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FINAL REPORT FOR THE WISCONSIN COASTAL MANAGEMENT PROJECT:

EVALUATING NEW TECHNIQUES FOR REESTABLISHING LAKE TROUT ON SURVEYED WISCONSIN REEFS AND SHOALS

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by

Robert A. Ragotzkie
Ross M. Horrall
J. Philip Keillor

of the

Marine Studies Center
University of Wisconsin

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BACKGROUND

Once the most abundant and productive predator in Lake Michigan, lake trout became extinct in that lake in the mid-1950s. The reasons for its demise are well documented and include predation by the sea lamprey and intensive fishing (Hile, Eschmeyer and Longer 1951; Eschmeyer 1957; Smith 1968, Wells and McLain 1973). Since 1965, after sea lamprey control was begun, the Wisconsin Department of Natural Resources in conjunction with the Great Lakes Fishery Commission has maintained a strong and active program on the rehabilitation of lake trout in Wisconsin waters. With the exception of certain areas in Lake Superior, the lake trout presently found in the Great Lakes are of hatchery origin and the fishery is maintained entirely on a put and take basis. Therefore, both the DNR and the commission are striving to obtain the formation of self-sustaining, natural reproducing stocks of lake trout. Prior to the destruction of the native lake trout by the sea lamprey in the 1940s and 1950s this species spawned on many of the reefs and shoals in Wisconsin's coastal waters of Lake Michigan and in the Apostle Islands region of Lake Superior (Coberly and Horrall 1980; Brown et al. 1981). In order to make wise management decisions concerning the allocation and stocking of yearling lake trout, and for determining specific locations for the planting of lake trout eggs and/or sac fry several of the most important historic spawning areas were intensively surveyed during the summers of 1978, 1979, and 1980. These surveys were conducted by our group at the

University of Wisconsin Marine Studies Center with funding from the Wisconsin Coastal Management Program through the Wisconsin Department of Natural Resources and from the Wisconsin Sea Grant Institute. Three publications describing these surveys have been produced (Stamm et al. 1979; Stamm et al. 1980; Stamm et al. 1981). Underwater transects covering a distance of 127.6 km (79.3 miles) were traversed by our diver-biologists on the following reefs:

Lake Superior

Gull Island Shoal
Michigan Island Shoal
Devils Island Shoal
Sand Cut Shoals

Lake Michigan

Larsens Reef
Horseshoe Reefs
Whitefish Point Reef
The Spits
Jacksonport Deep Reef
Deathdoor Bluff Reef
Black Can (North Clay Banks)
Clay Banks-Stony Creek Reefs
Jacksonport Reefs
Baileys Harbor Reefs

Since traditional methods of raising and stocking lake trout (hatchery rearing to yearling stage, then stocking fish at shoreline sites) have largely failed to reestablish naturally reproducing populations, we proposed to the Coastal Management Program an experimental program to test a new technique for rehabilitating lake trout--that of diver planting lake trout sac fry of different genetic strains (Krueger et al. 1981) directly over the best substrates found on the UW-CMP-DNR reef surveys. After stocking, the sac fry will remain protected in the reef substrate for one to two months during which time they should become naturally imprinted to the characteristics of the reefs (Horrall 1981). Natal homing back to a specific reef area when sexually mature would insure that the trout would spawn on suitable substrate. If these experiments are successful then this relatively inexpensive and "more natural" method of stocking, compared to rearing the fish in a hatchery for 15 to 18 months to the yearling stage, would offer great potential for inducing the formation of naturally reproducing stocks of lake trout on a large scale.

In order to produce lake trout sac fry with developmental stages in synchrony with lake temperatures we obtained permission to construct and operate an experimental lake trout hatchery in the Green Bay pumping station on Lake Michigan just north of Kewaunee starting in the fall of 1980. In addition we obtained a permit to operate an experimental lake trout hatchery from the Wisconsin DNR (Cooperative Agreement Fish Rearing Station). The water supply for the hatchery is pumped from the forewell of the pumping station (intake depth in Lake Michigan of 16.4 m [50 ft]) up into a reservoir tank above the trays. From the reservoir tank the water is then gravity fed into the top tray of each of the three rows of 16 vertically stacked hatchery trays.

The following describes the project activities during the second year (1981-1982) of the grant.

COLLECTION OF EGGS AND SPERM

The first collection of eggs for the experimental hatchery was obtained from native lake trout on Gull Island Shoal in the Apostle Islands of Lake Superior on 23 October 1981 (Table 1). This was the same time period that we were helping the Wisconsin DNR with the filling and placing of astroturf [redacted]TAB[redacted]. [redacted]tor[redacted] th[redacted]ggs [redacted]d i[redacted]e E[redacted]rime[redacted]l L[redacted]Tro[redacted]Hat[redacted]y. [redacted]

Egg Source

1981 - 1982	Apostle Islands (Gull Island Shoal)	Feral Lake Michigan: Larsens Reef	Feral Lake Michigan: LR X GIS	Feral Lake Michigan: Black Can -Clay Banks	Lake Superior Strain (1968D, 1969D)
Eggs spawned	23 October	27-30 October	27-30 October	3-6 November	25 November 2 December
Eggs hatched (50% hatch)	1 April	13 April	13 April	23 April	18 May
Incubation period	160 days	167 days	167 days	169 days	172 days
Swim-up stage (estimated; 50%)	27 May	4 June	4 June	10 June	27 June
Number of eggs	96,039	194,136	121,335	240,293	123,102
Egg mortality	~37%	~28%	~95%	~15%	~38%
Fry mortality (estimated)	Low	High	High	High	Low
Dates stocked	5 May	5 May	5, 21 May	5, 21 May	21 May
1980 - 1981					
Eggs spawned	29 October			4-6 November	12 November
Eggs hatched (50% hatch)	7 April			13 April	24 April
Incubation period	161 days			159 days	163 days
Swim-up stage (estimated; 50%)	21 May			27 May	11 June
Number of eggs	32,000			162,000	720,000
Egg mortality	~9%			~14%	~29%
Fry mortality (estimated)	Very Low			High	Low
Dates stocked	24 April			24 April	24, 25, 30 April; 5 May

incubators.

In addition to the eggs collected from the Gull Island Shoal trout, we collected lake trout sperm for making experimental crosses with Lake Michigan trout. Different batches of sperm were preserved by the following methods (Graham and Erdahl 1980; Dave Erdahl, University of Minnesota Sea Grant Program, personal communication 1981):

1. Neat sperm stored in vials at 5°C.
2. One part sperm to one part extender stored in vials at 5°C.
3. One part sperm to two parts extender stored in vials at 5°C.
4. One part sperm to one part extender (with 6% dimethyl sulfoxide) in plastic tubing frozen on dry ice and stored in liquid nitrogen.
5. One part sperm to one part extender (with 6% dimethyl sulfoxide) in plastic vials frozen on dry ice and stored in liquid nitrogen.

