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Evaluation of plankton surface pushnets and oblique tows for comparing the catch of diadromous larval fish

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Abstract

A bow-mounted surface pushnet and an obliquely towed plankton net were compared to evaluate gear efficiency and effectiveness in collecting larval fishes under daytime and nighttime conditions. The diadromous species targeted were striped bass *Morone saxatilis*, white perch, *Morone americana*, and river herring *Alosa* sp. We sampled the lower Roanoke River, North Carolina, from March through June of 2002 and 2003. Striped bass, white perch and river herring represented over 90% of the larvae collected during the study period. Mean larval densities (number/100 m^3) were 63.4 for striped bass, 26.4 for river herring, and 17.7 for white perch. Striped bass larval densities were significantly higher in the surface pushnet for both years ($P \leq 0.05$). In 2002, white perch mean larval density was significantly higher at night in the surface pushnet samples, but in 2003 there were no differences between day and night samples. River herring mean densities were significantly higher in the surface pushnets for both years, but showed no clear patterns between day and night samples. Larger larvae were consistently collected in the surface pushnets for all species. Overall, the surface pushnet was easier to operate. The pushnet was mounted on the bow of a small jon boat and required less specialized gear and fewer personnel than oblique sampling. The method also allows for sampling in shallow water or vegetated habitats. Because larvae were significantly larger in the surface samples, using surface pushnets may not allow for detection of the smaller-sized larvae therefore underestimating the abundance of smaller fish. Depending on the question being asked, we recommend that sampling programs should use both gear types to reduce any gear biases.

Keywords: Ichthyoplankton; Striped bass; White perch; River herring

1. Introduction

Sampling planktonic larval fishes is a method used to develop an index of stock abundance and is often used as a management tool to estimate reproduction and year-class strength (Uphoff, 1989; Sammons and Bettoli, 1998). Investigating the early life histories and population dynamics of larval and juvenile fishes is important because year-class strength is established during these early stages (Cushing, 1990). A monitoring program for larval distribution, growth, timing and location of spawning, and mortality provides information on recruitment dynamics (Castro and Hernandez, 2002). Understanding the underlying principles that control recruitment and year-class strength are required for effective fisheries management at the species level.

Estimates of abundance and size distributions of larval fish are important in studying early life histories of fish. Traditionally, assessments are based on field collections using a variety of types, sizes, and configurations of plankton nets. Interpretation of abundance estimates may depend on the strengths and weaknesses of the collection gear. These may affect the diversity of the catch as well as the size distribution. Plankton nets can be deployed and towed either behind or beside a vessel, or mounted to a fixed platform to push the net through the water. The gear selected and the methods used are assumed to provide samples representative of the fish assemblage and the relative abundances of the constituents, but each gear type has strengths and weaknesses that affect the diversity of the catch as well as fish size distribution.

Understanding the strengths and weaknesses of the gear will govern the interpretation of abundance estimates. Larval fish patchiness, diel patterns, and vertical distribution patterns vary among species (Power, 1984; Hare and Govoni, 2005). The question of where and when to sample, and what type of gear to use, may depend on the species of interest. *A priori* knowledge of

