STUDY PERFORMANCE REPORT

State: Michigan

Project No.: F-80-R-1

Study No.: 689

Title: Projecting piscivore predation in Lake Huron.

Period Covered: October 1, 1999 to September 30, 2000

Study Objective: Work with other investigators to refine and expand stock assessment models for major predators in Lake Huron; and package the results of these models into an integrated and easy to update projection model for evaluating consequences of stocking levels and changes in mortality rates from sea lamprey or harvest controls.

Summary: During the past year we have applied the Wisconsin bioenergetics model to provide improved estimates of gross conversion efficiency (GCE) for the major predators in the main basin of Lake Huron. We have updated existing projection models with these estimates and other information to assess the overall consumption of prey fish by predators in the main basin. Our application of the Wisconsin bioenergetics models involved analysis of whole body energy density data we collected for fish from Lake Huron, together with Lake Huron specific information on temperature regimes, growth, and diets. We applied these to seven populations (lake trout from three regions, chinook salmon, burbot, and walleye from two regions). We updated the corresponding population models with the new GCE values, diet compositions and growth (through 1998 data) along with updated information on recruitment and mortality based on recent assessment modeling. Estimates of prey fish consumption in the main basin have reached a high during recent years for the period being modeled. This reflects the temporal pattern of stocking of hatchery reared fish, and a time lag so that recent reductions in the number of predators stocked are not yet reflected in consumption estimates. We note that our estimates of consumption are most uncertain for recent years because they reflect year-classes that have been subject to observation in fishery and survey data for only a few years. Our current estimates of consumption were summarized and were contributed as part of the Lake Huron Case Study, as a report to the Great Lakes Fishery Commission and as a presentation at the SCOL-II (Salmonid Communities of Oligotrophic Lakes) symposium.

Job 1. Title: Review literature on Great Lakes, Lake Huron, and Models.

Findings: The purpose of this task was for the Graduate Student Research Assistant to become familiar with background literature and to develop a comprehensive understanding of past work directly related to this project. Ongoing efforts in this job include keeping up with current literature. To this end, she has reviewed additional literature on bioenergetics, predator-prey dynamics, Great Lakes fisheries, and the Lake Huron system.

Job 2. Title: Develop a flexible projection model.

Findings: During the modeling efforts for 1836 Treaty Waters, the student (and a collaborator) created a computer program to project the effect of management alternatives on northern Lake

Huron lake trout and lake whitefish. This computer program has served as the basis for building the projection model. While work on this effort is progressing, the job had been amended to extend into the 2000-2001 timeframe. The current version of the program accepts ADModel Builder software formatted input as well as text tab-formatted data. It can estimate gross production, instantaneous growth, and consumption for years in the model. Future work will address adding projection estimates.

Job 3. Title: Update projection models.

Findings: It is important to update the existing spreadsheet models so they can serve as a baseline for measuring accuracy of the new projection model program. Both the spreadsheet models and the projection program have been updated with 1998 data, including growth and gross conversion efficiency data [GCE] (see Tables 6, 7a, 7b, and 8). These models will be updated to 1999 data by the end of this year.

Job 4. Title: Bioenergetics models.

Findings: We used the Wisconsin bioenergetics model (Hewett & Johnson 1995, updated to V3.0b) to estimate consumption for an average individual fish by employing the option to fit consumption as a function of change in weight. Separate input data sets were built to represent each predator within each spatial unit and age-class. This allowed Gross Conversion Efficiency (GCE) to be estimated at the appropriate detail level for the population models. Default physiological parameters from the Wisconsin model (Hewett & Johnson 1995) were used for each predator except burbot. Burbot physiological parameters were not available in the model so appropriate values were obtained from Rudstram et al. (1995) to create a physiological parameters file. Bioenergetics models were run for 365 days for burbot and lake trout, with simulation day 1 of January 1 and July 1, respectively. Chinook salmon and walleye were modeled in two time periods. For chinook salmon, simulation day 1 was January 1 for the pre-harvest period with the post-maturation period commencing on day 214. Age 4 chinook salmon were assumed to spawn and die on day 214. Simulation day 1 was May 1 for the walleye growth period and November 1 for the maintenance period.