All collecting in Lake Superior was done in cooperation with the Wisconsin DNR at Bayfield and netting was done from the vessel HACK NOYES, the DNR's gill net tug. The trout were collected with graded-mesh assessment gill nets set over the top of Gull Island Shoal.

Starting on 27 October collecting was conducted on Lake Michigan in cooperation with the Wisconsin DNR at Sturgeon Bay and aboard their vessel, the BARNEY DEVINE. From 27 to 30 October eggs were collected from Larsens Reef in Green Bay and from 3 to 6 November from the Black Can and Clay Banks Reefs in Lake Michigan. From these three locations a total of 555,764 eggs were collected of which 121,335 eggs from Larsens Reef were fertilized by the preserved sperm from native Gull Island Shoal trout (Table 1). These eggs were from feral Lake Michigan lake trout and were largely of the Lake Superior strain that were stocked as yearlings. For the most part the stocking site could not be determined because most fish had a lake-wide fin clip.

Two batches of eggs (25 November and 2 December) were obtained from the Marquette State Hatchery broodstock. These eggs were from the 1968 Domestic and the 1969 Domestic Lake Superior strains. The 1968 Domestic trout are "late" spawners and are composed of about 25% Green Lake strain which were descended from the native deepwater-spawning trout from Lake Michigan.

The collections from all sources totalled 774,905 eggs and there were 13,313 eggs from miscellaneous sources giving a grand total of 788,218 eggs. There was an average of about 17,500 eggs per stacked Heath tray. As was the case last year the water flow through the trays was 15.1 to 18.9 l/min (4 to 5 gal/min) of Lake Michigan water which was pumped from the forewell of the pumping station (intake depth of 16.4 m [50 ft]). The eggs were treated each day for 15 minutes with 1 part formaldehyde (37%) to 800 parts of water to prevent fungus formation. Eggs were not handled or picked until after the eyed-up stage had occurred. Water temperatures were taken each hour by the pumping station personnel.

INCUBATION AND HATCHING

The monthly mean temperatures at the hatchery during 1981-82 are given in Table 2 and, for comparison, temperatures for 1980-81 are also given (Table 3). The hatchery temperatures are graphed in Fig. 1 using 5-day mean temperatures. It can be seen that the fall temperatures in 1981 were warmer than in 1980, but the winter and spring temperatures were colder in 1982 than in 1981. In the 1981-82 season the eyed-up stage occurred earlier than

TABLE 2. Monthly mean temperatures at the hatchery during 1981-82.

		Mean Temperature		Range
		°C	°F	°C
1981	November	5.5	41.9	3.9 - 6.7
	December	3.1	37.6	1.7 - 5.6
1982	January	0.8	33.5	0.0 - 2.2
	February	0.5	32.9	0.0 - 1.1
	March	0.8	33.4	0.0 - 2.2
	April	2.8	37.1	1.1 - 5.6
	May	6.6	43.8	4.4 -10.0
	June	7.9	46.2	5.0 -12.2

TABLE 3. Monthly mean temperatures at the hatchery during 1980-81.

		Mean Temperature		Range
		°C	°F	°C
1980	November	4.7	40.5	3.3 - 6.1
	December	2.0	35.7	0.0 - 3.3
1981	January	1.0	33.8	0.0 - 2.2
	February	1.2	34.1	0.0 - 2.2
	March	1.6	34.8	1.1 - 3.3
	April	4.9	40.8	2.8 - 6.7
	May	6.4	43.6	4.4 - 8.9
	June	6.2	43.2	4.4 - 9.4

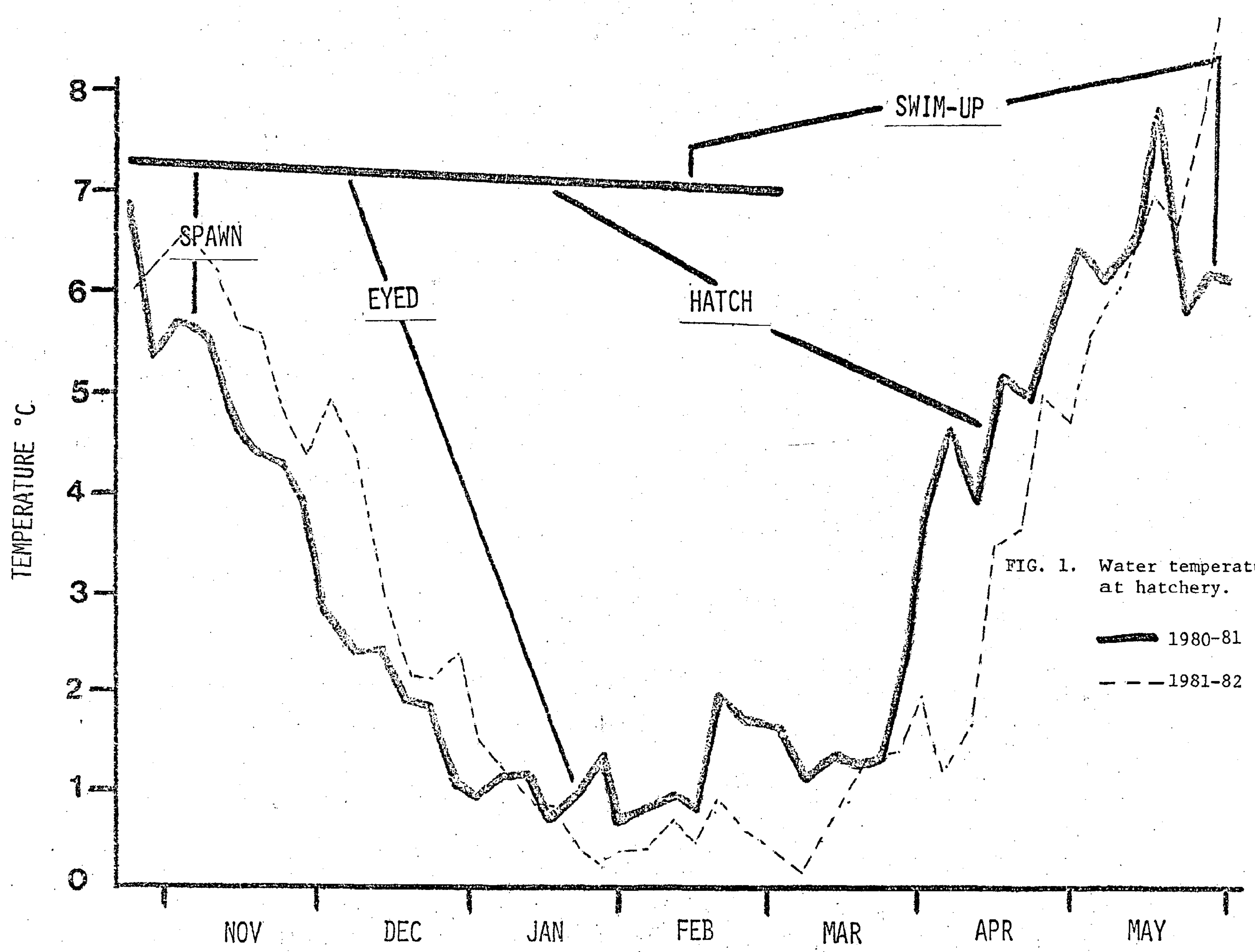


FIG. 1. Water temperatures at hatchery.

the previous year due to the warmer temperatures, but the colder winter and spring temperatures slowed development so that hatching occurred at similar dates and at similar TU's (Temperatures Units--see next section) on both years.