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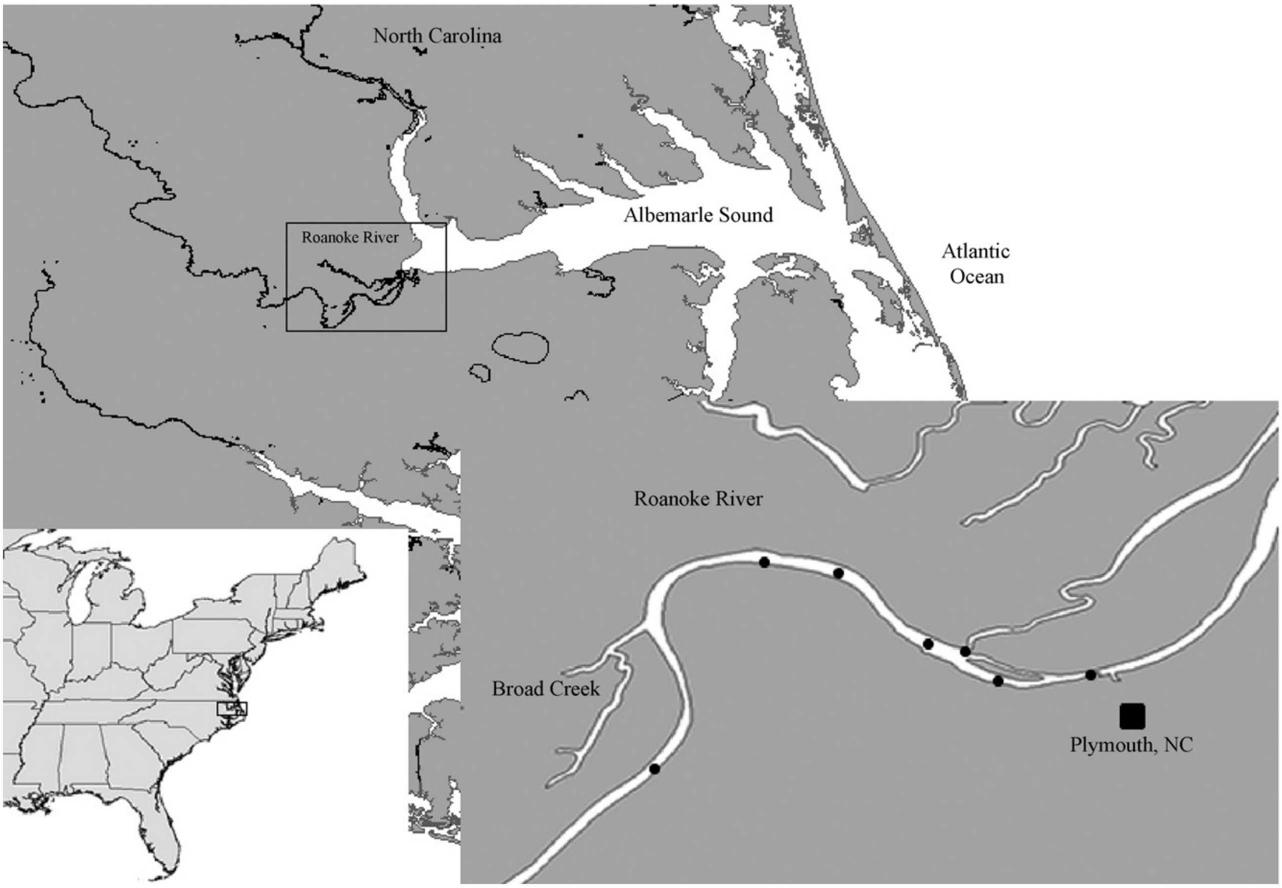

Fig. 1. Map of sampling stations (closed circles) in lower Roanoke River, North Carolina.

the vertical and diel distributions of larval fishes may be species specific; however, in most cases variation in the distribution and behavior of fish is often unknown by the scientist and is the subject of the research. Thus, if the sampling objective is to target a particular species of larvae, then a single sampling method may suffice. If the goal is to examine several larval species or a fish assemblage, then more than one sampling strategy may be required.

Bow mounted pushnets (Kriete and Loesch, 1980; Gallagher and Conner, 1983) and obliquely towed plankton nets (McGovern and Olney, 1996) are commonly used to sample ichthyoplankton. To determine whether larval catch differed between gear types we compared larval density estimates of three common diadromous fishes along the U.S. Atlantic coastline – river herring *Alosa* sp., white perch *Morone americana*, and striped bass *Morone saxatilis* – collected using a bow-mounted surface pushnet and obliquely towed plankton nets. We also compared the mean length of larval fishes between the two sampling gear types and between day and night (diel) samples. We hypothesized that the type of gear used would significantly affect larval abundance and length estimates.

2. Methods

Larval fish were collected approximately twice each week from March through June of 2002 and 2003 in the lower Roanoke River, North Carolina (Fig. 1: River kilometers 9.6–22.4). The fish community sampled was diverse with diadromous species including striped bass, white perch, American shad *Alosa sapidissima*, hickory shad *Alosa mediocris*, alewife *Alosa pseudoharengus*, blueback herring *Alosa aestivalis*, and American eel *Anguilla rostrata* dominating the springtime ichthyoplankton (Rulifson and Overton, 2005). Larvae of resident species from the Centrarchidae, Cyprinidae, and Ictaluridae were present but not targeted in this study.

