ILLINOIS NATURAL HISTORY SURVEY

TECHNICAL REPORT

# Current Reproductive Success of Lake Trout at the Port of Indiana Breakwater

John M Dettmers, Rebecca Redman, and Bryan Spindler

Division of Ecology and Conservation Science
Field Station and Ecosystem Studies Section

U. S. Fish and Wildlife Service

INT 301812J262 A7259 494792

INHS Technical Report 2007 (27)
Date of issue: 7 May 2007

INHS • 1816 S. Oak St. • Champaign, IL 61820 http://www.inhs.uiuc.edu

Natural History Survey

**Evaluating current reproductive success of lake trout at the Port of Indiana breakwater**

**October 1, 2002 – November 30, 2006**

John M. Dettmers, Rebecca Redman, and Bryan Spindler
Division of Ecology and Conservation Science
Illinois Natural History Survey

submitted to

US Fish and Wildlife Service

in partial fulfillment of the reporting requirements
for US Fish and Wildlife Service Project
Number 30181-2-J262

John M. Dettmers
Principal Investigator
Aquatic Ecology Section

John M. Epifanio
Interim Director, Division of Ecology and Conservation Science

May 2007

**Background.** Lake trout *Salvelinus namaycush* is the native top predator of Lake Michigan. It was extirpated from the lake by a combination of commercial overfishing and sea lamprey predation by the 1950s. Since then an aggressive program of stocking lake trout has been undertaken with the goal of establishing naturally self-sustaining populations of lake trout in Lake Michigan. Although this stocking program has built the population of adult lake trout to levels where substantial sport and commercial fisheries can be viable, no evidence of sustained natural reproduction has been documented in Lake Michigan.

The mechanisms that prevent establishment of reproducing stocks remain unclear. Current thinking centers on the possibility that adult stocks are not sufficiently high to spawn enough eggs to overcome the effects of egg and fry predators, many of which are exotic and have been introduced into the lake since 1960. In particular, there is concern that the exotic round goby *Neogobius melanostomus* can act as a more efficient egg predator than native sculpins (Fitzsimons et al. 2006). Alewife *Alosa pseudoharengus* also can prey on emerging lake trout fry (Krueger et al. 1995), potentially reducing recruitment success at this life stage if alewives are present over the spawning grounds when fry emerge.

With this background, it is important to note that the US Army Corps of Engineers (USACE) renovated the north and west break walls of the Port of Indiana during 1995-1996, including the addition of several small barrier reefs north of the breakwall to reduce wave energy impacting the breakwall itself. Lake trout spawned successfully there during 1992-1996, and lake trout fry were observed during 1993-1997 (Marsden and Chotkowski 2001). Since then, no research has been conducted at this site. During Fall 2001 assessments at the Port of Indiana, Indiana DNR personnel discovered about 18% of lake trout collected in their assessment nets were unclipped (69 of 361; B. Breidert, personal communication). This evidence strongly suggests that lake trout did reproduce at the Port of Indiana location, likely during the period when fresh cobble-sized stone was placed at the break wall and barrier reefs. The timing is such that we may now be seeing these first individuals returning to their hatching location as spawning adults.

Given this evidence of possible natural reproduction at the Port of Indiana, it is of critical importance to evaluate the condition of the substrate, the egg and fry predator density, the number of eggs and fry produced, the parental strain(s) of emerging fry, the average number of eggs and /or fry consumed by each predator, and the age and genetic structure of returning unmarked lake trout to determine whether the Port of Indiana still successfully produces lake trout. As a result, a detailed evaluation of the current habitat and spawning success of lake trout is needed to compare to work originally done during 1992-1997.

## Methods

Study location. The Port of Indiana is located at the southern tip of Lake Michigan. We sampled three locations at the port, reflecting a gradient of zebra mussel density (Figure 1). A site along the west breakwall was heavily fouled by zebra mussels. A site along the north breakwall was largely unfouled by zebra mussels. A site along the submerged north breakwall reef was lightly fouled by zebra mussels. These sites were used in the sampling conducted by Chotkowski and Marsden (2001) during the mid 1990s.

Although the three sites exhibited a gradient of zebra mussel fouling intensity, round gobies were very abundant at all three locations.

Adult Spawners. Indiana DNR personnel lifted graded mesh gillnets at the Port of Indiana on November 21, 2003. We accompanied their lift to collect tissue samples to be stored for future genetic analyses if needed.

