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SAMPLING BIAS OF MINNOW TRAPS IN SHALLOW AQUATIC HABITATS ON THE EASTERN SHORE OF VIRGINIA

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Abstract: This study demonstrated sampling biases of minnow traps in shallow, estuarine locations on the Eastern Shore of Virginia, USA. We exhaustively seined six shallow-water sites (including semi-permanent barrier island ponds, permanent mainland marsh ponds, tidal pools, and tidal rivulets) and compared these collection data to those obtained with minnow traps. The relative frequency of occurrence of fish species was significantly different between the two methods in all cases. Further comparison of the two techniques at ten additional sites representing a wide variety of habitat types and sizes suggested similar biases inherent to minnow traps. Specifically, minnow traps bias toward collection of a common marsh resident, the mummichog *Fundulus heteroclitus,* and bias against collection of several other resident species and juveniles of estuarine transient species. Minnow traps can be an effective collection technique for certain nekton species; however, specific biases inherent to the technique preclude their use as a method to accurately describe fish assemblages in shallow-water estuarine habitats.

Key Words: minnow traps, sampling bias, marsh, estuarine, fish, *Fundulus heteroclitus,* Virginia Coast

INTRODUCTION

Shallow estuarine habitats typically support large populations of resident and transient nekton species. However, accurately describing these assemblages with traditional sampling techniques remains problematic. In a recent review of estuarine sampling techniques, Rozas and Minello (1997) discussed drawbacks of passive sampling devices to characterize shallow water fauna. First, these devices are regarded as extremely species-selective. Second, these devices have a low and variable catch efficiency (i.e., proportion of fish collected from the area of interest). Third, the total area sampled by these techniques is unknown, thus making quantitative density estimates impossible (Rozas and Minello 1997).

Despite these drawbacks, passive sampling devices (e.g., minnow traps and Breder traps—see Breder 1960) are often used to sample fishes because they are simple, inexpensive, and easily replicable (Sargent and Carlson 1987, Rozas and Minello 1997). For example, in shallow coastal habitats, passive sampling techniques have been used to examine use of tidal creek habitat by *Fundulus heteroclitus* (Halpin 1997), describe nekton use of a restored marsh (LaSalle et al. 1991), assess fish composition in estuaries (Ambrose and Meffert 1999), and collect killifish from tidal saltmarsh rivulets (Rozas and LaSalle 1990). Minnow traps have been used frequently in freshwater systems, including freshwater wetlands (Norland and Bowman 1976, Schooley and Page 1984, Suthers and Gee 1986, Botsford et al. 1987, Langston and Kent 1997).

Biases of passive sampling devices have been well-described in freshwater systems. For example, He and Lodge (1990) emphasized the effect that placement site has on minnow trap collections. Additionally, these authors demonstrated that the presence of certain fish species in traps affects subsequent collections. Blaustein (1989) discussed effects of fish size and fish density on collection efficiency. He also described the important role that habitat parameters, especially water depth, can have on collections. Pot et al. (1984) suggested the importance of species-specific characteristics, including behavior and size, in determining the composition of minnow trap samples. Kubecka (1996)

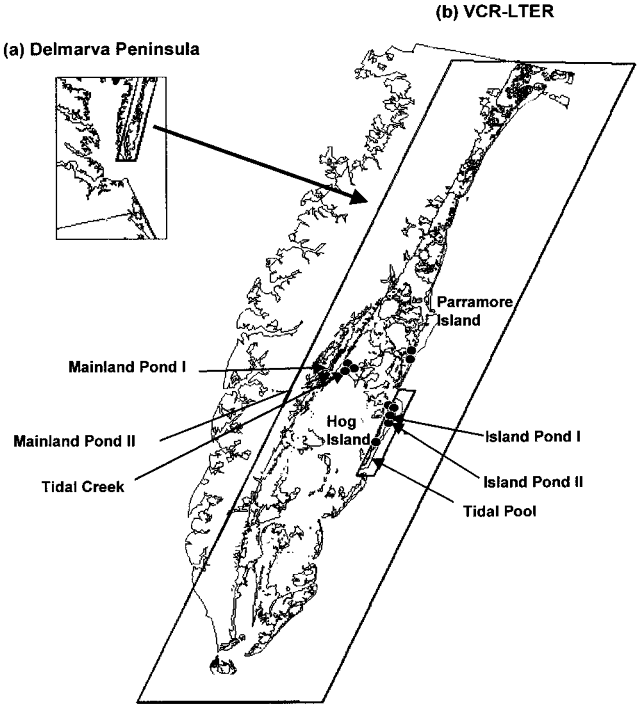

Figure 1. Map of the (a) Delmarva Peninsula and (b) Virginia Coast Reserve Long-Term Ecological Research Site (VCR-LTER). The six exhaustively seined sites are designated with bold arrows. Ten additional sites are indicated with a black circle.

similarly emphasized bias in Breder trap collections due to behavioral differences among species.

