Fish Composition and Abundance in New Jersey Salt Marsh Pools: Sampling Technique Effects

KENNETH W. ABLE1,*, KELLY J. SMITH2, AND STACY M. HAGAN1

Abstract - Unaltered salt marsh pools in southern New Jersey were sampled during the summer over a number of years, with a variety of techniques, to compare fish species and size composition relative to sampling gear type and to enhance our understanding of marsh pool fishes. These pools were dominated by a few species (Fundulus heteroclitus, Cyprinodon variegatus, Menidia beryllina, Lucania parva, and M. menidia made up 98.3% of all fish [n = 33,731] collected). However, species composition clearly varied with sampling technique, with some species common in multiple gears, e.g., F. heteroclitus in quatrefoil traps (38.6% of total number) and wire mesh traps (35.5%), and C. variegatus collected in quatrefoil traps (47.6%) and mini-seine (30.9%). Other species were most abundant in selected gears, e.g., M. beryllina (83.8%), L. parva (72.6%), and M. menidia (99.6%) in quatrefoil traps. Size composition, which included young-of-the-year and adults for most species, varied with sampling technique and species as well. In all of the above, we cannot rule out the possibility that annual variation influenced species composition and abundance; however, given the stability of these measures in other informal observations, we are convinced that most of the variation is due to sampling technique. Continued studies are relevant because marsh pools have been eliminated by a variety of practices, but are also being created as the result of some mosquito-control techniques and for restoration purposes.

Introduction


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Despite their potential importance, relatively little is known about the structure and function of marsh pools in salt marsh ecosystems (Minello et al. 2003). We know that dissolved oxygen is often very low in marsh pools at night during the summer and that this may influence fish species composition (Christian 1981, Layman et al. 2000, Smith and Able 2003, Whoriskey et al. 1985).

Our need to know about the structure and function of salt marsh pools is heightened because there have been numerous attempts to modify salt marshes and these particular micro-habitats over the last 200 years. Marsh pools have disappeared along with marshes in historical attempts to convert marshes to other uses (see Lathrop et al. 2000 and Sebold 1992 for examples in New Jersey). More specifically, marsh pools may have declined in abundance as a result of the large-scale effort to drain marshes for mosquito control in the northeastern US (Bourn and Cottam 1950, Clark 1977, Meredith et al. 1985, Redfield 1972, Shisler 1978). Often this effort consisted of creating parallel grid ditches, which have been shown to reduce marsh pool occurrence relative to undisturbed marshes (Lathrop et al. 2000). In some situations, pools are becoming more abundant as the result of sea level rise (Stevenson et al. 2000). In addition, marsh pools are being created to control mosquito populations as part of a more recent approach known as Open Marsh Water Management (OMWM) (Ferrigno and Jobbins 1968, Ferrigno et al. 1975, Meredith et al. 1985, Shisler 1978); this approach is being applied in the general study area we used in our research (Lathrop et al. 2000). Considering the significant human impact on marshlands, the role of marsh pools as fish habitat should receive increased attention. For this reason, we have determined fish species composition and abundance relative to sampling gear type and, as a result, enhanced our understanding of marsh pool fishes.

Study Area

We conducted the study in unaltered polyhaline salt marshes in the Sheepshead Meadows (approximately 39°30'N), a salt marsh peninsula near Tuckerton, NJ (Fig. 1). The mean tidal range of waters surrounding the salt marsh surface is 0.99 ± 0.2 m (Able et al. 1992), and the dominant emergent vegetation on the marsh surface is short-form *Spartina alterniflora* Loiseleur (smooth cordgrass) (Able et al. 1996). For the purposes of this paper, we define salt marsh pools or ponds as sunken areas in the marsh peat that typically hold water that is refreshed on spring and storm tides or by rainfall (see Pennings and Bertness 2000). Salt marsh pools are a common feature of the salt marsh surface (Fig. 1), and are inundated only during spring and storm tides, which occur 24–34 times during the spring and summer at the elevation of the marsh
pools in this marsh system (Halupa and Howes 1995; K.L. Hunter, M.G. Fox, and K.W. Able, pers. observ.). *Ruppia maritima* L. (widgeon grass) is the major form of submerged vegetation in the salt marsh pools (Smith 1995). Many of the marsh pools occasionally have partially submerged clumps of algae (primarily of *Cladophora* sp. and blue greens [Moul 1958]). The algae are temporally variable because they are dispersed during tidal inundation (K.W. Able, pers. observ.).