Bioenergetics data specific to Lake Huron, such as water temperature, predator diet composition, and energy density of predators and prey, were collected to aid in estimating gross conversion efficiencies. Water temperature information appropriate for each region modeled (Table 1) was obtained from NOAA/GLREL reports (Grumblatt 1976; McCormick 1996; Nalepa et al. 1996; Johengen et al. 2000). Fish were assumed to occupy their preferred temperature when available. The preferred temperature for chinook salmon and lake trout were set as in Stewart and Ibarra (1991). Burbot ages 1-3 prefer 12^{o}C, while ages 4+ prefer 10^{o}C (Rudstram et al. 1995). All walleye ages used 22^{o}C for the preferred temperature (Kitchell et al. 1977). Spawning losses must be accounted for in Wisconsin bioenergetics calculations and estimates of GCE. For lake trout, spawning losses were incorporated as in Stewart et al. (1983). Burbot began spawning at age 3, loosing 11% of body mass (Rudstram et al. 1995). Walleye also began spawning at age 3 with an average loss of 12% (Hurley 1986). This occurred on May 1st between simulated periods of growth and gonadal development.

Age-class and region-specific data on diet proportions were used in the bioenergetics models. Diet information was obtained from the Biological Research Division – U.S. Geological Survey, Chippewa/Ottawa Treaty Fishery Management Authority, Michigan Department of Natural Resources, and Ontario Ministry of Natural Resources. Prey counts were multiplied by mean prey weight to determine proportion by weight of each prey item for each data source. Prey item proportions were determined by taking the proportional mean across data sources. For lake trout, prey item counts and weights were pooled over the data time periods to provide a large enough sample size. Mean prey weights for individual age categories were equal to total weight of each prey item divided by the number of items sampled. In instances where data were lacking, mean prey weights were set equal to adjacent age classes. Some rounding corrections were needed to adjust diet composition sum to 1.0 (see Table 2).

Predator energy density may be constant or change as a function of growth. We used energy density estimates we derived from Lake Huron specimens of both predators and prey. A linear regression relating energy density to weight was fit for each predator. As in Stewart and Ibarra (1991), some species exhibited a change in the relationship at a certain weight threshold. Separate regressions were used to fit each weight group. Predator energy densities are summarized in Table 3.

For all prey species except alewife, the mean energy density was used (Table 4). Alewife energy density has been found to vary seasonally (Rand et al. 1994; Flath and Diana 1985). Lake Huron alewife samples were available from June, July, and August and were not sufficient to determine the seasonal pattern. We assumed that the monthly seasonal pattern in Lake Huron was the same as discovered by Stewart et al. (1983) and Hurley (1986) in other Great Lakes. Energy densities for unsampled months were taken as the values reported in the literature multiplied by an adjustment factor. This adjustment factor represented the energy we saw in our samples relative to that seen by Stewart et al. (1983) and Hurley (1986) for the same months (Table 5).

GCE is calculated by dividing the total weight gain of an organism by the total biomass consumed during a specific period of time. Using our growth estimates and consumption information provided by the bioenergetics models, we computed GCE for each predator in each region (Table 6). The current projection models have been updated to reflect these new GCEs.

Job 6. Title: <u>Publish results and prepare annual reports.</u>

Findings: This progress report was prepared. Results from this work contributed to the Lake Huron Case Study Report prepared as part of the "Salmonid Communities of Oligotrophic Lakes" Symposium, to be published as a Great Lakes Fishery Commission report.

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Table 1.–Lake Huron water temperatures used in the bioenergetics model.

Month	Estimated temperature on 1st day of month				
	Lakewide	North	Central	South	SagBay
Jan	1	1	1	1	3
Feb	1	0	0	2	3
Mar	1	0	1	3	4
Apr	4	1	3	6	7
May	8	7	8	9	11
Jun	11	12	11	11	19
Jul	19	19	19	20	22
Aug	20	19	20	22	23
Sep	15	14	15	16	19
Oct	12	10	11	14	12
Nov	8	8	8	8	6
Dec	3	3	2	2	4

NOTES:

1. Temperatures obtained from NOAA/GLREL reports (Grumblatt 1976, McCormick, M.J. 1996, Nalepa et al. 1996, Johengen et al. 2000).

2. In Saginaw Bay, inner bay data from 1994-1996 was used except for missing months (January-March and November-December) which were estimated from 1993 Bay City data.

Table 2.–Diet Composition for predators in Lake Huron used in the bioenergetics model.