Unlike freshwater systems, the nature of minnow trap bias in estuarine systems has rarely been quantified. Sargent and Carlson (1987) found a behavioral bias associated with Breder traps in shallow mangrove habitats of Florida, but the source and magnitude of the bias was unclear because the authors compared three different sampling techniques. To identify biases associated with passive sampling traps, sampling biases of other techniques must be excluded. The present study compares minnow trap collection data to those obtained by exhaustive seining, allowing the efficiency of minnow traps to be quantified. By specifically comparing minnow trap samples to excellent approximations of fish assemblages present in a suite of estuarine habitats, these potential biases were investigated directly.

METHODS

Study Site

This study was conducted at the Virginia Coast Reserve Long-Term Ecological Research Site (VCR-LTER), which includes a 100-km stretch of barrier islands, mainland marsh, and associated lagoons along the Virginia portion of the Delmarva Peninsula (Figure 1). There are numerous shallow-water habitats in the area, including tidal creeks, permanent brackish marsh ponds, semi-permanent barrier island ponds, and tidal pools.

Exhaustively Seined Sites

In the first part of the study, five relatively small (19–760 m^2), shallow (0.3 to 0.7 m) ponds, with no undercut banks, were chosen. These sites could be exhaustively seined with traditional sampling techniques (see Results). Minnow trap collections were made first in the five ponds, the fish released into the ponds, and the ponds exhaustively seined. Commercially available minnow traps were made of galvanized wire and measured 42 cm in length and 23 cm wide at their largest diameter, with a 1.9-cm hole and 0.64-cm square mesh. Six traps were placed in each pond, three baited with canned sausage and three unbaited. All traps were completely submerged and placed on the substrate. After approximately six hours, traps were removed from the ponds and the fishes identified, enumerated, and released back into the ponds. Twenty-four hours later, the ponds were exhaustively seined with a net 4 m long and 1.5 m deep with a 1-m square bag and 1-mm square mesh throughout. Ten consecutive seines were conducted in each site; all fishes were identified, enumerated, and placed in a holding tank until sampling was completed.

A mainland tidal rivulet (*sensu* Rozas et al. 1988) was also exhaustively sampled, albeit in a slightly different manner. A larger seine, 8 m long and 1.5 m deep, with a 1-m square bag, and 0.48-cm mesh throughout, was placed across the mouth of the rivulet at high tide. The lead line of the net was pushed into substrate mud along the entire rivulet width. The top of the net was suspended above the water using wooden stakes to prevent fish from jumping over the net. This method allowed us to entirely block the rivulet at high tide. Immediately after setting up this net, three traps baited with canned sausage and three unbaited traps were placed on the substrate of the rivulet. After two hours of falling tide, traps were removed, and the fish captured were identified, enumerated, and released back into the blocked rivulet. Soon after, the area had drained, leaving only a 1–2 cm deep pool of water. The smaller seine described previously was then pulled through the shallow pool up to the front of the larger block seine. The large seine was immediately removed and all fish identified and enumerated.

Additional Sites Sampled

To further validate our findings, we sampled ten additional shallow-water sites, each of which was too large to be exhaustively seined (see Figure 1). Six minnow traps, three unbaited and three baited with canned sausage, were placed on the substrate. After approximately six hours, traps were removed and fish identified and enumerated. The large seine described above was then pulled at random locations in each site. Seining trials were conducted until two consecutive trials yielded no additional fish species. A standard seining strategy could not be employed because of the variety of sizes, shapes, depths, and types of sites examined. No effort was made to enumerate the fish. Ponds were sampled between June 1997 and August 1998. All fishes collected were identified using Murdy et al. (1997).

Statistical Analyses

For the five exhaustively seined pond sites, we assessed the effectiveness of our seining technique by examining the cumulative number of individuals and species collected with each seine haul. Asymptotically-shaped curves would suggest that the habitats were adequately sampled, as catch per unit effort would decline substantially with each additional haul. Should the curves not display such a pattern, it would be questionable as to whether seine hauls resulted in a sample representative of actual fish assemblages in the ponds.