Figure 1. Map of sampling area in Sheepshead Meadows portion of Jacques Cousteau National Estuarine Research Reserve in southern New Jersey (approximately 39°30' N). Sampling sites located within ovals at the southern and central portion of the Sheepshead Meadows. (Revised from Lathrop et al. 2000).
Methods

Environmental data

During 1990 and 1991, data on marsh pool environmental variables were collected at the start of each sampling period (between approximately 0500 and 1200 hours depending on sampling sequence) in order to provide more uniform measurements across all pools and because these are the periods of lowest dissolved oxygen concentrations during a 24-h period (Smith and Able 2003). Water parameters measured included: surface and bottom water temperatures (mercury thermometer), surface and dissolved oxygen concentrations (YSI Model 58 DO meter), pH (Hydrion paper test strips), ammonia concentration (phenolhypochlorite method; Solorzano 1969), and turbidity (H.F. Scientific, Inc., Turbidimeter model No. DTR-15B). Salinity was measured using the Practical Salinity Scale (American Optical refractometer). Surface areas of marsh pools were estimated from digitized images of aerial photographs taken during March 1991 (Lathrop et al. 2000). Percent coverage of the pool surface by floating filamentous algae and percent coverage of the pool bottom by *Ruppia maritima* were visually estimated to the nearest 5%. Average depth of the marsh pools was determined by measuring from the water surface to sediment surface every 3 m around the perimeter of each pool, approximately 30 cm from the pool edge. To determine submerged aquatic vegetation (SAV) biomass during 1991, we removed submerged vegetation from the first of three throw traps sets in each pool for each sampling date. *Ruppia maritima* was collected as whole plants, including epiphytes, and floating clumps of blue-green algae were collected and rinsed of detritus. Both types of SAV were dried at 60 °C until there was no further change in sample weight, and expressed as grams per 0.25 m². During 1993, 1995, and 1996, temperature and salinity (‰) were measured in each pool at the time of sampling.

Sampling techniques

We used a variety of sampling techniques during the summers of several years (Table 1). During 1990, we deployed three unbaited standard conical galvanized steel wire mesh traps (42-cm length, 22.5-cm diameter, 6-mm mesh, 35-mm entrance diameter) during the day in each of 10 pools for 1 h. These wire mesh traps have been shown to be effective in collecting fishes over 35 mm total length (TL) (Smith and Able 1994). We identified, measured (TL), and released all fish into the same pool in which they were captured. In 1991, a 0.25-m² aluminum-sided throw trap was used to quantitatively sample fishes in 30 pools. The throw trap was 45 cm in height with a 45-cm skirt (1.5 mm mesh) supported by a float line for sampling in deeper sites. This device was a smaller version of the 1-m² trap described in Sogard and Able (1991), and was used because larger traps were too difficult to deploy in the smaller
salt marsh pools. For each sample, the throw trap was tossed approximately 1 m from the edge of a marsh pool and the contents were removed with a bar seine (1.5 mm mesh). Pools were sampled once in each of two periods (1–3 and 30–31 July), with 10 pools sampled each day (pool sampling sequence was determined randomly). The 10 pools were divided into two groups of five, one group sampled in the morning and one sampled in the afternoon. This sampling sequence allowed approximately 45 min for fish to redistribute between collections in each pool. In 1993, we sampled with quatrefoil traps, consisting of clear plexiglass tubes with spaces that allow fish to enter a trap from four directions (Secor et al. 1992), in two pools (n = 2–4 traps per pool) three days each week in order to sample larvae and small juvenile fishes more extensively. The quatrefoil traps were deployed at the water surface without a light during the morning and retrieved approximately 6 hours later. In 1995, sampling was conducted in six marsh pools, all of which had some submerged \textit{Ruppia maritima} vegetation. Sampling was conducted with unbaited rectangular experimental traps (33 x 46 x 91 cm, 3-mm mesh). The V-shaped entrance at one end of the trap was a 3- x 50-cm opening. The other end was a mesh bag cod-end (3-mm mesh) through which the samples were removed. Sampling occurred in each pool over three days within three separate weeks (Table 1). Each trap was set flat on the bottom for three hours at approximately 1 m from the pool’s edge. In 1996, a 1-m mini-seine (3 mm mesh) was towed across the length of a marsh pool to capture fish. This sampling was conducted weekly in the same marsh pools sampled in 1995.

