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GREAT LAKES FISHERY COMMISSION
Research Completion Report *

COMPARISON OF SUBSTRATE SELECTED BY SPAWNING LAKE TROUT, AND EVALUATION OF TECHNIQUES FOR EGG COLLECTION

by

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July, 1990

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Final Report to the Great Lakes Fishery Commission

June 30, 1990

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INTRODUCTION

Lake trout (*Salvelinus namaycush*) were native to Lake Ontario until 1960. Prior to that time they provided a flourishing commercial fishing industry for both Canada and the U. S. The decline and eventual extinction of lake trout has been attributed to a combination of overfishing, predation by sea lamprey (*Petromyzon marinus*), and degradation of habitat. A program to restore a self-perpetuating population of lake trout to Lake Ontario has been underway since 1971. In the past decade, up to one million lake trout yearlings have been stocked in the lake each year. The survival of lake trout after stocking has been adequate to develop an important sport fishery in New York and Ontario. In addition, assessment surveys conducted by the New York State Department of Environmental Conservation (DEC) have found aggregations of mature lake trout at several sites in the eastern basin of the lake. In 1982, a single lake trout fry was captured (Clif Schneider, personal communication). In 1986 the first evidence of multiple lake trout fry was documented by our collection of 75 fry off the north end of Stony Island (Marsden et al. 1988).

The goal of the fisheries agencies involved in lake trout management (U.S. Fish and Wildlife Service, Ontario Ministry of Natural Resources, Department of Fisheries and Oceans, Canada, and New York Department of Environmental Conservation) is to reestablish naturally reproducing lake trout populations. For population reestablishment to be successful, reproduction must occur at many sites lakewide, and must produce large year classes of fry. Fry production by hatchery lake trout in the other Great Lakes has been documented since 1975 (Lake Superior, Peck 1981; Lake Michigan, Wagner 1981 and Jude et al. 1981; Lake Huron, Nester and Poe 1984), but has so far been inadequate for rehabilitation in Lakes Michigan and Huron. Several reasons have been proposed for the lack of adequate natural reproduction, such as contaminants in the eggs, lack of homing to spawning sites, and failure of hatchery lake trout to locate and lay eggs on appropriate spawning habitat (Peck 1979, Eshenroder et al. 1984). Reproductive failure due to contaminants in the eggs is unlikely, because eggs have been taken from adult lake trout in Lake Ontario and successfully incubated and reared in hatcheries. Lack of homing to spawning sites also does not appear to be a problem, because for several years the DEC has noted large aggregations of ripe lake trout at historic spawning sites. In 1987 we conducted a preliminary investigation of substrate-specificity of egg deposition by mature hatchery-origin lake trout, using egg nets developed by Horns (Horns et al. 1989). Data from the capture of 2145 eggs and from visual observations of lake trout adults and eggs by divers suggested that egg deposition is non-random with respect to substrate type. This work was funded by the Great Lakes Fishery Commission.

In order to coordinate future research and management efforts, two inter-agency lake trout task force meetings were held by the Board of Technical Experts in Ann Arbor in January 1988 and June 1989. The task force identified three areas of primary concern for future research related to lake trout rehabilitation. One of the priority areas identified for future research can be described by the question that follows:

Do lake trout randomly distribute their eggs over all substrates, or do they select specific substrate types? Specifically:

- A. How can egg deposition on spawning substrates best be studied? What methods of sampling eggs are best for shallow water or deep water spawning sites?
- B. Can lake trout recognize substrate which will successfully incubate eggs, e.g., clean substrates and/or large cobbles?
- C. Do hatchery lake trout differ from native lake trout in their ability to recognize and spawn on appropriate substrate?

The research performed as part of the GLFC-funded project focused on the questions above. The work was conducted on Stony Island reef in the eastern basin of Lake Ontario, where a 100% hatchery origin population of lake trout has spawned for several years. Preliminary work on egg deposition conducted in the fall of 1987 at this site indicated that (1) a number of different substrate types were present on this reef, (2) large numbers of lake trout congregated on the reef during the spawning season, (3) large numbers of eggs were deposited on the reef, and (4) egg nets (Horns et al. 1989) could be used successfully to capture eggs. This work also suggested modifications to the egg nets which would make them more effective in shallow water (3-7m). As a result of this preliminary work, we developed the following research objectives, as stated in the proposal:

1. **Compare the effectiveness of three techniques for collection of lake trout eggs during spawning.**
2. **Describe, quantify, and compare the substrate specificity of egg deposition by hatchery origin adult lake trout over two spawning seasons.**

METHODS

Study site: Stony Island reef is a flat plateau which extends to 180m north-east of an exposed cobble-gravel bar at the tip of Stony Island to a maximum depth of 5.3m at the eastern edge of the reef. The plateau is composed of gravel-pebble particles (0.8-6.4cm) infilled with sand, with occasional large, flat rocks 20-40cm in diameter embedded in the gravel. At its eastern edge the reef drops steeply from 5m to 8-10m, along a line running approximately NNE-SSW. The northern portion of the slope is composed of large cobbles and boulders (12.8-40cm) with interstitial spaces extending more than 45cm below the surface of the substrate. The cobble-boulder substrate extends approximately 50m southward from the northern end of the reef edge, and from the bottom of the slope to approximately 4m west of the top of the slope. South of this area, the substrate along the slope becomes increasingly infilled with sand, and the substrate size decreases to small pebbles (1.6-3.2cm). At the base of the slope the substrate is sand embedded with large cobbles. The sand is deepest at the south edge of the reef, with the embedded rocks being most exposed at the north end.

Substrate characterization: Four 33m transects were set up on the reef on four different substrate types (Figure 1). Transect I ran N-S along the upper edge of the northern portion of the slope, across the largest substrate type. Transect II was parallel to and 10m west of transect I, and crossed gravel-pebble-sand substrate. Transect III ran N-S along the upper edge of the southern portion of slope, along gravel-cobble-sand substrate. The northern end of transect II was 47m south of the southern end of transect I. Transect IV ran N-S along the sand substrate east of the bottom of the slope, parallel to and between transects I and III. The distance from the bottom of the slope to transect IV varied from 3-15m between years. Divers positioned the transects using compass bearings, visual observations of the substrate and the edge of the reef, and a 100m rule on a hand spool. The divers placed a small buoy at the end of each transect. These buoys were then replaced from the surface with semi-permanent marker buoys. In 1987 and 1988 the marker buoys were anchored with 2-3 cinder blocks chained together. However, these often moved during severe fall storms. In 1989 we made permanent anchors by filling feed sacks with 50-60kg of concrete and inserting large eye bolts into the upper surface before the concrete set. These pillow-shaped blocks were then buried by divers below the surface of the substrate at either end of each transect. In 1988 two 2m lengths of fence-post were driven 1m into the substrate at the center of transect I, one at the upper edge of the slope and one at the lower edge. These posts provided permanent markers between seasons, and allowed us to assess the extent to which substrate moved over the winter.

