Spatial and Temporal Patterns in Abundance and Distribution of Juvenile Ladyfish (Elops saurus) in Florida Waters (USA)
Spatial and Temporal Patterns in Abundance and Distribution of Juvenile Ladyfish (*Elops saurus*) in Florida Waters (USA)

Juan C Levesque*

Geo-Marine Inc., Environmental Resources Division, Marine Science Department, 2201 Avenue K, Suite A2, Plano, Texas 75074, USA.

*Present Address: Cardno ENVIRONMENTAL, Ecological Division, 3905 Crescent Park Drive, Riverview, Florida 33578, USA.

Correspondence: Juan.Lovesque@cardno.com, shortfin_mako_shark@yahoo.com

Accepted: Apr 25, 2013; Published: May 20, 2013

Abstract

Relative abundance and distribution are two of the most important life-history characteristics that fishery managers use to make informed decisions, such as identifying nursery grounds or protecting specific habitats. Many researchers have already estimated the relative abundance and distribution of various commercially and recreationally important species (e.g., permit [*Trachinotus falcatus*], tarpon [*Megalops atlanticus*], and bonefish [*Albula vulpes*]) found within and outside of the United States. Unfortunately, comparative information for ladyfish (*Elops saurus*) is limited and nonexistent for most regions of the world. Given the need to examine the early life-history of ladyfish in more detail, and at a finer scale, the specific objectives of this study were to evaluate the annual relative abundance and distribution (spatial and temporal) of juvenile ladyfish in nine distinct Florida estuaries (USA). Findings showed that juvenile ladyfish recruitment and abundance in Florida waters varied seasonally and annually. Also, the results indicated that juvenile ladyfish recruited into secluded freshwater sites from late-winter to summer depending on the estuary. Annual juvenile ladyfish abundance demonstrated an alternating pattern, and the findings showed that the estimated annual abundance had increased in Tampa Bay and in the Indian River Lagoon during 1987 through 1995. Results also showed that juvenile ladyfish were unevenly distributed throughout Florida estuaries; juvenile ladyfish distribution was skewed towards a limited number of specific locations. It was evident that juvenile ladyfish did not recruit to a wide-variety of habitats; they required specific micro-habitats. In summary, juvenile ladyfish were collected primarily at specific stations located near, or adjacent to, freshwater input or protected bayou areas during late-winter through early summer months.

Keywords: Conservation; fishery management; life-history; recruitment; young-of-the-year.

1. Introduction

Fishery managers need to understand early life-history traits to make sound fisheries conservation and management decisions. Relative abundance and distribution are two of the most important life-history characteristics that fishery managers use to make informed decisions, such as identifying nursery grounds or protecting specific habitats. This type of life-history information can also be used to recognize habitat use patterns of juvenile fishes, and to assess potential impacts associated with anthropogenic activities [1]. Stevens *et al.* [2] stated that it is “important to apply life-history models in a variety of estuarine settings to fully define a species’ suite of juvenile habitats.” The researchers also indicated that having this type of early life-history information can be useful in resource management at the local level, which facilitates managers to target specific areas for protection, land acquisition, and restoration. Many researchers have already estimated the relative abundance and distribution of various commercially and recreationally important species (e.g., permit [*Trachinotus falcatus*]; [1]; tarpon [*Megalops atlanticus*] and bonefish [*Albula vulpes*]; [3]) found within and outside of the United States. Unfortunately, comparative information for ladyfish (*Elops saurus*) is limited and nonexistent for most regions of the world.

Ladyfish inhabit coastal beaches, bays, and estuaries of the southeastern United States [4, 5], and other subtropical and tropical regions worldwide [6, 7]. Ladyfish commercial landings in Florida (1989–1995) averaged 2,064,048 kg (4,550,447 pounds) and valued at $US 1,175,775 [7]. Peak ladyfish landings occurred in 1990 at 2,721,446 kg (5,999,763 pounds) and the estimated value was $1,439,750 [8]. In 1994, ladyfish landings in Florida were 2,174,804 kg (4,795,599 lbs) and the estimated value was $1,859,106 [8]. Overall, ladyfish ranked seventh in

Co-Publisher: OMICS Group, www.omicsonline.org http://astonjournals.com/faj
total finfish landings and eleventh in estimated commercial value. Commercial ladyfish landings have declined since the State of Florida prohibited the use of gillnets in 1995 (Figure 1; \( r^2 = 0.74 \)), but the most recent economic fishery data continues to prove that ladyfish are still a valuable commercial fish in Florida waters. Today, ladyfish are an important Florida commercial species averaging $828,959 during 1996 through 2007 [9]. Commercial value has declined over time ($187,553 in 2012), but ladyfish continue to be targeted by commercial fishermen in Charlotte Harbor, Florida (G. Poulakis, pers. comm., 2 June 2010) and other world-wide locations, such as Africa and India [6, 7]. Besides having commercial value, ladyfish are also an important recreational game fish to the light-tackle angler with recreational catch rates in Florida averaging between two and three ladyfish per fishing trip [8].

