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Comparisons of Catch and Precision of Pop Nets, Push Nets, and Seines for Sampling Larval and Juvenile Yellow Perch

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Abstract.—Abundance estimates of larval and juvenile fish require unbiased and precise sampling techniques. Even if an appropriate sampling technique is chosen, fish abundance estimates can be inaccurate if there is no assessment of the gear precision. Our first objective was to compare catch characteristics of pop nets, push nets, and seines for sampling occurrence, abundance, and size of age-0 yellow perch *Perca flavescens* in shallow habitats with different vegetation densities. The second objective was to estimate the precision (coefficient of variation [CV]) with which each sampling gear measured larval and juvenile yellow perch abundance. Larval fish were collected in May 2003 via pop nets and push nets, and juveniles were collected in July 2003 via pop nets and seines. Significant differences in yellow perch occurrence and abundance were observed between sampling gears and sampling periods. May occurrence and abundance of larval yellow perch were higher for push nets than for pop nets in open-water habitats but were the same in vegetated sites. The seine was the most effective gear for sampling juvenile yellow perch in both sparsely and densely vegetated habitats during July. The average total length of larval yellow perch sampled with pop nets in May was significantly higher than that of fish sampled with push nets. Average total length of juvenile yellow perch in July was significantly higher for seine samples than for pop-net samples. Our results showed that (1) high precision levels can be reached with pop nets and push nets during May sampling of yellow perch larval stages but (2) the precision level is lower in July when pop nets and seines are used to sample juvenile stages. The CV suggests that aggregations of age-0 yellow perch increased between May and July, which has important implications for sampling design.

Quantitative estimates of larval and juvenile fish populations are essential for managing fish stocks and developing new theories on population dynamics (Cyr et al. 1992; Clapp and Dettmers 2004). Habitat utilization by age-0 fish is often complex and heterogeneous, leading to sampling constraints. Sampling heterogeneous habitats might require several fishing gears that have different catch success in terms of species richness, frequency of occurrence, abundance, and size spectrum. Active gears (e.g., bongos, Tucker trawls, and push nets) that are designed to collect age-0 fish in open waters (Pepin and Shears 1997; Wanzenböck et al. 1997) are generally not appropriate for use in shallow, densely vegetated habitats (Bagenal and Nellen 1980; Whiteside and Hatch 1997; Tischler et al. 2000). In contrast, passive gears (e.g., pop nets) are relatively unbiased for sampling age-0 fish in shallow, vegetated waters, and they allow for density estimation (Serafy et al. 1988; Dewey et al. 1989; Dewey 1992); however, the area sampled is small. Habitat with dense vegetation might interfere with efforts to collect fish, bias catch estimates, and lead to an underestimation of their importance as nursery or feeding habitats (Serafy et al. 1988). It might also be necessary to use different sampling gears when comparing the same sites over time because of ontogenetic, morphological, and behavioral changes in the fish (Whiteside et al. 1985;

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Fulford et al. 2006); increased swimming capability with increasing fish size (Tischler et al. 2000); or seasonal changes in vegetation at each site. In this context, knowledge of the catch characteristics of different fishing gears used to sample fish larvae and juveniles is necessary to determine gear complementarity and reliability.

Due to the patchy distribution of age-0 fish and high variance among replicate samples, abundance estimates are often inaccurate even when made by use of the least biased sampling gear (Cyr et al. 1992; Karjalainen et al. 1996). Abundance estimates can thus be useless without any assessment of gear precision. The precision with which age-0 fish density is measured can be estimated as the coefficient of variation (CV; calculated as SE/mean). Although the precision of the push net and purse seine for sampling age-0 fish has been estimated for some ecosystems (Whiteside and Hatch 1997; Tischler et al. 2000), our study is the first to compare the precision of the pop net with that of other sampling gears targeting age-0 yellow perch *Perca flavescens*.

The first objective of our study was to compare the catch characteristics of pop nets, push nets, and seines for measuring occurrence, abundance, and size of age-0 yellow perch in different vegetation densities and during two periods of the growing season (larval versus juvenile stages). The second objective was to estimate the precision with which age-0 yellow perch abundance was measured by each sampling gear and compare precision among gear types.