Egg Deposition. We sampled for lake trout eggs at the three sites using a combination of two methods. We set gangs of 50 egg nets (Horns et al. 1989) at each site and also 8-10 egg bags (Perkins and Krueger 1994) at each site. Egg nets were deployed and retrieved by boat whereas egg bags were deployed and retrieved by divers. During some years, egg bags could not be retrieved by divers because of poor visibility, equipment malfunctions, or extremely cold water temperatures. Net gangs were set on 24 October 2003 and retrieved on 4 December 2003 (north wall) and 9 December 2003 (west wall). The gang on the north reef was lodged in the substrate and could not be retrieved, even after sending divers down to try to unfoul the gang. During 2004, net gangs were set on 21 October and retrieved on 6 December. During 2005, net gangs were set on 12 October and retrieved on 13 December.

Egg bags were set on 10 October 2003 and retrieved on 4 December 2003 (north wall) and 9 December 2003 (west wall). Low visibility prevented divers from retrieving egg bags from the north reef. On 21 September 2004 egg bags were set; they were retrieved on 6 December 2004. Bags were also set on 24 September 2005. We attempted to retrieve bags during December 2005, but could not retrieve the bags due to poor visibility before ice conditions prevented further attempts. Upon retrieval, egg nets and bags were sorted by site in containers and returned to the laboratory where their contents were examined. Live eggs, dead eggs, and egg chorions were identified and enumerated. Round gobies and crayfish were identified and enumerated. All round gobies were measured (nearest 0.1 mm TL) and preserved for later diet analysis.

Fry Emergence. We deployed fry emergence traps consisting of a 51-cm-square base of angle iron with mesh sides tapering to a collection container on top (Marsden et al. 1988) by boat on 5 May 2004, 4 April 2005, and 20 April 2006. The collection area under each trap was 0.26 m$^2$. Initially, 10-12 traps were set at each site, except in 2006, when 10 traps were set at the two breakwater sites and 7 were placed at the breakwater reef location. We then checked traps weekly until 15 June 2004, 9 June 2005, and 6 June 2006, weather depending. Each week, all traps were lifted, checked for emergent fry or other fish, and redeployed. Fry and predators were preserved in ethanol for later analysis. In the laboratory, all fry were positively identified to species and then measured. Predators were measured and weighed prior to stomach analysis.

Estimates of lake trout egg consumption. Based on our estimates of lake trout egg deposition, round goby density, and daily round goby egg consumption, we calculated the population-level consumption of lake trout eggs by round goby at the Port of Indiana during 2002-2004. Specifically, we employed estimates of lake trout egg deposition and of round goby predators from our egg bags expressed as density per m$^2$ of substrate. The mean number of lake trout eggs in round goby stomachs was estimated from stomach contents of round gobies recovered from egg bags. We also estimated the minimum size of a round goby capable of consuming a lake trout egg based on the smallest round goby that we observed with lake trout eggs in its stomach. Daily estimates of lake trout egg consumption by round goby were then calculated following the methodology of Chotkowski and Marsden (1999). Thus, the daily estimate of predation by round gobies on lake trout eggs can be expressed as:

$$P = D * p(e) * r,$$

where

P = Population consumption of lake trout eggs, expressed as number/$m^2$/d
D = density of round gobies, number/$m^2$
p(e) = the proportion of round gobies able to consume eggs,
r = the daily rate of lake trout egg consumption.

Taking this daily rate of lake trout egg consumption and dividing by the density of eggs deposited then provided the number of days that lake trout eggs could persist in the face of round goby predation.

We also calculated the lake trout egg: predator ratio as described by Fitzsimons et al. (2003). This index was developed to assess the likelihood that lake trout fry would emerge the following spring, given the number of egg predators available to feed on lake trout eggs throughout the winter. Based on sampling in lakes Michigan, Huron, and Champlain, a ratio of at least 24:1 was deemed necessary to ensure fry emergence the following spring.

**Results.**

Adult spawners. A total of 141 adult lake trout were collected on November 21, 2003, of which 6 were unclipped. This rate of 4% unclipped fish is close to the accepted rate of up to 3% unclipped fish, suggesting that if any naturally reproduced lake trout were returning to spawn, their numbers were quite low. However, these spawners were sampled only one time near the end of the spawning season and it is possible that other unclipped fish spawned at the Port of Indiana earlier in the spawning season. To more fully understand the possibility for naturally produced fish to be spawning at this site, several adult assessments would need to be done throughout the spawning season each fall.

Egg Deposition.

*2002*

Four diver-deployed egg bags were retrieved from the north breakwall reef on 6 December 2002. The bags held 6 live lake trout eggs, 7 dead eggs, and 3 chorions, yielding a CPUE of 0.04 eggs/device per day. This translated to a rate of lake trout egg deposition of 10.39 eggs/$m^2$. No other egg bags were retrieved during this year due to icing problems with the regulators.