	Age	Alewife	Bloater	Invertebrate	Sculpin	Rainbow Smelt	Stickleback	Other fish
Burbot	1-3	0.23	0.00	0.28	0.34	0.14	0.00	0.01
	4-7	0.38	0.04	0.10	0.22	0.24	0.01	0.01
	8+	0.38	0.04	0.03	0.12	0.41	0.00	0.02
Chinook salmon	0	0.13				0.35	0.00	0.52
	1	0.27				0.70	0.00	0.03
	2+	0.87				0.08	0.04	0.01
Lake trout (North)	1-3	0.31	0.00		0.14	0.51	0.04	0.00
	4-6	0.18	0.00		0.02	0.77	0.02	0.01
	7+	0.45	0.04		0.04	0.45	0.00	0.02
Lake trout (Central)	1-3	0.52	0.00		0.01	0.46	0.01	
	4-6	0.60	0.00		0.00	0.4	0.00	
	7+	0.85	0.01		0.00	0.14	0.00	
Lake trout (South)	1-3	0.57			0.01	0.42		
	4-6	0.61			0.00	0.39		
	7+	0.94			0.00	0.06		
Walleye (South)	2-3	0.68				0.32		0.00
	4+	0.78				0.18		0.04
Walleye (Saginaw Bay)	2-3	0.34				0.16		0.50
	4+	0.39				0.09		0.52

Table 3.–Predator energy density used in the bioenergetics model.

Predator models	Weight Range	Energy Density (1)	Slope (2)
Burbot	All	5394	N/A
Chinook salmon	<4 Kg	4699	0.830
	>4 Kg	6941	0
Lake trout			N/A
North	<1.4 Kg	5040	2.514
	>1.4 Kg	7350	0.715
Central	<1.4 Kg	5040	2.514
	>1.4 Kg	7350	0.715
South	<3 Kg	6429	1.144
	>3 Kg	8807	0.026
Walleye	All	6053	0.379

NOTE:

(1) These values are the intercept of the allometric mass function ($J.g^{-1}$)
(2) Slope of the allometric mass function

Table 4.–Prey energy density used in the bioenergetics model.

Predator model	Alewife (1)	Bloater	Sculpin (2)	Rainbow smelt	Stickleback (3)	Other (2)
Burbot		5635	4909	5121	5038	5700
Chinook salmon				5121	5038	5700
Lake trout-North		5635	4909	5097	5038	5700
Lake trout-Central		5635	4909	4695	5038	
Lake trout-South			4909	5743		
Walleye-South				5743		5700
Walleye-Saginaw Bay				5743		5700

NOTES:

(1) Alewife energy density varied seasonally. See Table 5 for details.
(2) Sculpin and invertebrates are also represented in the diet composition but energy density for these species was not obtained from bomb calorimetry. The following values were obtained from the literature.
(3) One sample was omitted as possible erroneous value of 16,354 J/g. and unlikely 44% water compared to 77% average for other samples

Table 5.–Alewife seasonal energy densities.

Date	joules/g
1/1	5490
2/1	4766
3/1	4010
6/1	4001
7/1	3913
8/1	4978
9/1	4917
10/1	5870
11/1	6929
12/1	6253

Table 6.–Gross Conversion Efficiency used in the bioenergetics model.

		Chinook salmon		Lake trout			Walleye	
Age	Burbot	73-81	85-99	North	Central	South	Sag Bay	South
0		0.248	0.245					
1	0.079	0.220	0.229	0.200	0.155	0.213		
2	0.067	0.166	0.151	0.179	0.175	0.176	0.174	0.181
3	0.084	0.078	0.075	0.135	0.141	0.143	0.180	0.243
4	0.083	0.054	0.060	0.108	0.116	0.115	0.159	0.166
5	0.078			0.092	0.103	0.094	0.155	0.162
6	0.073			0.093	0.100	0.103	0.144	0.152
7	0.069			0.080	0.089	0.091	0.132	0.139
8	0.067			0.071	0.079	0.082	0.119	0.126
9	0.064			0.063	0.071	0.074	0.109	0.115
10	0.061			0.057	0.064	0.068	0.093	0.099
11	0.059			0.053	0.060	0.063	0.080	0.086
12	0.057			0.049	0.056	0.059	0.081	0.086
13	0.056			0.047	0.052	0.055		
14	0.054			0.044	0.049	0.069		
15+	0.052			0.049	0.055	0.070		

Table 7a.–Burbot, lake trout (northern and southern), and walleye weight-at-age in kilograms used in the bioenergetics model.

		Lake trout		
Age	Burbot	*North*	*South*	Walleye
1	0.39	0.05	0.06	
2	0.54	0.21	0.32	0.44
3	0.68	0.57	0.79	0.71
4	0.83	1.03	1.4	1.04
5	0.98	1.51	2.06	1.36
6	1.12	1.96	2.72	1.72
7	1.25	2.36	3.34	2.08
8	1.37	2.69	3.89	2.41
9	1.48	2.97	4.37	2.69
10	1.59	3.19	4.78	2.91
11	1.68	3.36	5.12	3.03
12	1.76	3.50	5.4	3.08
13	1.84	3.60	5.63	
14	1.91	3.69	5.82	
15+	2.02	3.75	6.07	

Table 7b.–Lake trout (central) weight-at-age in kilograms used in the bioenergetics model.