As there was no difference in number of species or total number of individuals caught in baited and unbaited traps, minnow trap data were pooled for the six traps at each exhaustively seined site for χ^2 analysis. Likewise, the numbers of fish captured in the seine hauls were pooled. Pearson χ^2 analyses of contingency tables were carried out independently for each of the six exhaustively seined sites. Goodness-of-fit tests, based on proportional abundance and not frequency data (Zar 1996), were also carried out. Results of the goodness-of-fit tests agree with those of χ^2 analysis and are not reported here. Since multiple comparisons were made (six separate contingency tables were analyzed), the alpha level of 0.05 was adjusted downward to 0.0083 according to the Bonferroni procedure (Howell 1987). In order to avoid statistical bias in calculating the chi-squared statistic, Zar (1996) suggests that average expected frequency in a contingency table exceed 6.0. Average expected frequency is calculated by dividing the total number of data in the table by the product of the number of columns and rows (Zar 1996). We met this criterion for each of the six contingency tables.

Adjusted standardized residuals are reported for each contingency table. Adjusted residuals are a measure of departure of actual observed data values from that which would be expected in the contingency table. Since the seining technique provided an excellent description of the fish fauna, only residuals associated with minnow traps are reported. Positive adjusted residual scores indicate that fish species of interest make up a larger percentage of total individuals in minnow trap counts than would be expected based on data in the contingency table. Negative scores indicate that the species is underrepresented in minnow trap counts. Larger values indicate a stronger departure from expected values and thus a stronger sampling bias for or against a species (see Haberman 1978).

Data from the ten additional sites were analyzed differently from the exhaustively seined sites due to the manner in which data were collected. The number of species captured in minnow traps in these ponds was compared to the number of species captured with the seining technique using a paired t-test. Significance was evaluated at the 0.05 significance level. All statistical tests were carried out using SPSS for Windows software package (Norusis 1993).

RESULTS

Exhaustively Seined Sites

It is possible that some fishes escaped all ten seines in each of the five ponds, perhaps by burrowing into the mud or swimming under the net lead line, but these fishes likely make up a small proportion of total fish populations. Sampling data support this assumption. Both individual and species catch curves provide clear evidence that the fish assemblages were adequately sampled (Figure 2). In each of the five ponds, less than 1.0 % of individuals were collected in the last three seine passes combined. Species catch curves show that all species were represented by the fifth seine haul.

A total of 3,544 fish representing 16 different species and eight families were captured with the seine hauls in the six exhaustively sampled sites. Five species from two families, a total of 654 individuals, were collected with minnow traps in these six sites. Within a single site, the most fish (1808) were collected from the tidal rivulet. In ponds, the total number of individuals ranged from 58 to 1073. Nine species were collected in the five ponds, while 11 were found in the tidal rivulet. *Fundulus heteroclitus* was the only fish species that was captured in each of the six sites with both sampling techniques.

Fundulus heteroclitus was the most commonly captured species in minnow traps at all sites (Table 1). This species comprised up to 99.5% of the total number of individuals captured in minnow traps. Relative numerical proportion of *F. heteroclitus* was always less in seine hauls than in minnow traps (Figure 3). The largest discrepancy in the proportion of *F. heteroclitus* between the two techniques was recorded in the second mainland pond, where 93.8% of fish in minnow traps were *F. heteroclitus*, compared to only 14.9% in seine hauls.