For all pools sampled, fish were identified to lowest taxa, counted, and a sub-sample of fifty of each species from each gear on each date were measured to the nearest millimeter total length (TL) or fork length (FL) and then replaced at the capture site. Small individuals that were difficult to identify were preserved in 5% formalin and identified with a dissection table.

Table 1. Sampling effort in marsh surface pools in the Sheepshead Meadows portion of the Jacques Cousteau National Estuarine Research Reserve. See Figure 1 for sampling locations.

<table>
<thead>
<tr>
<th>Sampling gear</th>
<th>Sampling period</th>
<th># of collections</th>
<th>Sample locations</th>
<th>Surface area of pools (m(^2))</th>
<th># of fish collected</th>
<th>Temp. range (°C)</th>
<th>Salinity range (‰)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire mesh trap</td>
<td>Jun–Aug 1990</td>
<td>374</td>
<td>30</td>
<td>5–90</td>
<td>7095</td>
<td>18–34</td>
<td>16–36</td>
</tr>
<tr>
<td>Throw trap (0.25 m(^2))</td>
<td>Jul 1991</td>
<td>180</td>
<td>30</td>
<td>5–90</td>
<td>1946</td>
<td>20–25</td>
<td>21–35</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td>747</td>
<td>79</td>
<td></td>
<td>33,750</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
microscope. Shrinkage due to preservation was negligible for these fishes, so measurements were made after preservation. Definition of young-of-the-year (YOY) followed size information provided by Able (1990) for killifishes. Size cutoff for YOY was 35 mm TL for *Fundulus heteroclitus*, 25 mm TL for *F. luciae* (Baird) (spotfin killifish), 30 mm TL for *Cyprinodon variegatus* Lacepède (sheepshead minnow), and 35 mm TL for *Lucania parva* (Baird & Girard) (rainwater killifish).

Species composition of each gear was compared by using a chi-square analysis of the total number collected of each species within each gear. For each species, analysis of variance was used to test for the effect of gear on length of fish collected. If significant differences were detected (p ≤ 0.05), a Student-Newman-Keuls multiple range test was used to identify specific differences.

**Results**

**Environmental characteristics**

Some of the environmental characteristics of marsh pools (Table 1) were somewhat unique, probably due to their isolation from most tidal cycles and their relatively shallow depths and small water volumes. Temperatures, as measured during the summer sampling period, ranged from 17–34 °C. Salinities were high with values of 35–42‰. During 1990 and 1991, we made detailed measures of additional characteristics of the marsh pools at the southern end of the Sheepshead Meadows (Fig. 1). These pools varied in surface area (5–90 m²) and included the range of sizes typical of this unaltered marsh system (Lathrop et al. 2000). Depths ranged from 17–69 cm. Algal cover of the water surface (0–75%) and algal dry weight (0–75 g/0.25 m²) varied extensively as did the amount of the pool bottom covered by submerged vegetation (*Ruppia maritima* 0–100%, dry weight 0–21.9 g/0.25 m²). Turbidity (1–41 NTU), ammonia (0–3.1 mg/l), and pH (4.7–6.0) varied as well.