Methods

Fish sampling and laboratory analyses.—Yellow perch in the Lake Saint-Pierre area (St. Lawrence River, Québec, Canada) were sampled in two shallow wetlands of about 3 km^2 each (Maskinongé Bay: 46°12′N, 72°56′W; Fer à Cheval Bay: 46°09′N, 72°48′W). Lake Saint-Pierre is a large (about 315 km^2), fluvial, shallow (average depth = 3.17 m at mean discharge) system that is extensively covered by macrophytes during summer. Submerged vegetation is predominately composed of water celery *Vallisneria americana*, Richardson's pondweed *Potamogeton richardsonii*, and sago pondweed *Potamogeton pectinatus*. The bays of Lake Saint-Pierre are also colonized by emergent species, such as bulrush *Schoenoplectus lacustris*, broadleaf arrowhead *Sagittaria latifolia*, and broadfruit bur-reed *Sparganium eurycarpum*. Plant bed distribution is patchy, and the above-ground dry biomass of the sampled sites ranged from approximately 0 to 250 g/m^2 (see Frenette et al. [2003] and Vis et al. [2003] for detailed descriptions of the study site). At each sampling site, depth was measured and vegetation density was estimated according to a semiquantitative scale (0 = open water; 1 = sparse vegetation; 2 = dense vegetation, bottom visible; 3 = very dense vegetation, bottom not visible, but open water present at the surface; and 4 = extremely dense vegetation, bottom not visible, and no open water at the surface). Vegetation density was visually evaluated inside the pop net, inside the area swept by the seine, and along the transect sampled with the push net. Pictures were also taken at each sampling site to reduce observer-related bias.

Fish larvae were collected in spring 2003 (26 May–9 June; hereafter, May), and juveniles were collected during summer of the same year (2–17 July; hereafter, July). Sampling gears were chosen according to their a priori effectiveness in capturing age-0 fish (which exhibit fast growth and ontogenetic development) and sampling habitats with variable vegetation density. The push net is inadequate for larvae greater than 30 mm total length (TL; Tischler et al. 2000); the seine can be labor intensive, and the catch of small posthatch larvae can be biased (Whiteside and Hatch 1997; Tischler et al. 2000). Age-0 yellow perch generally reach the limiting size of 30 mm in early July (Tischler et al. 2000; Tardif et al. 2005); thus, we compared the pop net with the push net in May and the pop net with the seine in July. Fish were collected during daylight at both sites according to a stratified sampling procedure, where each site was divided into three depth strata (0.50–0.75, 0.75–1.00, and 1.00–1.25 m). Within each stratum, replicate samples were collected at randomly selected locations using the pop net (7–16 replicates in May; 9–22 replicates in July), push net (4–10 replicates in May), and seine (5–10 replicates in July). To avoid biases due to temporal and spatial variations, the sampling techniques were used simultaneously in the same depth strata.

Each pop net consisted of two frames (4 × 4 m) of rigid, 5-cm-diameter polyvinyl chloride pipe; one frame floated with trapped air, and one frame was weighted with steel rods and anchored to the bottom (Serafy et al. 1988; Dewey et al. 1989). Netting (1.5 m high, 1.2-mm mesh) linked the two frames; the top and bottom were open (no netting). The upper and lower frames were tied together and held to the bottom of the sampling site. After the pop net was set, it was left undisturbed for 12 h to allow fish to recolonize the site. At the end of the recolonization period, a pin-key attached to a trip cord (see Figure 1a of Morgan et al. [1988]) was used to release the buoyant frame from the ballast frame. Fish confined in the pop net were collected using a small stick seine (4 m long, 1.5 m high) with the same mesh size (1.2 mm). Vegetation inside the pop net was removed manually if it was too