**Figure 1:** Florida commercial ladyfish landings and value during 1989 through 2007. The two linear lines depict total landings before (1989-1994) and after (1995-2007) the State of Florida prohibited the use of gillnet gear in state waters.

\[
y = -127265x + 3E+06 \\
R^2 = 0.4334; \ (1989-1995)
\]

\[
y = -62516x + 1E+06 \\
R^2 = 0.2459; \ (1996-2007)
\]

Previous research has demonstrated that ladyfish are estuarine dependent [10-14], but only one study has investigated ladyfish nursery habitats in any detail. According to McBride et al. [5], ladyfish metamorphosing larvae recruit to specific sites within two main Florida estuaries (Tampa Bay and Indian River Lagoon) mostly in the spring. The researchers reported that ladyfish metamorphosing larvae were primarily collected in waters with low salinities (23–25 ppt). In Tampa Bay, ladyfish were collected in mesohaline and oligohaline waters, and in the Indian River Lagoon ladyfish were collected in mesohaline and polyhaline waters. Despite this foundational information, neither published information describing juvenile ladyfish recruitment (e.g., monthly or annual relative abundance) is unavailable nor is there any information about how juvenile ladyfish use other Florida estuaries as habitat. In addition, researchers have yet to examine the specific spatial distribution of juvenile ladyfish within an estuary. Given the need to examine the early life-history of ladyfish in more detail, and at a finer scale, the specific objectives of this study were to evaluate the annual relative abundance and distribution (spatial and temporal) of juvenile ladyfish in nine distinct Florida estuaries (USA).
2. Methods

2.1. Study area
Field-collections were made at nine distinct locations throughout the State of Florida, USA (Figure 2). Sampling stations were located in Tampa Bay (TB), Little Manatee River (LMR), Choctawhatchee Bay and Santa Rosa Sound (CB-SRS), Charlotte Harbor (CH), Indian River Lagoon (IRL), Volusia County (VC [Tomoko River Basin, Ponce de Leon Inlet, and Mosquito Lagoon complex]), and Florida Bay (FB) (Figures 3–8). Three locations (TB, CB-SRS, and CH) were located on the west coast and two (IRL and VC) on the east coast of Florida.

2.2. Sampling methodology and gear
Field sampling was conducted by Florida Fish and Wildlife Conservation Commission (FWC), Fisheries Independent Monitoring Program (FIM) personnel at pre-determined stations (i.e., fixed-stations). Fixed-stations were selected according to geographical location, habitat, and depth [15]. Further details on sampling procedures and site descriptions are provided by [5, 16–23], and J. Colvocoresse (unpubl). Fixed-station field sampling was conducted once a month during daylight hours (i.e., the period between one hour after sunrise and one hour before sunset). Depending on the location (bay) and year the state established its FIM program, the time-series dataset varied among geographical location: TB [September 1987–1995], LMR [January 1988–1991], IRL [January 1991–1995], CH [January 1991–1995], CB-SRS [October 1992–1995], VC [January 1993–1995], and FB [January 1994–1995]).

Juvenile ladyfish were collected primarily with two types of sampling gear: a center-bag seine and otter trawl. However, at some sites, other types of sampling gears were used, such as gillnets, blocknets, and seines of various sizes (Table 1). Regardless of the gear type, three repetitions (i.e., hauls) were made at each sampling station. Specific gear descriptions for each estuary sampled can be found in the above references.

Based on the profile of the beach (bank) and water depth, one of three deployment methods (beach, boat, and offshore) were used to deploy the seine at each sampling station [15]. For instance, a beach deployment was used when the water depth was shallow and the bank had a gradual decline. The beach method consisted of the seine being pulled parallel to shore by two biologists for a total distance of 9.1 m; a 15.5 m line stretched between each seine pole was used to assure the net was being pulled the same inner-pole distance for every haul. A boat deployment was used at stations with deep waters (water depth 0.7–1.2 m), or when the bank profile was too shallow to reach the beach or bank by boat. The offshore deployment followed the same procedures as the beach method with one minor difference; at the end of the 9.1 m distance, two biologists worked the center-bag seine using a stationary pivot pole to ensure the catch did not escape [15].

2.3. Data
The FWC used two experimental approaches in the 1990s to survey fish populations throughout Florida: monthly fixed-station (FS) and year-round stratified random (SRS) sampling [15]. For these analyses, data were restricted to monthly FS collections because preliminary analyses of SRS data showed that most ladyfish collected with this approach were larger (> 300 mm Standard Length [SL]) and older than one year [5]. Moreover, fewer juvenile ladyfish were collected with SRS than with the FS approach, so pooling SRS with FS datasets would not have benefited this study given the primary objective was to report relative abundance and distribution for young-of-the-year (YOY) ladyfish. In fact, using SRS data could have potentially biased the results (i.e., under or overestimating). A maximum cut-off length of 100 mm SL was chosen because previous work by Levesque (unpubl) suggested that ladyfish larger than 100 mm SL can avoid some types of sampling gear (i.e., small-mesh center-bag seines). After every haul, fish were sorted, enumerated, and measured (20 individuals); ladyfish were measured to the nearest 1 mm SL. Because of gear-selectivity bias and small sample sizes for many of the sampling gears, these analyses were restricted to field-collections associated with beach seines. For these analyses, the only gear examined was the center-bag seine; center-bag seines were 21.3 m by 1.8 m center bag constructed of 3.2 mm #35 knotless nylon Delta mesh (Table 1). Although deployment methods could potentially affect catch, specific seine deployment methods were not analyzed separately; seine deployment methods were assumed to have no sampling selectivity issues (i.e., assumed to be equal).
Figure 2: Map of Florida’s Fisheries Independent Monitoring program sampling locations in Florida (USA) during September 1987 through December 1995.
Figure 3: Map of fixed-station sampling sites in Tampa Bay during September 1987 through December 1995.
Figure 4: Map of fixed-station sampling sites in Choctawhatchee Bay and Santa Rosa Sound during October 1992 through December 1995.

