*North American Journal of Fisheries Management* 25:86–92, 2005

DOI: 10.1577/M03-146.1

[Article]

# Comparison of Push Nets and Tow Nets for Sampling Larval Fish with Implications for Assessing Littoral Habitat Utilization

RANDALL M. CLARAMUNT,[1] DANIEL E. SHOUP,* AND DAVID H. WAHL

*Kaskaskia Biological Station, Illinois Natural History Survey, Rural Route 1, Box 157, Sullivan, Illinois 61951, USA*

*Abstract.*—Understanding sampling effectiveness is critical to gear selection and the determination of larval fish dynamics. We evaluated bow-mounted push nets for collecting larval fish across reservoirs and habitats and compared them with traditional tow nets. By means of a pushed 0.5-m-diameter conical net and towed 0.5-m-diameter and 0.75-m-diameter conical nets, ichthyoplankton samples were taken during daylight hours from May to July on 21 reservoirs that varied in morphological and environmental characteristics. The push net had higher catches than the same-diameter tow net. However, the push net was not as efficient as the larger-sized tow net in July, when larvae are larger. For pelagic habitats, bow-mounted push nets or large tow nets will sample the larval fish community more efficiently than traditional 0.5-m-diameter conical tow nets. We also assessed push nets for sampling nearshore littoral habitats (<1.0 m in depth). Across reservoirs the littoral areas had much higher catch rates than did the offshore pelagic zone; estimates of peak larval fish densities were four times as high in the littoral zone. Deriving estimates of larval fish abundance from pelagic habitats only will probably lead to underestimation of total larval fish densities. The versatility of the push net in sampling littoral habitats is an important consideration when designing surveys to estimate larval fish communities. Bow-mounted push nets can be used to effectively sample both pelagic and littoral larval fish communities, whereas traditional tow nets are only suited for pelagic habitats.

Estimates of larval fish abundance and size structure are important in understanding year-class strength, and population models should include a component of prerecruitment surveys (Walters and Collie 1988). Accurate estimates of densities and size distributions of larval fish are critical in assessing early life history dynamics and several types of ichthyoplankton gears (seines, dip nets, light traps, push nets, and tow nets) are employed in fisheries assessments with varying efficiencies (Choat et al. 1993; Hale et al. 1995; Isermann et al. 2002). Understanding the strengths and limitations associated with the different gear types is critical to interpreting estimates of larval fish densities and size distributions. The size of the net mouth (Barkley 1972; Hale et al. 1995), size of the net mesh (Colton et al. 1980; Jessop 1985; Isermann et al. 2002), and sampling speed (Barkley 1972; Colton et al. 1980) have been shown to affect catch of different species and sizes of larval fish. Other environmental variables such as water clarity, turbulence (caused by boat wash), and net-clogging due to plankton can also affect net efficiency (Anderson et al. 1998). Traditional towed nets are commonly used to sample larval fish, but bow-mounted push nets of the same size may reduce gear avoidance bias and influences of boat propeller wash for ichthyoplankton surveys. Previous studies comparing push and towed nets have used different sized nets (Gallagher and Conner 1983; Hale et al. 1995), so direct comparison of the sampling bias of these two designs was not possible. Information on the efficiency and utility of push nets compared with traditional towed nets will improve our ability to accurately estimate larval fish densities and size distributions.

Studies aimed at investigating the early life history of fishes should include sampling of a wide range of species, larval sizes, and habitats. However, sampling is often focused in the pelagic zone where traditional gears such as tow nets can be easily used to assess ichthyoplankton and avoid the difficulties of sampling shallow (<1.0 m) habitats (e.g., Sammons and Bettoli 1998). Several gear types developed to sample shallow water, such as the larval seine (Leslie et al. 1983), are effective in littoral habitats, but they tend to be qualitative and cannot be compared directly with pelagic gears. Because fishes found in reservoirs and inland lakes typically spawn inshore (Auer 1982), the potential for misrepresenting population

* Corresponding author: dshoup@uiuc.edu
[1] Present address: Michigan Department of Natural Resources, Charlevoix Fisheries Research Station, 96 Grant Street, Charlevoix, Michigan 49720, USA.

Received August 1, 2003; accepted June 25, 2004
Published online February 28, 2005

levels is high without information on ichthyoplankton abundance and diversity in nearshore areas. Therefore, the objective of this study was to describe differences in catches across habitats between traditional towed ichthyoplankton nets and push nets.