To obtain quantitative measurements of the four substrate types, divers collected three substrate samples from each transect. A sample was taken at either end of each transect, and a third sample was taken approximately in the middle of each transect. For each sample the divers removed substrate by hand from within a 42cm diameter circular transect, and placed the material into a reinforced plastic garbage bag within a 5-gallon plastic bucket. Material was removed from within the transect until the bucket was half full, so that each sample contained a uniform volume of substrate. Divers were careful to include embedded fines in the sample; however, loss of fines during sample collection was unavoidable, but was consistent between samples. Once the sample was complete the plastic bag was tied closed to retain the fines, and the bucket was marked with a diver buoy for later retrieval from the surface.

Each substrate sample was measured by washing the material through a series of five sieves with the following opening sizes: 2.5cm, 1.2cm, 3.35mm, 2mm, and 1mm. The largest size class of rocks (those that did not pass through the 2.5cm sieve) was additionally subdivided into two size classes (>10cm and 2.5-10cm) by measuring the largest dimension of each rock. The volume of particles in each size class was measured by placing the material in a beaker and adding a known volume of water, which was then subtracted from the total volume in the beaker.

We also characterized substrate sizes by taking photographs of the substrate at 3m intervals along each of the transects. Each photo was taken with an underwater camera held at 2m above the substrate. A marked scale was included in each photo.

Egg collection devices

In the fall of 1987 we tested a new device, the egg net, designed to collect demersally spawned eggs (Horns et al. 1989). Although the egg nets captured 2145 eggs, they tended to be overturned by underwater currents during storms. In addition, captured eggs were frequently crushed in the nets. We collaborated with Harry Hawkins, director of the Center for Innovative Technology Transfer (CITT) at SUNY Oswego, to design an egg collection device which would overcome these problems. Three egg trap designs were developed based on the same overall size and shape as the original egg net. Each trap design permitted capture of eggs whether the trap was right-side-up or upside-down. Construction of a weighted trap, which was suggested in the original project proposal, proved to be unfeasible.

The three trap designs were tested in conjunction with the egg nets in laboratory and field trials in the fall of 1988. The egg trap designs and the trials are described in a manuscript (see Appendix) which has been submitted to the North American Journal of Fisheries Management. The trap design that was most effective at egg capture and retention in laboratory and field trials was deployed in 1989 on Stony Island reef, Yorkshire Shoal, Charity Shoal, Galloo Island, and Grimsby Shoal in Lake Ontario, near Meaford Yacht Basin in Georgian Bay, and in Duluth Harbor, Lake Superior. This work was done in cooperation with the New York Department of Environmental Conservation, the Department of Fisheries and Oceans, Canada, the Ontario Ministry of Natural Resources, and the Minnesota Department of Natural Resources.

Egg collections

Egg nets (Horns et al. 1989) and egg traps (Appendix) were used to collect lake trout eggs on Stony Island reef in 1987-1989 (Table 1). On October 13, 1987, as part of a pilot study, a line of 25 egg nets was deployed along transect I, and a second line of 25 nets was deployed parallel to the first on sandy substrate 7m east of the bottom of the slope. The first line of nets was retrieved and reset once on November 13, and was retrieved on November 24. In 1988, a line of 25 egg nets was set along each of the four transects described above. All lines used in 1987 and 1988 to attach traps consisted of 40m of 7 or 10mm nylon rope with nets attached every 1.6m. The positioning of the lines was determined using the transect buoys. The lines were lifted and replaced every 3 to 15 days. Whenever possible the locations of the lines of nets were checked by divers after deployment and prior to retrieval. In 1989 the sampling effort was repeated in 1989 using egg traps attached every 1.3m to 33m lengths of 5mm (3/16") proof coil chain.

RESULTS

Substrate characterization

Substrate samples from transect I were unique among the samples due to the absence of any material smaller than 2.5cm and the large volume of boulders (>10cm; Table 2, Figure 1). Samples from transects II and II had similar volumes of all sizes classes of material measured. Samples from transect IV had very high volumes of fines smaller than 1mm and suspended particles, which were present in only trace amounts in the other transects. The volume of this suspended material was not measured. Two to three freshwater clam shells (*Unio* spp?) per sample were present only in the samples from transect IV.

Photographs taken along each transect provided a comparison of substrate sizes, but did not reveal the presence of sand or the depth of the interstitial spaces. For example, many areas along transect II appeared similar in photographs to areas in transect I, despite the presence of large quantities of sand and silt below the surface layer in transect II. The photographs were not used for quantitative or comparative substrate analysis because of their inability to resolve sub-surface substrate differences.

During the summer, the large cobble and boulders at the edge of the slope were covered in filamentous algal growth (*Cladophora* spp.) up to 17cm thick (Figure 2b). Little or no algal growth appeared on the plateau area and the southern edge of the reef, although many rocks had thin encrustations of bryzoans, fresh-water sponges, and diatoms. A few strands of European milfoil were seen on the northern portion of the edge of the slope. By late October the entire upper portion of the reef was free of algal cover. However, the rocks at the north of the reef, at the bottom of the slope, retained mats of algae. Crayfish (*Orconectes* sp.), slimy sculpins (*Cottus* spp.), darters (*Etheostoma* spp.), and trout-perch (*Percopsis omiscomaycus*) were frequently noted in the interstitial spaces among the rocks. Small-mouth bass (*Micropterus dolomieui*) were abundant in the spring and summer, and spawned along the upper edge of the reef. Other species found on the reef are listed in Marsden et al. (1988).

Egg collection devices

The results of laboratory trials of the new egg collection devices are described in detail in the attached manuscript (Appendix). One hundred egg traps deployed from October 14 to Dec 6, 1989, on Stony Island reef captured a total of 757 eggs. The numbers of eggs captured were highly variable between traps within a transect; coefficients of variance calculated for each transect that caught eggs were between 0.6 and 2.5, with a median of 1.3. Within a transect, the variance between traps increased linearly with the mean.

