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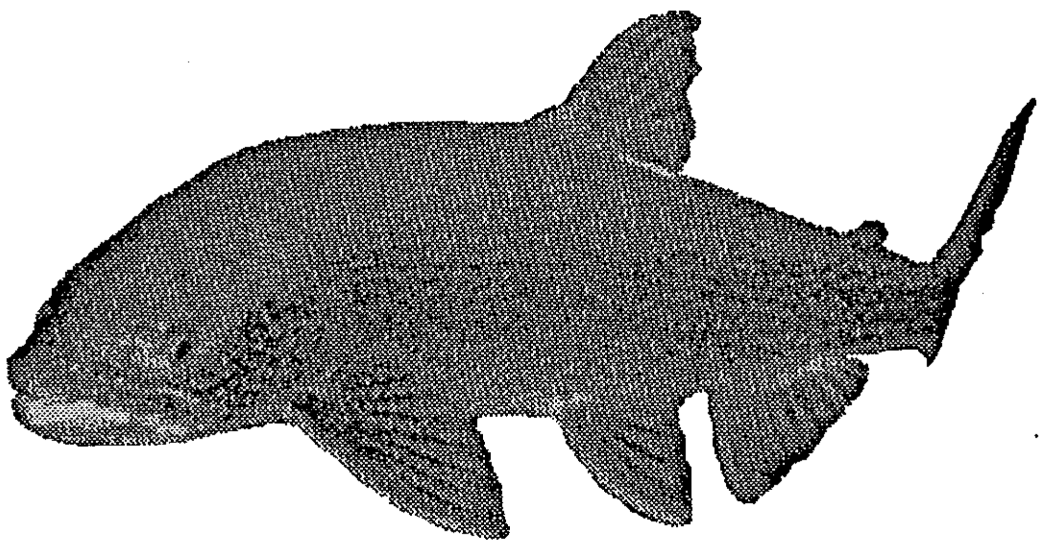

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Bayfield, Wisconsin 54814

ABSTRACT. – Fecundity was determined for wild Lake Superior lake trout, *Salvelinus namaycush*, from Gull Island Shoal. The following relationships were determined between egg number and length, weight, and age:

Fecundity = -12143.30 + 24.46TL (mm)
Fecundity = 354.92 + 1.37W (g)
Fecundity = -646.80 + 612.03 (age)

I applied fecundity rates by length interval to annual population estimates and calculated egg deposition estimates for 1964-1991. Estimated egg deposition ranged from 2.4 million in 1970 to 38.2 million in 1987. Fecundity and egg deposition estimates provide a guide for lake trout egg seeding experiments on other historical but unproductive Apostle Island spawning reefs.

INTRODUCTION

Lake Superior lake trout, *Salvelinus namaycush,* abundance rapidly declined in the 1950's because of the combined effects of sea lamprey, *Petromyzon marinus*, predation and over-exploitation (Lawrie and Rahrer, 1973). In Wisconsin, the combination of planting hatchery-reared fish in the late 1950's, controlling sea lamprey populations in mid-1961, and closing the commercial fishery from 1962-1970 reversed the trend of declining lake trout abundance (Swanson and Swedberg, 1980).

The Gull Island Shoal stock in the Apostle Islands was one of a few Lake Superior lake trout stocks that survived and continued to reproduce from a small number of mature fish (Dryer and King, 1968; Swanson and Swedberg, 1980). Stock size has steadily increased since 1961 when no females were sampled during annual spawning assessments (Dryer and King, 1968). The stock was given protection in 1976 when a permanent year-around fish refuge was created (Fig. 1).

For the Gull Island Shoal spawning population, the Wisconsin Department of Natural Resources (WDNR) has a data series that includes population estimates, sizes, sex ratios, and ages. However, fecundity data are lacking. Because estimates of fecundity and total egg deposition are useful in management, this study was under taken to determine the fecundity of wild lake trout and to use those data to quantify egg deposition on Gull Island Shoal.