Results of χ^2 analysis of the six contingency tables

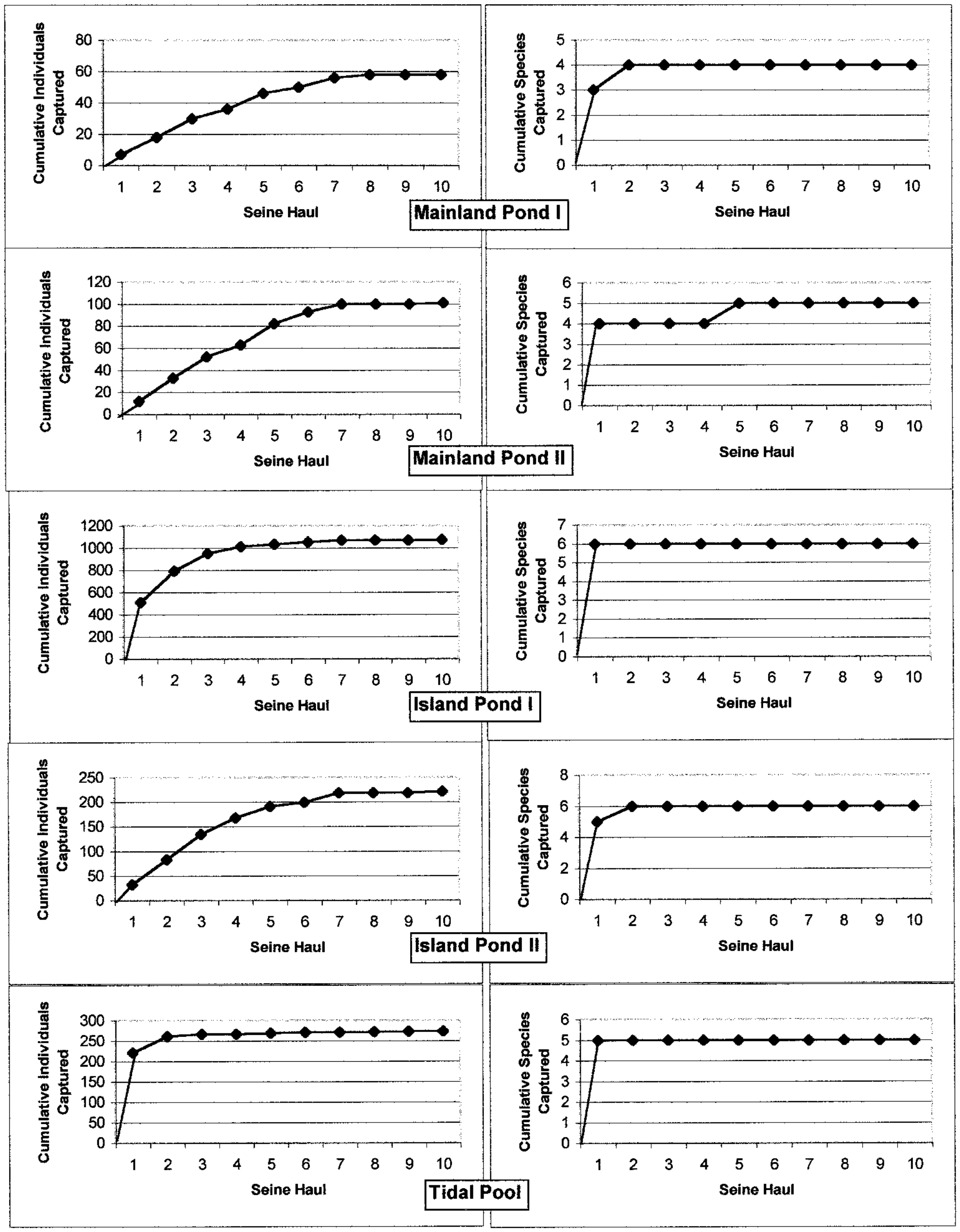

Figure 2. Cumulative number of individuals and species captured in ten seine hauls within each of the five exhaustively seined ponds.

were highly significant (p = 0.001 or less) for each site (Table 2). Consequently, minnow trap collections characterized a fish assemblage that is significantly different from the actual assemblage found in each of the six sites. Two particular biases were apparent when examining adjusted standardized residual scores in Table 3. First, *F. heteroclitus* is strongly selected for with minnow traps. In each site, residual scores for *F. heteroclitus* are relatively large positive values, ranging from 3.0 to 19.4. In contrast, juveniles of common estuarine species *Leiostomus xanthurus, Bairdiella chrysoura, Paralichthys dentatus, Pogonias cromis,* and *Anguilla rostrata* are selected against by minnow traps. Second, minnow traps also biased against several estuarine resident species, including *Menidia menidia, Fundulus majalis, Symphurus plagiusa, Lucania parva, Gambusia affinis, Gasterosteus aculeatus,* and *Gobiosoma bosc. Cyprinodon variegatus* and *Fundulus luciae* were selected for in some sites and against in others.

Additional Sites Sampled

Results from ten additional sites supported results of above statistical analyses (Table 4). Significantly

Table 1. Number of fish captured using minnow traps (MT) and exhaustive seining (S) in six sites sampled. In each instance, minnow trap totals are based on six traps, and seine values are based on ten separate seine hauls. The overall estimated fish density in each pond is based on the cumulative number from exhaustive seining. A dash (—) indicates that the species was not captured in the habitat with that particular sampling technique.