2.4. Statistical analysis
Prior to data analyses, all datasets were tested for normality and homoscedacity (variance equivalently standard deviation) are equal using Kolmogorov-Smirnov [24] and Bartlett [25, 26] tests, respectively. If the datasets passed the normality test, then parametric procedures were employed; otherwise, the data were log-transformed [log (X+1)] to meet the underlying assumptions of normality [24]. However, if the data still did not meet the assumptions of normality after transformation, then non-parametric tests were applied. For all analyses, statistical significance was defined as \( P < 0.05 \). In the presence of significance at the 95% confidence level for the omnibus Analysis of Variance (ANOVA) or Kruskal-Wallis non-parametric multi-sample test, a post-hoc multiple comparison test was used to perform pairwise comparisons. Arithmetic means were presented with associated standard deviations. All analyses were conducted using Microsoft Excel\textsuperscript{1} and WINKS SDA Software.

Juvenile ladyfish relative abundance was estimated by using the metric catch-per-unit-effort (CPUE). To examine temporal and spatial abundance variability within each estuary, annual and monthly catches were standardized as CPUE defined as the total number of juvenile ladyfish captured by haul. To determine within estuary variability in relative abundance, CPUE was calculated for each fixed-station and then an ANOVA test was used to test the null hypothesis that the relative abundance (CPUE) of juvenile ladyfish among month, year, and location (fixed-station) was equal. For each individual estuary, annual juvenile ladyfish abundance and spatial distribution was estimated by comparing mean CPUE values among fixed stations using an ANOVA test. If no significant differences were detected in mean CPUE among fixed stations, then the data were pooled.
Figure 5: Map of fixed-station sampling sites in Charlotte Harbor during January 1991 through December 1995.
Figure 6: Map of fixed-station sampling sites in the Indian River Lagoon during January 1991 through December 1995.
Figure 7: Map of fixed-station sampling sites in Volusia County during January 1993 through December 1995.
3. Results

A total of 22,674 hauls (all gear types) were conducted in the Florida state-wide survey during 1987 through 1995 (Figure 8). Of these, a total of 7,762 hauls were made in TB, 3,857 in the IRL, 3,578 in VC, 2,446 in CH, 1,537 in the LMR, 1,401 in CB-SRS, and 1,970 in FB. In total, 3,692 juvenile ladyfish (17% of all hauls) were collected in Florida waters during 1987 through 1995. Forty-seven percent \((n = 1,718)\) of the juvenile ladyfish were collected in Tampa Bay, 39% \((n = 1,454)\) in the IRL, 9% \((n = 326)\) in VC, 3.6% \((n = 130)\) in the LMR, 1% \((n = 50)\) in CH, and 0.4% \((n = 14)\) in FB (Figure 9). Owing to the inadequate sample size in FB \((n = 14; [1994–1995])\) and CB-SRS \((n = 0; [1992–1995])\) to provide adequate statistical power, these data was not included in further analyses.

Throughout the Florida state-wide survey, juvenile ladyfish were collected with different types of sampling gear (Table 1). Eighty-four percent \((n = 3,107)\) of juvenile ladyfish were collected with seines, 8% \((n = 279)\) with gillnets, 4% \((n = 148)\) with blocknets, and 4% \((n = 158)\) with trawls. Overall, annual juvenile ladyfish abundance varied significantly within each estuary and by gear \([F(9, 20928) = 22.66, P < 0.001]\). Because of gear-selectivity (Levesque unpubl.), data were unable to be pooled; therefore, findings were reported as bay-specific.

3.1. Regional relative abundance patterns

3.1.1. Annual abundance

A total of 5,252 seine hauls were conducted in TB during 1987 through 1995 (Figure 8). Of these, a total of 1,194 juvenile ladyfish \((< 100 \text{ mm SL})\) were collected in TB. Most juvenile ladyfish were collected in 1990 \((n = 580, 49\%)\), 1994 \((n = 204, 17\%)\) and 1995 \((n = 202, 17\%)\). Annual juvenile ladyfish CPUE ranged from 0.0056 juvenile ladyfish per haul in 1989 to 0.0843 juvenile ladyfish per haul in 1990 (Figure 9; Table 2), and significant difference was detected \([F(8, 5243) = 22.66, P < 0.001]\).
Table 1: Numbers of juvenile ladyfish (*Elops saurus*) collected in Florida waters (1987-1995) by sampling gear and method.