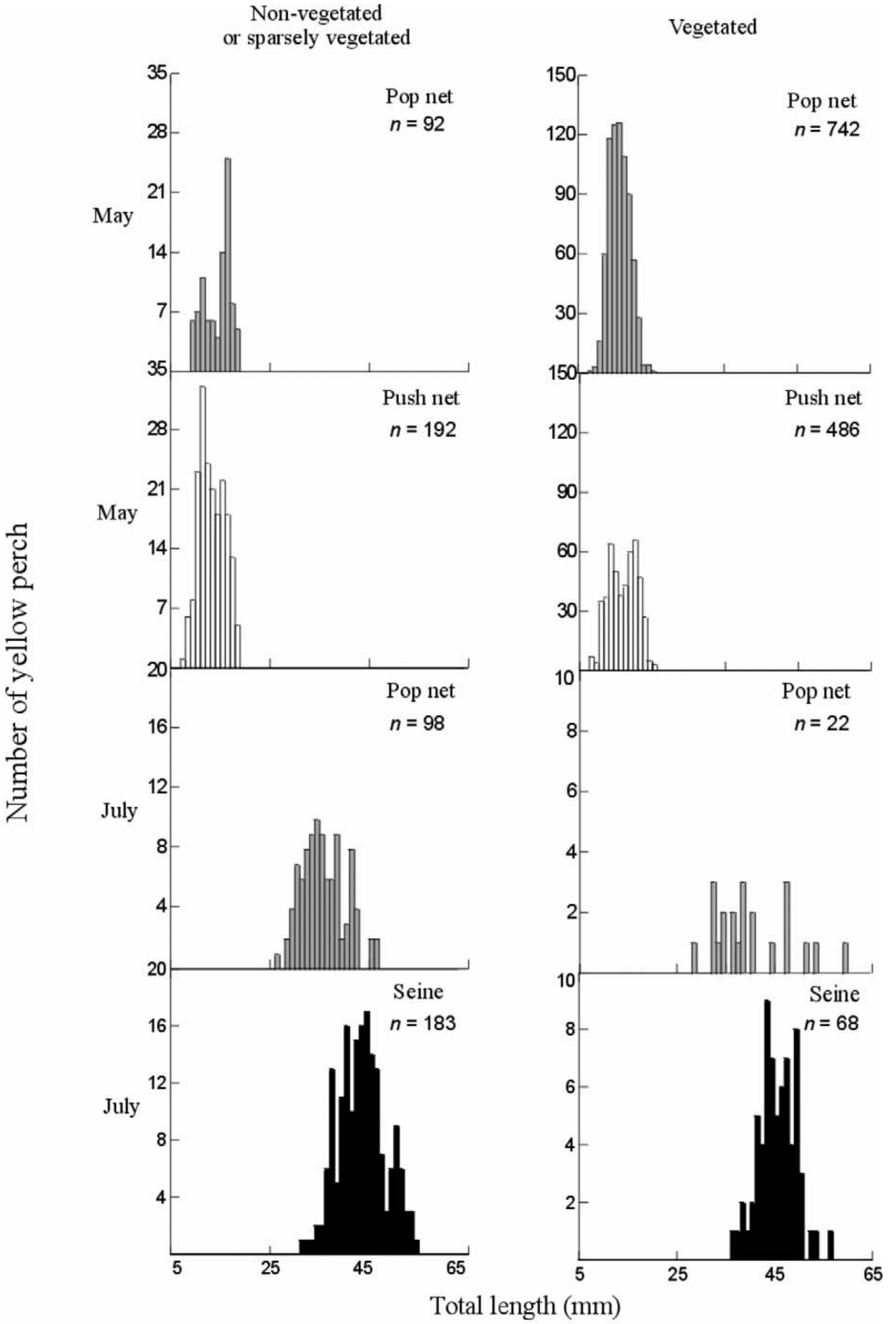

FIGURE 1.—Length frequency distributions of larval and juvenile (age-0) yellow perch captured in nonvegetated (May) or sparsely vegetated habitat (July) and vegetated habitat (May and July) within two shallow wetlands of the Lake Saint-Pierre system, Québec (N = number of measured fish). Larvae were sampled by use of a pop net and push net in May, and juveniles were sampled by use of a pop net and seine in July; the *y*-axis scale differs between May and July samples.

abundant. Four hauls were collected within each trap (Dewey 1992). At the end of each sweep, the leadline was rapidly pulled to the surface and fish were collected using a sieve (0.355-mm mesh). The water volumes sampled using the pop net ranged between 7.8 and 18.9 m^3 (12.2 ± 2.7 m^3, mean ± SE) depending on the depth of the water column.