METHODS

Lake trout were sampled during routine spawning assessments on Gull Island Shoal during 1985-88. Fish were captured using 5½-inch and 6-inch (stretch mesh) monofilament gill nets. All fish used in this study were measured to the nearest 0.1 inch (later converted to mm), and weighed to the nearest gram on a Pennsylvania dial scale (for fish up to 5500 grams), or to the nearest 100 grams on a Chatillon spring scale (for fish over 5500 grams). Ages were assigned from otoliths using the break and burn technique (Chilton and Beamish, 1982).

Eggs were obtained from dead pre-spawn wild lake trout. Fish were selected only if no eggs protruded from the anal vent when slight pressure was applied to the ventral area, and if the eggs were still attached to the ovarian sac. Eggs and ovarian tissue were placed in plastic freezer bags with canning salt to cover the eggs, and frozen for 3 to 8 months prior to counting.

In the laboratory, individual samples were thawed in warm water and the eggs were separated from the ovarian tissue. Total counts were done for 23 fish and estimates were made for the other 80 fish using the following wet gravimetric method. The eggs were thoroughly mixed, rinsed, drained, and weighed on a Pennsylvania dial scale. Approximately 1/3 of the eggs were weighed and counted. Total fecundity was estimated using the following equation:

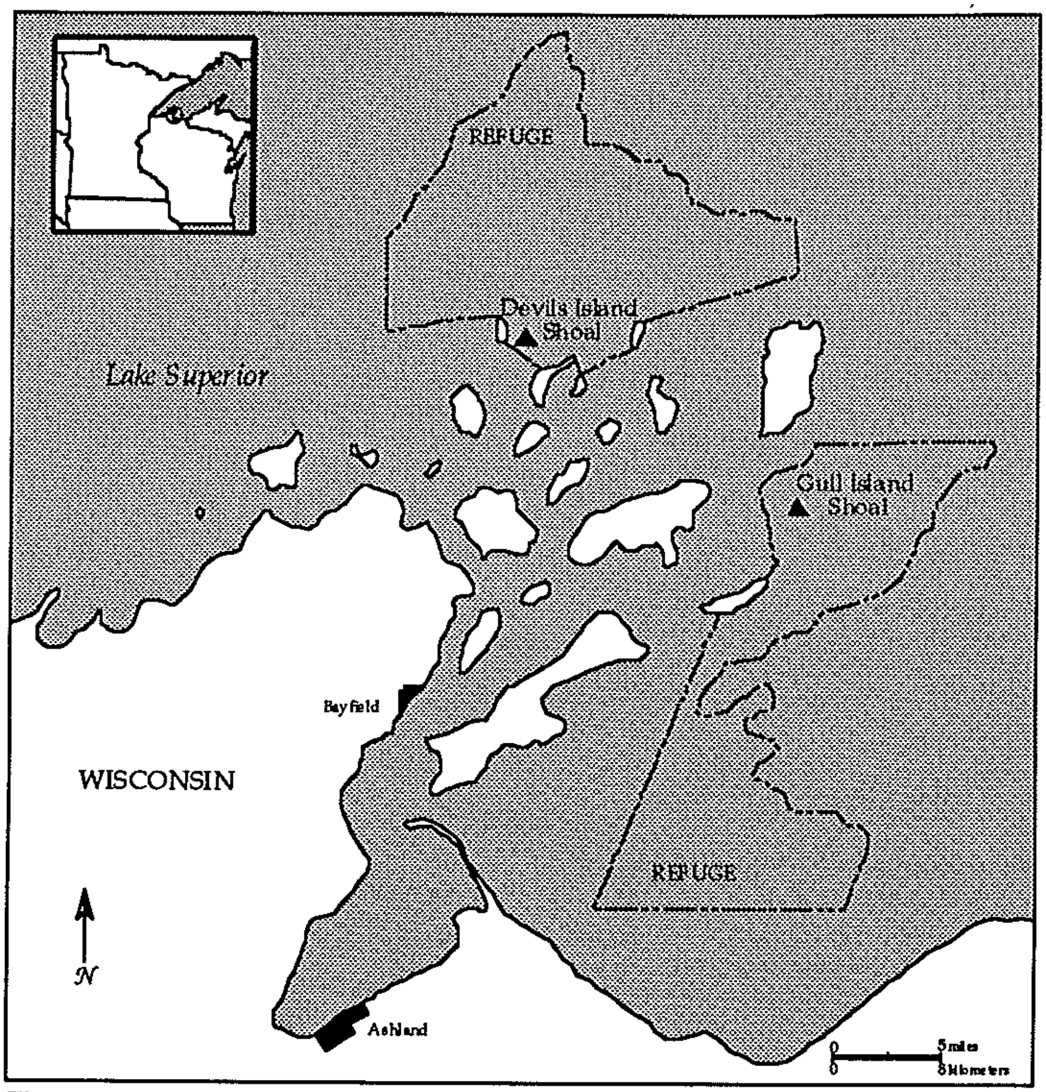

Figure 1. The Apostle Island area with the location of Gull Island and Devils Island Shoals.

$$\frac{\text{number of eggs in sample}}{\text{weight of sample}} = \frac{\text{total fecundity}}{\text{total weight of eggs}}$$

Once individual fecundity estimates were made, I calculated linear regressions between length and fecundity, weight and fecundity, and age and fecundity. I estimated egg deposition by multiplying the predicted fecundity for each length interval times the population estimate of females in that interval, and summing across all length intervals.