<table>
<thead>
<tr>
<th>Number of Juvenile Ladyfish Collected</th>
<th>Number of Gear Hauls</th>
<th>Gear Type and Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>941</td>
<td>2,728</td>
<td>21.3 m center-bag seine, 3.1 mm mesh, leads spaced every 150 mm; boat set</td>
</tr>
<tr>
<td>728</td>
<td>2,074</td>
<td>21.3 m center-bag seine, 3.1 mm mesh, leads spaced every 150 mm; onshore set w/o boat (beach set)</td>
</tr>
<tr>
<td>618</td>
<td>1,335</td>
<td>21.3 m center-bag seine, 3.1 mm mesh, 300 mm mesh lead spacing, on shore; deployed from boat (boat set)</td>
</tr>
<tr>
<td>398</td>
<td>273</td>
<td>183 m center-bag seine, green dipped, 37.5 mm stretch-mesh (18.8 mm bar mesh), 150 mm lead spacing; net set from skiff in a rectangular pattern on shore in water depth &lt; 0.5 m</td>
</tr>
<tr>
<td>166</td>
<td>3,375</td>
<td>21.3 m center-bag seine, 3.1 mm mesh, leads spaced every 150 mm; offshore-circular set</td>
</tr>
<tr>
<td>157</td>
<td>6,297</td>
<td>6.1 m otter trawl w/ 3.1 mm liner and tickler chain; a straight tow</td>
</tr>
<tr>
<td>153</td>
<td>696</td>
<td>198 large mesh gillnet with five panels: 15 m of 50 mm mesh (#139 twine), and 46 m each of 75 mm, 100 mm, 125 mm, and 150 mm mesh (#208 twine); not set in association w/ reverse set gillnet; normal set: small mesh to shore</td>
</tr>
<tr>
<td>115</td>
<td>1,460</td>
<td>12.2 m center bag seine, 6.3 mm mesh, 1.2 m deep</td>
</tr>
<tr>
<td>95</td>
<td>861</td>
<td>184 large mesh gillnet with four panels: 46 m each of 75 mm, 100 mm, 125 mm, and 150 mm mesh; normal set: small mesh to shore</td>
</tr>
<tr>
<td>77</td>
<td>137</td>
<td>61 m blocknet, 300 mm lead spacing; set in association with mangroves</td>
</tr>
<tr>
<td>71</td>
<td>118</td>
<td>61 m blocknet, 300 mm lead spacing; set in association with seawall</td>
</tr>
<tr>
<td>48</td>
<td>245</td>
<td>21.3 m center-bag seine, 3.1 mm mesh, 300 mm lead spacing; onshore w/o boat (beach set)</td>
</tr>
<tr>
<td>15</td>
<td>77</td>
<td>6.1 m center bag seine, 1.6 mm mesh, 1.2 m deep</td>
</tr>
<tr>
<td>9</td>
<td>8</td>
<td>183 m center-bag seine 25.4 mm stretch mesh (12.7 mm bar mesh), 150 mm lead spacing; net set from skiff in a semicircular pattern on shore in water depth &lt; 0.1 m</td>
</tr>
<tr>
<td>1</td>
<td>535</td>
<td>21.3 m terminal-bag seine, 3.1 mm mesh, leads spaced every 300 mm; offshore-circular set</td>
</tr>
<tr>
<td>1</td>
<td>420</td>
<td>6.1 m otter trawl w/ 3.1 mm liner and tickler chain; arc tow</td>
</tr>
<tr>
<td>1</td>
<td>62</td>
<td>21.3 m terminal-bag seine, 300 mm lead spacing; offshore-circular set in association with seawall blocknet sets</td>
</tr>
<tr>
<td>0</td>
<td>79</td>
<td>6.1 m seine w/o bag, 3.1 mm mesh</td>
</tr>
<tr>
<td>0</td>
<td>81</td>
<td>6.1 m center bag seine, 3.1 mm mesh, leads spaced at 150 mm; modified beach set</td>
</tr>
<tr>
<td>0</td>
<td>126</td>
<td>21.3 m center-bag seine, 3.1 mm mesh, 300 mm lead spacing; offshore set</td>
</tr>
<tr>
<td>0</td>
<td>72</td>
<td>21.3 m terminal-bag seine, 3.1 mm mesh, leads spaced every 150 mm; offshore-circular set</td>
</tr>
<tr>
<td>0</td>
<td>6</td>
<td>21.3 m center-bag seine, 3.1 mm mesh, 150 mm lead spacing, w/many ends line; onshore set w/o boat (beach set)</td>
</tr>
<tr>
<td>0</td>
<td>87</td>
<td>21.3 m terminal-bag seine, 300 mm lead spacing; offshore-circular set in association with mangrove blocknets</td>
</tr>
<tr>
<td>0</td>
<td>12</td>
<td>21.3 m terminal-bag seine, 150 mm lead spacing; offshore-circular set in association with seawall blocknets sets</td>
</tr>
<tr>
<td>0</td>
<td>12</td>
<td>21.3 m terminal-bag seine, 150 mm lead spacing; offshore-circular set in association with seawall blocknet sets</td>
</tr>
<tr>
<td>0</td>
<td>18</td>
<td>21.3 m center-bag seine, 150 mm lead spacing; offshore-circular set in association with seawall blocknet sets</td>
</tr>
<tr>
<td>0</td>
<td>18</td>
<td>21.3 m center-bag seine, 150 mm lead spacing; offshore-circular set in association with mangrove blocknet sets</td>
</tr>
<tr>
<td>0</td>
<td>6</td>
<td>183 m center-bag seine 25.4 mm stretch mesh (12.7 mm bar mesh), 150 mm lead spacing; net set from skiff in a semicircular pattern on shore in water depth &gt; 0.1 m</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>183 m center-bag seine, green dipped, 37.5 mm stretch mesh (18.8 mm bar mesh), 150 mm lead spacing; net set in a rectangular pattern on shore with water depth &lt;0.1m</td>
</tr>
<tr>
<td>0</td>
<td>3</td>
<td>6.1 m otter trawl w/ 3.1 mm liner and tickler chain; combination tow (straight trawl/arc boat)</td>
</tr>
</tbody>
</table>
Figure 9: The total number of hauls (all gear types), seine hauls, and juvenile ladyfish collected (n = 3,692) in Florida waters during 1987 through 1995. Tampa Bay (TB), Indian River Lagoon (IRL), Volusia County (VC), Charlotte Harbor (CH), Florida Bay (FB), and Choctawhatchee Bay and Santa Rosa Sound (CB-SRS). Mean ± Standard error are plotted.