Seven stations were sampled from pelagic areas in the river channel during the day and at night starting 45 min after sunset. Secchi visibility (cm) was measured at each station. Two types of plankton net configurations were used to collect larvae: (1) paired conical nets towed behind a 6.4-m boat equipped with an inboard engine and (2) paired push nets supported from a mount on the bow of a 4.8-m boat equipped with an outboard engine. The paired conical nets were 0.5 m in diameter constructed of 505-μm nitex mesh with a tail-to-mouth ratio of 5:1. These nets were towed against the current for 6 min in an oblique manner (i.e., raising the nets through the water column during the tow). The paired push nets were 0.5-m^2 and constructed of 505-μm nitex mesh with a tail to mouth ratio of 5:1. The nets were connected to an aluminum frame mounted on the bow of the boat and the nets could be lowered to sample 0.5-m below the surface. The surface nets were pushed for two minutes against the current to prevent the clogging of the nets with floating debris. At each station samples from both gear types were collected within 30 min of each other. Each net was equipped with a flowmeter mounted inside the mouth of the net to estimate the volume of water filtered. The mean volume of water sampled and sampling speeds were 313.3 m^3 (S.E. ± 0.592) and 1.11 m/s (S.E. ± 0.002) for oblique tows, and 65.5 m^3 (S.E. ± 0.540) and 1.28 m/s (S.E. ± 0.007) for surface pushnets. Tow speeds ranged from 1.06 to 1.29 m/s and mean volume of water sampled ranged from 65 to 299 m^3. Catches from the paired nets were summed together and we standardized the catch to density (number of larvae/100 m^3).

Samples were preserved in 10% formalin containing rose bengal dye. Larvae were separated from debris, counted, and identified (Lippson and Moran, 1974; Auer, 1982). Up to 10 larvae from each net were measured to the nearest 0.01 mm (Standard-Notocord Length). The four alosines inhabiting the Roanoke River were treated as groups. Because of the difficulty in differentiating between alewife and blueback larvae (Sismour, 1994), we grouped these species as “river herring”. We separated this river herring group from other alosines based on size-specific characteristics, mainly on the size at hatch. The hatch size of hickory shad (ca. 5.9 mm) and American shad (ca. 10.0 mm) is larger than the hatch size of alewife and blueback herring (ca. 3.5 mm). The yolk is also retained in hickory shad until about 7.0 and 12.0 mm in American shad and 6.0 mm in the other alosines.

A repeated measures analysis of variance (ANOVA) was used to compare monthly larval density (number/100 m^3) for each year, with density or length as the dependent variable and diel period, gear type (oblique and surface), and station as class variables, and the sampling dates were treated as the time variable (Proc Mixed; SAS Institute, 2000). Data were $\log_{10}$ transformed to homogenize the variances. A multiple comparison procedure (LSMEANS; SAS Institute, 2000) was used to separate means following significance.

3. Results

The three target species groups comprised over 90% of the larvae collected. Striped bass represented 54.4% of the catch, and river herring and white perch represented 31.8% and 13.7% of the total catch, respectively. Mean larval density was 26.4/100 m^3 for river herring, 63.4/100 m^3 for striped bass, and 17.7/100 m^3 for white perch. Secchi disk transparency values were 1.07 m (±0.40S.E.) and 0.66 m (±0.01S.E.) in 2002 and 2003, respectively.

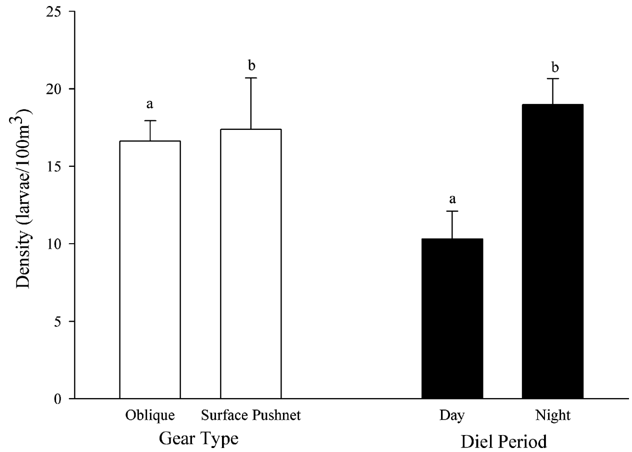

Fig. 2. Mean (±1S.E.) density (number/100 m^3) of white perch collected in 2002 in oblique tows and surface pushnets and in day and night in lower Roanoke River, North Carolina, USA. Vertical bars with the same letter are not significantly different ($P > 0.05$).