The push net (Kelso and Rutherford 1996; Wanzenböck et al. 1997; Tischler et al. 2000) consisted of three plankton nets (1.5 m long, 500-μm mesh, opening = 0.40 × 0.40 m) mounted on an adjustable steel frame placed in front of the boat so that three depths of the water column were sampled simultaneously. The nets were pushed at a rate of approximately 1 m/s along 50-m transects (sometimes, transects were 25 m to avoid clogging by aquatic vegetation). The number of vertical strata sampled (0.40 m each) was adjusted according to the maximum depth at each site (i.e., one stratum for maximum depth < 0.90 m, two strata for 0.90–1.30 m, and three strata for >1.30 m). The volume sampled using the push net, calculated by multiplying the net opening by transect length, ranged between 4.0 and 16.0 m^3 (9.7 ± 4.9 m^3, mean ± SE).

Seine samples were collected with a beach seine (12.5 × 4 m, 3.2-mm stretched mesh, floats on the top line and a lead-core bottom line). All sampling sites were offshore and were carefully approached by boat. The seine was deployed in a circle by wading, and the boat was used as the starting and ending point. From the boat, the bottom line was pulled from both ends of the net to enclose the sample. Estimates of sample volume, based on the theoretical cylinder of water enclosed by the net (i.e., 122.7 m^2 × water depth), ranged between 66.3 and 147.2 m^3 (109.1 ± 19.6 m^3, mean ± SE).

All captured age-0 fish were exposed to a lethal dose of eugenol and then were preserved in 10% formalin or 75% ethanol (for further analyses not presented here). In the laboratory, fish were identified to species (Scott and Crossman 1973; Auer 1982), weighed (±0.01 mg), and measured (±0.01 mm TL); larval TL was measured with an ocular micrometer mounted on a dissecting microscope, and juvenile TL was measured with a digital caliper. Because of the effect of preservatives on fish length, we used regression equations to convert the TLs of preserved fish to measurements approximating those of fresh specimens (Paradis et al. 2007).

Catch comparisons.—Occurrence, abundance, and average TL of yellow perch captured in May (pop net and push net) and July (pop net and seine) were compared between gears and between habitats with different vegetation densities (low and high). Samples from both study sites were combined according to vegetation density (nonvegetated and vegetated sites in May; sparsely and densely vegetated sites in July). Because of the presence of fast-growing macrophytes in the littoral zone, nonvegetated sites were not found in July.

Abundance of age-0 fish was expressed in terms of catch per unit effort (CPUE) for the different gears and was standardized to the number of fish per 100 m^3 of sampled water volume. The vertical strata sampled with the push net were pooled and considered as one unit of effort (Tischler et al. 2000). Captures of yellow perch were compared between sampling gears with a chi-square test for independent samples. Yellow perch abundance was nonnormally distributed, and there were a high number of zeros. Therefore, the comparison of CPUE between gear types was performed using a Mann–Whitney *U*-test for independent samples (Pepin and Shears 1997; Tischler et al. 2000). The average TLs of larval (May) and juvenile (July) yellow perch sampled in various vegetation densities were compared among the three gear types using an analysis of variance (ANOVA).

Precision.—Variability in larval and juvenile yellow perch CPUE was used as an index of gear precision. First, the relationship between variance and average density was computed for each gear type (Downing et al. 1987). Samples from each depth stratum at each study site were used as replicates. As was suggested by Karjalainen et al. (1996), the sampled volume was included in the relationship to improve the fit of the predicted variance:

$$\log_{10} s^2 = a + b \log_{10}(\text{mean CPUE}) + c \log_{10} V, \quad (1)$$

where s^2 is the variance, V is sampled volume, a is the intercept in a multiple regression model, b is the slope of mean CPUE, and c is the slope of sample volume. Second, the effect of the three sampling techniques on the variance of yellow perch CPUE was assessed with an analysis of covariance (ANCOVA) using $\log_{10} s^2$ as a function of $\log_{10}$(mean CPUE) (Pepin and Shears 1997; Tischler et al. 2000).