*2003*

Only 35 egg nets of the 50-net gang were retrieved from the north breakwall on 4 December 2003. The remaining 15 nets were impossibly tangled in the anchor stone and were abandoned. Two live lake trout eggs were recovered, although no dead eggs or chorions were present in these nets. CPUE of lake trout eggs with this gear was 0.001

eggs/device/day. We recovered 28 round gobies ranging in size from 26.8 to 48.4 mm. No round gobies were found with lake trout eggs in their stomachs. Egg nets collected from the west break wall on 9 December 2003 yielded 5 live eggs, no dead eggs, and no egg chorions. CPUE for the egg nets was 0.002 eggs/device/day. This gang of 50 nets also contained 25 round gobies, ranging in size from 27.7 to 50.9 mm. None of the round gobies had ingested lake trout eggs.

Eight diver deployed egg bags also were retrieved from this site on December 4, 2003. The bags held 7 live lake trout eggs and 4 dead eggs, yielding a CPUE of 0.02 eggs/device/day. This translated to a rate of lake trout egg deposition of 14.29 eggs/$m^2$. Thirty four round gobies ranging in size from 41.0 to 107.8 mm, along with 5 rusty crayfish *Orconectes rusticus* were also present in the bags. Of the round gobies, 9 contained lake trout eggs at the rate of 1 lake trout egg per round goby stomach. Four diver-retrieved egg bags from the west breakwall generated 124 live lake trout eggs, 10 dead lake trout eggs, and 2 egg chorions. CPUE from the egg bags at this site was 0.52 eggs/device/day. This translated to a rate of lake trout deposition of 509.30 eggs/$m^2$. Five round gobies ranging in size from 44.1 to 130.6 mm were also retrieved from the egg bags. Diets of the round gobies revealed that 4 of the 5 predators had consumed lake trout eggs, with only the 44 mm round goby not consuming a lake trout egg. A total of 5 eggs had been consumed by the predators, or 1.2 lake trout eggs per predator.

*2004*

All 50 nets of the gang were retrieved from the north breakwall on 6 December 2004. Thirteen live lake trout eggs were recovered, along with 1 dead egg and 1 chorion. CPUE of lake trout eggs with this gear was 0.007 eggs/device/day. We recovered only one 21-mm round goby from these nets. Nine diver-deployed egg bags also were retrieved from this site on the same day. The bags held 79 live lake trout eggs, 6 dead eggs, and 15 chorions, yielding a CPUE of 0.15 eggs/device/day. This translated to a rate of lake trout egg deposition of 115.49 eggs/$m^2$. Thirty nine round gobies ranging in size from 29 to 90 mm, along with three rusty crayfish *Orconectes rusticus* were also present in the bags.

The 50 egg nets collected from the north reef on 6 December 2004 yielded five lake trout eggs. No predators were recovered from this set of nets. CPUE of lake trout eggs with this device was 0.002 eggs/device/day. Eight diver-retrieved egg bags from this location on the same day produced 28 live lake trout eggs. CPUE from egg bags at this location was 0.05 eggs/device/day. This translated to a rate of lake trout deposition of 36.38 eggs/$m^2$. Twenty three round gobies ranging in size from 36 to 122 mm, as well as 10 crayfish, were also present.

Egg nets collected from the west breakwall on 6 December 2004 yielded no live eggs, no dead eggs, and no egg chorions. CPUE for the egg nets was 0 eggs/device/day. This gang of 50 nets contained one crayfish. Nine diver-retrieved egg bags from the same location generated 98 live lake trout eggs, 25 dead lake trout eggs, and 8 egg chorions. CPUE from the egg bags at this site was 0.19 eggs/device/day. This translated to a rate of lake trout deposition of 151.29 eggs/$m^2$. Twenty five round gobies ranging in size from 31 to 162 mm, plus 3 crayfish, were also retrieved from the egg bags.

*2005*

Egg nets were retrieved on 13 December 2005. Along the west breakwall, 31 live eggs, three dead eggs, and four chorions were collected. Four round gobies were also collected. CPUE for egg nets was 0.012 eggs/device/day. Along the north breakwall, 11 live eggs and 12 chorions were collected along with 1 round goby. CPUE for egg nets at this location was 0.007 eggs/device/day. Along the north reef, 16 live eggs, 9 dead eggs, and three chorions were collected. CPUE for egg nets at this location was 0.009 eggs/device/day.

Egg bags were not retrieved in 2005 because of very poor visibility and water temperatures that prevented both a thorough search of the area to find the egg bags and the opportunity to retrieve them without endangering diver safety.

Fry Emergence.

*2003*

One emergent lake trout fry measuring 18 mm TL was collected during spring 2003. Several small round gobies were collected in the traps. No lake trout fry were present in round goby stomachs.

*2004*

Emergence traps were fished for 36 days but no emergent lake trout fry were collected during spring 2004. Several small round gobies were collected in the traps. No lake trout fry were present in round goby stomachs.

*2005*

One emergent lake trout fry measuring 22 mm TL was collected during spring 2005. Several small round gobies were collected in the traps. No lake trout fry were present in round goby stomachs.