## Methods

We compared catch rates between push nets (mouth diameter = 0.5 m, mesh = 0.5 mm) and two traditional towed nets—a small (mouth diameter = 0.5 m, mesh = 0.5 mm, mouth: net length ratio = 1:3) and a large (mouth diameter = 0.75 m, mesh = 0.75 mm, mouth: net length ratio = 1:3) tow net—in samples from 21 reservoirs located throughout Illinois that varied in ichthyoplankton densities and water quality attributes (see Claramunt and Wahl 2000). We divided the length of each reservoir into three strata and randomly selected an inshore and adjacent offshore site within each strata (stratified-random sampling design). Inshore sites were defined by depth (≤1.0 m) and proximity to shore (≤25 m). Temperature, dissolved oxygen, and Secchi disk depth readings were also collected at each site and are reported in Claramunt and Wahl (2000).

Larval fish were sampled during daylight hours every other week from May to July 1995. The nets were pulled or pushed at a uniform speed of 1.5 m/s for 5.0 min just under the water surface. To estimate the volume of water filtered in all samples, a calibrated flowmeter was mounted inside the mouth of the net; it indicated that the mean water volume sampled was 85 $m^3$ (SE = ±0.88). The towed nets were deployed 23 m behind the boat and pulled in a wide circle to avoid the direct prop wash from the boat. The push net was mounted to the bow of the boat and pushed in the same wide circle as the towed nets. The sequence of gear type was selected randomly so that neither gear was always sampled first or last at a given site.

Using offshore samples from the two June sample dates on each lake, we compared push nets with same-sized, small tow nets. Larger tow nets are traditionally used for sampling larger size larvae. Therefore, we also compared, again using offshore samples from two July sample dates, the push net with a large tow net.

We also evaluated the utility of push nets for sampling littoral habitats (<1.0 m deep) and compared the resulting catches with those of pelagic ichthyoplankton surveys. We sampled offshore sites and adjacent inshore sites using the push net every other week from May through July (six dates). Because littoral habitats tend to be composed of aquatic vegetation, woody debris, and uneven bottom depths, traditional towed nets clog rapidly or become snagged, and will not effectively sample this complex habitat (e.g., Conrow et al. 1990). Therefore, we designed our push net to enable samples to be collected with similar speed and duration as samples collected using offshore conical nets. To do this, the net was mounted on a lightweight aluminum frame that did not extend below the net mouth, allowing us to sample depths as shallow as 0.5 m. The frame was also equipped with a breakaway feature that would absorb impact if the net collided with a permanent structure. In addition, the person operating the net on the bow had the capability to move the net in any direction or temporarily pull the net from the water to avoid submerged structure and dense vegetation mats.

Samples were preserved in 95% ethanol, and larvae were counted and identified to species or families using larval taxonomic keys (Auer 1982; Holland-Bartels et al. 1990). Larval fish densities were calculated as the number of fish sampled per cubic meter of water filtered for each species and gear comparison. To determine differences in length frequencies, a random sample of up to 200 fish of each species were measured using a digitizing tablet (Welker et al. 1994). Only those samples from which we were able to measure 30 or more fish were included. To account for changes in larval populations (number/$m^3$) through time, catch rates between gear types and habitats were compared via repeated-measures analysis of variance (ANOVA), where lakes were the subjects and sample sites were nested within lakes (Proc Mixed; SAS Institute 1999). Data were log-transformed to correct for proportionality between the standard deviations and means. Mean length (mm) of the catch was calculated for one sample site per lake, which was therefore analyzed as above, but without sample sites in the model. Because the large tow net had a larger mesh, we used only larvae 5 mm or more in length to compare size differences of larvae with the push. Data showing significant differences from ANOVA procedures ($P < 0.05$) were subsequently analyzed with Tukey's tests.