Equation (1) was used to compute the levels of precision in abundance estimates of age-0 yellow perch (Downing et al. 1987). To do so, the precision of age-0 fish abundance was estimated as the CV (Cyr et al. 1992). Sampling gears that produce the most precise estimates of abundance will have the lowest CV (Cyr et al. 1992). The CV is a function of the average number of yellow perch larvae (mean CPUE), the interreplicate s^2, the number of replicates (n), and V (Downing et al. 1987):

$$\text{CV} = \left\{ n \times \left[a \times (\text{mean CPUE})^{(b-2)} \times V^c \right]^{-1} \right\}^{-0.5}, \quad (2)$$

where a, b, and c are the regression coefficients from

TABLE 1.—Catches of age-0 yellow perch sampled during 2003 in two shallow wetlands of the Lake Saint-Pierre system, Québec; larvae (7.2–20.4 mm) were sampled with pop nets and push nets in nonvegetated and vegetated sites during May, and juveniles (14.9–66.6 mm) were sampled with pop nets and seines in sparsely and densely vegetated sites during July. Significance ($P < 0.05$) of comparisons between sampling gears is presented (chi-square test for occurrence data; Mann–Whitney U-test for catch per unit effort [CPUE], fish/100 m^3).

Habitat type	Sampling gear	Sample size (*N*)	Occurrence			CPUE (fish/100 m^3)			
			Frequency (%)	Chi-square	*P*	Range	Median	*U*	*P*
Larvae sampled in May									
Nonvegetated	Pop net	18	44.4	4.21	0.040	0–233	0.0	99.0	0.040
	Push net	18	77.8			0–1,593	31.3		
Vegetated	Pop net	50	64.0	0.45	0.504	0–6,893	30.3	583.0	0.214
	Push net	28	71.4			0–31,325	137.5		
Juveniles sampled in July									
Sparsely vegetated	Pop net	61	23.0	10.733	0.001	0–477	0.0	447.0	0.014
	Seine	21	61.9			0–46	1.4		
Densely vegetated	Pop net	28	42.9	4.077	0.043	0–78	0.0	119.0	0.462
	Seine	10	80.0			0–22	3.3		

equation (1). All computations using the regression coefficients of equation (1) were corrected after being transformed from the logarithmic scale to the arithmetic scale (Sprugel 1983). Statistical analyses were performed using SYSTAT version 10.2 (Wilkinson 2002).

Results

Catch Comparisons

In May, estimates of the frequency of occurrence and abundance of larval yellow perch sampled in nonvegetated habitats were significantly higher for push nets than for pop nets; estimates for vegetated sites did not differ between gears (Table 1). In July, the seine was more effective than the pop net for estimating occurrence of juvenile yellow perch in both vegetation densities. The seine was also more effective than the pop net for estimating juvenile abundance in sparsely vegetated habitats; no differences between gears were observed for densely vegetated sites.

Length comparisons with ANOVA revealed that in May, the average TL of larval yellow perch sampled with the pop net (14.51 ± 0.27 mm, mean ± SE) was significantly higher than the TL of fish sampled with the push net (13.32 ± 0.19 mm) in nonvegetated sites ($F = 12.96$; df = 1, 282; $P < 0.001$). Although the effect was small and not necessarily biologically meaningful, differences were also observed between larval TLs sampled with the pop net (13.49 ± 0.09 mm) and push net (13.99 ± 0.11 mm) in vegetated habitats ($F = 12.60$; df = 1, 1,226; $P < 0.001$; Figure 1). In July, the average TL of juveniles sampled using the seine (43.73 ± 0.36 mm) was significantly higher than that of juveniles sampled with the pop net (35.77 ± 0.49 mm) in sparsely vegetated habitat (45.52 ± 0.62 mm; $F = 170.94$; df = 1, 279; $P < 0.001$) and in densely vegetated habitat (40.30 ± 1.09 mm; $F = 17.30$; df = 1, 88; $P < 0.001$).