Severe storms resulted in damage and loss of many of the traps on Galloo and Charity Shoals; a single egg was captured at each location. Twenty-eight eggs were captured on Grimsby Shoal, and 12 eggs were captured on Yorkshire Shoal during an 8-hour set of traps. A single egg was captured from a location adjacent to Duluth Harbor, and 236 eggs were captured in 47 traps in Meaford Yacht Basin, Georgian Bay.

Egg collections

In 1987 the line of egg traps deployed along the upper edge of the slope collected 261 eggs from October 13-November 13, and 1830 eggs from November 13-November 24. The line of egg nets deployed on the sand at the base of the slope collected 3 eggs from October 13 to November 13 (Table 1). The eggs collected in the first line of nets were mostly collected on the northern half of the transect line (Figure 2).

In 1988, egg captures were difficult to correlate with the substrate on which they were collected, due to movement of the lines of nets during storms. Less than 6% (N=190) of the total eggs captured in 1988 were collected in traps that remained in place between deployment and retrieval (Table 1). Most of these eggs were captured in transect IV, on sandy substrate (N=106). Because the prevailing wind direction was west to east, the nets always moved in an easterly direction. Nets that were set on transects I, II, and III, and were moved off the edge of the reef before retrieval captured 1058, 1278, and 1118 eggs, respectively (Table 1).

In 1989, egg traps remained in place between deployment and retrieval due to the weight of the chain which held them. However, the traps were checked less often than in previous years due to several severe storms which prohibited work on the reef. Traps on transect I captured a total of 18 eggs; traps on transect IV captured a total of 636 eggs; no eggs were captured on transect III, and 3 were captured on transect II. On November 7, after a storm, divers noted windrows of loose eggs on the sand at the base of the slope.

During dives to check the location of egg nets and traps, divers made frequent observations of eggs in the substrate and of adult lake trout in the vicinity of the reef. By the end of October in each year of the study, eggs could readily be found in the vicinity of transect I by lifting a single rock or by looking into the crevices between rocks. As many as 12 eggs could be found under a single rock. Eggs tended to be jammed in crevices between rocks. Eggs were only occasionally noted near transects II and III, and never on the sand beyond a few feet past the base of the slope. Eggs near transect II were resting on the surface of the substrate, and moved when there was wave-generated surge present. In spring (April-May), divers occasionally saw dead lake trout eggs near transect I, but they never saw live eggs or fry, although 75-500 live fry have been captured with fry traps in this area each year since 1986. Dead eggs, because they are opaque white, are much easier to see than the translucent live eggs.

Adult lake trout were observed on the reef each year as early as October 14, and as late as December 6. Early in the season the fish tended to swim away from the divers. Later, the lake trout could be approached and touched by divers, or would actively approach a stationary diver. Large, darkly colored lake trout were often seen hanging motionless 0.6m above the substrate. These fish would occasionally turn toward and strike or gape at a diver. Up to 20 lake trout could be observed at a time within a visibility radius of 2.5-3m. The highest concentrations of lake trout were seen along the top of the north end of the slope. Lake trout were never seen along the south part of the slope or at the bottom of the slope, and were only rarely seen more than 10m west of the slope. Dark lateral stripes, noted by DeRoche (1969) and Royce (1951) in males, were never seen. However, this coloration may only be present at night, when spawning occurs. Pair swimming was occasionally observed, when two fish would swim side by side in an undulating path. In addition, lake trout were heard and seen leaping at the surface. This behavior has also been noted by Merriman (1935) and Royce (1951).

DISCUSSION

Our studies on Stony Island suggest that, even on a relatively small reef, the portion of the reef actually used by lake trout for egg deposition may be quite small. Data from egg captures, fry captures, and direct observation of adult lake trout and eggs *in situ* all suggested that the majority of spawning occurs only along the northern half of the eastern slope of Stony Island reef. This area is approximately 50m from north to south, and 10m from east to west, and comprises less than 10% of the total area of the reef. The substrate in this area is characterized by a high volume of large rocks (>10cm diameter) and an absence of sand and fines (Table 2). All other substrates on the reef contained high ratios of fines to larger substrate.

The egg collection data at first appear difficult to interpret, due to the movement of egg nets during 1987 and 1988. However, the consistent movement of drifting nets from west to east must be taken into account. All lines of nets which captured large numbers of eggs (>80), with one exception, passed across and over the edge of the reef and came to rest at the base of the reef (Table 1). In addition, traps and nets which remained in place on transects I, II, and III over the period of immersion tended to capture few eggs (<30; Table 1). These data suggested that the movement of the nets and traps was correlated with their eventual capture of eggs. One hypothesis is that the nets scoop large quantities of eggs as they are rolled along the bottom during surge. Alternatively, eggs may have been captured at the base of the reef. Because the prevailing wind direction, and therefore surge direction, was west to east, and due to the protecting wall of the slope, the base of the reef was a zone of deposition. Dislodged equipment almost invariably ended up at the base of the reef; after heavy storms, windrows of algal debris were seen in a narrow line within half a meter of the base of the slope. In addition, lake trout eggs were observed on November 7, 1989 in large numbers at the base of the reef. Thus, eggs that were not entrapped into the substrate may drift over the edge of the reef and come to rest at the base of the reef. Any nets lying at the base of the reef would collect these eggs in large quantities. This hypothesis was supported by the observation that nets containing large quantities of eggs also tended to contain large quantities (up to 10cm^3) of sand and algae. The sand, in particular, could only have been picked up by movement of the nets and/or substrate at the base of the reef. This hypothesis would also explain why, of the nets and traps which remained in place, those deployed on the sandy substrate (transect IV) sometimes collected many eggs. These eggs would have been remnants of those drifting off the edge of the reef. Because transect IV was located at least 3m from the base of the reef, and sometimes considerably further away, less eggs were collected by nets and traps on this transect than in nets and traps from transects I-III that moved to the base of the reef. On November 7, 1989, one end of transect IV had moved adjacent to the base of the reef, and 70 eggs were found in the 9 traps nearest to the base of the reef, whereas only 7 eggs were found in the traps further from the base of the reef.