*2006*

During spring 2006, fry emergence traps were fished at each site for 48 days. Two emergent lake trout fry were collected. The lake trout collected along the west breakwall on May 2 was 17 mm TL; the lake trout collected along the north breakwall reef on May 10 was 27 mm TL. A total of 31 round gobies that ranged in length from 20-76 mm TL were collected in the traps. No lake trout fry were detected in the stomach contents of these predators. Three juvenile yellow perch were also collected in the traps.

Lake trout egg predation. Crayfish were present at all sites at the Port of Indiana, with densities of crayfish ranging from 0 to 13 individuals/m$^2$. Because crayfish are a minor consumer of lake trout eggs compared to round gobies (Fitzsimons et al. 2006), we did not model crayfish consumption.

Round gobies were generally dense at all sites at the Port of Indiana (Figure 2), with densities most often between 30 and 35 individuals/m$^2$. Round gobies smaller than 50 mm did not consume lake trout eggs in the field. Hence, we used this size as the smallest size at which round gobies could consume lake trout eggs. The size distribution of round gobies varied among our three sampling locations, with the west wall having the largest round gobies (Figure 3). Along the north wall, about 60% of the round gobies collected were too small to consume lake trout eggs. About 40% of round gobies at the north reef also were too small to consume lake trout eggs. Conversely, only 4% of round gobies along the west wall could not consume lake trout eggs.

Rates of egg deposition by adult lake trout varied substantially across sites and years (Figure 4). Generally, egg deposition rates were lowest at the north reef and highest along the west wall. Egg deposition ranged between 10 and 509 eggs/$m^2$, and averaged 139 eggs/$m^2$ across sites and years.

Daily consumption of lake trout eggs was about one lake trout egg per goby. Expanding this by the density of round gobies able to consume eggs, consumption of lake trout eggs by round gobies was generally between 15 and 20 eggs/$m^2$/d across sites and years (Figure 5). However, as many as 57 eggs/$m^2$/d were consumed by round gobies along the west wall in 2004. Given this daily rate of egg consumption, round gobies could consume all lake trout eggs deposited in less than 30 days, and often in less than 10 days.

The lake trout egg: predator ratio also was extremely low across most sites and years (Figure 6). Only along the west wall in 2003 did the ratio exceed 24:1 (at 65:1). All other ratios were < 5:1, indicating that round gobies were extremely abundant relative to the density of lake trout eggs deposited.

**Discussion.**

During our sampling, densities of lake trout eggs collected by egg bags were at least an order of magnitude greater than the densities collected by egg nets. We agree with Marsden and Chotkowski (2001) that egg bags are a much more efficient sampler of lake trout eggs. As a result, we recommend that egg bags be used whenever possible in future research or monitoring efforts.

Although the round gobies present in fry traps were too small to consume lake trout fry, this does not mean that round gobies do not feed on newly emerged lake trout fry. In fact, it is quite likely that round gobies can feed on lake trout fry while they are in the cobble substrate.

Although egg deposition rates as measured by egg bags have not changed substantially since the mid-1990s, fry emergence rates have plummeted. We collected 1 emergent lake trout fry during spring 2003, none during spring 2004, 1 during spring 2005, and two during spring 2006. Given our more extensive trap effort than was consistently used during the mid-1990s (Marsden and Chotkowski 2001), it is worrisome that the number of emergent fry we observed is among the lowest observed by Marsden and Chotkowski during the mid 1990s. Harsh weather conditions during spring 2005 resulted in the loss of over 50% of our fry traps. Because our sampling effort was greatly reduced in 2005, we added another sampling season in 2006, generating two emergent lake trout fry. This additional sampling allowed us to be much more certain of our conclusion that round gobies strongly negatively affect survival of lake trout eggs.

Round gobies constitute a significant new threat to successful lake trout reproduction through predation on eggs and newly hatched fry. They are very abundant as compared to native predators such as mottled sculpin *Cottus bairdi* and crayfish *Orconectes* spp. We documented substantial numbers of round gobies in both egg nets and egg bags. However, our estimates of the number of round gobies in egg bags is certainly an underestimate because many round gobies escaped from the bags while divers were removing bags from the substrate. An accurate count of the number of round gobies escaping from each bag could not be made because of poor visibility. However, divers could regularly see and feel round gobies escaping from the bags. Nevertheless, lake trout egg deposition rates did not appear to be substantially different from those reported by Marsden and Chotkowski (2001), especially for egg bags. CPUEs for egg nets were at least an order of magnitude lower in 2003 and 2004 than for 1993-1996 (Marsden and Chotkowski 2001). However, egg nets are not thought to be completely representative of egg deposition rates owing to the likelihood that some nets would not land face-up and that wave action could displace several members of each net gang off of suitable spawning substrate. When looking at CPUEs for egg bags, however, deposition rates in 2002-2004 were within the range of those reported during 1994-1996 (Marsden and Chotkowski 2001).