There were several severe winter storms during the 1981-82 season. These storms riled up the water causing a high silt load in the hatchery water for several days. The eggs "filtered" out large amounts of this silt, but there was no evidence to indicate that this caused any large increases in egg mortality.

DEVELOPMENT OF EGGS AND FRY IN TEMPERATURE UNITS

Temperature units are a convenient way of expressing and comparing the effects of time and temperature on the development of eggs and fry. One temperature unit (TU) equals one degree centigrade for a 24 hour period. For example if the 24-hour mean water temperature in the hatchery was 3.7°C, then the eggs were "exposed" to 3.7 TUs.

The number of TUs and days to hatching and to swimup for the different groups are given in Table 4 for 1981-81 and for the previous year (1980-81) for comparison. The range of values for all groups are:

	Range of TU's	Range of days
To hatching	349-382	159-172
To swim-up	612-673	40-57

Considering the differences in water temperature regimes and egg collection dates in the two seasons studied, the TUs to hatching and to swimup

TABLE 4. Developmental History and TU's of Eggs and Fry in the Experimental Lake Trout Hatchery.

	Egg Source				
		Feral Lake Michigan			
1981 - 1982	Apostle Islands (Gull Island Shoal)	Larsens Reef	LR X GIS	Black Can -Clay Banks	Lake Superior Strain (1968D, 1969D)
Mean temperature to hatch	2.4°C	2.2°C	2.2°C	2.1°C	2.0°C
Incubation period	160 days	167 days	167 days	169 days	172 days
TU's to hatch	382	368	368	357	352
Hatch to swimup	57 days	52 days	52 days	47 days	40 days
TU's to swimup	638	672	672	673	660
1980 - 1981					
Mean temperature to hatch	2.4°C			2.2°C	2.3°C
Incubation period	161 days			159 days	163 days
TU's to hatch	361			349	372
Hatch to swimup	44 days			44 days	48 days
TU's to swimup	617			612	672

were fairly consistent and therefore would be very useful for predicting these events in nature. For example they could be used to make decisions about the timing of sampling for naturally produced fry.

EGG AND FRY MORTALITY

Mortality of the eggs was higher during the 1981-82 season than it was during the previous season (Table 1). In the case of the Gull Island Shoal eggs the higher mortality was very probably due to the long transportation time from Bayfield to the hatchery as a result of a snow storm which necessitated an overnight stop. In addition it was difficult to maintain constant temperatures in the two milk cans in which the eggs were transported. The temperatures varied between 5.5°C and 10.0°C in the 51.5 hours between collection and arrival at the hatchery. This and the jarring which occurred during transportation may have been harmful to the eggs causing a higher mortality than in the previous year (37% vs. 9%).

The eggs collected at Black Can-Clay Banks in Lake Michigan had the highest survival (85%) and the lowest mortality (15%) of any of the groups and was essentially the same as last years survival from the same locations (86%). Mortality of eggs collected from Larsens Reef (28% [72% survival]) was roughly twice as high as the eggs from the Black Can - Clay Banks area (15% [85% survival]). It is interesting to note that eggs collected from Larsens Reef were smaller (8,089 eggs/qt) than the eggs from Black Can - Clay Banks (6,965 eggs/qt).

The very high mortality (95%) of the crosses between Larsens Reef eggs and the preserved sperm of native Gull Island Shoal male trout remains unexplained. Several reasons, however, are possible explanations: contaminated extender; samples stored at 5°C were not stored in an oxygen atmosphere;

improper timing of the freezing on dry ice before emersion in liquid nitrogen; improper sizes of freezing containers; and improper thawing techniques before fertilization of the eggs. The highest survival of these crosses (10%) was from a tray of eggs fertilized with a mixture of neat sperm and of one part sperm to two parts of extender stored at 5°C.

The eggs obtained on 25 November and 2 December from the Marquette State Hatchery broodstock (1968 Domestic and 1969 Domestic Lake Superior strains) suffered 38% mortality. This was probably due to the lateness of the season which caused eggs from some of the females to be of poor quality and/or due to poorer temperature tolerance of these broodstock eggs.

In order to make estimates of fry mortality samples of sac fry were held in the hatchery after the majority of fry had been stocked out on 5 May and 21 May. Fry mortality was low (generally less than 3%) from hatching until shortly before the absorption of the yolk sac and swimup. At this time both groups of fry from Lake Michigan feral trout began to show signs of "distress" and "sluggishness." Mortality increased after the swimup stage and over 60% were dead by 20 June and all were dead by 11 July. Because the Gull Island Shoal fry hatched the earliest of any group, the effects of starvation could not be separated from other causes of mortality by mid-June and this was probably also true of some of the Lake Michigan fry.

Similar findings were reported by the U.S. Fish and Wildlife Service (Quarterly Report Great Lakes Fishery Laboratory: April-June 1982):

> Survival of Lake Trout Eggs and Fry in Waters of the Upper Great Lakes
>
> We previously reported the poor survival of lake trout fry hatched from eggs collected from spawning adults in southeastern Lake Michigan during the fall of 1980. These results were confirmed by again incubating Lake Michigan eggs collected during the fall of 1981, rearing the resulting fry, and comparing their survival to that of lake trout eggs and fry from hatchery brood stock.
>
> When Lake Michigan eggs and fry were maintained in a temperature cycle simulating ambient Lake Michigan conditions (1-9°C), only 27% of the fry survived to 60 days after hatch. By comparison, fry from hatchery eggs exhibited a 69% survival rate to 64 days after hatching under the same conditions. These survival rates were similar for fry hatched from both groups of eggs at a constant 8°C (see previous quarterly report). The life stage at which mortality occurred, together with other symptoms, correspond to the results of our 1980 study and indicate the potential for serious development problems in the young lake trout produced in southeastern Lake Michigan.
>
> An interesting sidelight of this study is the observation that trout eggs from Lake Michigan experienced excellent hatching at ambient temperature with 93% of the fertilized eggs surviving, whereas eggs from hatchery stock experienced only a 59% hatching rate. When maintained at constant temperature, hatchery eggs exhibited an 86% hatching rate. The comparatively poor survival of hatchery eggs at ambient lake temperatures was also observed in our previous studies. It thus appears that eggs of hatchery broodstock have a more restrictive temperature tolerance than do eggs of planted lake trout that have spent several years in the lake.