3.1. White perch

The gear type (ANOVA: $F_{1,235} = 4.93$; $P = 0.0274$) and diel period (ANOVA: $F_{1,235} = 19.06$; $P < 0.0001$) were significant in 2002. Mean density in the surface pushnets was higher than density in the oblique tows (LSMEANS: $P = 0.0274$; Fig. 2) and higher in the samples collected at night than during the day (LSMEANS: $P < 0.0001$; Fig. 2). In 2003, there was no difference in mean density between day and night samples (ANOVA: $F_{1,235} = 0.04$; $P = 0.8416$). However, gear type had a significant effect (ANOVA: $F_{1,221} = 6.46$; $P = 0.0117$) where the mean density was three times higher in the surface pushnets than in the oblique tows (LSMEANS: $P = 0.0117$). The mean length of white perch larvae in 2002 did not differ between gear type (ANOVA: $F_{1,236} = 1.60$; $P = 0.2074$) or diel period (ANOVA: $F_{1,236} = 1.98$; $P = 0.1606$). In 2003 the mean length of larvae collected in the surface pushnets (3.72 SL mm S.E. ± 0.042) was higher (LSMEANS: $P = 0.0264$) than that of larvae in the oblique tows (3.66 SL mm S.E. ± 0.14).

Table 1
Results from repeated measures analysis of variance (ANOVA) testing the effects of gear type, diel period on the estimated density of larval river herring

Year	Variable	Measurement					
		Density			Length		
		d.f.	*F*	*P*	d.f.	*F*	*P*
2002	Diel period	1,362	0.67	0.4141	1,370	1.38	0.2405
	Gear type	1,362	50.03	<0.0001	1,370	52.54	<0.0001
	Gear type × period	1,362	0.51	0.4774	1,370	0.37	0.3763
2003	Diel period	1,288	0.69	0.4060	1,278	1.53	0.2165
	Gear type	1,288	18.04	<0.0001	1,278	15.91	<0.0001
	Gear type × period	1,288	0.17	0.6792	1,278	0.10	0.7550

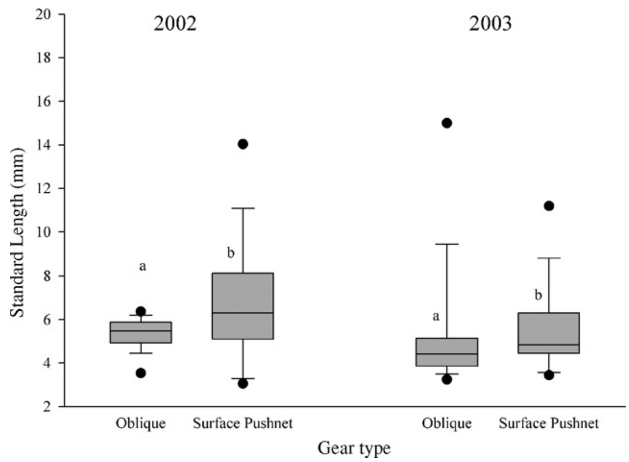

Fig. 3. Box plot diagram of river herring lengths in oblique and surface pushnet samples in 2002 and 2003. The upper and lower boundaries represent the quartiles, the horizontal bar represents the median, and the solid dots represent the 5th and 95th percentiles. Within each year, boxes with the same letter are not significantly different ($P > 0.05$).

3.2. River herring

In 2002 and 2003, gear type had a significant effect on mean larval density for river herring (Table 1). The mean densities were 9.2 and 2.7 times higher in the surface pushnet samples in 2002 and 2003, respectively. Gear type also affected the size of larvae collect for both years (Table 1). Significantly larger larvae were collected in the surface pushnet samples in 2002 and 2003 (Fig. 3).

3.3. Striped bass

Mean striped bass larvae density was different between gear types in 2002 (ANOVA: $F_{1,206} = 5.36$; $P = 0.0216$) and 2003 (ANOVA: $F_{1,215} = 5.92$; $P = 0.0182$). For both years, mean density was higher in the surface pushnet samples than the oblique tows (Fig. 4). There was no significant effect of diel period or the diel period gear type interaction on mean density for both years. The mean size of striped bass larvae did not differ between diel period (ANOVA: 2002: $F_{1,206} = 1.36$; $P = 0.2449$; 2003: $F_{1,213} = 0.84$; $P = 0.9584$) or gear type (ANOVA: 2002: $F_{1,206} = 0.18$; $P = 0.6737$; 2003: $F_{1,213} = 2.70$; $P = 0.1059$) (Fig. 5).