Habitat	Tidal Rivulet		Mainland Pond I		Mainland Pond II		Island Pond I		Island Pond II		Tidal Pool	
Fish Density (Fish/m^2)	10.4		3.2		2.8		56.5		8.9		0.4	
	MT	S	MT	S	MT	S	MT	S	MT	S	MT	S
Mummichog, *Fundulus heteroclitus* (Linnaeus)	423	858	37	37	15	15	49	311	18	25	60	61
Sheepshead minnow, *Cyprinodon variegatus* (Lacepède)	—	21	—	3	—	—	39	159	4	29	—[a]	—[a]
Striped killifish, *Fundulus majalis* (Walbaum)	—	—	—	—	—	—	—	—	—	—	1	164
Atlantic silverside, *Menidia menidia* (Linneaus)	—	871	—	—	—	—	—	—	—	—	—	—
Mosquitofish, *Gambusia holbrooki* (Girard)	—	—	—	17	—	7	—	—	—	—	—	—
Spotfin killifish, *Fundulus luciae* (Baird)	2	10	1	1	1	1	—	208	1	22	—	—
American eel, *Anguilla rostrata* (Lesueur)	—	—	—	—	—	76	—	8	—	9	—	—
Rainwater killifish *Lucania parva* (Baird and Girard)	—	22	—	—	—	2	—	16	—	26	1	10
Black drum, *Pogonias cromis* (Linneaus)	—	5	—	—	—	—	—	—	—	—	—	—
Spot, *Leiostomus xanthurus* (Lacepède)	—	7	—	—	—	—	—	—	—	—	—	—
Silver perch, *Bairdiella chrysoura* (Lacepède)	—	4	—	—	—	—	—	—	—	—	—	—
Southern flounder, *Paralichthys dentatus* (Jordon and Gilbert)	—	3	—	—	—	—	—	—	—	—	—	—
Blackcheek tonguefish, *Symphurus plagiusa* (Linneaus)	—	1	—	—	—	—	—	—	—	—	—	—
Naked goby, *Gobiosoma bosc* (Lacepède)	—	6	—	—	—	—	—	—	—	—	—	—
Threespine stickleback, *Gasterosteus aculeatus* (Linnaeus)	—	—	—	—	—	—	—	371	1	120	—	—
Rough silverside, *Membras martinica* (Valenciennes)	—	—	—	—	—	—	—	—	—	—	—	38
Total Fish Captured	425	1808	38	58	16	101	88	1073	24	231	62	273

[a] There were too many *Cyprinodon variegatus* to enumerate in the tidal pool. Only one individual was captured in the minnow traps, but there were an estimated 3500 juveniles captured during seining. The Chi-squared statistic was calculated without this species, and the results would have been even more significant had it been included.