Because earlier studies had showed that the effects of PCB and DDT on lake trout fry mortality had been declining (Willford et al. 1981) this very high mortality of fry which has been observed might be related to recent evidence which shows 6 to 11 ppm toxaphene in Lake Michigan lake trout. The following is taken from the September-October 1982 issue of Wisconsin Natural Resources (Vol. 6, No. 5):

Catch-all

Toxaphene may cut reproduction in Great Lakes fish

bin J. Irwin
torial Assistant

Madison — High levels of the pesticide toxaphene have een reported in Great Lakes out and salmon by the US Fish and Wildlife Service's Great Lakes Fish Laboratory at Ann rbor, Michigan. It probably ts there as "toxaphene rain" similar to the way acid rain happens.

A 1976 study estimated that 3 million pounds are spread on US field crops annually. **In the South, it is the most popular secticide to control boll eevils, cutworms and a wide range of other pests on cotton.**

Like its cousin DDT, toxaphene is incredibly long-lived. Research suggests it can remain unchanged in the environment r up to 11 years before break-g down into simpler compounds, and even those chemicals may be harmful.

Also like DDT, toxaphene what scientists call "bioaccumulative," meaning it builds to higher and higher vels in the fatty tissue of h and animals as you ascend the food chain.

Toxaphene concentra-ons discovered so far in the reat Lakes do not pose much danger to humans.

While the threat to people is w, researchers are concerned out what the pesticide may do to fish.

At sub-lethal levels, the chemical causes calcium to build up excessively and unevenly along a fish's backbone, bringing about what is known as the "bowed back syndrome."

Biggest concern is what toxaphene does to eggs and fry. Experiments show that when brook trout eggs are exposed to levels even lower than one part per million (ppm), only about one-fifth of them hatch. This has scientists worried because the US Fish and Wildlife Service's National Fish Research Laboratory at Columbia, Missouri, has detected levels from six to 11 parts per million — with most ranging from seven to eight — in otherwise seemingly healthy adult lake trout. Toxaphene may explain mysterious die-offs of young trout and salmon fry at Great Lakes fish hatcheries.

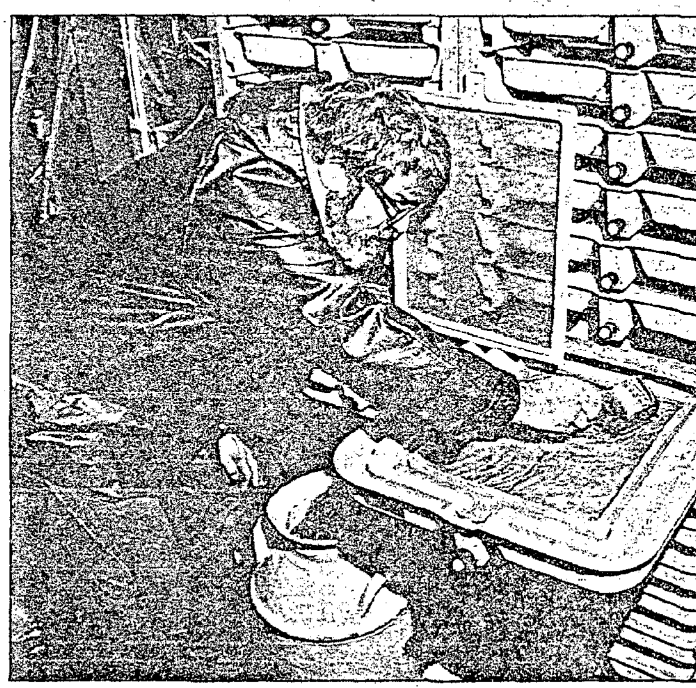
The toxaphene revelation may answer other questions. Last year a University of Wisconsin Sea Grant Institute experiment found that eggs taken from Lake Michigan lake trout, hatched and reared in Lake Michigan water, all died within four months. Yet, eggs taken from Lake Superior fish lived, even though kept in the same water. **The evidence pointed to something being passed on through the eggs from adult fish to fry. Now scientists have reason to suspect it might be toxaphene.**

The toxaphene sprayed on cotton in the South gets into the Great Lakes from the atmosphere as "toxaphene rain." Some 50 to 60% of it evaporates within 58 days and becomes airborne long before it breaks down. **The chemical has turned up in lake trout from a totally landlocked lake on Isle Royale in Lake Superior.**

Because of this pervasiveness, toxicity and the difficulty of identifying the chemical in the environment, toxaphene has been banned in New York, New Hampshire and Connecticut. California is considering such a prohibition and Arizona has an 18-month moratorium against using the product. It has been likewise banned or restricted in Canada, Sweden, Finland, Denmark, France, Switzerland, Hungary, Italy, Algeria and the United Kingdom. Use of the chemical in Wisconsin is insignificant.

However even if there were a national prohibition in the US, there is no guarantee reproductive failure in Great Lakes trout would be corrected.

"We can't identify 80% of the chemicals that show up on testing equipment," says Wayne Wilford of the Great Lakes Fish Research Lab. "That represents something like 476 compounds — of which toxaphene, until recently, was just one. Toxaphene looks like a likely culprit, but the other 475 could also be working separately or together to harm fish in the Great Lakes."



Researcher Ross Horrall checks incubation trays at Sea Grant's experimental lake trout hatchery in Kewaunee. Some scientists now think toxaphene, recently found in Lake Michigan trout, may be linked to their reproductive failure and to occasional, mysterious die-offs of fry in hatcheries. Photo by Rick Evans, UW Sea Grant Institute.

SAC FRY STOCKING ON TRADITIONAL SPAWNING REEFS

The majority of sac fry were stocked out on 5 May (Northeast Reef) and on 21 May (Horseshoe Reef)--however approximately 38,000 fry were retained at the hatchery for mortality studies and for Y-maze experiments.