**Species composition and abundance**

The fishes in these series of observations with different gears included fundulids (*Fundulus heteroclitus, F. luciae, F. majalis* (Walbaum) [striped killifish], *Lucania parva*), a cyprinodontid (*Cyprinodon variegatus*), atherinids (*Menidia menidia* (L.) [Atlantic silverside], *M. beryllina* (Cope) [inland silverside]), and a gasterosteid (*Gasterosteus aculeatus* L. [threespine stickleback]) (Table 2). The most abundant species was *F. heteroclitus*, which represented 51.1% of all fishes collected with all gears in all years (n = 33,741) and occurred in 58.8% of all the samples. The second most abundant species was *C. variegatus*, which made up 20.4% of the total fish and occurred in 34.2% of samples. Other abundant species were *M. beryllina* (16.7% of total number, 10.8% of samples), *L. parva* (5.3% of total number, 16.6% of samples), and *M. menidia* (4.9% of total number, 4.9% of...
samples). Together, these species made up 98.3% of all fish collected. The atherinids would have made up a slightly larger percentage if all the small, recently hatched individuals (*Menidia* spp., n = 428) could have been identified to species.

The species composition clearly varied with gear type (Chi-Square: $\chi^2_{24} = 11,426.7$, p < 0.0001) (Table 2). *Fundulus heteroclitus* and *C. variegatus* were abundant in the collections from all gears, but the former was most abundant and fairly evenly divided between wire mesh traps (35.5%) and quatrefoil traps (38.6%), while the latter was most abundant and fairly evenly divided between quatrefoil traps (47.6%) and mini-seine (30.9%). Other species were more effectively collected with selected gears. *Menidia menidia* and *Menidia* spp. were most abundant in the quatrefoil trap (99.6% and 99.5% of total number, respectively). *Menidia beryllina* was very abundant and frequently collected in the quatrefoil trap (83.8% of total number) and mini-seine (15.6% of total number) and very infrequently collected with the other gears. *Lucania*

<table>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Species</strong></td>
<td>Wire mesh #</td>
<td>%</td>
<td>Throw #</td>
<td>%</td>
<td>Quatrefoil #</td>
<td>%</td>
<td>Exper. #</td>
<td>%</td>
<td>Mini-seine #</td>
<td>%</td>
<td>Totals #</td>
<td>%</td>
</tr>
<tr>
<td><em>Fundulus heteroclitus</em> (Linnaeus)</td>
<td>6117</td>
<td>69.1</td>
<td>1226</td>
<td>71.7</td>
<td>6658</td>
<td>94.2</td>
<td>1901</td>
<td>98.1</td>
<td>1329</td>
<td>100.0</td>
<td>17,231</td>
<td>59.2</td>
</tr>
<tr>
<td><em>Cyprinodon variegatus</em> Lacepède</td>
<td>895</td>
<td>27.3</td>
<td>330</td>
<td>46.1</td>
<td>3272</td>
<td>73.1</td>
<td>256</td>
<td>58.5</td>
<td>2122</td>
<td>100.0</td>
<td>6875</td>
<td>34.3</td>
</tr>
<tr>
<td><em>Menidia beryllina</em> (Cope)</td>
<td>0</td>
<td>0</td>
<td>27</td>
<td>10.0</td>
<td>4725</td>
<td>49.0</td>
<td>9</td>
<td>3.8</td>
<td>877</td>
<td>86.1</td>
<td>5638</td>
<td>10.8</td>
</tr>
<tr>
<td><em>Lucania parva</em> (Baird &amp; Girard)</td>
<td>2</td>
<td>0.4</td>
<td>322</td>
<td>22.8</td>
<td>1360</td>
<td>73.1</td>
<td>52</td>
<td>43.4</td>
<td>49</td>
<td>41.7</td>
<td>1785</td>
<td>16.6</td>
</tr>
<tr>
<td><em>Menidia menidia</em> (Linnaeus)</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1.1</td>
<td>1631</td>
<td>37.5</td>
<td>1</td>
<td>1.9</td>
<td>4</td>
<td>11.1</td>
<td>1638</td>
<td>4.9</td>
</tr>
<tr>
<td><em>Menidia</em> spp.</td>
<td>0</td>
<td>0</td>
<td>428</td>
<td>1.9</td>
<td>0</td>
<td>2</td>
<td>2.8</td>
<td>428</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Fundulus luciae</em> (Baird)</td>
<td>64</td>
<td>4.2</td>
<td>39</td>
<td>8.3</td>
<td>20</td>
<td>10.6</td>
<td>4</td>
<td>5.7</td>
<td>0</td>
<td>127</td>
<td>4.7</td>
<td></td>
</tr>
<tr>
<td><em>Fundulus majalis</em> (Walbaum)</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1.9</td>
<td>0</td>
<td>2</td>
<td>2.8</td>
<td>4</td>
<td>0.3</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><em>Gasterosteus aculeatus</em> Linnaeus</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>2.9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0.3</td>
<td></td>
<td></td>
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<tr>
<td>Unidentified fish</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1.9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Totals:</strong></td>
<td>7078</td>
<td>1946</td>
<td>18,101</td>
<td>2223</td>
<td>4385</td>
<td>33,731</td>
<td></td>
<td></td>
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</tbody>
</table>
parva (76.2% of total number) was another species that was most abundant in the quatrefoil trap. Some species (L. parva, M. beryllina) were seldom or never collected with wire mesh traps.