## Results

Larval densities across reservoirs ranged from 0 to 286 fish/$m^3$ and averaged 6.5–10.4 fish/$m^3$, depending on gear type (Figure 1). Across all

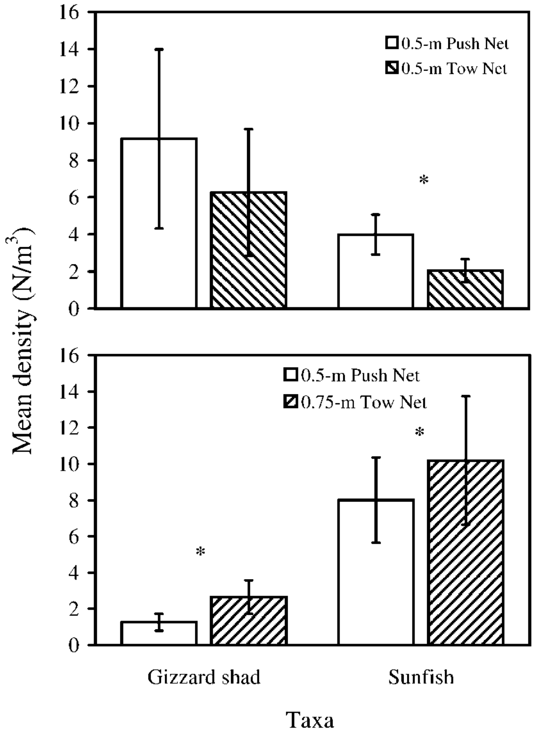


FIGURE 1.—Mean density (number/$m^3$; ±SE) of gizzard shad and sunfish collected with three types of gear from pelagic areas of 21 Illinois lakes. The top panel compares the catch of push nets (0.5-m mouth) and small tow nets (0.5-m mouth) during June. The bottom panel compares the catch of push nets and large tow nets (0.75-m mouth) during July. Asterisks indicate significant differences ($P < 0.05$) between net types within a taxon. Lakes where gizzard shad or sunfish were not captured were omitted from the analysis for that species.

lakes, gizzard shad *Dorosoma cepedianum* and sunfishes *Lepomis* spp. made up 87–99% of the fish collected from the three gear types (Table 1). Therefore, we compared catch rates (number/$m^3$) and mean length (mm) between gears for gizzard shad and sunfish larvae.

Only collections from lakes where gizzard shad or sunfish were captured during the sampling interval were included for comparisons of catch rates for that taxon. Larval sunfish catch rates were significantly higher ($F_{1,31} = 13.35$, $P < 0.01$; Figure 1) for the push net than for the small tow net, which had the same mouth size (0.5 m) as the push net. A similar pattern was observed for gizzard shad larvae, but the difference was not significant ($F_{1,69} = 1.94$, $P = 0.17$; Figure 1). Larval gizzard shad catch rates from both nets were significantly higher during early June than during late June ($F_{1,69} = 30.73$, $P < 0.01$). Net size and sample date did not show a significant interaction ($F_{1,69} < 0.01$, 0.97). We did not test larval sunfish for sample time effects because they were not captured in many lakes during the first half of June. To determine if the observed differences in catch rates between the push and tow nets were due to larval size, we also compared mean lengths through time. The mean length of larvae captured in the push net was not significantly different than lengths in the small tow net (gizzard shad: $F_{1,7} = 4.22$, $P = 0.08$; sunfish: $F_{1,3} = 1.89$, $P = 0.26$; Figure 2).

These comparisons were only made in July when fish sizes were larger. The large (0.75-m) tow net, which is traditionally used for sampling larger larvae, had significantly higher catch rates of gizzard shad ($F_{1,57} = 12.74$, $P < 0.01$) and sunfish ($F_{1,141} = 4.42$, $P = 0.04$) than the push net (0.5 m; Figure 1). Larval gizzard shad catch rates

TABLE 1.—Comparison of the mean percent of total catch (PTC) and mean density of larval fish (DLF; number/$m^3$), by taxon that were captured from the pelagic zone in push nets (0.5-m mouth) versus small (0.5-m mouth) or large (0.75-m mouth) tow nets and in push nets from the littoral and pelagic zones of 21 Illinois lakes. The ''other'' category includes *Catostomus*, *Etheostoma*, *Fundulus*, and *Morone* spp., as well as yellow perch *Perca flavescens*.