Because round gobies are such voracious predators, even at relatively cold water temperatures of 5 °C, they exert tremendous predation pressure on lake trout eggs. Our calculations indicate that even when egg deposition rates exceed 500 eggs/$m^2$, the existing density of round gobies could eliminate those eggs within 30 days. These numbers are telling because the egg deposition rates seen by us at the Port of Indiana are among the highest seen in all of Lake Michigan (Fitzsimons et al. 2003). Hence, if round gobies consume almost all lake trout eggs before hatching at the Port of Indiana, this bodes extremely poorly for other lake trout spawning reefs where round gobies are or will be present. Within the next decade it may be that the only spawning areas without substantial round goby populations will be offshore reef locations such as the mid-lake reef complex or Julian's Reef.

Conversely, round gobies are much reduced in thiaminase content compared to their primary prey, alewife. If, as round gobies expand throughout the lake, they are consumed with greater frequency by lake trout, lake trout may produce eggs with sufficient thiamine to be resistant to Thiamine Deficiency Complex. Thus, there is the potential for round gobies to have both significant positive and negative impacts on lake trout reproductive success. Additional research is needed to determine which force is the stronger with respect to lake trout reproduction. As a result, it is very likely that managers will need to take into consideration round goby expansion from both a negative and positive perspective as they formulate successive versions of the lake trout rehabilitation plan.

**Acknowledgments**
We thank the many staff at the Lake Michigan Biological Station who helped with fieldwork, but special thanks go to W. Brofka, S. Miehls, A. Jaeger, and R. Zehr. We appreciate the assistance of B. Breidert, D. Makauskas, S. Robillard, and Indiana DNR law enforcement personnel with logistical and sampling support.

**Literature Cited**

Chotkowski, M. A., and J. E. Marsden. 1999. Round goby predation on lake trout eggs and fry: field predictions from laboratory experiments. Journal of Great Lakes Research 25:26-35.

Fitzsimons, J. D., J. E. Marsden, B. J. Ellrott, J. Jonas, and R. M. Claramunt. 2003. Effects of egg and fry predators on lake trout recruitment in Lake Michigan. Great Lakes Fishery Commission Final Report, Ann Arbor, 239 p.

Fitzsimons, J., B. Williston, G. Williston, G. Bravener, J. L. Jonas, R. M. Claramunt, J. E. Marsden, and B. J. Ellrott. 2006. Laboratory estimates of salmonine egg predation by round gobies (*Neogobius melanostomus*), sculpins (*Cottus cognatus* and *C.bairdi*), and crayfish (*Orconected propinquus*). Journal of Great Lakes Research 32:227-241.

Horns, W. H., J. E. Marsden, and C. C. Krueger. 1989. An inexpensive method for quantitative assessment of demersal egg deposition. North American Journal of Fisheries Management 9:280-286.

Krueger, C. C., D. L. Perkins, E. L. Mills, and J. E. Marsden. 1995. Predation by alewives on lake trout fry in Lake Ontario: role of an exotic species in preventing restoration of a native species. Journal of Great Lakes Research 21(Supplement 1):458-469.

Marsden, J. E., and M. A. Chotkowski. 2001. Lake trout spawning on artificial reefs and the effect of zebra mussels: fatal attraction. Journal of Great Lakes Research 27:33-43.

Marsden, J. E., C. C. Krueger, and C. P. Schneider. 1988. Evidence of natural reproduction by stocked lake trout in Lake Ontario. Journal of Great Lakes Research 14:3-8.

Perkins, D. L., and C. C. Krueger. 1994. Assessment of lake trout spawning – evaluation of traps for measurement of egg abundance. Journal of Great Lakes Research 20:385-389.

Figure 1. Location of sampling sites at the Port of Indiana breakwall during 2002- 2005.