Size composition

The size composition of fishes collected varied with sampling gear and between species (Figs. 2–6). Mean length of fish collected by wire mesh and experimental traps were typically larger than other gears across almost all species. This pattern of size composition was most evident for F. heteroclitus (ANOVA: F4,10944 = 2212.8, p < 0.0001), F. luciae (ANOVA: F2,121 = 229.4, p < 0.0001), C. variegatus (ANOVA: F4,3880 = 953.9, p < 0.0001), and L. parva (ANOVA: F3,1239 = 1941, p < 0.0001). Mean length of M. beryllina collected was similar between gears (ANOVA: F2,2118 = 1.0, p = 0.38).

The smallest individuals collected varied between sampling gear and species. Small individuals (< 20 mm TL) were never collected with wire mesh traps. For F. heteroclitus, M. beryllina, and C. variegatus, all other gears collected small individuals, although for M. beryllina few individuals were collected in the experimental traps and none were collected in the wire mesh traps. For F. luciae and L. parva, both throw traps and quatrefoil traps collected the small individuals. The broadest range of sizes for F. heteroclitus were from wire mesh and experimental traps, but

![Figure 2](image-url). Comparison of Fundulus heteroclitus composite length-frequencies by gear. See Table 1 for further details.
Figure 3. Comparison of *Fundulus luciae* composite length-frequencies by gear. See Table 1 for further details.

Figure 4. Comparison of *Lucania parva* composite length-frequencies by gear. See Table 1 for further details.
Figure 5. Comparison of *Cyprinodon variegatus* composite length-frequencies by gear. See Table 1 for further details.

Figure 6. Comparison of *Menidia beryllina* composite length-frequencies by gear. See Table 1 for further details.
for *F. luciae* the greatest size range was from wire mesh, throw, and quatrefoil traps. For *L. parva*, the quatrefoil traps collected the greatest size range, followed closely by throw traps and experimental traps. For *M. beryllina*, a different set of gears, including throw and quatrefoil traps and mini-seine, captured the greatest size ranges. *Cyprinodon variegatus* differed from other species in that all gears caught a fairly wide range of size, but throw trap, experimental traps, and mini-seine had the greatest size ranges.

**Discussion**

**Environmental variables**

The wide variation in temperature and salinity is to be expected in estuarine habitats, but the marsh pools were even more variable because they reach higher values for these measures during the summer than adjacent intertidal (24–32 °C, 21–30‰e) and subtidal (19–28 °C, 25–33‰e) creeks (Able et al. 1996) and bay waters (Martino and Able 2003). This variation probably occurs because of their relatively small water volumes, shallow depths, and their isolation from adjacent waters during most of the tidal cycles. In fact, intensive studies at the pools in the southern portion of Sheepshead Meadows indicated that the marsh surface only flooded 24–34 times during the spring and summer (K.L. Hunter, M.G. Fox, and K.W. Able, pers. observ.). The wide ranges in almost all other environmental measures, including algal cover and dry weight, submerged vegetation cover and dry weight, turbidity, ammonia, and pH, indicate that the pools are likely a stressful environment for all animals and helps to explain the low diversity of fishes captured in these habitats (Dunson and Rowe 1996). This variability is further compounded by the extreme range of values for dissolved oxygen and resulting negative impacts of low dissolved oxygen on fish mortality (Christian 1981, Layman et al. 2000, Smith and Able 2003, Whoriskey et al. 1985). In addition, this variation not only occurs over the summer, but on daily/tidal cycles as well. Although the environmental extremes in marsh pools during the summer are likely stressful, in the winter these same habitats provide a thermal refuge in New Jersey (Smith and Able 1994) and Massachusetts (Raposa 2003) because temperatures are more moderate than in adjacent creeks.