| Gear or habitat | Gizzard shad | | Sunfishes | | Atherinidae | | *Pomoxis* spp. | | Cyprinidae | | Other | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PTC | DLF | PTC | DLF | PTC | DLF | PTC | DLF | PTC | DLF | PTC | DLF |
| **Push net versus 0.5-m tow net, June 1995** | | | | | | | | | | | | |
| Push net | 55.4 | 6.64 | 34.2 | 4.11 | 2.1 | 0.26 | 3.7 | 0.45 | 0.0 | <0.01 | 4.5 | 0.54 |
| Small tow net | 60.2 | 5.24 | 28.0 | 2.44 | 3.0 | 0.26 | 0.5 | 0.04 | 0.0 | 0.00 | 8.2 | 0.71 |
| **Push net versus 0.75-m tow net, July 1995** | | | | | | | | | | | | |
| Push net | 17.4 | 1.57 | 69.8 | 6.28 | 10.7 | 0.96 | 0.4 | 0.04 | 0.7 | 0.06 | 1.0 | 0.09 |
| Large tow net | 24.0 | 2.88 | 74.6 | 8.95 | 1.3 | 0.16 | 0.0 | <0.01 | 0.1 | 0.01 | 0.0 | <0.01 |
| **Push net habitat comparison, May–July 1995** | | | | | | | | | | | | |
| Littoral zone | 24.7 | 6.08 | 73.0 | 17.98 | 1.1 | 0.28 | 0.4 | 0.11 | 0.3 | 0.07 | 0.5 | 0.13 |
| Pelagic zone | 54.2 | 4.81 | 44.8 | 3.97 | 0.2 | 0.02 | 0.5 | 0.05 | 0.1 | 0.01 | 0.2 | 0.01 |

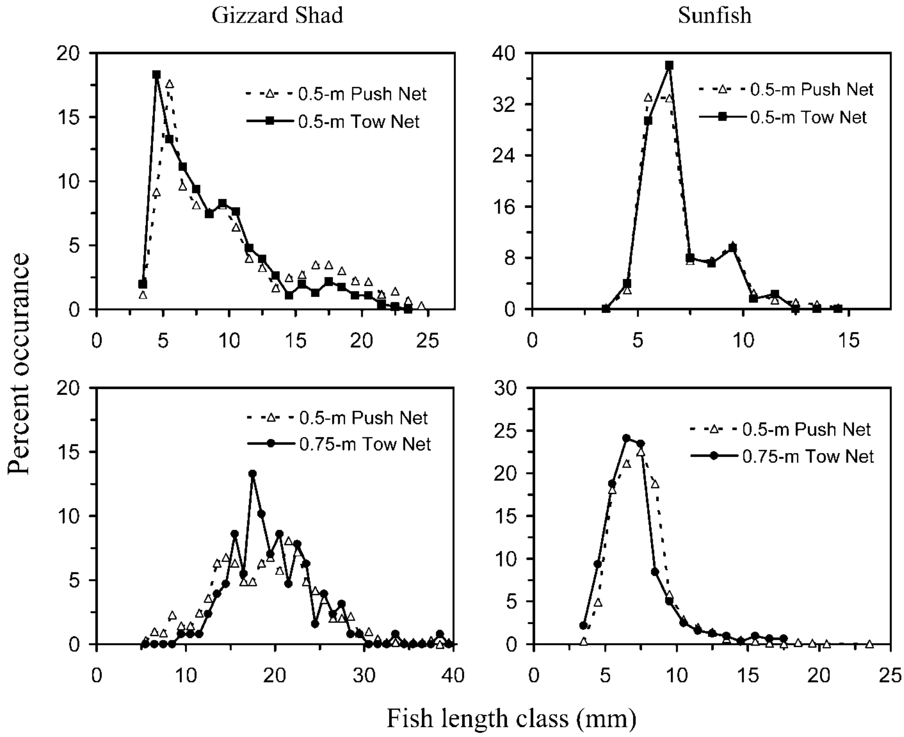


FIGURE 2.—Length frequency distributions (1-mm intervals) for gizzard shad and sunfish collected with three types of gear from pelagic areas of 21 Illinois lakes. The top panels compare the length distributions for push nets (0.5-m mouth) and small tow nets (0.5-m mouth) during June. The bottom panels compare the length distributions for push nets and large tow nets (0.75-m mouth) during July. Fish less than 5 mm were omitted from analyses because the small and large tow nets had different mesh sizes. Lakes where gizzard shad or sunfish were not captured were omitted from the analysis for that species.

were significantly higher ($F_{1,78}$ = 43.17, $P < 0.01$) in both net types during early July than late July. Sunfish catch rates were similar between both time intervals ($F_{1,57}$ = 2.85, $P$ = 0.09). Neither gizzard shad ($F_{1,78}$ = 0.26, $P$ = 0.61) nor sunfish ($F_{1,141}$ = 0.19, $P$ = 0.66) had significant interaction between net size and sample time. Mean sunfish length was significantly longer in the large tow net than in the push net ($F_{1,11}$ = 7.32, $P$ = 0.02; Figure 2); however, this difference was small (mean difference, 0.62 mm). Mean larval gizzard shad lengths were similar between gear types ($F_{1,\,4}$ = 0.31, $P$ = 0.60; Figure 2).