Precision

The relationship between s^2 and mean CPUE was significant for pop nets ($t = 17.16$, $P < 0.001$; $R^2 = 0.99$) and push nets ($t = 49.34$, $P < 0.001$; $R^2 = 0.99$) in May ($R^2 = 0.99$ for both gear types) and for pop nets ($t = 13.06$, $P < 0.001$; $R^2 = 0.98$) and seines ($t = 5.82$, $P < 0.05$, $R^2 = 0.92$) in July (Figure 2). For larvae sampled in May, the ANCOVA revealed that the slope of the relationship between s^2 and mean CPUE was significantly higher for push nets than for pop nets ($F = 12.70$, $P < 0.01$; Figure 2a). For juveniles sampled in July, the intercept of the relationship between s^2 and mean CPUE was significantly higher for pop nets than for seines ($F = 30.39$, $P < 0.01$; Figure 2b). Precision was similar for push nets and pop nets in May and was higher for seines than for pop nets in July (Table 2). Furthermore, precision of all sampling gears was higher in May than in July (Table 2).

Discussion

Pop Net versus Push Net

The occurrence and abundance of larval yellow perch were higher for the push net than for the pop net in open-water habitats, but estimates were the same between gears in vegetated sites. Although the two gears sampled a comparable volume of water, the push net covered a larger area (20 m^2) than the pop net (16 m^2) and sampled a greater variety of habitats. Enclosure traps like pop nets are known to be somewhat biased in that they usually underestimate fish density (Jacobsen and Kushlan 1987). This lower efficiency is explained by the reduced effective sampling area of the enclosure trap, which is induced

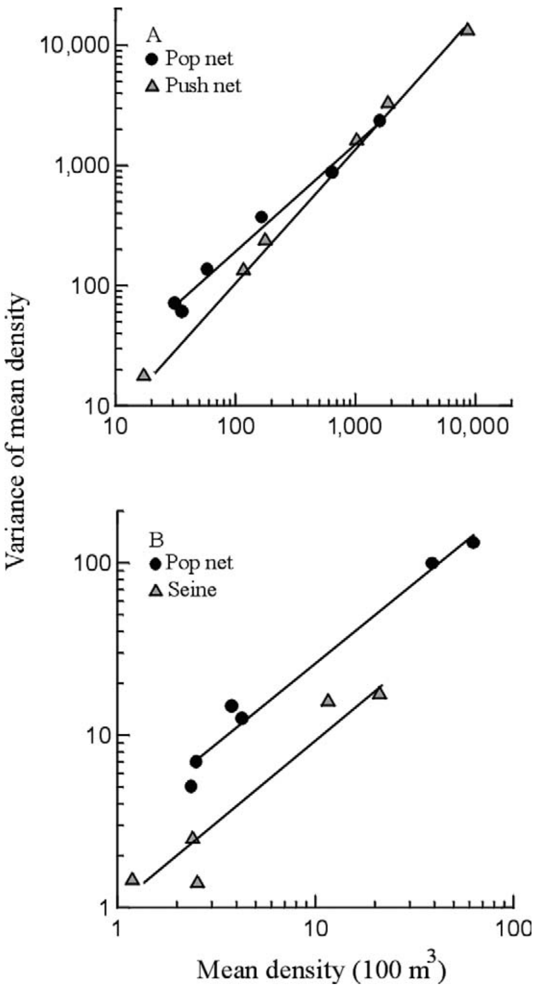

FIGURE 2.—Relationship between the variance of density (catch per unit effort; fish/100 m^3) and the mean density of age-0 yellow perch sampled in two shallow wetlands of the Lake Saint-Pierre system, Québec, for a comparison of gear types: **(A)** pop net and push net in May 2003 (larvae) and **(B)** pop net and seine in July 2003 (juveniles).

by the edge effect of the trap sides (Jacobsen and Kushlan 1987). In our study, the effective sampling area of the push net was probably higher than that of the pop net, which could explain the higher catches in open-water habitats. In vegetated sites, where clogging is known to reduce the efficiency of filtering devices, the effective sampling area was probably similar between sampling gears, leading to comparable larval catch characteristics. Although the accuracy of the push net in open-water and pelagic habitats has been demonstrated (Wanzenböck et al. 1997; Tischler et al. 2000), the efficiency of the push net for sampling fish larvae in shallow, vegetated habitats relative to that of a specialized sampling gear like the pop net had not been previously documented.