RESULTS

Mean fecundity of 103 fish ranging from 640 to 932 mm increased from 3,350 to 11,823 (Table 1). Mean fecundity by weight interval of 65 fish ranging from 2,281 to 8,626 g increased from 3,330 to 11,823 (Table 2). Mean fecundity by age group ranging from 6 to 20 years was determined for 84 fish and ranged from 2,786 to 12,608 (Table 3).

Fecundity was positively related to length, weight, and age of the fish. Linear relationships provided better fits than curvilinear in all regressions of fecundity on length, weight, and age. The following linear regression equations were calculated (Figure 2).

Fecundity = -12143.3 + 24.46 (TL) N = 103 $R^2 = 0.55$
Fecundity = 354.92 + 1.37 (W) N = 65 $R^2 = 0.58$
Fecundity = -646.80 + 612.03 (AGE) N = 84 $R^2 = 0.41$,

where TL = total length in millimeters, W = round weight in grams; and AGE = age in years.

Estimated annual egg deposition on Gull Island Shoal increased steadily after 1964 (Table 4). Deposition may have been underestimated after 1982 because the spawning population was sampled with 5½ and 6-inch mesh nets only. Large females may not have been vulnerable to the gear.

Table 1. Mean fecundity by length interval for Gull Island Shoal wild lake trout, 1985-1988.

Length Interval (mm)	Mean	(S.D.)	Sample Size	Fecundity Range	Fecundity Mean (S.D.)
626-650	653	(4.2)	6	1,876-5,058	3,350 (1,207)
651-675	665	(6.3)	10	1,594-6,279	3,998 (1,668)
676-700	684	(5.4)	13	1,140-8,341	4,281 (1,988)
701-725	710	(8.4)	8	3,100-6,801	5,349 (1,214)
726-750	737	(5.8)	12	5,169-8,854	6,442 (1,065)
751-775	760	(8.8)	11	2,698-8,623	6,281 (1,544)
776-800	787	(8.4)	7	5,572-10,219	7,656 (1,609)
801-825	816	(6.5)	15	3,457-10,614	7,958 (1,890)
826-850	833	(7.6)	3	6,412-8,262	7,351 (925)
851-875	860	(6.1)	10	5,818-10,012	8,051 (1,388)
876-900	886	(7.9)	5	8,473-15,224	11,425 (2,600)
901-925	911	(9.0)	2	5,604-9,866	7,735 (3,014)
926-950	932		1	11,823	11,823