Under the above hypothesis, the majority of eggs were captured due to drifting rather than by direct deposition into the nets and traps. The presence of two eyed eggs in an egg net which had been deployed for only a week is conclusive evidence that drifting eggs can be captured by the egg nets. Alternatively, eggs could have been spawned at the base of the reef. This hypothesis seems unlikely for several reasons. Lake trout were rarely seen at the base of the reef; inasmuch as male lake trout may either lek or defend spawning territories (Foster 1985), none of them appeared to have established territories at the base of the reef. Lake trout eggs were observed by divers at the top of the slope throughout the spawning season, but were only observed at the base of the reef after a heavy storm. Fry have been captured in fry traps on the top of the reef and along the slope, indicating that at least some eggs were present at the top of the reef throughout the winter. Eggs were unlikely to have drifted from the base of the reef to the top of the slope, due to the negative buoyancy of the eggs and the prevailing wind direction and reef contours. These observations supported the hypothesis that many of the eggs captured at the base of the reef were not spawned there, but drifted into the nets from the top of the reef. Consequently, most of the egg capture data cannot be used to determine substrate selection by spawning lake trout on the basis of eggs per unit area per substrate type, because we cannot determine how many eggs drifted into the nets and traps from other areas.

Egg deposition, as measured by egg captures, was higher on the northern half of the reef than the southern half. Of the nets that drifted, those that drifted across the north end of the slope (transect I to IV) collected twice as many eggs as nets that drifted across the south end of the slope (transect III to IV). Nets deployed on the plateau (transect II) that drifted across the north end of the slope into deeper water collected fewer eggs than those that were initially deployed directly on the north end of the slope. Presumably the transect II nets spent less time at the base of the reef than transect I nets, due to the additional distance they had to travel to reach the base of the reef.

Our trapping data did not permit quantification of the number of eggs deposited on the plateau versus the edge of the reef; however, of the nets and traps that remained in place, those on the plateau substrate (transect II) collected the least eggs. In addition, few eggs or adult fish were seen on the plateau by divers, although less time was spent by divers on the plateau as opposed to the edge or base of the reef. Eggs observed on the gravel-pebble substrate in the center of the reef were not entrapped into the substrate, and appeared to be vulnerable both to drifting and predation. Previous studies suggested that settlement into interstitial crevices does protect eggs from predation (Horns and Magnuson 1981, Stauffer and Wagner 1979). It appears highly unlikely that eggs deposited on the plateau remained in the vicinity to hatch in the spring. This supposition is confirmed by previous studies in which no fry were captured in fry traps deployed across the plateau. However, eggs spawned on the plateau could potentially drift eastward and become entrapped into the cobble substrate near the slope. Eggs readily drop into crevices, as noted by divers while turning over rocks (this study; Royce 1951).

In conclusion, our data suggested that stocked lake trout deposit their eggs non-randomly with respect to substrate type. We suspect that eggs are deposited over large cobble-boulder substrate at the north end of the reef, adjacent to a steep drop-off, and that substantial drifting of eggs occurs. This conclusion has two important implications for the rehabilitation of lake trout in the Great Lakes. First, despite the rearing of lake trout in raceways throughout their critical imprinting period, at least some adults are able to find spawning reefs and apparently identify substrate which will support egg incubation. However, we do not know what percentage of lake trout adults find 'good' spawning substrate. Lake trout have been noted aggregating near the mouths of several rivers and travelling upstream in tributaries of Lake Ontario (Clif Schneider, NYDEC; John Fitzsimons, CCIW, personal communications). Second, the relative paucity of direct evidence of lake trout spawning in the Great Lakes may be due to the substrate specificity of egg deposition. On Stony Island reef, lake trout appear to use less than 10% of the reef area for spawning. Thus, information about reef structure and substrate type may be essential for finding eggs and fry. Future studies on lake trout reproductive success would benefit greatly from a predictive model that would list the factors, in order of priority, which lake trout use to select a spawning site. The present study suggested that these factors include substrate size, interstitial spaces, and possibly a rapid change in depth. In addition, the development of modified egg collection devices has improved our capability for detecting lake trout spawning in the wild, and for studying the factors that affect successful reproduction.

A manuscript summarizing our research on lake trout spawning on Stony Island reef is currently in preparation. Copies will be sent to the Great Lakes Fishery Commission as soon as the manuscript is completed.

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Table 1. Lake trout eggs captured on Stony Island reef in Lake Ontario using egg nets and traps. The number of nets or traps retrieved from each substrate type is given in parentheses.

Year/ Sampling Device	Date Deployed	Date Retrieved	Location of Egg Nets and Traps[a]							Year Total
			I	II	III	IV	I-IV	II-IV	III-IV	
1987 Nets	Oct. 13	Nov. 13				2 (21)			261 (24)	
	Nov. 13	Nov. 24					1830 (23)			
Total						2	1830		261	2093
Percent						0.10	87.43		12.47	
1988 Nets	Oct. 15	Oct. 20	12 (25)		27 (25)		0 (25)		2 (25)	
	Oct. 20	Oct. 31				1 (25)	20 (25)		14 (25)	
	Oct. 31	Nov. 15				5 (25)	191 (25)	774 (25)	662 (25)	
	Nov. 15	Nov. 22				56 (22)	704 (22)	510 (25)	399 (25)	
	Nov. 22	Nov. 25	10 (25)	6 (24)	22 (25)	6 (24)				
	Nov. 25	Dec. 8		7 (22)		38 (25)	171 (22)		57 (23)	
Total			22	13	49	106	1086	1284	1134	3694
Percent			0.60	0.35	1.33	2.87	29.40	34.76	30.70	
1989 Traps	Oct. 14	Oct. 24	1 (24)							
	Oct. 14	Oct. 26		1 (22)	0 (25)	0 (10)				
	Oct. 24	Oct. 31	17 (18)							
	Oct. 26	Oct. 31		2 (20)	0 (20)	0 (22)				
	Oct. 31	Nov. 7		0 (18)		77 (22)				
	Oct. 31	Nov. 22	0 (13)		0 (3)					
	Nov. 7	Nov. 22		0 (6)		559 (21)				
	Nov. 22	Dec. 6	0 (22)							
Total			18	3	0	636				657
Percent			2.74	0.46	0.00	98.80				
Total Eggs			40	16	49	744	2916	1284	1395	6444
Percent of Total Eggs			0.62	0.25	0.76	11.55	45.25	19.93	21.65	

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[a] I, II, II, and IV refer to the transect locations described in the text. For example, I indicates a line of eggs and traps which remained on transect I between deployment and retrieval; I-IV refers to a line of nets and traps which were deployed on transect I, and drifted onto transect IV before retrieval.

Table 2. Volumes (in liters) of particle sizes from substrate samples taken on Stony Island reef, Lake Ontario, 1989. Each figure is the mean of three samples; standard deviations are given in parentheses. The transect numbers refer to locations indicated in Figure 1 and described in the text.