The difference in mean larval TL between samples from the pop net and push net at vegetated habitats was small (0.5 mm), and statistical differences could be an artifact of the high number of observations (742 larvae in the pop net; 486 larvae in the push net). However, the 1.2-mm difference in mean larval TL at non-vegetated sites (pop net TL > push net TL) is biologically meaningful and suggests that the push net is size selective in some habitats. The difference in mean TL at nonvegetated sites is probably not explained by differences in gear mesh size (500 μm for the push net; 1,200 μm for the pop net). Isermann et al. (2002) showed that surface trawls with 500- and 1,000-μm mesh sizes gave similar results in terms of larval yellow perch abundance and size characteristics. Because the ability of age-0 fish to avoid pushed or towed nets increases exponentially with body length (Tischler et al. 2000), the size selectivity of the push net relative to the pop net is more likely attributable to gear avoidance in open-water habitats. Tischler et al. (2000) illustrated the size selectivity of the push net for yellow perch larger than 30 mm TL. Our study documents push-net size selectivity for 20-mm TL and smaller yellow perch and indicates that the size selectivity of a given sampling gear should be carefully

TABLE 2.—Precision (coefficient of variation [CV]; see equation 2) of sampling gear and parameters (mean ± SE) of multiple regression models describing the catch of age-0 yellow perch (equation 1; a = intercept; b = slope of mean catch per unit effort, fish/100 m^3; c = slope of sampled water volume, m^3) in two shallow wetlands of the Lake Saint-Pierre system, Québec, 2003. Larvae were sampled by use of a pop net and push net in May, and juveniles were sampled by use of a pop net and seine in July.

Sampling gear	N	a	b	c	R^2	CV
May samples: larvae						
Pop net	6	1.65 ± 0.42	0.79 ± 0.05	−0.44 ± 0.16	0.996	0.02
Push net	6	−0.34 ± 0.15	1.10 ± 0.02	0.12 ± 0.06	0.999	0.01
July samples: juveniles						
Pop net	6	−0.66 ± 0.45	0.97 ± 0.05	0.49 ± 0.19	0.993	0.24
Seine	5	−0.77 ± 2.08	0.98 ± 0.23	0.27 ± 0.76	0.924	0.20

considered when comparing length distributions obtained with different sampling techniques.

Variation among replicate samples of yellow perch larvae was relatively low for both the pop net (CV = 0.02) and the push net (CV = 0.01). However, the significantly steeper slope of the relationship between s^2 and mean CPUE for the push net suggests that it was more precise than the pop net when mean larval abundance was low (Figure 2a). The higher precision of the push net indicates that less sampling effort is required to reach comparable abundance estimates. Although it has been described as an effective sampling gear (Serafy et al. 1988; Dewey et al. 1989; Dewey 1992), the pop net was not more efficient than the push net for sampling yellow perch, even in vegetated habitats.

Pop Net versus Seine

For juvenile yellow perch, the seine was more efficient than the pop net in terms of occurrence, abundance, and precision, even in densely vegetated habitats. The high efficiency of the seine in sampling juveniles could be explained by the fact that it sampled a large area. Furthermore, the difficulty in operating the pop net in July might have contributed to its lower efficiency. This reduced efficiency and escapement effect could explain why the mean juvenile TL was lower for the pop net than for the seine. In July, mats of filamentous algae covered the water surface, slowing the movement of the pop net's upper frame to the surface. Although the pop net was designed and presented as an effective technique for collecting age-0 fish in vegetated habitats (Serafy et al. 1988; Dewey et al. 1989; Dewey 1992), our results suggest that its efficiency is limited at very high vegetation densities. The higher efficiency of the seine relative to the pop net contrasts with the results of Serafy et al. (1988), who showed that pop nets had greater efficiency than seines in areas of dense, submerged macrophytes. Dewey et al. (1989) found inconsistencies in catch between the two gears in vegetated and nonvegetated sites; those authors reported that the seine was more efficient than the pop net in nonvegetated sites. The study of Serafy et al. (1988) did not involve a rigorous comparison, as there were just two replicates; the study of Dewey et al. (1989) included a seasonal effect (fish were caught from May to October) that might have interfered with their analyses.