The first plant was conducted on Northeast Reef about 20 miles southeast of Port Washington (Figure 2). Since the top of the reef is about 180 feet in depth it was not possible to plant the fry with divers. Therefore a hopper connected to a 4-inch hose about 170 feet in length was used for placing the sac fry near the reef's surface. Sac fry were poured into the hopper which was receiving water pumped from the lake. The sac fry were transported via stock tanks both from the hatchery to Port Washington (by truck) and from Port Washington to the reef (on the vessel R/V AQUARIUS). About 220,000 sac fry were planted near the following Loran C positions (also see Figure 3):

Beginning of Plant:

A 32852.1

B 49208.3

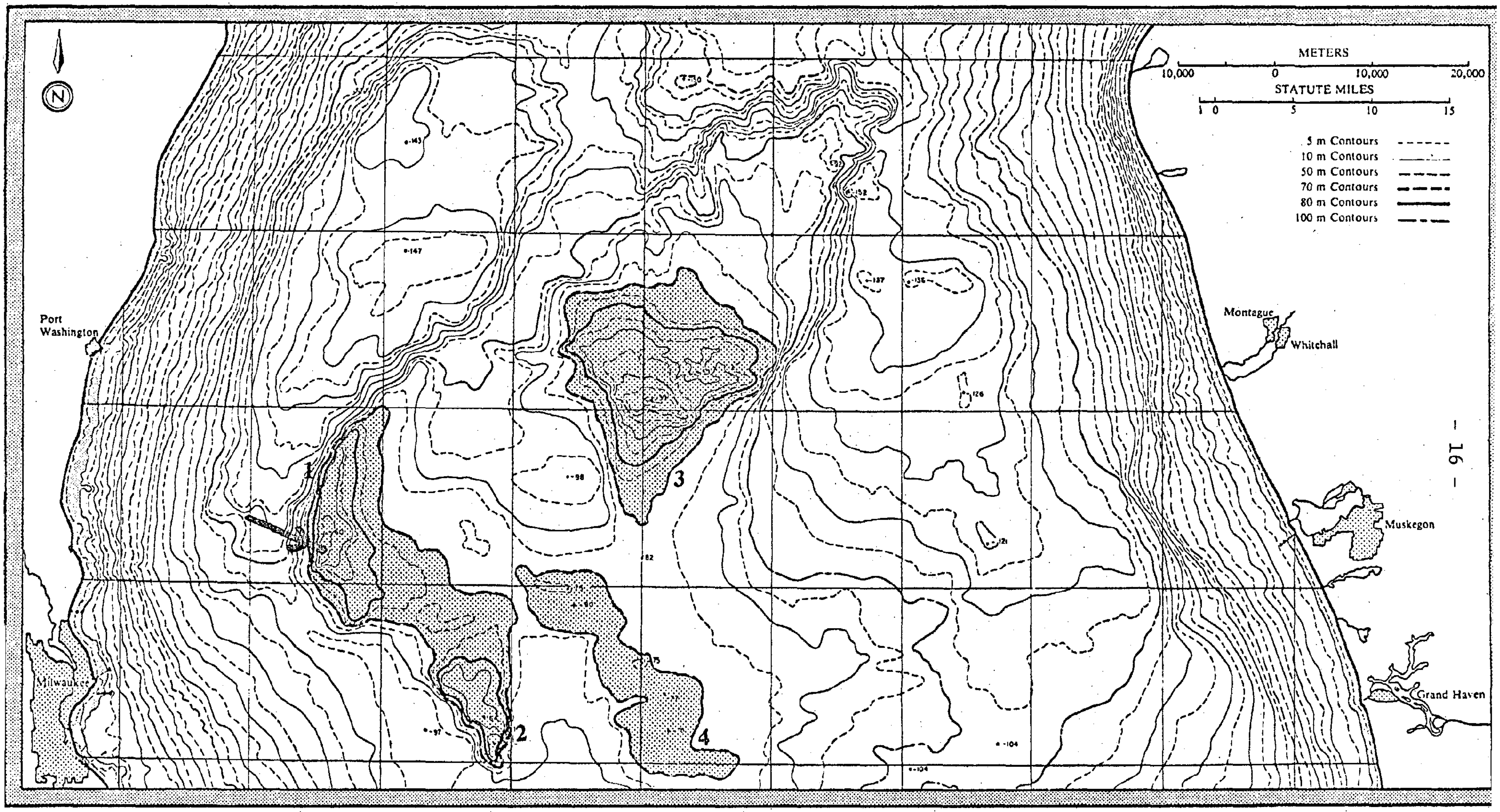
End of Plant:

A 32851.6

B 49207.0

Surface temperature at the release site was 2.9°C while hatchery temperatures were 5.5°C.

Because of the depth and the inability to use divers it was not possible to monitor the condition of the fry as they emerged from the 4-inch hose near the reef. Therefore a sac fry plant on a shallow reef was necessary in



From Bathymetric Chart of Middle Lake Michigan by R. J. Ristic and C. H. Mortimer, Center for Great Lake Studies, University of Wisconsin-Milwaukee

Chart 12 Central Regi

FIGURE 2. Bathymetric chart of Middle Lake Michigan showing locations of historic lake trout spawning grounds: 1. Northeast Reef; 2. East Reef; 3. Sheboygan Reef; 4. Milwaukee Reef (Coberly and Horrall 1980). Arrow shows location of sac fry plant.

