Design and Use of Mesh Bags to Estimate Deposition and Survival of Fish Eggs in Cobble Substrate

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Abstract.—A sampler is described and evaluated for use in early life history studies of demersally spawning fishes that broadcast eggs over rocky substrate. The sampler was designed to be buried in substrate and to collect spawned eggs under natural environmental conditions (including natural water flow). Each sampler consisted of a metal ring (32-cm inside diameter) with a 51.5-cm-deep nylon mesh bag attached (mesh size = 0.16 cm). Egg deposition in the substrate per unit area, survival of embryos at various developmental stages, and predator density in the substrate were estimated based on data from 135 bags buried by scuba divers on a spawning reef used by lake trout Salvelinus namaycush in Lake Ontario. None of the bags were dislodged during storms. Bags were easier to construct, bury, and retrieve than many other devices previously described.

A variety of equipment and techniques have been described for studying the deposition and survival of eggs broadcast by demersally spawning fish in lakes. Unfortunately, every method has drawbacks when quantitative estimates are needed. Disk-shaped egg nets and traps placed on top of the substrate have been used to capture eggs (Horns et al. 1989; Marsden et al. 1991); however, these devices should not be used to provide estimates of eggs per unit area because no consistent relationship has been demonstrated between the capture of eggs in these devices and egg abundance in the substrate (Perkins and Krueger 1994). In addition, these devices were not designed to mimic natural conditions in the substrate and thus cannot be used to estimate survival. Air-lifts and pumps have been used to suction eggs from the substrate (e.g., Manz 1964; Mackey 1972; Stauffer 1981); however, suctioned samples may inaccurately estimate the number of eggs per unit area because the size of the area sampled is difficult to measure due to substrate irregularities. In addition, eggs may be sucked in from adjacent substrate or may drift out of the sample area. Plexiglas incubators that hold each egg in a separate, mesh-covered hole have provided estimates of survival (Kennedy 1980); however, estimates may be biased high because the embryos are protected from drifting, which can shock eggs and cause substantial mortality (Crisp 1990). Closed containers made entirely of screen that are filled with substrate and seeded with fertilized eggs (Shelton 1955; Harris 1973) simulate natural conditions but are not designed to estimate the abundance of naturally spawned eggs. These closed containers also exclude predators (as do the egg nets, egg traps, and incubators) which could bias survival estimates. Pails with small mesh windows in their sides that are buried in the substrate to capture and incubate eggs (Stauffer 1981) avoid many of the problems described above; however, they may have unnaturally low inside water flow because most of the pail is not mesh. Flow reduction could increase sedimentation and decrease water quality within the pail and thereby affect estimates of embryo survival. In addition, pails are time-consuming to bury because the rigid walls do not conform to the irregularities of holes dug in stony substrate, and thus the volume of substrate that must be excavated is much greater than the pail volume.

In this paper, a mesh bag sampler is described and it is evaluated for use in early life history studies of demersally spawning fishes that deposit eggs in cobble and gravel substrate. Evaluation was conducted on a spawning reef used by lake trout Salvelinus namaycush in Lake Ontario. The sampler has substantial advantages over other methods because it can be easily buried in the substrate and natural environmental conditions in the sampled area are maintained. These advantages should make the samplers useful for quantitative studies of reproductive dynamics that are often an important aspect of fisheries management.

Bag Construction

Each bag consisted of a metal ring (32 cm inside diameter; sample area = 0.08 m²) attached to a 51.5-cm-deep nylon-mesh bag (Figure 1). The rings were made of metal pipe (electrical conduit, 1.25 cm in diameter) bent to form a circle. Bags were

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made from 122 × 60-cm pieces of nylon mesh netting (0.16-cm mesh; see Figure 2 for details). Stitching was strengthened by nylon seam tape sewn around seams. The top of each bag was folded down and sewn to form a tube. Only nylon thread was used because cotton deteriorates in water. The tube ends were left open to allow insertion of the metal ring. Once in the tube, the ends of the metal ring were covered with duct tape to prevent abrasion of the mesh. The seam where the ends of the mesh tube met was then closed with several plastic cable ties. The estimated cost per bag in 1992 was U.S. $10.50 ($4.50 for material, $6.00 for labor).

Covers for the bags were made from circular pieces of nylon mesh (45 cm in diameter) with cord interlaced around the perimeter. An overlapping lacing pattern was used for the cord to allow a tighter cinch below the bag ring than was possible with a nonoverlapping pattern (see Figure 2). Plastic, spring-loaded cord locks were used to prevent cords from loosening.

Field Studies and Evaluation

Studies were conducted on a lake trout spawning reef near Stony Island in the eastern basin of Lake Ontario (43°54'45"N, 76°17'30"W). The reef drops steeply from 4 to 8 m and is composed of large cobbles (6–30 cm) with interstitial spaces extending from 30 to more than 60 cm below the surface of the substrate (Marsden and Krueger 1991).

In September 1991 (4–8 weeks before lake trout spawning), 135 bags were buried by scuba divers on the reef (Figure 3). Divers dug holes (about 0.05 m$^3$) in the reef substrate, placed the bags in the holes with rings flush with the substrate, and then filled the bags with displaced substrate (Figure 4). Three bags were buried within 30 cm of each other at each of 45 sites. Fifteen sites were evenly spaced along each of three parallel transects that followed depth contours of 4, 6 and 8 m. Each diver buried about 10 bags/h. Burial time was shortest in areas of larger substrate. Because the mesh conformed to hole contours, less substrate needed to be excavated for each bag than for smaller egg pails (Stauffer 1981). Thus, burial time per bag was substantially less than for the pails. In preliminary tests, a few bags were accidentally buried with the ring (i.e., tops of the bags) above the original substrate level and with rocks mounded around the bag (Figure 4). This kind of burial led to dislodgment of several bags located at the top and middle of the reef during storms.