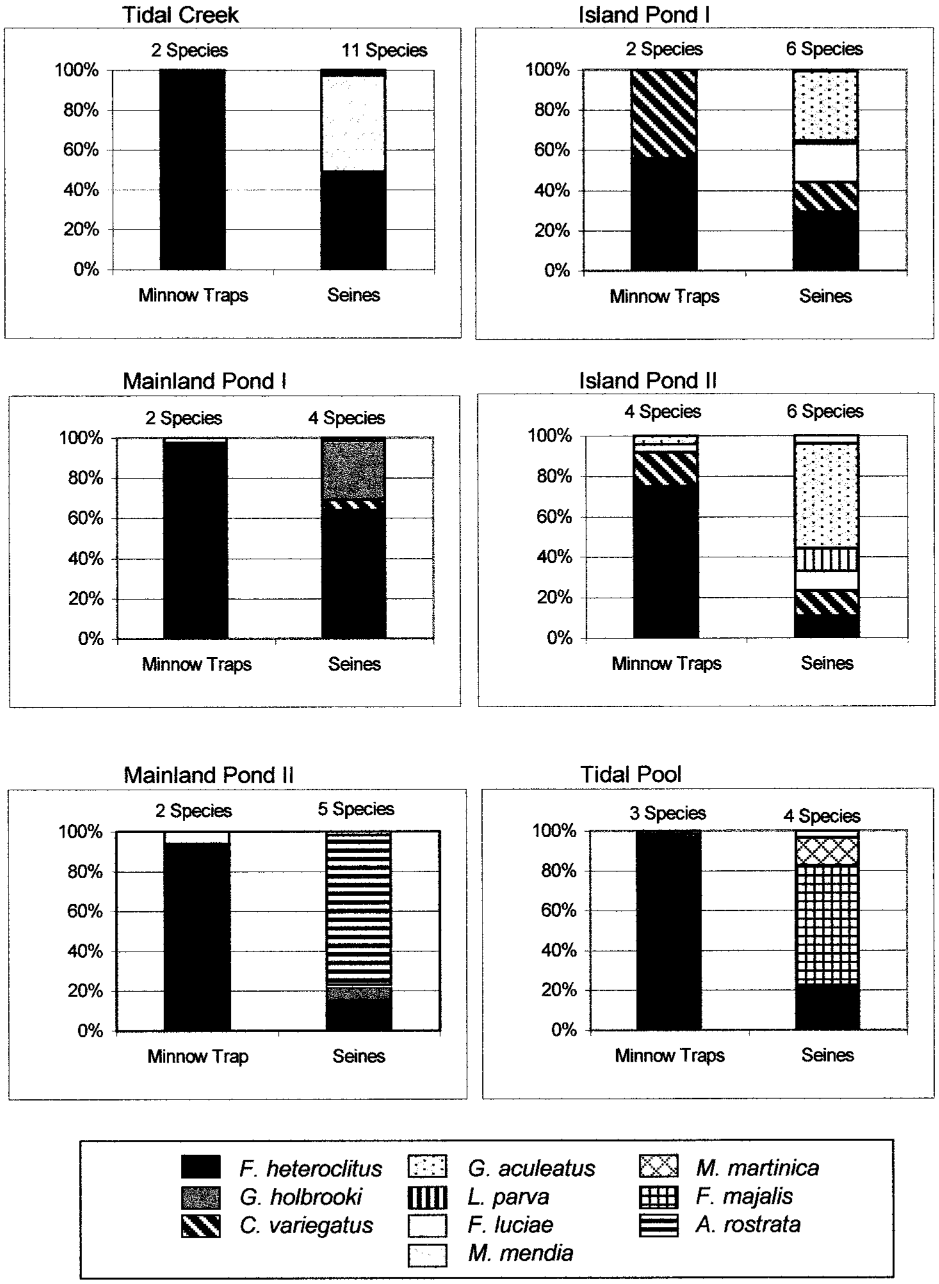

Figure 3. A comparison of the relative numerical proportion of each species expressed as a percentage of the total individuals captured with that sampling technique. The minnow trap and seine comparison is shown separately for each of the six sites. Numbers above each graph are total number of species caught with the technique at that location.

more species were captured (df=9; $p < 0.001$) in seine hauls than were collected with six minnow traps. *Fundulus heteroclitus* were collected in minnow traps in all sites in which they were captured using seines. There was only a single site, a tidal pool adjacent to the ocean surf zone, where no *F. heteroclitus* were collected using either sampling technique. In all sixteen sites sampled, there were no instances where a fish was captured in minnow traps but not collected in seine trials.

DISCUSSION

Allen et al. (1995) found that *F. heteroclitus* was the most evasive fish species in a South Carolina tidal pool, and in general, seining is not an efficient method of estimating abundance of this and similar species. However, we chose sites so that the net was large enough to sample 100% of each site with each seine pass. Catch curves support our contention that ponds were adequately sampled (Figure 2). Likewise, our methodology allowed us

Table 2. Results of Pearson Chi-square tests from six contingency tables, where each table represents data from a single site. Cases are equal to total number of fish in a site and degrees of freedom equal to the number of species minus one.

Habitat	Cases	χ^2	df	p-Value
Tidal Rivulet	2223	388.9	10	<.001
Mainland Pond I	96	16.5	3	.001
Mainland Pond II	117	49.2	4	<.001
Island Pond I	1161	109.6	5	<.001
Island Pond II	255	68.1	5	<.001
Tidal Pool	336	125.0	4	<.001

to thoroughly sample the mainland tidal rivulet. Since the rivulet completely dried at low tide, it was apparent that no non-burrowing fish remained in the channel. A small number of fishes may have escaped under the lead line, but additional species captures would have only increased the magnitude of the bias. Importantly, it is not critical that every single fish was collected from exhaustively sampled sites, only that our sampling provided an accurate approximation of fish assemblages. Any differences between the two sampling techniques could then largely be attributed to biases inherent to minnow traps. We believe three primary factors account for the biases.

(1) Attraction to Traps

In fourteen of sixteen sites sampled, each species captured in a baited trap was also found in an unbaited trap. In three of the ponds, a species captured in an unbaited trap was not found in a baited trap. Furthermore, in a related study, we found no significant differences in the number of species or total number of individuals that were collected in traps with a variety of different bait types (Layman, *unpubl. data*). This finding suggests that some fish species are attracted to structure provided by traps, not just by bait. It has been well-established that fishes use structurally complex habitats for various reasons. For example, structurally complex habitats serve to reduce predator-prey encounter rates and reduce overall prey capture efficiency of predators (Crowder and Cooper 1982, Anderson 1984, Savino and Stein 1989a,b, Christensen and Persson 1993, Persson and Eklov 1995). The most commonly collected species in this study, *F. heteroclitus,* often aggregates around structurally complex objects such as logs and docks (Layman, *pers. obs*). Therefore, *F. heteroclitus* initially may be attracted to minnow traps due to structure, perhaps as a behavioral adaptation to minimize predation risk. The affinity of *F. heteroclitus* for traps would thus result in a large collection of *F. heteroclitus* relative to other species.