	Particle Size							
Transect	Boulder >100mm	Cobble 25-100	Pebble 12-25	Gravel 3.35-12	Sand 2-3.35	Fines 1-2	<Fines <1	Total Volume
I	3.18 (0.99)	1.42 (0.03)	0.00	0.00	0.00	0.00	0.00	4.60 (0.96)
II	0.80 (1.18)	2.53 (0.58)	1.47 (0.97)	0.21 (0.13)	0.28 (0.43)	0.17 (0.16)	0.00	5.45 (1.20)
III	1.22 (0.43)	2.22 (1.22)	1.32 (0.79)	0.45 (0.49)	0.08 (0.12)	0.22 (0.31)	0.00	5.51 (1.22)
IV	1.53 (1.11)	1.47 (1.47)	0.46 (0.10)	0.35 (0.07)	0.18 (0.11)	0.61 (0.57)	2.37 (0.85)	6.95 (2.67)

Figure 1. Stony Island reef at the north-eastern tip of Stony Island in Lake Ontario, showing location of fry traps and lines of egg nets and traps described in the text.

Figure 2. Distribution of eggs captured in 1987 in a line of egg nets deployed along the eastern edge of Stony Island reef, Lake Ontario. Net #10 was lost prior to retrieval.

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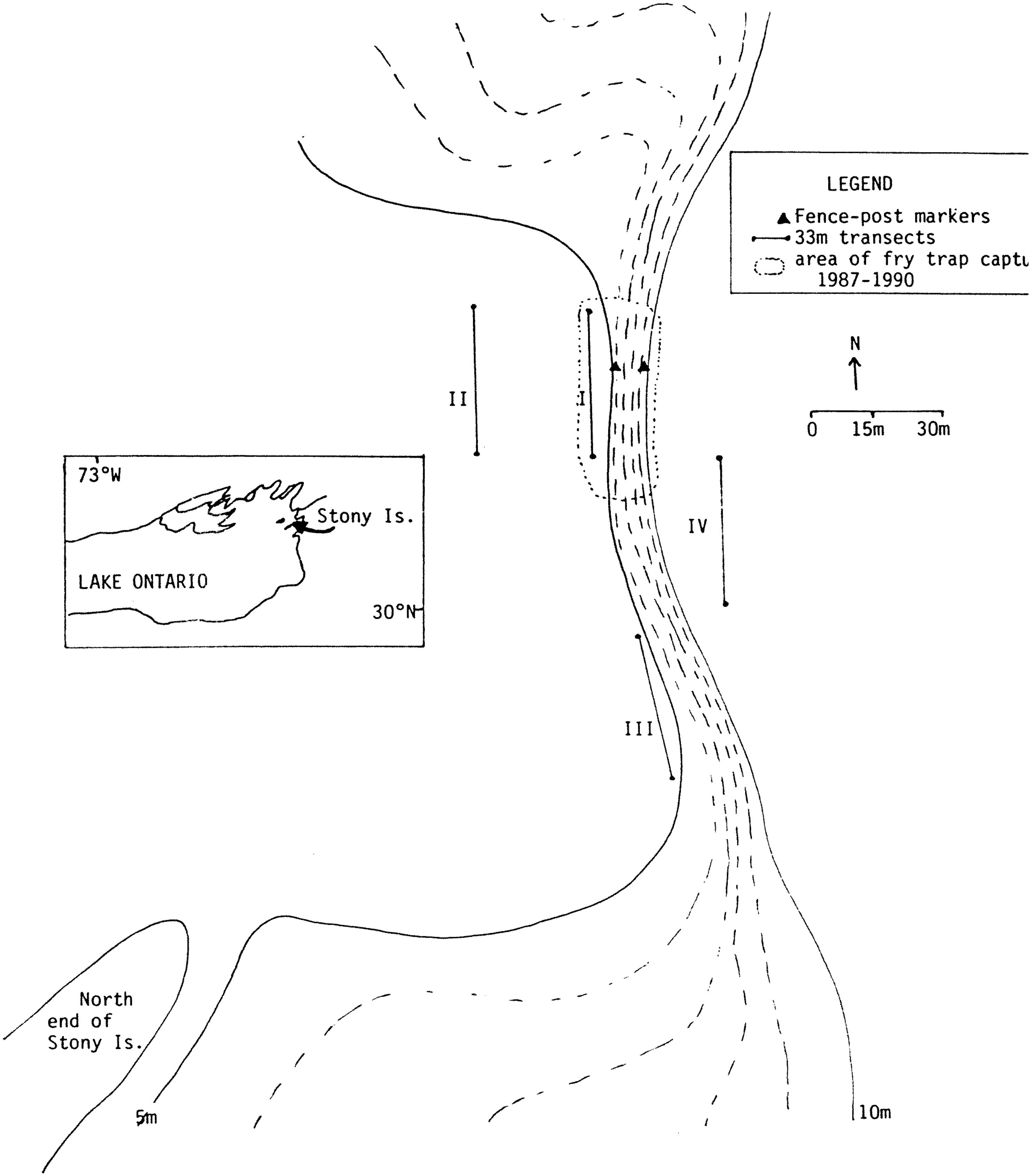
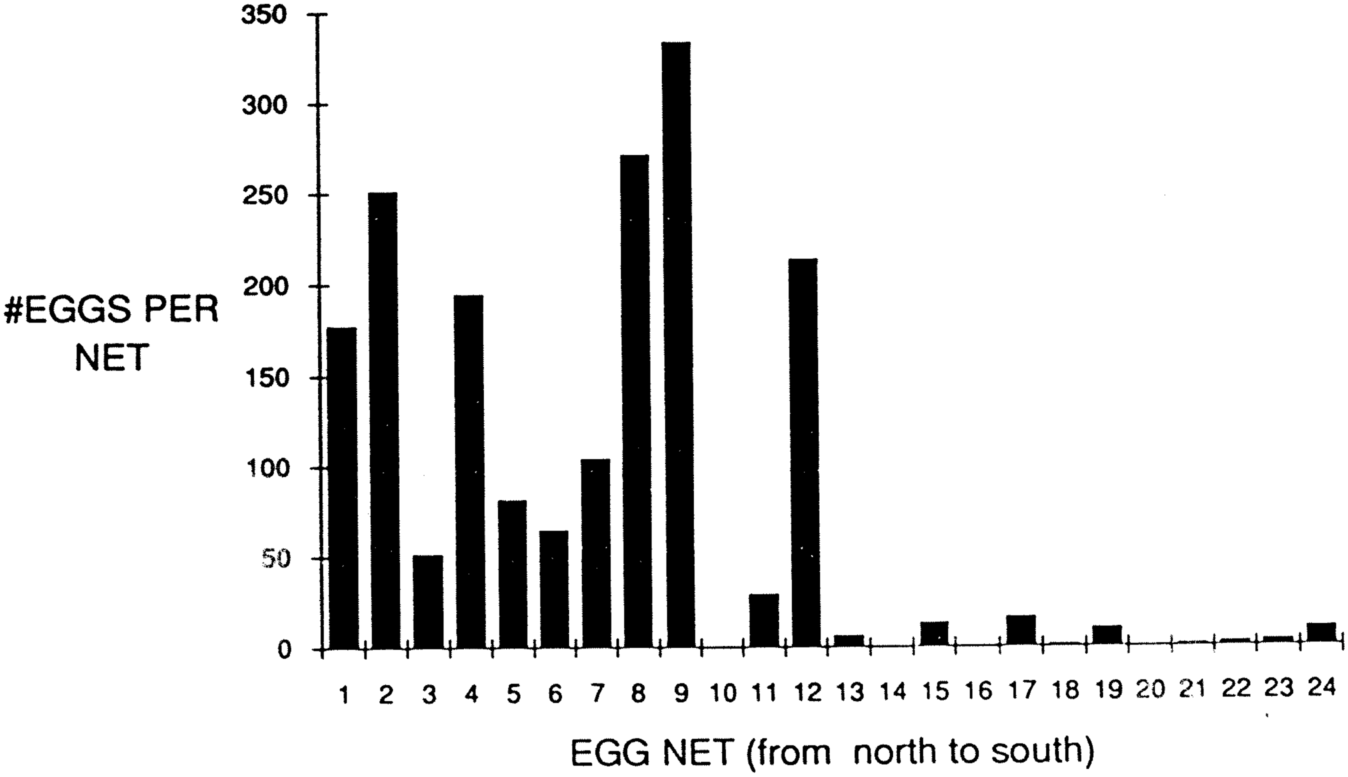