Bags were left uncovered to sample naturally
spawned eggs at 10 sites along each of the three transects. Bags at the other five sites along each transect were covered immediately after burial and later (November 8) seeded with 50 fertilized eggs (Figure 3). To seed the eggs, small slits were cut in each cover, eggs were squirted in from preloaded tubes, and the slits were stapled shut. This procedure worked well, but a faster method would be to precut small holes in the covers and have a ring-shaped piece of hook-and-loop material (i.e., Velcro®) secured around the hole with a grommet. A second piece of Velcro would cover the hole and could be quickly removed for egg seeding and then reattatched.

On December 10, April 10, and May 15, one bag was retrieved from each of the 45 sample sites. To retrieve bags, divers carefully removed most rocks, closed the bag openings with cable ties (secured around the mesh just below the rim), and then placed the bags in crates attached to buoy lines. The filled crates were gathered from the surface by boat. Uncovered bags retrieved on May 15 had been covered on April 10 to prevent the escape of fry. Upon retrieval, the mesh of some bags, particularly those at 4 m, was abraded around the metal rim, but all bags were functional. None of the covers were loosened from the bags. Sculpins Cottus spp. and crayfish Orconectes spp. that had recolonized the substrate in the bags usually swam towards the bottom of the bag during retrieval and were also collected. No sculpin or crayfish were found in bags covered immediately after burial. On the boat, bags were stored in containers of water and later processed on shore. The time required to sort the contents of each bag varied between 10 and 40 min.

In December 1991, the sum of live and dead eggs and egg chorions captured per uncovered bag ranged from 32 to 589 (mean, 274; SE, 34). Chorions made up an average of 15% of total egg capture. Sculpin and crayfish densities in December were estimated to be 6.3 and 6.6/m², respectively. In April and May 1992, there were 0–97 live embryos (including alevins and fry) retrieved from bags that collected naturally spawned eggs (mean, 11.7; SE, 2.5). In the 15 covered bags seeded with 50 eggs on November 8 and retrieved December 10, an average of 36.9 eggs (SE, 1.7) and 6.7 chorions (SE, 0.7) were identified from each bag. Thus, over a one month period, 12.8% of the seeded eggs became unidentifiable. Retrieval of live embryos from the seeded bags averaged 6.2 (SE, 1.4) in April and 1.9 (SE, 0.5) in May.

Total egg deposition for the entire study area was estimated as follows:

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\text{deposition} = \sum_{i=1}^{30} \left( \frac{\text{live eggs} + \text{dead eggs} + \text{chorions}}{\text{capture area of bag} \times \text{reef area at site } i} \right) \times \text{reef area at site } i \text{ (m}^2\text{)}
\]

where \( i \) = sites with uncovered bags. The amount of reef area at each site with uncovered bags was either 11.12, 16.68, or 22.24 m² (Figure 3). Egg deposition was estimated from bags retrieved December 10, shortly after all spawning was completed, to curtail egg losses from (1) water currents that caused eggs to drift out of the spawning area, (2) decomposition or disintegration of dead eggs, and (3) predation. Because egg loss undoubtedly occurred (e.g., 12.8% loss of seeded eggs in covered bags in 1991), the estimate of egg deposition (3,572/m²) should be considered a minimum estimate. Egg abundance can vary substantially over small distances (Stauffer 1981); thus, many bags were used to increase the accuracy of the estimate.
Survival of naturally spawned eggs was calculated at each of the retrieval dates by dividing the total number of live embryos estimated to be in the reef at a given time by total egg deposition (estimated as described above). The total number of live embryos was estimated the same way as total egg deposition (given above) except that only the number of live embryos was used for the numerator. If total estimated egg deposition was biased low, estimated survival of naturally spawned eggs (1.8% from between November and May) would be biased high. Survival in each of the seeded bags was calculated by simply dividing the number of live embryos present at a given time by the number of eggs originally seeded (mean survival to May 15, 3.8%; SE, 1.0). Use of seeded bags allowed for comparisons of survival rates among sites.

Summary

The mesh bags described here have a unique combination of features that make them useful for early life history studies of fish that broadcast eggs over rocky substrate. The bags were easier to construct, bury, and retrieve than many other devices previously described. Properly buried bags were not dislodged or destroyed during storms, which has been a problem with other egg collection devices (Marsden and Krueger 1991). However, because divers are required for bag deployment, there are depth limits to their use, unlike the surface-deployed devices described by Horns et al. (1989) and Marsden et al. (1991). The bags enable quantitative estimation of (1) egg deposition, (2) survival of naturally spawned or seeded eggs, (3) fry abundance, and (4) abundance of predators, such as sculpins and crayfish in the substrate. Embryos and fry collected can also be used for other purposes such as determination of fertilization rates and contaminant burdens. Estimates derived from bags will likely be more accurate than from other methods because the bags should better maintain the natural incubation environment. Although the bags were tested only with lake trout, they may be useful for studies of other fish that also broadcast eggs over rocky substrate (e.g., whitefish Coregonus spp. and sturgeon Acipenser spp.).

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