A total of 1,684 seine hauls were conducted in the IRL during 1991 through 1995 (Figure 9). Of these, a total of 1,167 juvenile ladyfish were collected in the IRL. Most juvenile ladyfish were collected in 1993 (n = 555, 48%) and 1995 (n = 261, 22%). Annual juvenile ladyfish CPUE ranged from 0.0278 juvenile ladyfish per haul in 1991 to 0.128 juvenile ladyfish per haul in 1993 (Figure 9; Table 2), and a significant difference was detected [F (4, 1678) = 9.02, P < 0.001]. A post-hoc multiple comparison test showed there was no significant difference in juvenile ladyfish CPUE for the years 1991, 1992, 1994, and 1995.

A total of 1,538 seine hauls were conducted in the LMR during 1988 through 1991 (Figure 9). Of these, a total of 236 juvenile ladyfish were collected in the LMR. Most juvenile ladyfish were collected in 1988 (n = 154, 65%). Annual ladyfish CPUE ranged from 0.004 juvenile ladyfish per haul in 1991 to 0.058 juvenile ladyfish per haul in 1988 (Figure 11; Table 2), and a significant difference was detected [F (3, 1533) = 16.36, P < 0.01]. A post-hoc multiple comparison test showed there was no significant difference in juvenile ladyfish CPUE for the years 1989, 1990, and 1991.

A total of 1,942 seine hauls were conducted in VC during 1993 through 1995 (Figure 9). Of these, a total of 198 juvenile ladyfish were collected in VC. Most juvenile ladyfish were collected in 1993 (n = 131, 66%). Annual juvenile ladyfish CPUE ranged from 0.0076 juvenile ladyfish per haul in 1994 to 0.031 juvenile ladyfish per haul in 1993 (Table 2), and a significant difference was detected [F (2, 1938) = 9.22, P < 0.001]. A post-hoc multiple comparison test showed there was no significant difference in juvenile ladyfish CPUE between the years 1994 and 1995.

A total of 1,504 seine hauls were conducted in CH during 1991 through 1995 (Figure 9). Of these, a total of 44 juvenile ladyfish were collected in the CH. Most juvenile ladyfish were collected in 1995 (n = 22, 50%). Annual juvenile ladyfish CPUE ranged from 0.0024 juvenile ladyfish per haul in 1992 to 0.0126 juvenile ladyfish per haul in 1995; no significant difference was detected among years [F (4, 1498) = 1.97, P = 0.10, Table 2].
Table 2: Mean annual abundance (CPUE) of juvenile ladyfish in Florida waters (1987-1995): Tampa Bay (TB), Indian River Lagoon (IRL), Little Manatee River (LMR), Volusia County (VC), Charlotte Harbor (CH), and Florida Bay (FB). * symbol indicates ANOVA test significance ($P < 0.05$). ** symbol indicates Post-hoc (Newman-Keuls) comparison test (no significant difference) and superscripts depict relative annual abundance ranking in ascending order. S.D is the standard deviation and $n$ is the number of ladyfish collected.

<table>
<thead>
<tr>
<th>Year</th>
<th>TB (*)</th>
<th>IRL (*)</th>
<th>LMR (*)</th>
<th>VC (*)</th>
<th>CH</th>
<th>FB</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>0.0074 (S.D ± 0.0507, $n = 226$)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1988</td>
<td>0.0071 (S.D ± 0.0458, $n = 296$)</td>
<td>-</td>
<td>0.058 (S.D ± 0.1903, $n = 418$)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1989</td>
<td>0.0056 (S.D ± 0.0522, $n = 689$)</td>
<td>-</td>
<td><strong>0.0061 (S.D ± 0.0626, $n = 334$)</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1990</td>
<td>0.0843 (S.D ± 0.2591, $n = 741$)</td>
<td>-</td>
<td><strong>0.0228 (S.D ± 0.1244, $n = 408$)</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1991</td>
<td>0.0104 (S.D ± 0.723, $n = 689$)</td>
<td><strong>0.0278 (S.D ± 0.1234, $n = 131$)</strong></td>
<td><strong>0.0004 (S.D ± 0.0345, $n = 377$)</strong></td>
<td>-</td>
<td>0.0104 (S.D ± 0.0667, $n = 190$)</td>
<td>-</td>
</tr>
<tr>
<td>1992</td>
<td>0.0175 (S.D ± 0.1274, $n = 592$)</td>
<td><strong>0.0388 (S.D ± 0.1616, $n = 392$)</strong></td>
<td>-</td>
<td>-</td>
<td>0.0024 (S.D ± 0.0311, $n = 328$)</td>
<td>-</td>
</tr>
<tr>
<td>1993</td>
<td>0.0141 (S.D ± 0.0873, $n = 557$)</td>
<td>0.128 (S.D ± 0.3268, $n = 444$)</td>
<td>-</td>
<td>0.031 (S.D ± 0.1382, $n = 699$)</td>
<td>0.0046 (S.D ± 0.0369, $n = 328$)</td>
<td>-</td>
</tr>
<tr>
<td>1994</td>
<td>0.0401 (S.D ± 0.1638, $n = 707$)</td>
<td><strong>0.0598 (S.D ± 0.2218, $n = 400$)</strong></td>
<td>-</td>
<td><strong>0.0076 (S.D ± 0.0529, $n = 606$)</strong></td>
<td>0.004 (S.D ± 0.0452, $n = 326$)</td>
<td>0.0013 (S.D ± 0.02, $n = 452$)</td>
</tr>
<tr>
<td>1995</td>
<td>0.0518 (S.D ± 0.1644, $n = 755$)</td>
<td><strong>0.085 (S.D ± 0.2651, $n = 316$)</strong></td>
<td>-</td>
<td><strong>0.0144 (S.D ± 0.0892, $n = 636$)</strong></td>
<td>0.0126 (S.D ± 0.0844, $n = 331$)</td>
<td>0.0028 (S.D ± 0.0362, $n = 579$)</td>
</tr>
</tbody>
</table>