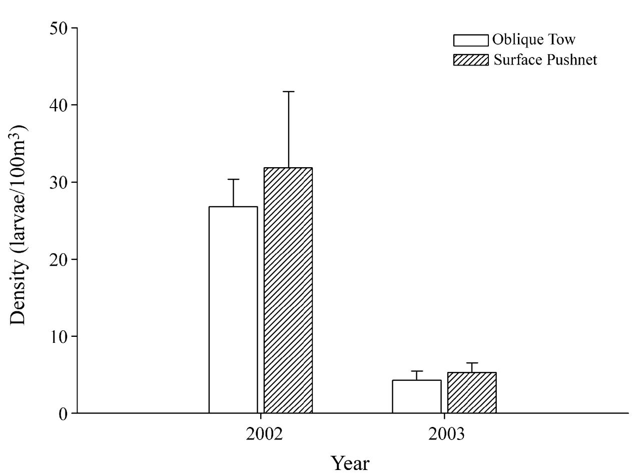

Fig. 4. Mean (±1S.E.) density (number/100 m^3) of white perch collected in 2002 and 2003 in oblique tows and surface pushnets in lower Roanoke River, North Carolina, USA. Vertical bars with the same letter are not significantly different ($P > 0.05$).

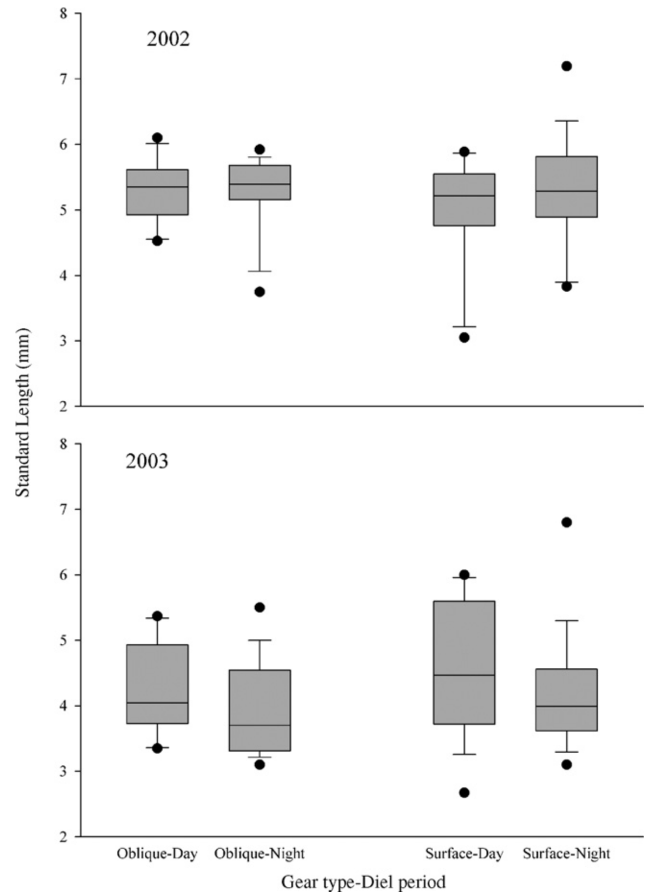

Fig. 5. Box plot diagram of striped bass larval lengths for 2002 and 2003 in oblique and surface pushnet samples in 2002 and 2003 in lower Roanoke River, North Carolina, USA. The upper and lower boundaries represent the quartiles, the horizontal bar represents the median, and the solid dots represent the 5th and 95th percentiles. Within each year, boxes with the same letter are not significantly different ($P > 0.05$).

4. Discussion

We compared two common methods for sampling larval fish and showed that gear type has a significant effect on the density estimates and larval fish size sampled. We also showed that gear type effect varies with diel period, and the effect can differ among species between years. For white perch, river herring, and striped bass, surface pushnets routinely collected more larvae than oblique tows.