DISCUSSION

Fecundity increased with length, weight, and age, but a large amount of variation in fecundity was unexplained by any of the three independent variables. Widely varying fecundity in wild Lake Superior lake trout was also reported from Michigan waters by Eschmeyer (1955), and Peck (1988). Fecundity rates from this study were higher than Eschmeyer's (1955) for fish less than 765 mm, but were lower for fish over 765 mm (Table 5). Studying wild and hatchery lake trout off Marquette, Michigan, Peck (1988) reported higher fecundity rates than those found in this study or by Eschmeyer (1955). Large variations in lake trout fecundity have also been reported in Lake Tahoe by Hanson and Wickwire (1967) and in several Canadian lakes by Healy (1978). Some variations in lake trout fecundity have been attributed to changes in growth, exploitation, and brood stock culture (Healey, 1978; Peck 1988).

Egg deposition estimates for Gull Island Shoal demonstrate that the stock recovered from extremely low abundance of spawning females in the early 1960's. Increased numbers of lake trout were the result of reduced sea lamprey abundance and control of fishing mortality. In addition, female lake trout of hatchery-origin made up 44% of the spawning population in the early 1970's (Swanson and Swedberg 1980), and may have contributed to increased egg deposition. But in 1991, only 9.6% of the female spawners were of hatchery-origin (Schram, 1992), so recent egg deposition is primarily attributable to wild fish. Since egg deposition and stock abundance were not quantified prior to the sea lamprey invasion, I was unable to determine if total egg deposition was comparable to former levels.

The WDNR has been stocking fertilized lake trout eggs in astro-turf bundles on Devils Island Shoal since 1980 (Swanson 1982). Even though Devils Island Shoal is much smaller than Gull Island Shoal (approximately 207 ha vs. 3,096 ha), eggs

Table 2. Mean fecundity by weight interval for Gull Island Shoal wild lake trout, 1985-1988.

Weight Interval (grams)	Mean	(S.D.)	Sample Size	Fecundity Range	Fecundity Mean (S.D.)
2000 - 2999	2,643	(231)	12	1,594 - 5,058	3,330 (1,059)
3000 - 3999	3,361	(253)	18	1,140 - 6,801	5,078 (1,409)
4000 - 4999	4,296	(235)	11	5,518 - 10,219	7,354 (1,399)
5000 - 5999	5,389	(323)	17	3,457 - 10,509	7,695 (1,759)
6000 - 6999	6,467	(306)	3	6,351 - 9,941	8,030 (1,806)
7000 - 7999	7,267	(289)	3	5,604 - 15,224	10,097 (4,841)
8000 - 8999	8,626		1	11,823	11,823

Table 3. Mean fecundity by age group for Gull Island Shoal wild lake trout, 1985-88.

Age	Sample Size	Fecundity Range	Mean	(S.D.)
6	1	6,484	6,484	
7	3	1,140 - 3,974	2,786	(1,471)
8	5	1,876 - 6,279	3,676	(1,638)
9	11	2,377 - 7,321	4,582	(1,682)
10	10	3,659 - 10,509	6,336	(2,283)
11	12	1,594 - 8,854	5,723	(2,396)
12	12	4,876 - 8,923	6,915	(1,381)
13	10	3,457 - 9,941	7,304	(1,722)
14	11	5,138 - 15,224	7,839	(2,866)
15	1	8,000	8,000	
16	3	5,818 - 10,879	8,318	(2,531)
17	4	7,689 - 11,823	10,035	(1,736)
20	1	12,608	12,608	