Finally, we compared push net catches in pelagic versus littoral habitats. Littoral samples always had higher catch rates than pelagic samples. The proportion of each taxon captured also varied between habitats (Table 1). Littoral samples had significantly higher larval densities of sunfish ($F_{1,635}$ = 18.16, $P < 0.01$) but not gizzard shad ($F_{1,504}$ = 1.87, $P$ = 0.17; Figure 3). In both habitats, there was a significant sample date effect, peak catches occurring during the second half of May for gizzard shad ($F_{1,504}$ = 72.94, $P < 0.01$) and during the end of June and beginning of July for sunfish ($F_{1,635}$ = 111.49, $P < 0.01$; Figure 3). Neither gizzard shad ($F_{1,504}$ = 0.52, $P$ = 0.76) nor sunfish ($F_{1,635}$ = 0.43, $P$ = 0.83) had significant interactions between sample date and habitat.

## Discussion

The larval fish densities observed in our study are within the range of values previously reported for push nets and tow nets (Storck et al. 1978; Gallagher and Conner 1983; Hale et al. 1995). Previous studies comparing push nets and tow nets have not found consistent differences in the catch of the two designs (Gallagher and Conner 1983; Hale et al. 1995). However, these studies were not controlled comparisons using the same size nets for both the push and towed applications. Our results indicate that bow-mounted push nets have higher larval fish catch rates for some species than traditional towed nets of the same size. These dif-

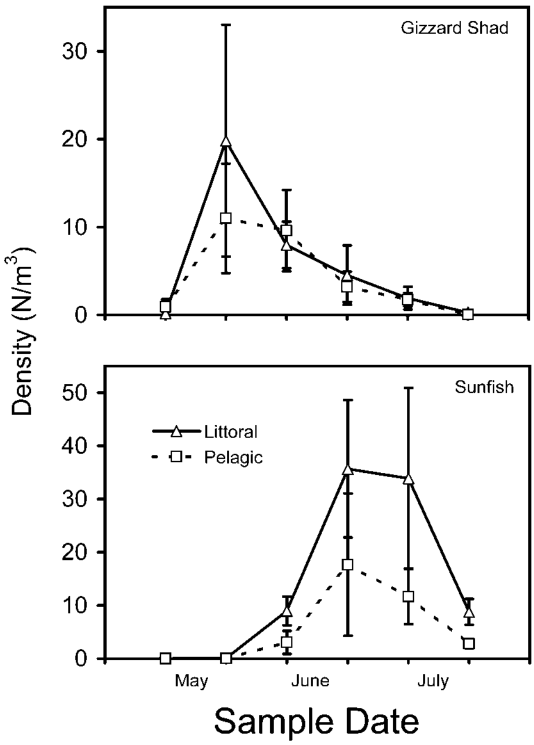


FIGURE 3.—Mean density (number/m$^3$; ±SE) of larval gizzard shad and sunfish sampled via a push net in littoral versus pelagic habitats of 21 Illinois lakes, May to July 1995. Lakes where gizzard shad or sunfish were not captured were omitted from the analysis for that species.

ferences occurred across lakes that varied in a number of abiotic conditions (Claramunt and Wahl 2000). The most effective sampling gear should be chosen to minimize the influence of abiotic variables that can affect the ability of sampling gear to be representative of the population (Bowles et al. 1978). Because larval fish may react to sound and turbulence, gear avoidance may also be reduced by using bow-mounted push nets that reduce the effect from the boat.