Figure 10: The mean annual relative abundance (number of juvenile ladyfish per haul) of juvenile ladyfish collected in Florida estuaries during 1987 through 1995 ($n = 3,107$). Mean ± Standard Error are plotted.
3.1.2. Monthly abundance

Differences in monthly juvenile abundance varied significantly in each estuary, but demonstrated similar cyclical patterns. In TB, juvenile ladyfish peak recruitment months were April through June (Figures 10, 11). Although juvenile ladyfish were collected in every month, most were collected during April (25%, n = 296), May (46%, n = 555), and June (11%, n = 130). Monthly juvenile ladyfish CPUE ranged from 0.0007 juvenile ladyfish per haul in November to 0.1412 juvenile ladyfish per haul in May (Figure 12; Table 3), and a significant difference was detected \[ F (11, 5240) = 37.7, P < 0.001 \].

In the IRL, juvenile ladyfish peak recruitment months were February through June (Figures 10, 11). Again, juvenile ladyfish were collected in every month; however, most were collected during March (17%, n = 199), April (15%, n = 171), May (21%, n = 249), and June (16%, n = 187). Monthly juvenile ladyfish CPUE ranged from 0.0132 juvenile ladyfish per haul during December to 0.1447 juvenile ladyfish per haul during in June (Figures 10, 11; Table 3), and a significant difference was detected \[ F (11, 1671) = 6.16, P < 0.001 \]. A post-hoc multiple comparison test showed that the CPUE for December, September, October, November, August, June, July and February were similar. Also, the test showed there was no significant difference in juvenile ladyfish CPUE among the following months: August, January, July, February, March, May, April, and June.

Juvenile ladyfish peak recruitment months in the LMR were January through June. Juvenile ladyfish were collected throughout the year; however, most were collected in January (44%, n = 105) and June (22%, n = 52). Monthly juvenile ladyfish CPUE ranged from 0.0 juvenile ladyfish per haul during October and November to 0.2864 juvenile ladyfish per haul during January (Figures 10, 11; Table 3), and a significant difference was detected \[ F (11, 1525) = 12.31, P < 0.001 \]. A post-hoc analysis multiple comparison test showed that there was no significant difference in juvenile ladyfish CPUE among February, May, and June or during April, July, August, December, September, March, February, and May. Also, the test showed there was no significant difference in juvenile ladyfish CPUE among the following months: November, October, April, July, August, December, September, March, and February; January ladyfish CPUE were distinct from any other month.

Figure 11: The monthly total number of juvenile ladyfish collected in two primary Florida estuaries [Tampa Bay (1987-1995), Indian River Lagoon (1991-1995)]. The dash line depicts the moving average.
Juvenile ladyfish peak recruitment months in VC were March through June. Juvenile ladyfish were collected in every month, except November. Most juvenile ladyfish were collected during March (10%, \(n = 20\)) and April (68%, \(n = 135\)). Monthly juvenile ladyfish CPUE ranged from 0.0 juvenile ladyfish per haul during July, November, and December to 0.0961 juvenile ladyfish per haul during in April (Figures 10, 11; Table 3), and a significant difference was detected \([F (11, 1929) = 14.35, P < 0.001]\). A post-hoc multiple comparison tests showed that only April CPUE was significantly different than the other months.

In CH, juvenile ladyfish peak recruitment months were April and May. Juvenile ladyfish were collected throughout the year; however, most were collected in April (30%, \(n = 13\)) and May (30%, \(n = 13\)). Monthly juvenile ladyfish CPUE ranged from 0.0 juvenile ladyfish per haul during January, August, and December to 0.0242 juvenile ladyfish per haul during May (Figures 10, 11; Table 3), and a significant difference was detected \([F (11, 1491) = 2.91, P < 0.001]\). A post-hoc multiple comparison test showed that there was no significant differences in juvenile ladyfish CPUE among the following months: April, May, and June or between January–April, and June–December.

**Figure 12:** The mean monthly relative abundance (number of juvenile ladyfish per haul) of juvenile ladyfish collected in Florida waters during 1987 through 1995 \((n = 3,107)\). Mean ± Standard Error are plotted.
3.2. Regional spatial distribution patterns
Spatial differences in juvenile ladyfish abundance within each estuary were evident. In TB, depending on the month, at least one juvenile ladyfish was collected at most of the fixed stations. However, 68% of all juvenile ladyfish were collected at only two stations: station 1 (49%, n = 590) and station 4 (19%, n = 222). Juvenile ladyfish CPUE ranged from 0.0 juvenile ladyfish per haul at stations 5, 9, 10, and 48 to 0.291 juvenile ladyfish per haul at station 47 (Figure 12), and a significant difference was detected [F (19, 4773) = 15.95, P < 0.001]. A post-hoc multiple comparison test showed there was no significance difference in juvenile ladyfish CPUE among the following stations: 48, 6, 7, 11, 8, 12, 3, 2, 42, 1, 44, 43, 41, and 54. In addition, the test showed there was no significant difference in juvenile ladyfish CPUE among the following stations: 52 and 47 or 5, 9, 10, 48, 6, 7, 11, 8, 12, 3, 2, 42, 1, 44, 43, 41, and 54.