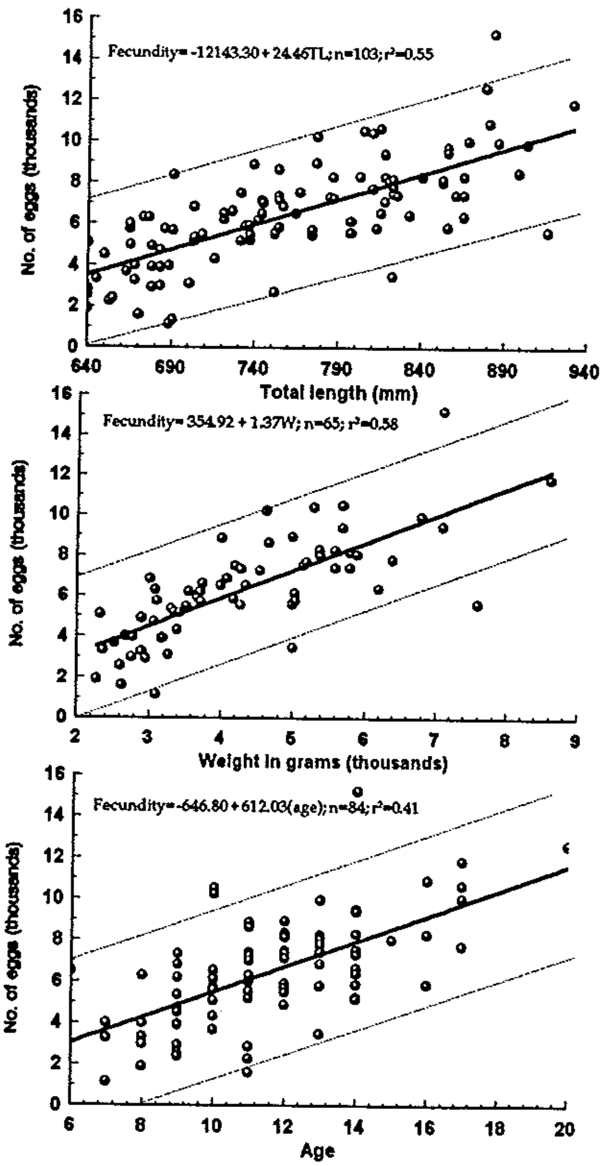

Figure 2. Relationship between fecundity and total length (mm), weight (g), and age for wild Gull Island Shoal lake trout. Confidence intervals are the upper and lower 95% of the predicted values.

stocked in astro-turf bundles on Devils Island Shoal have exceeded the egg deposition per hectare that occurred on Gull Island Shoal during its early recovery period (Fig. 5). It has taken 31 years for the Gull Island Shoal stock to reach its present egg deposition level. If the astro-turf program is successful, applying current Gull Island Shoal egg deposition levels to historical but unproductive spawning areas could significantly reduce reef recovery time.

MANAGEMENT RECOMMENDATIONS

1. Use fecundity estimates from Gull Island Shoal lake trout to estimate fecundity from other Apostle Island spawning populations.

2. Lake trout egg deposition estimates on Gull Island Shoal provide a guide for egg seeding experiments on other historical but unproductive Apostle Island spawning reefs. Multiplying the reef size times the egg deposition level desired (from Fig. 5) will estimate the number of eggs to stock.

3. Egg deposition needs can be used to allocate surplus hatchery produced eggs for early life stage stocking programs.

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Table 4. Annual estimated lake trout egg deposition on Gull Island Shoal, 1964-1991. Estimates from 1964-1979 were adjusted from Swanson and Swedberg (1980) using fecundity estimates from this study.

Year	Estimated Egg Deposition	Year	Estimated Egg Deposition
1964	4,217,830	1978	14,141,168
1965	3,100,519	1979	25,072,419
1966	5,039,610	1980	20,708,640
1967	5,314,181	1981	15,521,057
1968	7,291,050	1982	16,599,114
1969	6,098,881	1983	30,403,360
1970	2,420,024	1984	26,711,060
1971	6,571,580	1985	34,962,471
1972	5,994,028	1986	28,523,630
1973	7,112,554	1987	38,237,710
1974	6,984,185	1988	30,546,042
1975	4,783,262	1989	33,996,431
1976	5,726,557	1990	32,091,831
1977	4,343,809	1991	35,423,243

Table 5. Lake Superior lake trout fecundities estimated by three studies.