Push nets had somewhat lower catch rates for the two most abundant taxa than the large tow nets. This could be due to the larger mouth size or larger mesh size (Isermann et al. 2002) of this tow net. The only differences in fish size occurred for sunfish larvae, but this difference was probably too small to be biologically meaningful (0.62 mm). For some applications, push nets have the ability to capture a wide range of larval fish sizes and can be effective throughout the entire sampling season, replacing the need for large tow nets. Investigators using even larger towed nets (>0.75 m in diameter; e.g., neuston nets) should also consider push nets as a potentially effective gear type.

The push net was also effective for sampling larval fish in littoral habitats. These inshore habitats (<1.0 m deep) are recognized as important fish nursery areas (Breder 1936; Chubb and Liston 1986) but are difficult to sample (Leslie et al. 1983). Several littoral area sampling gears have been developed (larval seines, dip nets, and fry traps), but their catch rates are not easily compared with pelagic ichthyoplankton gears (Leslie et al. 1983; Kelso and Rutherford 1996). Direct comparison between pelagic and littoral larval fish communities has been limited by the lack of an adequate gear to sample both habitats effectively. Comparisons between inshore and offshore areas using the push net indicated there can be large differences in ichthyoplankton communities between these two habitats. Inshore larval fish densities were much higher than offshore densities. Differences in densities may be due to the tendency of the fishes we examined to spawn inshore (Auer 1982). If the early detection of fish larvae is important, sampling should be designed to include spawning areas where larvae first appear (Leslie and Timmins 1992).

In addition to spawning location, other factors may be responsible for the patterns of inshore and offshore larval fish densities that we observed using the push net. These relationships will be important in understanding changes in littoral and pelagic larval fish communities through time (Werner 1967). Furthermore, early life stage migration patterns are not well understood and will probably vary by species (Cole and MacMillan 1984). For example, movement patterns of bluegill larvae are thought to be genetically controlled (Werner and Hall 1988), whereas gizzard shad larvae movements are attributed to active selection of habitats with higher food abundance, lower predation risk, or favorable abiotic conditions (Allen and DeVries 1993). To fully understand causative factors and how these migration patterns relate to larval fish recruitment, a universal sampling gear, such as the push net, is needed to comparatively assess pelagic and littoral larval fish communities.

Traditional towed ichthyoplankton nets have been used in the past because they are easy to deploy and may be more cost-effective. Tow nets may sample better in high winds and waves that would cause push nets mounted to rigid structures to rise above the water surface, albeit we did not encounter such problems. Our results suggest push nets are more efficient and capture more larvae over a wider size range than tow nets. There are also several advantages to being able to use a consistent gear to assess both littoral and pelagic larval fish communities. The ability to compare habitat use of larval fish will be a useful tool for understanding spawning success, larval migration patterns, life stage duration, and ultimately recruitment processes.

## Acknowledgments

We thank K. Eisenbarth, K. Goodwin, K. Schnake, M. Herbert, B. Nerbonne, L. Einfalt, and numerous other individuals associated with the Kaskaskia Biological Station, Illinois Natural History Survey, for help with data collection and analysis. We also thank D. Clapp and P. Hanchin for providing critical review of earlier drafts of the manuscript. Partial funding was provided by Federal Aid in Sport Fish Restoration, Project F-118-R, administered by the Illinois Department of Natural Resources (IDNR). S. Stuewe, D. Austen, M. Conlin, and L. Dunham coordinated activities with IDNR. Additional support was provided by the Center for Aquatic Ecology, Illinois Natural History Survey, and the Department of Animal Sciences, University of Illinois.

## References

Allen, M. S., and D. R. DeVries. 1993. Spatial and temporal heterogeneity of larval shad in a large impoundment. Transactions of the American Fisheries Society 122:1070–1079.

Anderson, M. R., S. J. Fisher, and D. W. Willis. 1998. Relationship between larval and juvenile yellow perch abundance in eastern South Dakota glacial lakes. North American Journal of Fisheries Management 18:989–991.

Auer, N. A. 1982. Identification of larval fishes of the Great Lakes Basin with emphasis on the Lake Michigan drainage. Great Lakes Fishery Commission, Special Publication 82-3, Ann Arbor, Michigan.

Barkley, R. A. 1972. Selectivity of towed-net samplers. Fisheries Bulletin 70:799–820.

Bowles, R. R., J. V. Merriner, and G. C. Grant. 1978. Factors associated with accuracy in sampling fish eggs and larvae. U.S. Fish and Wildlife Service FWS/OBS-78/83.