Table 3: Mean monthly abundance (CPUE) of juvenile ladyfish in Florida waters (1987-1995): Tampa Bay (TB), Indian River Lagoon (IRL), Little Manatee River (LMR), Volusia County (VC), Charlotte Harbor (CH), and Florida Bay (FB). * symbol indicates ANOVA test significance (P < 0.05). ** symbol indicates Post-hoc (Newman-Keuls) comparison test (no significant difference) and superscripts depict relative annual abundance ranking in ascending order. S.D is the standard deviation and n is the number of ladyfish collected.

<table>
<thead>
<tr>
<th>Month</th>
<th>TB (*)</th>
<th>IRL (*)</th>
<th>LMR (*)</th>
<th>VC (*)</th>
<th>CH</th>
<th>FB</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>0.0022 (S.D. ± 0.0258, n = 405)</td>
<td>0.0628 (S.D. ± 0.2425, n = 128)</td>
<td>0.1283 (S.D. ± 0.2864, n = 114)</td>
<td>0.009 (S.D. ± 0.0564, n = 154)</td>
<td>0.0 (n = 117)</td>
<td>0.0 (n = 90)</td>
</tr>
<tr>
<td>February</td>
<td>0.0062 (S.D. ± 0.61, n = 386)</td>
<td>0.0991 (S.D. ± 0.2726, n = 152)</td>
<td>0.0339 (S.D. ± 0.1179, n = 130)</td>
<td>0.0062 (S.D. ± 0.0556, n = 146)</td>
<td>0.0026 (S.D. ± 0.0277, n = 118)</td>
<td>0.0178 (S.D. ± 0.0948, n = 73)</td>
</tr>
<tr>
<td>March</td>
<td>0.0045 (S.D. ± 0.0365, n = 402)</td>
<td>0.1141 (S.D. ± 0.3428, n = 135)</td>
<td>0.0082 (S.D. ± 0.0491, n = 147)</td>
<td>0.0313 (S.D. ± 0.1084, n = 164)</td>
<td>0.0026 (S.D. ± 0.0277, n = 118)</td>
<td>0.0 (n = 76)</td>
</tr>
<tr>
<td>April</td>
<td>0.0708 (S.D. ± 0.0244, n = 404)</td>
<td>0.1358 (S.D. ± 0.3238, n = 144)</td>
<td>0.0037 (S.D. ± 0.0418, n = 130)</td>
<td>0.0961 (S.D. ± 0.2482, n = 204)</td>
<td>0.0159 (S.D. ± 0.1094, n = 120)</td>
<td>0.004 (S.D. ± 0.0345, n = 76)</td>
</tr>
<tr>
<td>May</td>
<td>0.1412 (S.D. ± 0.3249, n = 441)</td>
<td>0.1381 (S.D. ± 0.3758, n = 136)</td>
<td>0.046 (S.D. ± 0.1807, n = 135)</td>
<td>0.0125 (S.D. ± 0.1603, n = 168)</td>
<td>0.0242 (S.D. ± 0.1059, n = 123)</td>
<td>0.0 (n = 78)</td>
</tr>
<tr>
<td>June</td>
<td>0.0621 (S.D. ± 0.1798, n = 413)</td>
<td>0.1447 (S.D. ± 0.3288, n = 147)</td>
<td>0.0658 (S.D. ± 0.2084, n = 117)</td>
<td>0.0186 (S.D. ± 0.0849, n = 181)</td>
<td>0.0203 (S.D. ± 0.0931, n = 121)</td>
<td>0.0 (n = 84)</td>
</tr>
<tr>
<td>July</td>
<td>0.0313 (S.D. ± 0.1099, n = 462)</td>
<td>0.0765 (S.D. ± 0.2134, n = 137)</td>
<td>0.0039 (S.D. ± 0.0432, n = 122)</td>
<td>0.0 (n = 150)</td>
<td>0.005 (S.D. ± 0.0387, n = 120)</td>
<td>0.0 (n = 90)</td>
</tr>
<tr>
<td>August</td>
<td>0.0195 (S.D. ± 0.0934, n = 497)</td>
<td>0.0591 (S.D. ± 0.183, n = 130)</td>
<td>0.0048 (S.D. ± 0.0379, n = 125)</td>
<td>0.0961 (S.D. ± 0.2482, n = 204)</td>
<td>0.0 (n = 121)</td>
<td>0.0031 (S.D. ± 0.0306, n = 97)</td>
</tr>
<tr>
<td>September</td>
<td>0.012 (S.D. ± 0.0742, n = 447)</td>
<td>0.136 (S.D. ± 0.0671, n = 146)</td>
<td>0.006 (S.D. ± 0.0495, n = 129)</td>
<td>0.0063 (S.D. ± 0.0434, n = 95)</td>
<td>0.0022 (S.D. ± 0.0257, n = 137)</td>
<td>0.0 (n = 96)</td>
</tr>
<tr>
<td>October</td>
<td>0.0216 (S.D. ± 0.1122, n = 478)</td>
<td>0.021 (S.D. ± 0.0849, n = 143)</td>
<td>0.0 (n = 137)</td>
<td>0.0016 (S.D. ± 0.0221, n = 185)</td>
<td>0.0044 (S.D. ± 0.0364, n = 136)</td>
<td>0.0031 (S.D. ± 0.0307, n = 96)</td>
</tr>
<tr>
<td>November</td>
<td>0.0007 (S.D. ± 0.0144, n = 439)</td>
<td>0.0228 (S.D. ± 0.119, n = 144)</td>
<td>0.0 (n = 137)</td>
<td>0.0 (n = 182)</td>
<td>0.0022 (S.D. ± 0.0258, n = 136)</td>
<td>0.0 (n = 97)</td>
</tr>
<tr>
<td>December</td>
<td>0.0025 (S.D. ± 0.0337, n = 478)</td>
<td>0.0132 (S.D. ± 0.0909, n = 141)</td>
<td>0.0053 (S.D. ± 0.0397, n = 114)</td>
<td>0.0 (n = 128)</td>
<td>0.0 (n = 136)</td>
<td>0.0 (n = 96)</td>
</tr>
</tbody>
</table>