Figure 2. Distribution of eggs captured in 1987 in a line of egg nets deployed along the eastern edge of Stony Island reef, Lake Ontario. Net #10 was lost prior to retrieval.



APPENDIX

An Improved Trap for Passive Capture of Demersal Eggs During Spawning: an Efficiency Comparison with Egg Nets

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Abstract

Assessment of spawning activity by deep-water spawners would be facilitated by egg collection devices which could be deployed and retrieved from the surface, were resistant to heavy weather conditions, and protected eggs after capture. The egg trap described herein fulfills these criteria, is easy to remove eggs from after retrieval, and can be manufactured inexpensively in large quantities. Laboratory tests indicated that, while the egg traps excluded more eggs than previously described egg nets ($p < 0.001$), the traps retained eggs more effectively after capture. During field trials of paired nets and traps, the traps captured almost three times more eggs than the nets ($p < 0.05$) during natural spawning. A higher percentage of the eggs were undamaged after retrieval in the traps than in the nets.

Introduction

An important information need in fisheries research is the assessment of natural reproduction. Information about where fish are spawning, which fish are spawning, and the extent of reproductive success can be critical for effective management decision-making. For fish species which spawn in shallow, inshore waters or in streams, assessment of spawning activity can often be accomplished by observations from the surface, or by collecting eggs by hand-operated devices such as suction samplers. However, information on reproductive activity by deep-water lake-spawning species is more difficult to obtain. For example, gill-netting close to traditional spawning reefs is often used to assess spawning activity by stocked lake trout (Salvelinus namaycush). The capture of ripe and spent females is used to infer that spawning has taken place at the reef. While gill-netting provides important information about spawning aggregations of fish, this technique does not provide evidence that spawning has occurred. In addition, gill-netting data do not yield estimates of the density of egg deposition, the viability of the spawned eggs, the strain composition of the fish which successfully mate, or information about substrate specificity of spawning.

Assessment of the presence of spawning activity is best accomplished by the observation or collection of spawned eggs. An ideal egg collection device would have the following characteristics: (1) ease of deployment and retrieval, (2) ease of processing, (3) capture efficiency unimpaired by severe weather conditions, (4) protection of eggs after capture, (5) minimum avoidance by spawning fish, (6) durability, and (7) low cost. Low cost is particularly important in Great Lakes assessments because reef sites can encompass several square kilometers. For surveys to be effective in these areas, deployment of large numbers of egg collection devices is necessary. Techniques used in the past to assess spawning have mostly involved equipment operated or placed by divers. Such techniques include egg collection pails buried in the substrate (Stauffer 1981), various suction samplers and pumping devices (e.g., Stauffer 1981, Dorr et al. 1981), corers and grabs (Viljanen 1980 and references therein). However, use of divers is expensive and time consuming, and is generally restricted to shallow water (<25m) and good weather conditions. Horns et al. (1989) recently described egg nets for capturing demersally spawned eggs. These nets are simple and inexpensive to build, and can be deployed and retrieved from the surface. However, when the nets are used in shallow (<10m), unprotected water the nets can be damaged and/or turned upside-down by movement of the nets in currents and storm surge. In addition, the eggs are relatively unprotected in the net. Opening and emptying the nets is time-consuming and problematic if large numbers of nets are deployed.

The purpose of this paper is to describe a new fish egg capture device which fulfills the criteria listed above. We present the results of laboratory and field trials of the new egg trap in comparison with the egg net developed by Horns et al. (1989).

Methods

Trap design

We designed and tested three new egg traps. To permit ease of comparison, each of the designs was based on the same proportions as the egg net described by Horns et al. (1989). Trap designs B and C were ineffective at capturing eggs, and will not be described further here. Trap design A was constructed by vacuum-molding two white polystyrene plates, each in the shape of a Petri dish, to fit on either side of a PVC collar 22cm in diameter and 5cm high (Figure 1). The surface of each plate was indented with two cone-shaped depressions with 1.3cm holes in their centers. One plate was permanently attached to the PVC collar, and the other was held in place by a friction fit and could be readily removed. The two plates were oriented so that the axes running through the pairs of cones were at right angles to each other (Figure 1). The traps were painted dark brown to blend with stony substrates. Each trap had an eye-bolt in the PVC collar to permit attachment to line or chain. The traps were designed to be deployed from a boat by paying out a buoyed line to which the traps were sequentially attached. The traps were processed after retrieval by lifting off one side of the trap and removing the contents.