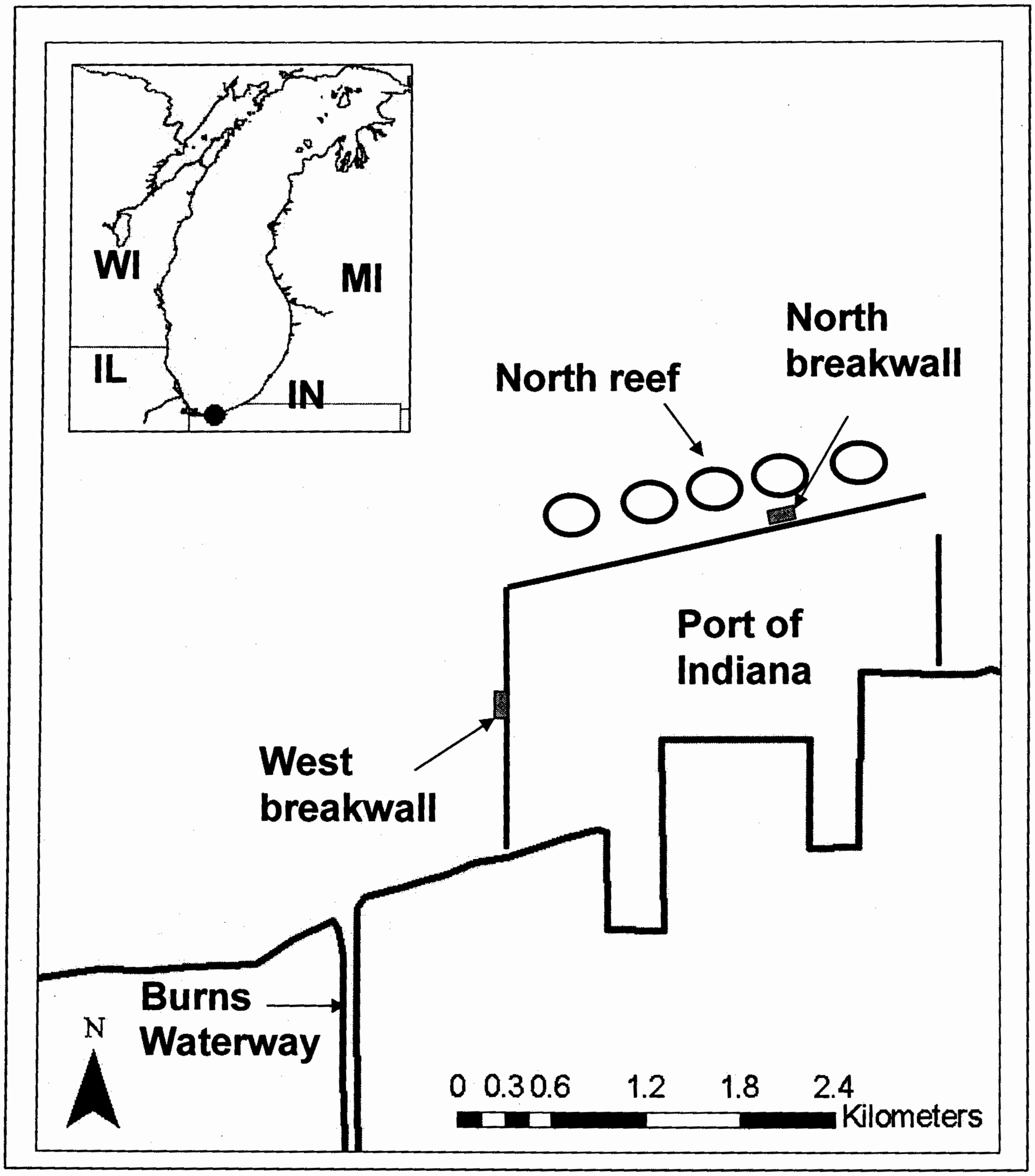

Figure 2. Estimated densities of round gobies collected from egg bags retrieved during December 2002-2004 at our three sampling locations at the Port of Indiana.