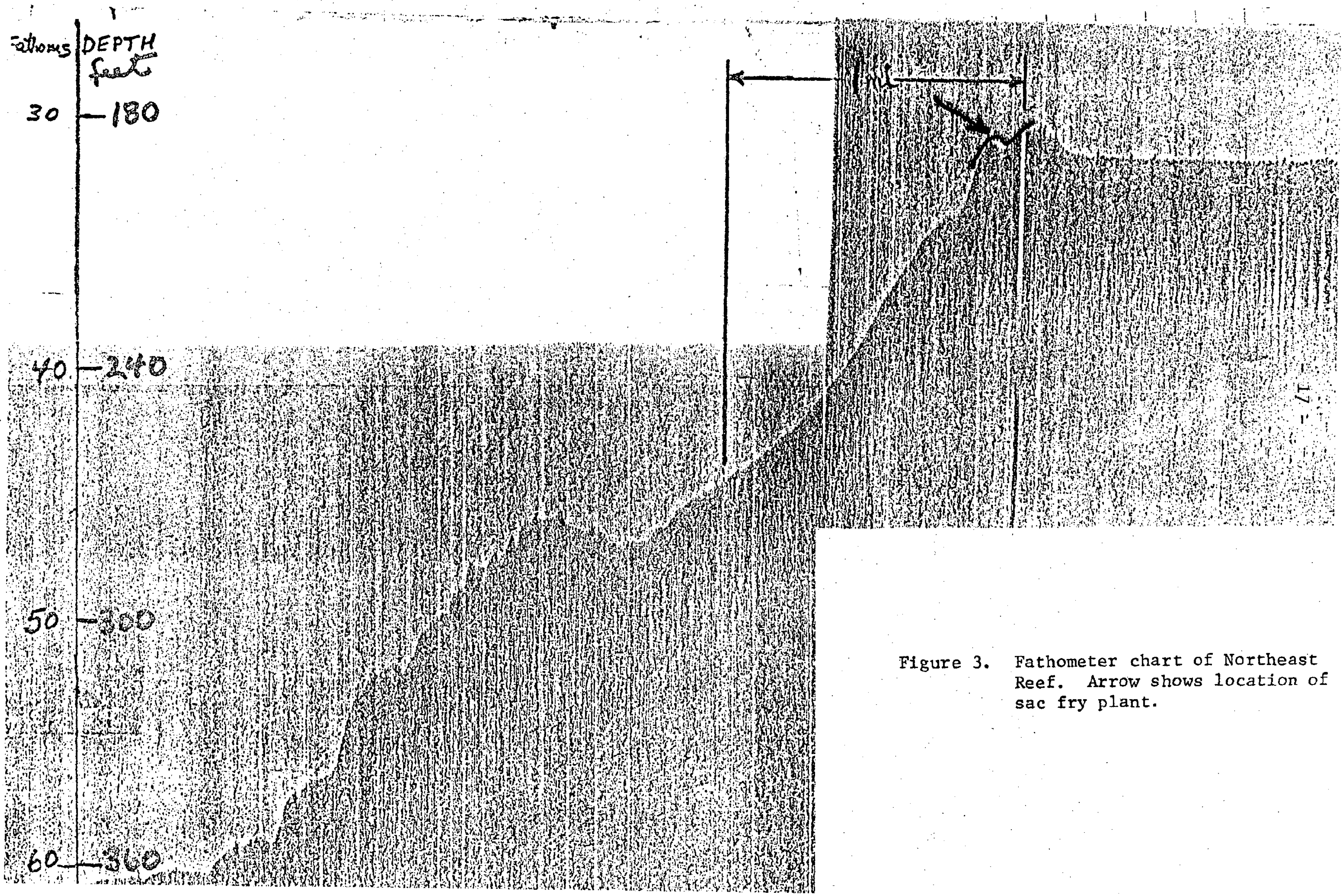


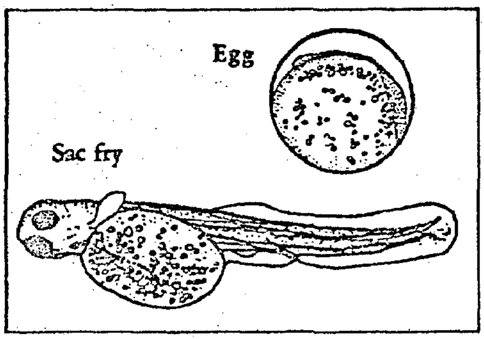
Figure 3. Fathometer chart of Northeast Reef. Arrow shows location of sac fry plant.

order to test the same planting system under shallow conditions where observation was possible. The following article describing the plant on Horseshoe Reef was taken from the June-July 1982 issue of LITTORAL DRIFT:

COOPERATION BOLSTERS LAKE TROUT PLANTING

Sea Grant programs in three states extended a helping hand in the introduction of almost 300,000 baby lake trout to their new home in Green Bay last month.

Assisting the UW Sea Grant lake trout rehabilitation research team were two divers from *the Michigan Sea Grant Program* who brought special underwater TV equipment. And techniques developed by scientists in Minnesota's Sea Grant program were used to propagate one of the lake trout strains planted.



Early life stages of the lake trout.

Research team leader Ross Horrall used cryogenic (sudden freezing) procedures developed by Edmund Graham, a University of Minnesota animal physiologist, to preserve sperm from an Apostle Island strain of lake trout and cross them with eggs from Lake Michigan lake trout. The sac fry that hatched out this spring from this crossing were an important part of a planting on central Green Bay's Horseshoe Reef.

"We're trying to introduce some of the genetic qualities of wild Lake Superior fish to the Lake Michigan fish to increase their vitality," says Horrall. "The lake trout that spawn on *Superior's Gull Island Shoal* appear hardier and more active than either fish in Lake Michigan or those from the broodstock at the Michigan state hatchery in Marquette."

Yet even the hardiest fish may have found that exchanging their snug hatchery tray for the lake was no picnic. Transported from the Algoma hatchery via van and research vessel, the fry then plunged 50 feet through a 4-inch plastic tube to the spawning reef that was to be their new home. The University of Michigan Sea Grant divers planted an underwater TV camera on the bottom to monitor the fish's arrival. Despite just 8-foot visibility at that depth, the super-sensitive camera required no artificial lighting to film the fry as they shot out the end of the tube.

The closed-circuit TV soon proved its worth. Observing the tiny fish on their shipboard monitor, the researchers decided that too many were obviously stunned by the force and turbulence of the water going through the tube. Though most of the fry recovered and scurried down into the protective rocks, the researchers will use a more gentle, flowing syphon next time to transfer the fish from shipboard tanks to the lake bottom.

"In Michigan, researchers are looking at lake trout reproduction on an artificial reef in southern Lake Michigan and in Hammond Bay in Lake Huron," says Horrall. "So we share interests and can profit by sharing equipment and research."

The televised planting was part of a larger lake trout rehabilitation project, supported in part by Wisconsin's Department of Natural Resources and Coastal Management Program.

Surface temperature at the release site was 7.8° and 6.2°C at the bottom (45 feet) while the hatchery temperature was 5.5°C. About 210,000 sac fry were planted near the following Loran C positions:

A 32100.7 - 32100.9

B 48011.4 - 48011.5

ASTROTURF INCUBATORS

We again cooperated with Bruce Swanson, Wisconsin DNR at Bayfield, in assembling and placing of astroturf incubators on Devils Island Shoal in the Apostle Islands of Lake Superior. Eggs from native lake trout collected from Gull Island Shoal were used in the incubators. Each astroturf "sandwich" incubator contained about 13,000 eggs. Twenty-one incubators containing approximately 273,000 eggs were placed on the northeast end of the shoal on 24 October 1981. Unfortunately the weather was too rough to deploy divers and therefore individual incubators with their railroad rail anchor had to be dropped off the HACK NOYES in the same area as last years deployment.

Divers searched the area on 2 and 3 June 1982 and were able to locate and retrieve 16 of the 21 incubators. Each sheet of astroturf in each incubator was examined for dead eggs and fry. Eggs survival was 88.6% (11,518 eggs per incubator) and only 9.2 dead fry were found in each incubator (Bruce Swanson, personal communication 1982). Of the fry which had hatched in the incubator 81.3% had migrated out by 2-3 June.

The following is an article written by Bruce Swanson (1982) on the astroturf incubators during the 1980-81 season:

Artificial Turf as a Substrate for Incubating Lake Trout Eggs on Reefs in Lake Superior

Bruce L. Swanson

Wisconsin Department of Natural Resources
Bayfield, Wisconsin 54814

ABSTRACT: In October 1980, more than 50,000 eggs of lake trout (*Salvelinus namaycush*) were placed between layers of artificial turf, 30 X 90 cm. These "sandwiches" were suspended from plastic jugs above the bottom at Devils Island Reef, Lake Superior, and anchored to pieces of railroad track. The total material cost for each sandwich was $45. When they were retrieved from the reef in May 1981, about 78% of the eggs had apparently hatched and most sac fry had left the sandwiches.