Laboratory observations support this hypothesis. Fishes collected in the field were placed in a large aquarium (114 liters) with a single minnow trap. *Fundulus heteroclitus* was the most likely species to enter traps, whether or not traps were baited. In contrast, other species would often take many hours to move into traps, if they entered at all. Further, many *F. heteroclitus* could easily find their way back out of a trap, and when startled, individuals that had previously been inside the minnow trap would re-enter it.

Table 3. Adjusted residual scores for each of the six contingency tables (Abbreviations: TR = Tidal Rivulet, MP = Mainland Pond, IP = Island Pond, TP = Tidal Pool). Positive adjusted residual scores indicate that the fish species of interest makes up a larger percentage of the total individuals in the minnow trap counts than would be expected based on the actual population of the fish in the pond. Negative scores indicate that the species is underrepresented in the minnow trap collections. Larger values indicate a stronger departure from expected values in the contingency tables. A dash (—) indicates the species was not captured with that particular sampling technique.

Species	TR	MP I	MP II	IP I	IP II	TP
Mummichog, *Fundulus heteroclitus*	19.5	3.0	6.7	5.2	8.0	11.0
Sheepshead minnow, *Cyprinodon variegatus*	−2.2	−1.4	—	7.1	—	—
Striped killifish, *Fundulus majalis*	—	—	—	—	—	−8.3
Atlantic silverside, *Menidia menidia*	−18.3	—	—	—	—	—
Mosquitofish, *Gambusia holbrooki*	—	−3.7	−1.1	—	—	—
Spotfin killifish, *Fundulus luciae*	−0.2	0.3	1.5	−4.6	−0.9	—
American eel, *Anguilla rostrata*	—	—	−5.9	−0.8	−1.0	—
Rainwater killifish, *Lucania parva*	−2.3	—	−0.6	−1.2	−1.7	−0.8
Black drum, *Pogonias cromis*	−1.1	—	—	—	—	—
Spot, *Leiostomus xanthurus*	−1.3	—	—	—	—	—
Silver perch, *Bairdiella chrysoura*	−1.0	—	—	—	—	—
Summer flounder, *Paralichthys dentatus*	−0.8	—	—	—	—	—
Blackcheek tonguefish, *Symphurus plagiusa*	−0.5	—	—	—	—	—
Naked goby, *Gobiosoma bosc*	−1.2	—	—	—	—	—
Threespine stickleback, *Gasterosteus aculeatus*	—	—	—	−6.7	−4.5	—
Rough silverside, *Membras martinica*	—	—	—	—	—	−3.1

Table 4. Presence/absence data from ten additional sites using minnow traps (MT) and seining (S). Six minnow traps were used at each site. Seines continued until no additional species were collected on two consecutive hauls. A star (*) designates the species was collected with the sampling technique.

Site	Hog Island											
Habitat Type	Marsh Pond A		Marsh Pond B		Marsh Pond C		Marsh Pond D		Marsh Pond E		Tidal Pool	
Species	MT	S	MT	S	MT	S	MT	S	MT	S	MT	S
Mummichog, *Fundulus heteroclitus*	*	*	*	*	*	*	*	*	*	*		
Sheepshead minnow, *Cyprinodon variegatus*	*	*	*	*		*		*		*		
Striped killifish, *Fundulus majalis*		*		*	*	*						*
Atlantic silverside, *Menidia menidia*												
Mosquitofish, *Gambusia holbrooki*												
Spotfin killifish, *Fundulus luciae*								*				
American eel, *Anguilla rostrata*								*				
Rainwater killifish, *Lucania parva*		*	*	*		*	*	*		*		
Spot, *Leiostomus xanthurus*		*		*								
Silver perch, *Bairdiella chrysoura*												
Summer flounder, *Paralichthys dentatus*												
Threespine stickleback, *Gasterosteus aculeatus*		*		*				*				
White mullet, *Mugil curema* (Valenciennes)				*								*
Menhaden, *Brevoortia tyrannus* (Latrobe)		*										
Blackcheek tonguefish, *Symphurus plagiusa*		*				*						
Rough silverside, *Membras martinica*		*		*		*						*
Total number of species	2	9	3	8	2	6	2	6	1	3	0	3

(2) Frequency of Encounter

Location of minnow traps within a site may change the frequency at which species encounter traps, thereby affecting composition of minnow trap collection. For example, non-resident marsh fish species adapted to an open water lifestyle are less likely to encounter a minnow trap placed on the substrate. Some species that are biased against by minnow traps are primarily zooplanktivorous water-column feeders, *M. menidia* for instance (Bengston 1984, Morgan 1990, Allen et al. 1995). Because of their feeding preferences, these fish species may not be attracted to bait or frequent the substrate for feeding.