Breder, C. M. 1936. The reproductive habits of the North American sunfishes (family Centrarchidae). Zoologica (New York) 21:1–48.

Choat, J. H., P. J. Doherty, B. A. Kerrigan, and J. M. Leis. 1993. A comparison of towed nets, purse seine, and light-aggregation devices for sampling larvae and pelagic juveniles of coral reef fishes. Fishery Bulletin 91:195–209.

Chubb, S. L., and C. R. Liston. 1986. Density and distribution of larval fishes in Pentwater Marsh, a coastal wetland on Lake Michigan. Journal of Great Lakes Research 12:332–343.

Claramunt, R. M., and D. H. Wahl. 2000. The effects of abiotic and biotic factors in determining larval fish growth rates: a comparison across species and reservoirs. Transactions of the American Fisheries Society 129:835–851.

Cole, R. A., and J. R. MacMillan. 1984. Sampling larval fish in the littoral zone of western Lake Erie. Journal of Great Lakes Research 10:15–27.

Colton, J. B., Jr., J. R. Green, R. R. Byron, and J. L. Frisella. 1980. Bongo net retention rates as effected by towing speed and mesh size. Canadian Journal of Fisheries and Aquatic Sciences 37:606–623.

Conrow, R., A. V. Zale, and R. W. Gregory. 1990. Distributions and abundances of early life stages of fishes in a Florida lake dominated by aquatic macrophytes. Transactions of the American Fisheries Society 119:521–528.

Gallagher, R. P., and J. V. Conner. 1983. Comparison of two ichthyoplankton sampling gears with notes on microdistribution of fish larvae in a large river. Transactions of the American Fisheries Society 112: 280–285.

Hale, R. S., G. L. Buynak, and J. R. Jackson. 1995. Catch comparisons of surface sampling methods for age-0 gizzard and threadfin shad. North American Journal of Fisheries Management 15:862–870.

Holland-Bartels, L. E., S. K. Littlejohn, and M. L. Huston. 1990. A guide to larval fishes of the upper Mississippi River. U.S. Fish and Wildlife Service, La Crosse, Wisconsin.

Isermann, D. A., P. A. Hanchin, and D. W. Willis. 2002. Comparison of two mesh sizes for collecting larval yellow perch in surface trawls. North American Journal of Fisheries Management 22:585–589.

Jessop, B. M. 1985. Influence of mesh composition, velocity, and run time on the catch and length composition of juvenile alewives (*Alosa pseudoharengus*) and blueback herring (*A. aestivalis*) collected by push net. Canadian Journal of Fisheries and Aquatic Sciences 42:1928–1939.

Kelso, W. E., and D. A. Rutherford. 1996. Collection, preservation, and identification of fish eggs and larvae. Pages 255–302 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Leslie, J. K., J. E. Moore, W. H. Hyatt, and C. A. Timmins. 1983. Seine for sampling larval fish in shallow water. Progressive Fish-Culturist 45:130–131.

Leslie, J. K., and C. A. Timmins. 1992. Enhancement of ecological studies of freshwater larval fish shore sampling. Journal of Applied Ichthyology 8:214–221.

Sammons, S. M., and P. W. Bettoli. 1998. Larval sampling as a fisheries management tool: early detection of year-class strength. North American Journal of Fisheries Management 18:137–143.

SAS Institute. 1999. SAS/STAT user's guide, version 8. SAS Institute, Cary, North .

Storck, T. W., D. W. Dufford, and K. T. Clement. 1978. The distribution of limnetic fish larvae in a flood control reservoir in central Illinois. Transactions of the American Fisheries Society 107:419–424.

Walters, C. J., and J. S. Collie. 1988. Is research on environmental factors useful to fisheries management? Canadian Journal of Fisheries and Aquatic Sciences 45:1848–1854.

Welker, M. T., C. L. Pierce, and D. H. Wahl. 1994. Growth and survival of larval fishes: roles of competition and zooplankton abundance. Transactions of the American Fisheries Society 123:703–717.

Werner, E. E., and D. J. Hall. 1988. Ontogenetic habitat shifts in bluegill: the foraging rate–predation risk trade-off. Ecology 69:1352–1366.

Werner, R. G. 1967. Intralacustrine movements of bluegill fry in Crane Lake, Indiana. Transactions of the American Fisheries Society 96:416–420.