Laboratory tests

To test the efficiency of the new egg trap at capturing eggs, egg nets (described in Horns et al. 1989) and egg traps were submerged in a tank of water 45cm deep and 100 formalin-preserved lake trout eggs were poured from the surface directly over each net or trap. The number of eggs that entered each trap was recorded. To test how many eggs could be lost from the trap during movement in currents or storm surge, the traps were filled with 100 eggs and overturned 10 times underwater using a line attached to the eye-bolt on the side of the trap. The number of eggs remaining in the trap after this procedure was completed was recorded. A single trap and a single net were each tested 5 times using this procedure. Due to the high standard errors in the results, the data from each test were compared using the non-parametric Mann-Whitney test (Conover 1980).

Field tests

Egg nets and traps were placed on a lake trout spawning reef at the north end of Stony Island in the eastern basin of Lake Ontario. Capture of newly-hatched lake trout fry at this site in previous years confirmed that lake trout spawn on the reef (Marsden et al. 1988). In 1988, eight pairs of traps and nets were set in water 5m deep on level rubble substrate of 15-40cm diameter. The traps and nets were attached with S-hooks to a nylon rope such that adjacent pairs were 1.5m apart, and each trap and net within a pair was less than 0.3m apart. The line of nets and traps was deployed from the surface, with a buoyed cinder-block anchor at either end, using sonar to locate the reef. The line was in place on the substrate from October 31 to December 8. During this time the line was retrieved, checked, and replaced approximately every seven days. Severe storms during the fall resulted in the loss of some traps, and movement of entire lines of traps and nets with their attached anchors. Egg captures in the remaining pairs of nets and traps were compared using the sign test (Conover 1980).

In 1989, four lines of 22-25 traps each were deployed on four types of substrate on Stony Island reef - sand, pea-gravel, infilled rubble, and clean rubble. The traps were attached 1.3m apart to 5mm gauge proof coil chain using metal snaps on swivels. The swivels permitted the traps to move independently of the chain so that tangling did not occur. The traps were deployed from October 14 to December 6 in depths of 4-11m. A buoy was attached with line to either end of the chain. The lines of traps were retrieved, checked, and replaced approximately every 10 days. The placement of the lines of traps was checked after deployment and before retrieval by SCUBA or free-diving.

Results

Laboratory tests

Laboratory tests indicated that, while the egg traps excluded more eggs than egg nets ($p < 0.001$), the traps retained eggs more effectively after capture, although egg retention was not statistically different between traps and nets (Table 1). No eggs were excluded from the egg nets, compared with an average of 24% excluded by the traps. The nets lost, on average 20% of their eggs, whereas the traps lost less than 1%. The high variance in egg loss from the nets was due to the manner in which eggs were lost. If the eggs rolled into the distal end of the net during overturing, they were retained in the net; if the eggs were caught by the bunched netting, they were carried towards the opening of the trap during overturning, and subsequently fell out of the net. Less variance occurred in the capture rate of eggs in traps than in the loss rate of eggs from nets (Table 1). Note that the measure of egg capture rates in these tests does not take into account the periods of zero capture efficiency of egg nets when they are upside-down in field conditions. Periodic observations of egg nets in the field (175 individual net observations) indicated that the nets may be upside-down 42% of the time on a shallow reef.

Eggs occasionally clumped in the depressions in the surface of the trap, thus blocking the holes. However, any movement of water in the test tank increased the probability that eggs resting on the trap surface or blocking the holes would enter the trap. In the wild, eggs are not likely to be released in high densities over a trap except possibly when a female spawns directly over the trap. In addition, movement of eggs by currents and removal of eggs by predators will reduce the blockage problem. A larger hole would alleviate the problem, but would increase the potential for predators, e.g., sculpins (Cottus spp.), to enter the trap.

Field tests

During field trials of paired nets and traps in 1988, the traps captured a total of 65 eggs while the nets captured a total of 22 eggs ($p < 0.05$; Table 2). Due to the loss of several nets and traps, only five pairs were retrieved intact. A comparison of the overall CPUE of traps versus nets, paired and unpaired, indicated that traps captured, on average, over twice as many eggs per unit effort as nets (Table 3). Captured eggs were either opaque, indicating that the chorion had been broken and the egg had subsequently died, or translucent. The translucent appearance of an egg indicated that the egg was undamaged. Fifty-one to 63% of the eggs captured in traps were undamaged upon retrieval of the traps, whereas only 32% of the eggs captured in nets were undamaged (Table 3). Egg damage in the egg nets was, in part, due to crushing of the eggs between the netting and the PVC rim.

In 1988, when traps and nets were deployed on nylon line, entire gang lines with their anchors were moved over 7m in the interval between deployment and retrieval during severe weather. In 1989, when traps were deployed on chain, no appreciable movement of the lines occurred. One line remained in place at 5m depth at the edge of a steep drop-off for 30 days, during which time several severe storms passed over the reef. Observations by divers confirmed that the traps always rested horizontally on the substrate.

Discussion

The new trap design was more effective than the egg nets for collecting lake trout eggs during natural spawning. In the field the traps capture eggs even if the traps are overturned. Thus, each trap may fish up to twice as long as an egg net, which is ineffective when upside-down. This factor makes the traps especially effective in shallow and unprotected water where the probability of movement and overturning is high. The traps were also more durable, easier to deploy and process than the egg nets, and they protected eggs more effectively than the nets. Movement of traps during storms was reduced by deploying the traps on chains. The chief limitation of the traps is that they need to lie nearly horizontally to work effectively. Thus, the traps will be less effective on steep contours, or in areas of very large boulders where they will rest at an angle between rocks. Based on our experience, gang lines of traps should not be drawn tight during deployment, but should be set with enough slack to allow the chain to conform to the irregularities of the substrate. The traps could be improved by devising a fastener to hold the two sides of the trap together. This would eliminate the need for a friction fit, and thus would make the traps easier to open.

The new egg traps can be mass-produced inexpensively. Therefore, the traps provide the potential for a uniform technique for assessment of lake trout spawning throughout the Great Lakes. A preliminary test of the traps by other researchers resulted in the first evidence of lake trout spawning on Grimsby shoal (J. Fitzsimons, Canada Centre for Inland Waters, personal communication), Yorkshire shoal (J. M. Casselman, Ontario Ministry of Natural Resources, personal communication), Galloo and Charity shoals (C. P. Schneider, New York Department of Environmental Conservation, personal communication) in Lake Ontario, in Meaford Yacht Basin, Georgian Bay (Robert Payne, Ontario Ministry of Natural Resources, personal communication) and in Duluth Harbor, Lake Superior (D. Schreiner, Michigan Department of Natural Resources, personal communication). The traps may also be useful for spawning assessment and capture of eggs of other demersally-spawning species such as walleye and whitefish.