**Sampling gear effects**

All sampling gears have some inherent biases (e.g., Able 1999, Kneib 1997), as do those used in this study. Such effects are evident in this study by the species- and size-biased compositions noted above. One of the most obvious sources of bias is the vertical location of gears in the pools. Those sampling gears that rested on the bottom (wire mesh and experimental traps) seldom captured fish that are found primarily in the water column, such as *M. beryllina* (K.W. Able, pers. observ. from underwater cameras). Captures
of large numbers of this species in the quatrefoil trap probably occurred because the trap floated at the surface. Further, few individuals would encounter the gears on the bottom, while the fish were surface skimming, a behavior that is common in all marsh pool species when subjected to long periods of low dissolved oxygen, as commonly occurs in the summer in these marsh pools (Smith and Able 2003) and elsewhere (Layman et al. 2000). Alternatively, gears that sampled the entire water column (throw trap and mini-seine) typically captured most species (Table 2).

Few of these gears have been evaluated for efficiency. The exception is wire mesh traps, which have been studied, at least relative to estimates of abundance (Kneib and Craig 2001) and size selection for *F. heteroclitus* (Smith and Able 1994). The former authors doubted the estimates of abundance because abundance varied with trapping duration. This is not likely to confound our use of the traps because in our study they were deployed for one hour and thus are not likely to influence abundance estimates (Kneib and Craig 2001). In addition, these traps were used primarily to determine species composition in marsh pools. In an effort to determine the lower size distribution of *F. heteroclitus*, Smith and Able (1994) found that few individuals less than 35 mm TL were retained in the wire mesh traps used in this study.

In an attempt to evaluate fish response to wire mesh traps, we deployed a wire mesh trap fitted with an underwater video camera (black-and-white Multi-Seacam 1050, Deep Sea Power and Light) in a tidal basin (Able et al., in press). The camera was hard-wired directly into a monitor in the senior author’s office at the Rutgers University Marine Field Station. The regular observations were made daily, 5 days per week. Each 10-min observation consisted of recording the number and species of fish in the trap as well as frequency of entry and escape. Based on 17.8 hours of observations during fall 2000 and spring 2001 it appeared that *F. heteroclitus* was capable of exiting the trap after entry.

However, the ratio of percent frequency of occurrence for entry/exits of *F. heteroclitus* was 0.6, a value smaller than that for *Tautogolabrus adspersus* (1.0), suggesting lower ability to escape. Most of the escape behavior by *F. heteroclitus* was directed at trying to investigate the sides of the trap and thus they seldom encountered the convex funnel opening in the trap. In addition, they were never observed to enter or exit this trap through the side walls. The ability to escape from the trap may be an underestimate because one of the funnel openings was blocked by the camera. Several other “normal” behaviors were observed in the trap including feeding and interspecific and intraspecific aggression.

**Species and size composition**

The observed species composition of marsh pools clearly is biased by the sampling gear, even in these relatively small, somewhat isolated habitats. This
was most obvious for wire mesh traps and throw traps in which *C. variegatus* was a distant second in overall numbers but was the most abundant species collected in the mini-seine (Table 2). Similarly, *M. beryllina* was never collected in the wire mesh traps, but was the second most abundant species in the quatrefoil trap and was common in the mini-seine collections. Further, the nature of gear walls (mesh or closed) and mesh size may influence the size of individuals collected (Figs. 2–6). Thus, future studies of fishes in salt marsh pools should take potential gear biases into consideration, just as it is an important consideration in other studies of estuarine fish habitat use (Able 1999, Kneib 1997). Although gear biases are likely responsible for some of the differences observed in species composition, we cannot rule out the possibility that some of the variation observed is the result of annual variation in abundance of certain species because different gears were used to collect fishes in different years. This might be a possible explanation for the abundance of *M. menidia* in the quatrefoil trap in 1993. However, mortality of this species due to low dissolved oxygen may have also influenced the abundance of this species (Smith and Able 2003).