Other studies have compared the effectiveness of towed and push nets and have observed no differences between the two gear types (Gallagher and Conner, 1983; Hale et al., 1995). However, our results may differ from the previous studies because different methods were used to tow the plankton nets. Our towed net was pulled obliquely through the water column whereas the towed nets of Gallagher and Conner (1983) and Hale et al. (1995) were pulled at or near the surface of the water in the upper water column. Our results are consistent with Claramunt et al. (2005) who showed significantly higher larval density in pushnets than nets towed behind a boat.

The density of river herring was significantly higher in our surface pushnet samples in 2002 and 2003 than oblique tows. This was consistent even when the overall mean density of river herring was about 2.4 times higher than in 2003 (Rulifson and Overton, 2005). This pattern suggests that clupeid-like larvae, shads, and herrings may be concentrated in the upper portion of the water column (Gallagher and Conner, 1983). Cada et al. (1980) and Gallagher and Conner (1983) showed higher catches of shads *Dorosoma* spp. in pushed nets versus towed nets.

Our data showed that only white perch catches exhibited a significant diel effect, while larval densities of the other target species showed no consistent differences between daytime and nighttime samples. White perch mean density was higher at night in 2002, but not in 2003. It is unclear why the diel effect differed between years. Gallagher and Conner (1983) reported that surface pushnets were more effective during daylight hours for young-of-year shads. Loesch et al. (1982) reported that age-0 *Alosa* spp. are negatively phototropic resulting in surface pushnet catches significantly higher at night than during day. Our results may be different because Loesch et al. (1982) focused on larger age-0 fish whereas our study focused on post-larvae. Another possibility for the differences may have resulted from combining blueback herring and alewife species into one group "river herring", which may have masked any inter-specific patterns.

Many species of larvae can actively avoid plankton nets. Avoidance increases with fish size, which causes an underestimation of mean lengths and densities leading to an overestimate of mortality and an underestimation of growth (Brander and Thompson, 1989). Avoidance can be affected by gear type, diel patterns, net speed, and mesh width (McGurk, 1992). We expected that larger larvae would be collected in nighttime samples presumably because larvae were unable to see the approaching net, but diel results were not significant.

The mean lengths of white perch and river herring larvae were strongly related to gear type where larger larvae were collected in the surface pushnets. This does not suggest that larger larvae are more susceptible to surface pushnets. It does however suggest that larger larvae are more distributed near the surface of the water. Kriete and Loesch (1980) compared the mean lengths of age-0 *Alosa* sp. and showed no significant differences between trawl and surface pushnet samples.

Hydrologic conditions likely did not influence gear performance, and we may have observed this phenomenon in our study. The mean spring (March–June) water velocity in 2002 was only 66 m^3/s compared to 2003, which was 676 m^3/s. Despite a 10-fold difference in river flow, the estimated densities remained higher in the surface pushnet samples.

Several caveats must be considered when interpreting the results from this study. First, similar conical nets were used but mounted in circular (bongo) frames or rectangular (pushnet) frames. Second, boat size and horsepower were different, with the oblique tows taken by a larger and more powerful vessel. Third, it was necessary to shorten the sample time of the pushnets to prevent the nets from clogging with surface debris; minimal clogging was observed in our oblique samples. Isermann et al. (2002) showed that clogging can inhibit the efficiency of larval surface sampling. Nevertheless, results of our study clearly indicate that surface pushnet sampling is an effective and productive method of sampling for diadromous species in estuarine and shallow water habitats, and can be used exclusively or in place of oblique sampling by larger vessels when this is not practical. However, our results suggest that surface pushnets may lead to samples that overestimate mean larval density and provide an inaccurate representation of larval size distribution.

5. Conclusion

Sampling the entire water column requires gear that may not be available to fishery managers. Often paired plankton nets require a larger boat equipped with an external frame to pull the net through the water column. The surface pushnet is easier to operate because it is mounted to the bow of a small boat, requires less specialized gear, and requires fewer personnel than oblique sampling. Surface pushnets allow for sampling in shallow water and vegetated areas, but under moderate wind and wave conditions surface pushnets are not effective because of the action of the small boat under these conditions. Because larvae were significantly larger in the surface samples, using surface pushnets may not allow for detection of the smaller sized larvae therefore underestimating the abundance of smaller fish. Depending on the question being asked, sampling programs may need to use both gear types to reduce any gear biases.

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