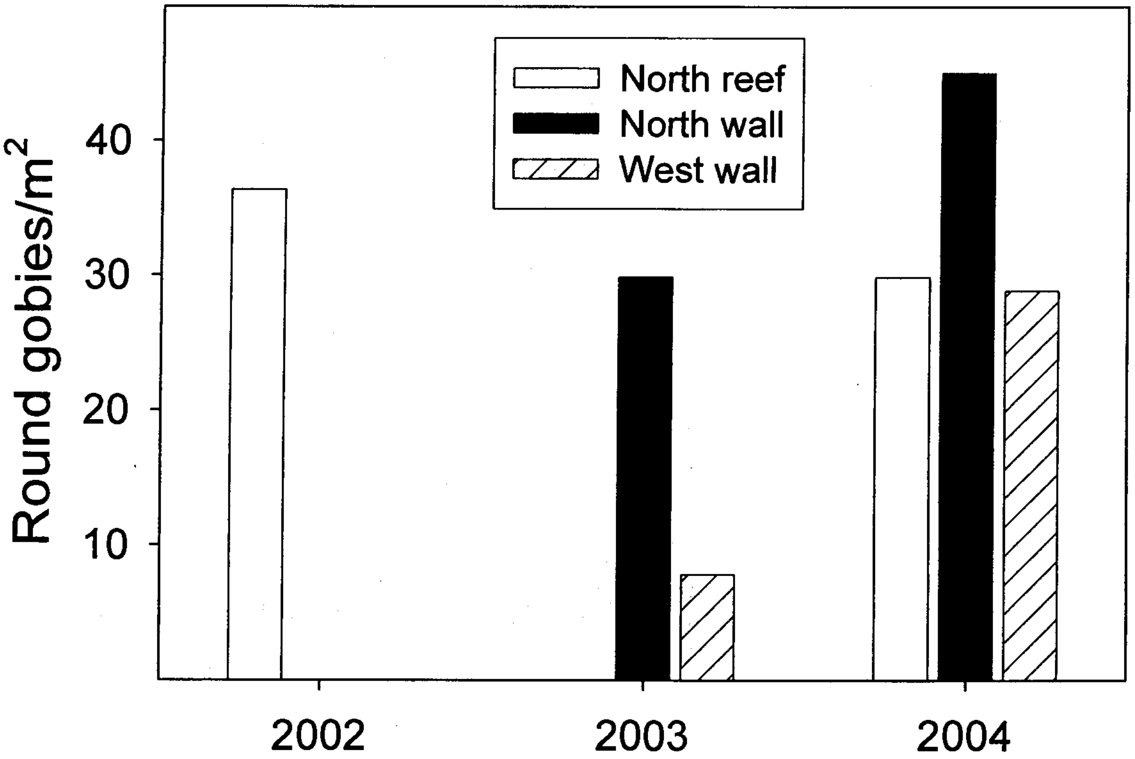

Figure 3. Percent occurrence of round gobies partitioned into 10-mm length bins. Round gobies were collected from egg bags during December 2002-2004 along the three sampling locations at the Port of Indiana

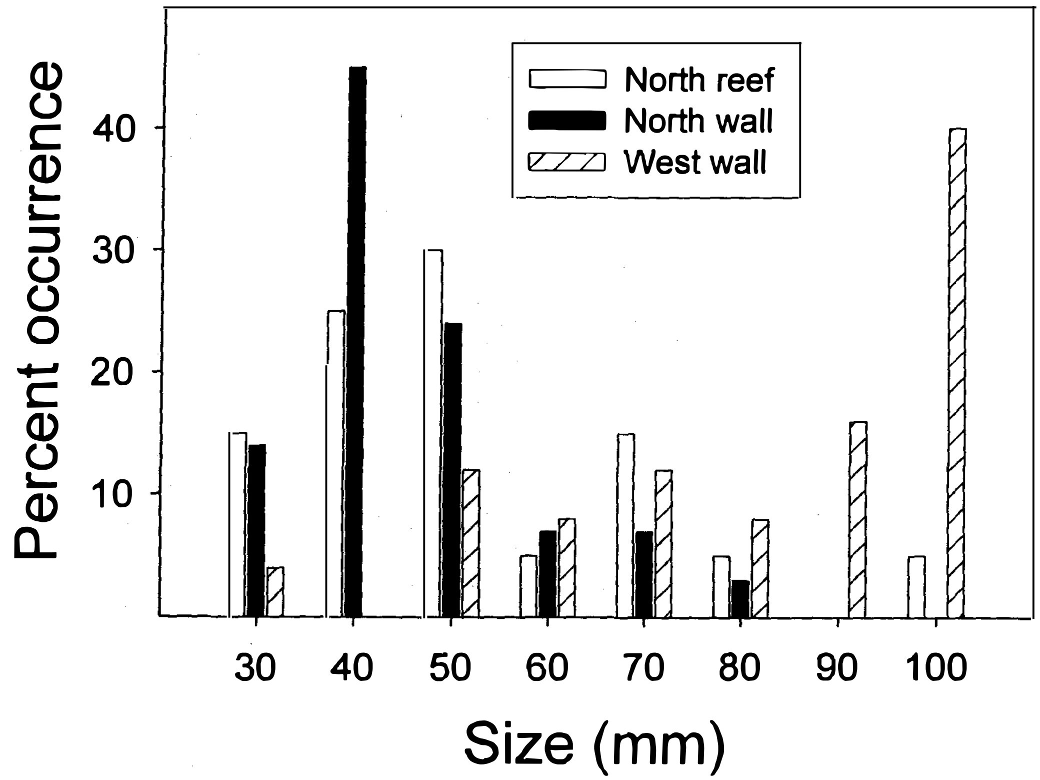

Figure 4. Lake trout egg deposition (eggs/$m^2$) as measured by egg bags at three sites along the Port of Indiana breakwall during fall 2002-2004.