Acknowledgements

We thank Randy Eshenroder of the Great Lakes Fishery Commission for facilitating this project. Don Feck of CITT, David Lansky of Cornell University, and Roger Bergstedt and Randy Owens of the U. S. Fish and Wildlife Service contributed ideas to help design the egg traps. Elizabeth and Matthew Mahoney constructed the traps. Lianna Jarecki, Peter Grewe, and Henry VanOffelen assisted with the field tests. This work was funded by a grant from the Great Lakes Fishery Commission. Additional support was also provided by the New York Agricultural Experiment Station, New York State College of Agriculture and Life Sciences, Cornell University, Hatch Project Numbers 1476402 and 1477402.

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Table 1. Comparison of egg captures and losses by nets and traps in laboratory tests. See text for a description of the test protocol. Each number is the mean of five tests ± one standard error.

Trap Type	% Eggs Excluded	% Eggs Lost
Egg Net	0.0	20.4±17.3
Egg Trap	24.2±12.4	0.4±0.8

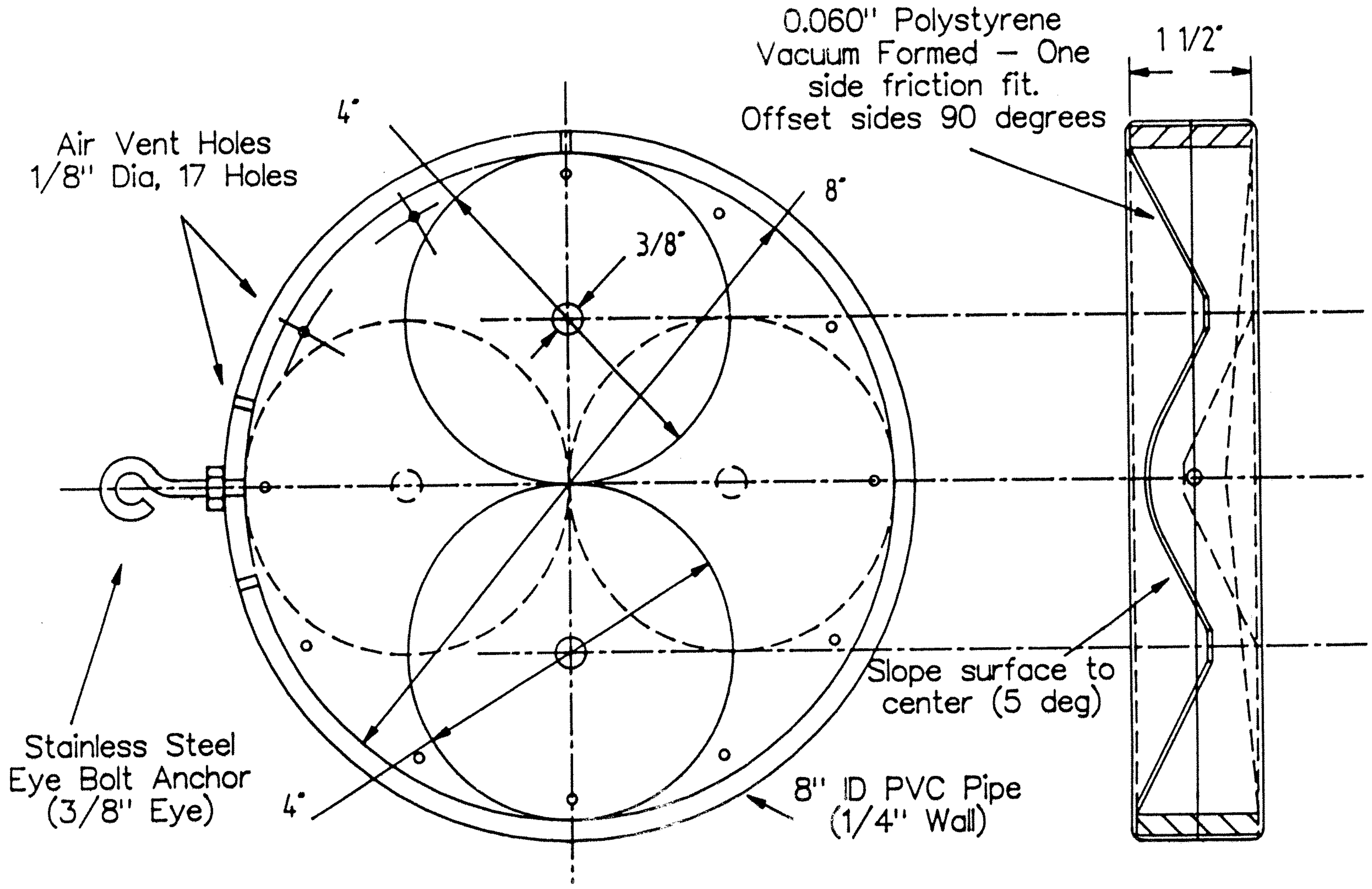
Table 2. Comparison of lake trout egg captures in paired nets and traps deployed on Stony Island reef, Lake Ontario in 1988. Numbers represent the eggs captured in each device. Each pair was fished for an average of 14 days.

Pair	trap	net
1	15	0
2	34	19
3	13	3
4	1	0
5	2	0
total	65	22

Table 3. Summary of lake trout egg captures in egg nets and traps deployed on Stony Island reef in Lake Ontario. Data are presented only from nets and traps deployed on similar types of substrate.

Year	Sampling Device	# Devices Retrieved	Total Eggs Captured	% Undamaged Eggs	# Eggs/ Trap/Day
1988	net	15	59	32.2	0.018
1988	trap	20	232	62.5	0.041
1989	trap	268	756	51.3	0.290

Figure 1. Diagram and photograph of the egg trap design.


0.060" Polystyrene
Vacuum Formed – One
side friction fit.
Offset sides 90 degrees
1 1/2"
4"
Air Vent Holes
1/8" Dia, 17 Holes
8"
3/8"
Slope surface to
center (5 deg)
Stainless Steel
Eye Bolt Anchor
(3/8" Eye)
4"
8" ID PVC Pipe
(1/4" Wall)