Mean Size (mm)	Eschmeyer (1955) Average Egg Number	Present Study Calculated Egg Number (95% C.I.)	Peck (1988) Calculated Egg Number (95% C.I.)
660	3,383	4,001 ± 3,490	3,594 ± 624
711	4,253	5,248 ± 3,468	5,342 ± 433
765	4,995	6,569 ± 3,462	7,192 ± 460
818	8,667	7,865 ± 3,471	9,008 ± 688
853	8,881	8,721 ± 3,485	10,208 ± 881
904	11,603	9,969 ± 3,520	–

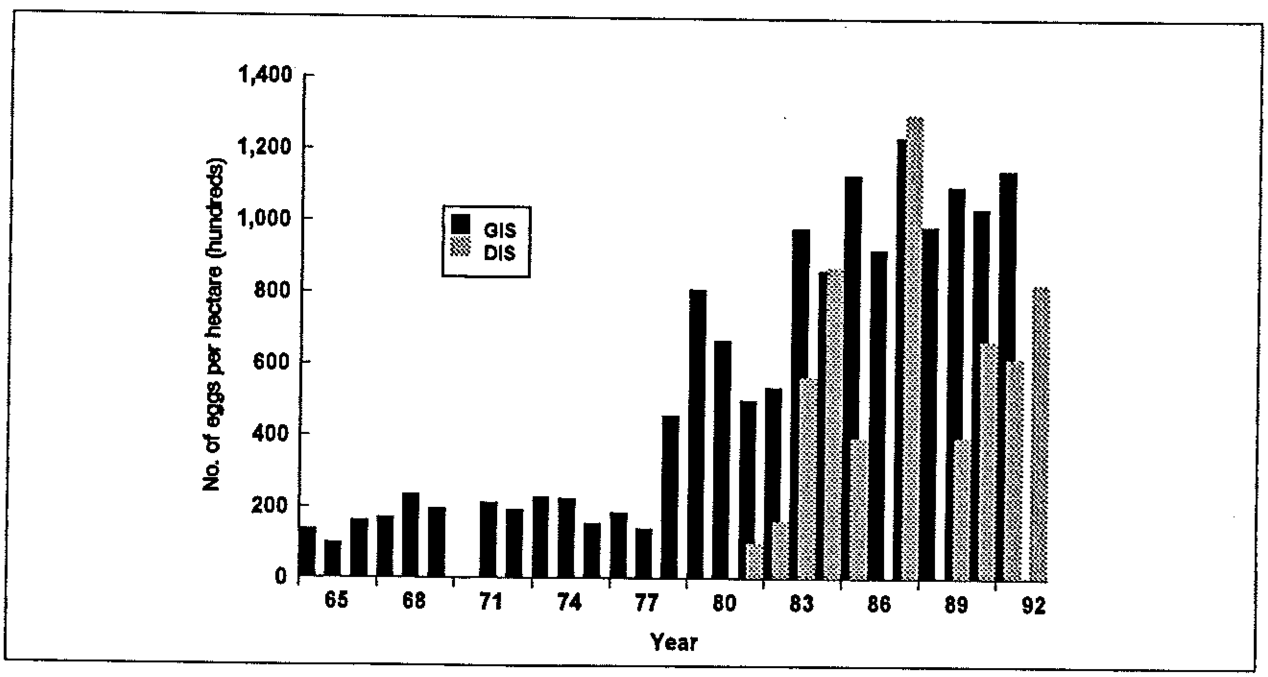

Figure 3. Estimated egg deposition per hectare for Gull Island Shoal (GIS) from 1964-91 and eggs stocked in astro-turf bundles on Devils Island Shoal (DIS) from 1980-92.

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ABOUT THE AUTHOR

I am currently the Lake Superior fisheries biologist stationed at Bayfield. My responsibilities include managing the Lake Superior salmonid and coolwater fisheries programs. I have a BS from Northern Michigan University and a MS from Central Michigan University.

Lake trout fecundity and egg deposition estimates addressed an essential management need necessary for lake trout egg seeding experiments in the Apostle Islands. I hope the results will be useful to other Great Lakes biologists working on lake trout rehabilitation.

Stephen T. Schram