	Years												
Age	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996-98
1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
2	0.15	0.14	0.13	0.15	0.16	0.16	0.15	0.13	0.13	0.12	0.14	0.17	0.17
3	0.41	0.50	0.46	0.37	0.51	0.58	0.56	0.50	0.40	0.35	0.30	0.41	0.66
4	1.11	0.91	1.02	0.97	0.85	1.03	1.12	1.10	1.01	0.88	0.81	0.74	0.90
5	1.70	1.72	1.50	1.63	1.58	1.44	1.64	1.74	1.72	1.62	1.48	1.39	1.31
6	2.23	2.33	2.36	2.14	2.26	2.21	2.07	2.28	2.38	2.35	2.26	2.11	2.03
7	2.80	2.85	2.94	2.97	2.76	2.88	2.83	2.70	2.89	2.99	2.96	2.88	2.74
8	3.47	3.38	3.42	3.51	3.53	3.34	3.45	3.40	3.28	3.46	3.54	3.52	3.45
9	3.95	3.98	3.89	3.93	4.01	4.03	3.86	3.96	3.92	3.81	3.97	4.04	4.02
10	4.43	4.39	4.42	4.34	4.37	4.44	4.46	4.32	4.40	4.36	4.27	4.41	4.47
11	4.80	4.80	4.77	4.79	4.73	4.75	4.81	4.83	4.70	4.77	4.74	4.67	4.78
12	5.11	5.11	5.11	5.09	5.10	5.05	5.07	5.12	5.13	5.03	5.09	5.07	5.00
13	5.37	5.37	5.37	5.37	5.35	5.37	5.32	5.34	5.38	5.39	5.31	5.35	5.33
14	5.59	5.59	5.59	5.59	5.59	5.57	5.58	5.55	5.56	5.59	5.60	5.53	5.57
15+	5.77	5.77	5.77	5.77	5.77	5.77	5.75	5.76	5.73	5.74	5.77	5.78	5.72

Table 8.–Chinook salmon fall weight-at-age in kilograms used in the bioenergetics model.

	Ages					
Year	0	1	2	3	4	5
1968	0.229	2.25411	5.89798	9.60914	12.6757	14.9609
1969	0.229	2.25411	5.89798	9.60914	12.6757	14.9609
1970	0.229	2.25411	5.89798	9.60914	12.6757	14.9609
1971	0.229	2.25411	5.89798	9.60914	12.6757	14.9609
1972	0.229	2.25411	5.89798	9.60914	12.6757	14.9609
1973	0.229	2.25411	5.89798	9.60914	12.6757	14.9609
1974	0.229	1.96031	5.55258	9.17931	12.1968	14.4538
1975	0.229	1.7347	4.92786	8.53439	11.4858	13.7075
1976	0.229	1.73248	4.64486	7.97391	10.9843	13.1938
1977	0.229	1.67513	4.57448	7.62974	10.4474	12.7263
1978	0.229	1.83325	4.68503	7.79655	10.4343	12.6119
1979	0.229	1.7279	4.76333	7.74513	10.395	12.4172
1980	0.229	1.65399	4.54364	7.70642	10.2302	12.2562
1981	0.229	1.55733	4.33522	7.35936	10.0348	11.9593
1982	0.229	1.52799	4.1772	7.12289	9.70821	11.7613
1983	0.229	1.44452	4.03997	6.84931	9.37485	11.3653
1984	0.229	1.09566	3.50173	6.16732	8.52575	10.4427
1985	0.229	1.12397	3.08686	5.7165	8.03268	9.86973
1986	0.229	1.14389	3.14906	5.34866	7.69887	9.53571
1987	0.229	1.07678	3.09444	5.30476	7.27184	9.14989
1988	0.229	1.0965	3.02828	5.28267	7.27028	8.85844
1989	0.229	1.15458	3.12449	5.30737	7.35422	8.96778
1990	0.229	1.49628	3.59798	5.90394	7.94611	9.64957
1991	0.229	1.54898	4.12291	6.45199	8.54447	10.2094
1992	0.229	1.28193	3.86724	6.54589	8.54826	10.1884
1993	0.229	1.2642	3.50417	6.28142	8.59296	10.1577
1994	0.229	1.12899	3.31633	5.72681	8.13436	9.93005
1995	0.229	1.22219	3.24881	5.69257	7.8459	9.7633
1996	0.229	1.20066	3.34876	5.594	7.7796	9.50129
1997	0.229	0.890832	2.93186	5.18849	7.12675	8.83415
1998	0.229	1.01925	2.67773	5.00263	7.03332	8.59561