Precision

In addition to the importance of choosing an accurate (unbiased) sampling technique, the precision level is especially important because the majority of the published larval fish density estimates have low precision (i.e., high CVs; Cyr et al. 1992). A CV of no more than 0.2 (i.e., 20% of the mean) has been suggested as essential for observing significant differences in mean larval fish density (Cyr et al. 1992). Our results for yellow perch indicate that this precision level can be reached with the pop net and push net in May but is more difficult to attain during pop-net and seine sampling of juveniles in July because of the decrease in mean age-0 abundance over the course of the season. The increased difficulty of catching age-0 yellow perch was reflected by the increased variability in abundance estimates, as measured by the CV. The precision of the pop net (CV = 0.24) and seine (CV = 0.20) in July was lower than that of the pop net (CV = 0.02) and push net (CV = 0.01) in May. During larval stages, age-0 yellow perch were abundant and evenly distributed in the environment. Later in the growing season, after fin and lateral line development was completed, yellow perch were less abundant and exhibited a more-patchy distribution. The decreasing abundance of age-0 yellow perch (and the European perch *Perca fluviatilis*) throughout the summer has been reported in other studies (Karjalainen et al. 1996; Whiteside and Hatch 1997; Tischler et al. 2000). Concomitant effects of mortality, habitat shift, and larval aggregation appear to be the most probable explanations (Coles 1981; Post and McQueen 1988; Tischler et al. 2000). Because of the decreasing abundance of age-0 yellow perch throughout the growing season, more replicates are needed to keep the CV of density estimates at or below the suggested level of 0.2. However, a CV of 0.2 may or may not be adequate to observe a significant difference between mean densities, depending upon the magnitude of the difference that must be discerned; important guidelines for optimizing sampling designs to test specific hypotheses are provided by Cyr et al. (1992).

Implications for Sampling Age-0 Yellow Perch

The design of an effective program for sampling larval and juvenile fish depends on the study objectives and the limits of the fishing gears. This is particularly true when fish abundance must be monitored over time, because complications arise with changes in habitat structure (e.g., vegetation density) and changes in fish morphology, swimming ability, behavior, and spatial distribution (Whiteside et al. 1985; Fulford et al. 2006). Each sampling technique has its own advantages and disadvantages, and rarely does a single gear achieve efficient and representative sampling across different conditions. To overcome the limitation of each sampling gear and to sample all usable habitats, the combined use of several techniques is recommended (Tischler et al. 2000).

The pop net can be used during the entire growing season in a variety of shallow habitats (0.5–1.3 m); this gear type is suitable for sampling age-0 fish, allows for estimation of density, and is adequate for relating fish catch to habitat characteristics. Furthermore, the pop net can be modified to sample fish in deeper waters (Morgan et al. 1988). In our study, pop-net or push-net sampling required three persons for field operations; however, the push net was faster, easier to use, and less cumbersome than the pop net. Due to its higher efficiency and precision in both vegetated and nonvegetated habitats, the push net appears to be the most appropriate for catching newly hatched larvae in littoral and pelagic zones (Claramunt et al. 2005). The push net also has the advantage of simultaneously sampling several depth strata, thus providing details about the vertical distribution of larvae (Post and McQueen 1988). The push net used in this study (opening = 0.40 × 0.40 m) appeared to be adequate for sampling young stages of yellow perch. Later in the growing season, when yellow perch larvae exceed 20 mm TL, the opening of the push-net system should be enlarged or the push net should be replaced with a gear type that is less size selective. The seine appears to be well suited for collecting age-0 yellow perch in a great variety of habitats, including densely vegetated ones, but the efficiency of the seine varies with the structure of the littoral zone. Physical obstructions, such as rocks, logs, branches, and some species of macrophytes, prevent sampling of the entire water column; therefore, abundance estimates should be corrected in these habitats (Pierce et al. 1990). The guidelines we present here are intended for researchers who need to establish a sampling strategy that leads to reliable abundance estimates, either for specific studies on habitat selection by age-0 yellow perch or for annual recruitment monitoring.

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