In the middle to late 1950's, the sea lamprey (*Petromyzon marinus*) devastated the fish stocks of Lake Superior. Many species increased after lamprey control took effect; however, stocks of lake trout (*Salvelinus namaycush*) have only slowly recovered in most of Lake Superior and the other Great Lakes (Smith and Tibbles 1980). Massive plantings of yearling lake trout in Lake Superior in 1960–70 were not overly effective in reestablishing the populations that used historical spawning reefs. There is considerable evidence that in the past lake trout have returned to their natal reef to spawn (Eschmeyer et al. 1953; Eschmeyer 1955; Martin 1957; Loftus 1958; Rahrer 1968; Swanson 1974). The prime reason for the failure of lake trout stocked in Lake Superior to spawn in these areas has been assumed to be the lack of homing instinct. Even fall fingerling and yearling lake trout stocked directly on these reefs have not demonstrated a strong tendency to home to the reefs after they mature. It has been speculated that lake trout imprint very early in life to the reef where they were hatched (Horrall 1981). If so, the seeding of eggs on these reefs should insure that on reaching maturity, the survivors would home to their natal reef to spawn.

I describe an artificial substrate for egg incubation to be placed directly on spawning reefs and present information on egg survival with the artificial substrate from an experiment conducted on Devils Island Reef in Lake Superior.

Materials and Methods

Artificial turf "sandwiches" were constructed of Monsanto C-4 Astro turf without cloth backing. Two mats (30 X 90 cm), placed turf side to turf side, composed one layer. Seven such layers were placed together in a pine wood frame and strapped together with plastic banding tape by using a dymax tensioner (Signode Company, Chicago, Illinois). The sandwiches were attached to 90-cm lengths of railroad track by two 75-cm lengths of chain 6 mm in diameter (Fig. 1). Sturdy plastic 3.8-L jugs were tied to both ends of the sandwich with 45-cm lengths of rope. The sandwiches were placed on the reef bottom by scuba divers at 13.5 m and the railroad track anchors were attached in series with 6.4-mm cable. The plastic jugs were filled with air from the divers' regulators to give added buoyancy to the sandwiches. The total material cost for each seven-layer sandwich was $45.

Lake trout eggs were sandwiched between the layers of artificial turf; a similar technique had previously been used to incubate eggs of pink salmon (*Oncorhynchus gorbuscha*) in a hatchery (Bailey and Taylor 1954). On 22 October 1980, wild lake trout eggs were taken from the spawning population on Gull Island

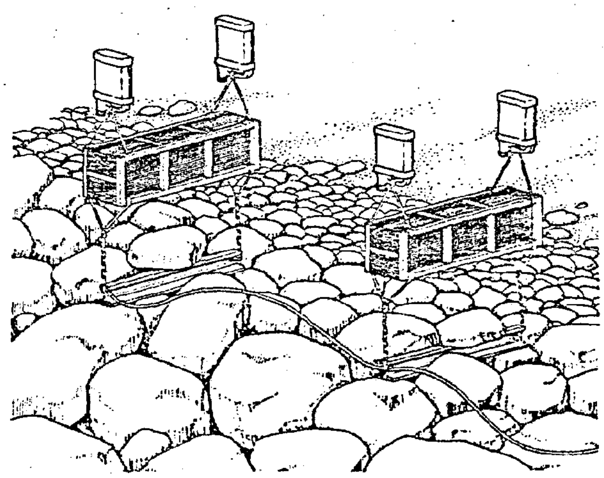


Fig. 1. Placement of artificial turf sandwiches on a spawning reef.

Reef, located just east of the Apostle Islands in Lake Superior, and transported to the Bayfield (Wisconsin) hatchery for placement in the artificial turf sandwiches. The mats were floated in a hatchery raceway while the water-hardened eggs were poured onto the mats (Fig. 2). An attempt was made to avoid clumping the eggs. The eggs were neither treated to control fungus nor picked over to remove dead or dying eggs. Three different quantities of eggs were used in the sandwiches: two sandwiches had 2,000 eggs per layer, one had 1,600 per layer, and two had 1,200 per layer (total, 52,400 eggs). Five sandwiches (four seven-layer and one four-layer) were packaged and placed in 8.3°C water in a hatchery raceway overnight. On the morning of 23 October 1980 the sandwiches were anchored on Devils Island Reef, on the northern fringe of the Apostle Islands in Lake Superior. During transportation to the reef, the sandwiches were held in a cattle-watering tank covered with canvas, and lake water was occasionally poured over them.

Two separate single layers were held in the hatchery at a constant 8.9°C to evaluate sac fry escapement. Each layer held 1,500 eyed eggs that had been treated with malachite green and had been picked over to remove dead eggs.

Results

After 3 months, the sac fry had ceased to leave the layers held in the hatchery. Examination of the two layers revealed 128 dead eggs in the mats; no dead sac fry were observed. Overall hatch and escape for these two layers was 96%.

On 7 May 1981 the sandwiches were removed from the lake and examined for wear and egg survival. Only one sandwich showed wear, and that was a minor scrape on one of the wood frames. One railroad track section had moved about 1.5-m, but the sandwich itself was unaffected. The sandwiches survived their first field test mainly because of their ability to flex and sway like a sea-fan in reaction to the rigorous wave action and currents of Lake Superior.

Egg survival of 79% was estimated by counting the dead eggs remaining between the layers of artificial turf and subtracting this number from the number originally known to be present. Survival was apparently higher in the layers with 2,000 eggs (83%) than in those with 1,600 (74%) and 1,200 (73%). A large number of large sac fry were still present but few dead fry were seen. The scarcity of dead fry suggests that if an egg hatched, the fry were able to escape from the sandwiches. Shipboard facilities did not permit the extraction and retention of live sac fry from the individual layers. Although I was unable to count the live sac fry, a conservative estimate of hatch and escape of fry from the sandwiches was 60–70%.

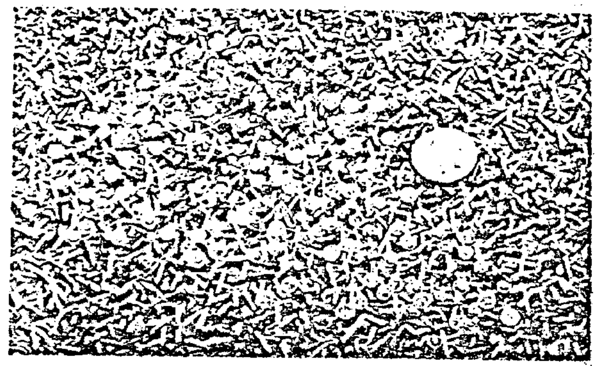


Fig. 2. Lake trout eggs on an artificial turf mat. The coin is a quarter (U.S.).

Discussion

In comparison with results from direct deposition of eggs on a reef, the artificial turf technique probably reduced predation and eliminated water-hardening as a factor in locking the eggs in the substrate. Reef-reared eggs are incubated at proper water temperatures and pressures, which cannot be duplicated at a hatchery. I suspect that the egg mortality greater than that in a hatchery (usually about 15%) was due to clumping of eggs when they were placed in the mats. If one or two eggs die in a clump, a fungus might infect the adjacent viable eggs.