The observations of fish species composition reported here reflect assemblages similar to those observed over a longer sampling period. In studies in some of the same marsh pools that occurred over June–October, species occurrence was identical with the exception of a few individuals of *Gobiosoma* spp. (Able et al. 1996). This array of species has also been reported for other marsh pools in New Jersey (Coorey et al. 1985, Talbot and Able 1984, Talbot et al. 1986) as well as in barrier island ponds in Virginia (Layman et al. 2000). The fauna of marsh pools in the St. Lawrence estuary in Canada is quite different as they are dominated by three species of sticklebacks (*Gasterosteus aculeatus*, *G. wheatlandi* Putnam [blackspotted stickleback], and *Pungitius pungitius* (L.) [ninespine stickleback]) (Whoriskey and FitzGerald 1989), while *F. luciae*, *M. menidia*, and *M. beryllina* do not occur that far north in this or any other habitat. The relatively depauperate nature of the species assemblage in marsh pools in New Jersey (7 species) is evident when they are compared to adjacent subtidal (15 species) or intertidal (31 species) creeks in the same marshes as in this study (Able et al. 1996). The depauperate species assemblage may be largely influenced by the extreme variation and low dissolved oxygen levels that appear to be common components of these marsh pools systems (Layman et al. 2000, Smith and Able 2003) although other environmental factors, (present study) and biological factors (Layman et al. 2000) could influence the fish assemblage as well.

**Importance of salt marsh pool habitat**

In previous studies of fish use of salt marsh habitats in the same study area, salt marsh pools were considered part of the marsh surface (Rountree and Able 1992). We now suggest that marsh pools be recognized as a
separate habitat because of their unique physical and biological characteristics. For example, 1) they tend to have higher and more variable summer temperatures and salinities than adjacent habitats (Able et al. 1996); 2) the extreme variation in some environmental characteristics in marsh pools, such as dissolved oxygen, cause mortality for some species and changes in the behavior of others (Layman et al. 2000, Smith and Able 2003); and 3) marsh pools provide habitat for the larvae and small juveniles of all the dominant species and thus may serve as nurseries (see Beck et al. 2001). In addition, in many marsh systems along the northeastern coast of the US, marsh pools have been drastically reduced or eliminated as part of the efforts to control mosquito populations by creating a series of parallel drainage ditches (Lathrop et al. 2000, Redfield 1972). In the process, marsh pools have been drained or filled, as occurred in a portion of the Sheepshad Meadows study area (Lathrop et al. 2000). However, in recent years the desire to control mosquito populations has also caused marsh pools to be created, as part of Open Marsh Water Management (Ferrigno and Jobbins 1968, Ferrigno et al. 1975, Meredith et al. 1985, Shisler 1978), to provide habitat for fish predators of mosquito larvae. This has occurred in the Sheepshad Meadows as well (Lathrop et al. 2000).

While we recognize that marsh pools may serve different habitat functions than other marsh habitats, it is important to recognize that their occurrence in salt marshes may vary geographically and as a result of human-induced changes (Adamowicz and Roman 2005). We know that many of the marsh pools we have sampled have been present, and of similar size, for over a decade (K.W. Able, pers. observ.); therefore they appear to be temporally stable features (Redfield 1972). Also, the pools we studied are within the range of values of size and density of unaltered pools in New England marshes (Adamowicz and Roman 2005). While marsh pools appear to be common features of New England-type salt marshes from Atlantic Canada (Reed and Moisan 1971, Ward and FitzGerald 1983) and throughout the northeastern US (Teal 1986), they do not appear to be consistent features along the coast of the southeastern US (Wiegert and Freeman 1990). Thus, despite the extensive attempts over the last century to remove and/or create marsh pools, the functional significance of these habitats is still not clearly understood and further studies are warranted.

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