The encounter rate of traps would seem to be higher in smaller sites than larger ones, as the number of traps used (6) was constant at every site. Thus, in smaller habitats, it could be reasonably expected that the relative abundance of species captured in minnow traps would more closely represent the actual fish assemblage at that site, if frequency of encounter is related to collection efficiency. However, the collections with minnow traps differed significantly from the actual fish populations at all sites, no matter the size. This suggests that the size of the site was less important than species-specific fish behavior.

(3) Fish Size and/or Morphology

Many juvenile and larval fishes, including *F. heteroclitus, C. variegatus, L. parva, G. aculeatus,* and *F. luciae*, can move freely through mesh of traps. Juveniles of two species of estuarine transients, *L. xanthurus* and *B. chrysoura*, were too large at our sites to enter traps and were underrepresented in minnow trap collections. Likewise, many flatfishes are unable to move into minnow traps because of body morphometry.

Results of other recent studies are elucidated by the bias described here. Sargent and Carlson (1987) compared Breder trap collections to throw and pull net samples in Florida mangroves. Their data demonstrated a clear bias against estuarine transient species (i.e., *Pogonias cromis, Sciaenops ocellatus, L. xanthurus, Lagodon rhomboides, Anchoa mitchilli*, and *Diapterus* sp.) by minnow traps. LaSalle et al. (1991) found that five fish species (*Cynoscion regalis, Mugil cephalus, A. mitchilli, M. menidia,* and *Brevoortia tyrannus*) prevalent in block net sampling, were not captured in Breder traps. Instead, trap captures were dominated by *Fundulus* spp. Likewise, Halpin (1997) reported that 91,436 of 93,560 fishes captured in Rhode Island tidal creeks using minnow traps were *F. heteroclitus*. This result likely reflects sampling bias of minnow traps as much as the actual numerical dominance of *F. heteroclitus* in these creeks.

Use of minnow traps should be dictated by the aim of the hypotheses being tested. If the overall objective is to collect a specific fish species, then the technique may be rather useful. If the primary objective is to sample and accurately describe nekton using a partic-

Table 4. Extended.

Site	Parramore Island				Mainland Marsh			
Habitat Type	Marsh Pond F		Marsh Pond G		Tidal Creek		Marsh Pond H	
Species	MT	S	MT	S	MT	S	MT	S
Mummichog, *Fundulus heteroclitus*	*	*	*	*	*	*	*	*
Sheepshead minnow, *Cyprinodon variegatus*	*	*		*		*		
Striped killifish, *Fundulus majalis*								
Atlantic silverside, *Menidia menidia*		*				*		
Mosquitofish, *Gambusia holbrooki*							*	*
Spotfin killifish, *Fundulus luciae*		*	*	*				
American eel, *Anguilla rostrata*								
Rainwater killifish, *Lucania parva*	*	*		*		*	*	*
Spot, *Leiostomus xanthurus*								
Silver perch, *Bairdiella chrysoura*						*		
Summer flounder, *Paralichthys dentatus*		*				*		
Threespine stickleback, *Gasterosteus aculeatus*		*						
White mullet, *Mugil curema* (Valenciennes)								
Menhaden, *Brevoortia tyrannus* (Latrobe)								
Blackcheek tonguefish, *Symphurus plagiusa*		*				*		
Rough silverside, *Membras martinica*								
Total number of species	3	8	2	4	1	7	3	3

ular habitat, then minnow traps are not an effective technique. As Rozas and Minello (1997) suggested, passive sampling traps should be considered ''collecting'' rather than ''sampling'' devices because of biases associated with these techniques. This study demonstrated that minnow traps are indeed effective collecting devices for certain species, *F. heteroclitus,* for example. However, this study empirically showed that minnow traps constitute a biased sampling technique that cannot be used to assess accurately the total number of fishes or number of species in shallow water habitats. Passive sampling traps do not seem to be effective methods of quantitatively sampling nekton of estuarine systems.

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