The benefits of successful lake trout egg seeding on non-producing historical spawning reefs are twofold. The clearest benefit would be the return of mature spawners developed from surviving eggs, due to imprinting. Studies by Swanson and Swedberg (1980) indicated that the return rate of spawning fish (from eggs) on Gull Island Reef was 0.18%. (This return occurred in the presence of an annual fishing mortality rate of only 7.3% due to the protection of a fish refuge.) If the rate to maturity of sandwiched eggs at Devils Island Reef were similar, each sandwich (7 layers with 2,000 eggs per layer; total, 14,000 eggs) could produce about 25 homing spawners. About 6 of these would be expected to be females, since females constitute about 25% of the spawning population on Gull Island Reef (Swanson 1974). At an estimated fecundity of 5,000 eggs (Eschmeyer 1964), the females ultimately resulting from each sandwich could be expected to deposit about 30,000 eggs on Devils Island Reef.

The second benefit of hatching lake trout eggs on former lake trout spawning reefs is the possibility that spawning, egg hatching, or the presence of fry may be necessary to attract stocked hatchery lake trout that have matured to suitable sites. Preliminary work being done by the U. S. Fish and Wildlife Service Great Lakes Fishery Laboratories has indicated that spawning lake trout may be attracted to specific sites by the chemical residue (pheromones) in the fecal material from fry developing on the site (Neil Foster, personal communication). If this is true, mature stocked lake trout may be attracted to the area in which fry from the sandwiches develop.

The initial apparent success of the technique warrants continuation of the project. More fry would undoubtedly escape if the sandwiches were left in the lake until the end of May. This technique may have application for initiating spawning on the deeper lake trout spawning reefs of the Great Lakes, where the sandwiches could probably be lowered from a vessel without the aid of scuba divers.

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CONCLUSIONS AND RECOMMENDATIONS

1. The experimental lake trout hatchery built in the fall of 1980 in the City of Green Bay's Lake Michigan pumping station has had two seasons of successful operation. Approximately 1,702,000 eggs have been incubated and about 1,109,000 sac fry produced and planted on two traditional, but presently barren, lake trout spawning reefs. These sac fry plants are part of an ongoing experimental program to test the hypothesis that early imprinting experiences on the reef are necessary for appropriate homing behavior in lake trout. In addition sac fry stocking may prove to be a practical and economical technique for lake trout rehabilitation.

The homing orientation of returning spawners probably requires a complex set of environmental stimuli acting as cues which are apparently imprinted on the very young trout on their natal spawning grounds (Hasler et al. 1978; Horrall 1981). These imprinted cues may include the olfactory characteristics of the water flowing over the reef and/or pheromones emitted from fry mucus and feces; information on depth (pressure) of the reef; and magnetic fields giving geographic information.

2. The experimental lake trout hatchery program should be continued as a research tool:

   a. To continue bioassay studies on effects of microcontaminants on the survival of eggs and fry.

   b. To continue sac fry planting on traditional spawning reefs as a test of the hypothesis that imprinting during early life stages in lake trout on the reef is necessary for appropriate homing behavior in sexually mature trout. These experiments may also give indications as to whether pheromones from fry mucus and feces attract sexually mature hatchery-stocked trout to traditional reefs where sac fry have been planted (pheromone hypothesis of Neal Foster, USFWS).

c. To conduct research on the behavior of lake trout fry (e.g. effects of "hatchery imprinting," timing of imprinting, responses to water currents, pheromones, fungicides and temperature changes).

d. To determine the timing of developmental stages (hatching, yolk absorption and swimup) at ambient lake temperatures of eggs collected at different locations. This would permit appropriate scheduling of field sampling for naturally produced fry.

3. As a result of the experiences gained during two seasons of transporting sac fry from the hatchery to the release site it is recommended that following procedure be used in future plants. About 10,000 sac fry can be placed in a plastic bag with 3 gallons of water. The bag is then completely filled with oxygen and the bag tied off. These bags are then floated in a stock tank partially filled with water. This procedure minimizes the chances that the sac fry will sufficate due to "piling up" on the bottom of the bag because the water movement in the tank displaces the bags enough to prevent this from occurring.

4. If divers cannot be used to plant the sac fry directly on the substrate of the reef then the sac fry should be siphoned from the stock tank

(after the plastic bags have been emptied into the tank) through a 1 1/2 inch or 2 inch hose extending to near the bottom. Another method would involve lowering the plastic bags down to near the surface of the reef and opening or slitting the bags to release the fry. With either method the vessel would be drifting slowly during the release process so that the fry would be distributed along the bottom.

5. Both eggs in astroturf incubators and hatchery-reared sac fry are being used to test the hypothesis that early imprinting is necessary for successful homing and reproduction in lake trout. However each method has certain advantages and certain disadvantages:

   a. Astroturf incubators need a source of green eggs--preferably the incubators should be placed on the reef within 48 hours after egg collection due to the sensitive condition of the eggs after this period. Eyed eggs are no longer sensitive and therefore could be used in the incubators if the eggs can be incubated at ambient lake temperatures (or by simulating lake temperatures through the use of chillers) and if weather conditions would permit placement of incubators in December or January in Lake Michigan or as early as late November in Lake Superior because of the warmer water temperatures during the fall season.

   b. In terms of total effort, the astroturf incubators probably take less time and effort per surviving fry in the substrate than a small hatchery (1 million eggs) raising sac fry. However if you have a hatchery with a larger capacity (2 to 5 million eggs) then the effort advantage swings greatly in favor of rearing sac fry.

c. Because of the ease of transporting and the "good" weather in April and May during stocking, sac fry offer a much greater flexibility as to stocking sites and timing of stocking than do the *in situ* incubators.

d. At the present time we do not know whether imprinting would be "better" with egg incubators or with planted sac fry. Certainly the eggs in the incubators are exposed to the "near" reef environment longer but it is also unclear how rapidly the sac fry move out of the astroturf into the reef substrate. We also do not know what are the effects of the pressure change on the stocked sac fry. If the critical period for imprinting is between hatching and swimup (Horrall 1981) then either method should be satisfactory as far as imprinting to the reef is concerned assuming that the sac fry leave the astroturf fairly soon after hatching. This needs to be checked experimentally.

6. A very important part of the program will be to monitor the lake trout in the vacinity of the stocking sites. This can be accomplished by examining the lake trout for fin clips during creel census and monitoring of incidental lake trout catches in assessment and/or commercial gill nets, pound nets and trap nets set mainly for chubs and whitefish. These are routinely carried out by the Wisconsin DNR. We would hope to monitor during the fall spawning period via gill nets and/or trap nets the sac fry planting sites 5 and 6 years following planting.

For example:

Sac Fry Plant:	Sample Years:		
1981 Horseshoe Reef	1986,	1987	
1981 Horseshoe Reef		1987,	1988
1982 Northeast Reef		1987,	1988

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