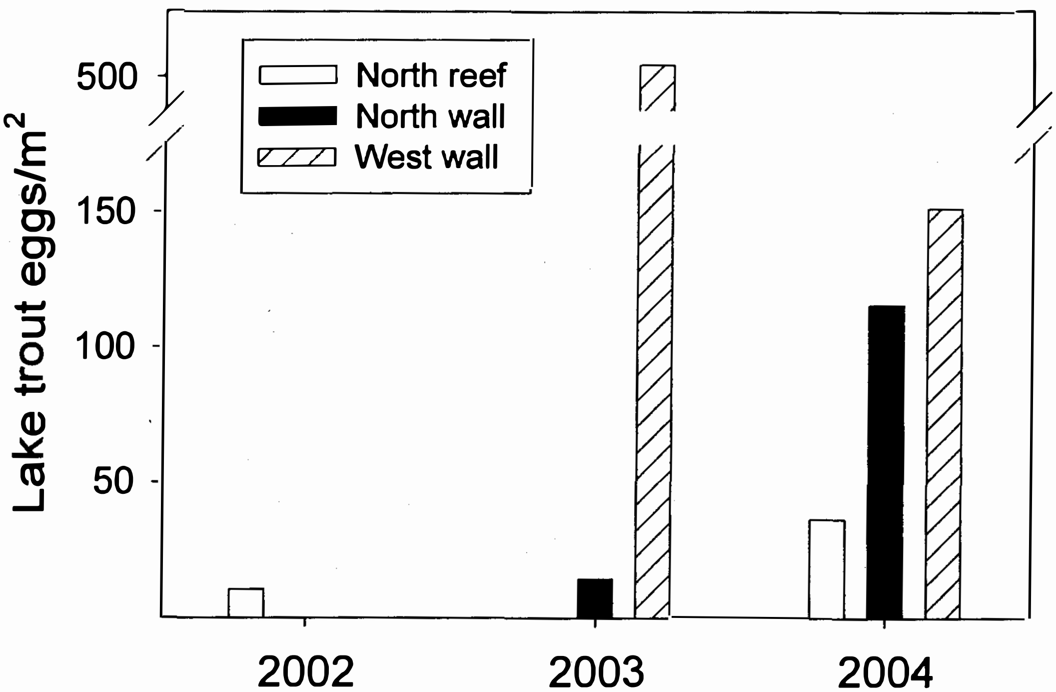

Figure 5. Estimated number of lake trout eggs consumed/m$^2$/d by the round goby population large enough to consume lake trout eggs. Estimates are for the north wall, north reef, and west wall of the Port of Indiana during fall 2002-2004. LAT = lake trout.

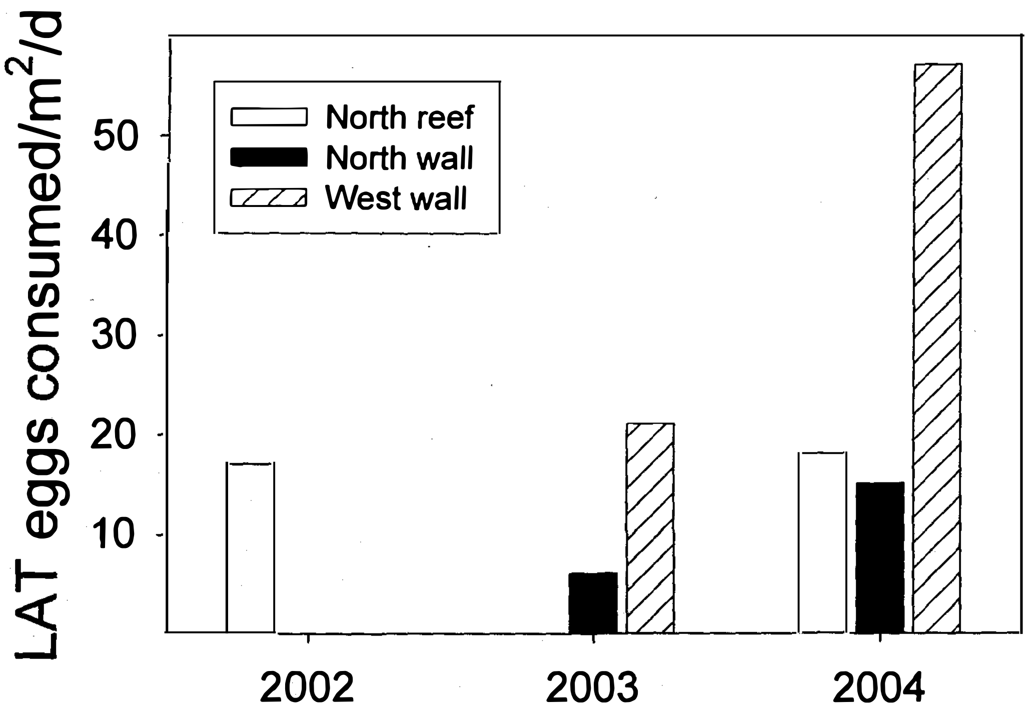

Figure 6. The lake trout egg: egg predator ratio at the north reef, north wall, and west wall of the Port of Indiana during fall 2002-2004. An egg: predator ratio of 24:1 is considered necessary to ensure emergence of fry the following spring.