) wounds per 100 chinook salmon >=700 mm total length, Au Sable and Swan Rivers, combined fall spawning escapement collections.

Year	Wound rate	Sample size
1996	8.0	375
1997	3.4	523
1998	2.4	544
1999	5.5	605
2000	3.1	381

Table 5.–Lengths (mm), weights (gm), and condition factors for chinook spawning runs in Swan and Au Sable rivers, September-October, 1996-2000.

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
		1999	629	2468	0.98	46
		2000	593	2250	1.06	58
	2	1996	776	4414	0.93	52
		1997	840	4040	0.74	3
		1998	691	3150	0.95	61
		1999	789	5025	0.99	52
		2000	824	5705	1.00	37
	3	1996	852	5769	0.92	25
		1997	822	4973	0.89	40
		1998	846	5610	0.90	86
		1999	864	6365	0.97	91
		2000	915	7577	0.98	89
	4	1996	967	8886	0.97	13
		1997	860	5706	0.88	16
		1998	866	5860	0.88	56
		1999	864	6257	0.96	10
		2000	921	7182	0.91	16
Au Sable River	1	1996	543	1727	1.05	126
		1997	528	1580	1.08	34
		1998	561	1970	1.06	11
		1999	608	2464	1.07	40
		2000	572	2003	1.09	186
	2	1996	766	4590	1.00	124
		1997	724	3730	0.97	190
		1998	710	3300	0.92	95
		1999	771	4627	0.99	56
		2000	786	4799	0.97	96
	3	1996	857	6246	0.98	149
		1997	827	5260	0.92	239
		1998	783	4490	0.92	310
		1999	847	6092	0.99	278
		2000	875	6545	0.96	114
	4	1996	911	7513	0.98	27
		1997	858	5830	0.91	92
		1998	825	4840	0.85	33
		1999	863	6233	0.96	136
		2000	899	6862	0.94	38

*Condition = $(\text{Weight}/\text{Length})^3 \text{X} 10^5$

Table 6.–Summary of lengths, weights, and condition factors of age-3 chinook salmon, Au Sable River, 1973-2000.

Year	Length (mm) Mean	Length (mm) Std. dev.	Weight (g) Mean	Weight (kg) Std. dev.	Condition Mean	Condition Std. dev.
1973	886	54	8,685	1,540	1.24	0.09
1974	909	53	9,276	1,554	1.23	0.11
1975	952	50	10,719	1,265	1.25	0.14
1976	904	48	8,850	1,382	1.19	0.09
1977	888	51	8,298	1,421	1.18	0.08
1978	887	50	8,424	1,442	1.20	0.10
1979	899	34	8,785	1,401	1.20	0.10
1980	882	52	7,946	1,386	1.15	0.10
1981	897	47	8,425	835	1.17	0.11
1996	857	63	6,246	1,529	0.99	0.11
1997	827	60	5,265	1,320	0.92	0.13
1998	783	72	4,492	1,304	0.92	0.17
1999	847	61	6,092	1,449	0.99	0.12
2000	875	63	6,545	1,537	0.96	0.12