Most juvenile ladyfish (76%, $n = 1,052$) in the IRL were collected at three stations: station 4 (36%, $n = 421$), station 1 (29%, $n = 334$), and station 2 (11%, $n = 123$). Juvenile ladyfish CPUE ranged from 0.0 juvenile ladyfish per haul at station 8 to 0.2043 juvenile ladyfish per haul at station 2 (Figure 12), and a significant difference was detected [$F (11, 1671) = 14.55, P < 0.001$]. A post-hoc multiple comparison test showed there was no significance difference in juvenile ladyfish CPUE among stations 1, 2, and 4. The test also showed there was no significant difference in juvenile ladyfish CPUE among the following stations: 1 and 2 or 8, 9, 19, 22, 6, 5, 11, 21, 18, and 1.

In the LMR, significant numbers of juvenile ladyfish were collected at every station (A–F); however, most were collected at station D (36%, $n = 86$). Juvenile ladyfish CPUE ranged from 0.0084 juvenile ladyfish per haul at station B to 0.401 juvenile ladyfish per haul at station D (Figure 12), and a significant difference was detected [$F (5, 1531) = 2.92, P < 0.01$]. A post-hoc multiple comparison test showed there was no significance difference in juvenile ladyfish CPUE among the following stations: B, F, A, C, E, and D. Also, the test showed there was no significant difference in juvenile ladyfish CPUE among the following stations: B, E, A, C, and D.

Most juvenile ladyfish (67%) in VC were collected at two stations: station 3 (42%, $n = 83$) and station 10 (25%, $n = 50$). Juvenile ladyfish CPUE ranged from 0.0 juvenile ladyfish per haul at stations 22, 24, and 26 to 0.0641 juvenile ladyfish per haul at station 3 (Figure 12), and significant difference was detected [$F (13, 1927) = 4.88, P < 0.001$]. A post-hoc multiple comparison tested showed there was no significance differences in juvenile ladyfish CPUE among the following stations: 28, 10, and 3. The test also showed there was no significant difference in juvenile ladyfish CPUE among the following stations: 22, 24, 26, 18, 12, 2, 1, 9, 11, 4, 20, and 10.

In CH, juvenile ladyfish were only collected at a few stations. In fact, most were collected at one station: station 2 (77%, $n = 34$). Juvenile ladyfish CPUE ranged from 0.0 juvenile ladyfish per haul at stations 9–13 to 0.0354 juvenile ladyfish per haul at station 2 (Figure 12), and there was a significant difference detected [$F (8, 1494) = 8.25, P < 0.001$]. A post-hoc multiple comparison test showed that juvenile ladyfish CPUE for all stations were significantly similar, except for station 2.

Figure 12: The overall mean relative abundance (number of juvenile ladyfish per haul) of juvenile ladyfish collected at fixed-stations in Florida waters during 1987 through 1995 ($n = 3,107$). Tampa Bay (TB), Indian River Lagoon (IRL), Volusia County (VC), Charlotte Harbor (CH). Little Manatee River Stations A = 1, B = 2, C = 3, D = 4, E = 5, and F = 6. Mean ± Standard Error are plotted.
4. Discussion
To decipher early life-history characteristics of fish, the present study demonstrated how important it is for long-term fisheries independent monitoring programs, such as the State of Florida’s FIM program to conduct extensive systematic sampling throughout a variety of estuaries and habitats. Within estuaries, many juvenile fish exhibit predictable annual and seasonal abundance patterns [16-18], which is helpful for numerous fishery management purposes. Many researchers have previously reported that long-term state fisheries independent monitoring programs can be used to quantify annual/seasonal habitat-use patterns, abundance, and species composition for numerous commercial and recreational species, especially the juvenile life-stage [18-23, 27]. Typically, seasonal juvenile fish collections are often numerically dominated by a limited number of species at specific locations; thus, extensive sampling is often required to achieve reliable population estimates. However, depending on the sampling goals, intensive sampling efforts might not be necessary as demonstrated by this study. As the findings show, using restrictive datasets (i.e., fixed station sampling) can yield similar results as extensive and labor intensive sampling programs (e.g., SRS; [5]). Nonetheless, when designing sampling programs, fishery managers must develop specific goals and objectives for their individual sampling program, or their efforts might be useless and inapplicable. Based on these results, it is recommended that state fishery managers annually evaluate the goals and objectives of their monitoring program to ensure that extensive sampling efforts are necessary and cost-effective, especially during today’s state budget deficits.

In this study, juvenile ladyfish were common throughout every Florida estuary investigated excluding Choctawhatchee Bay, Santa Rosa Sound, and Florida Bay. Despite making 1,401 seine and otter trawl hauls at eight sites in Choctawhatchee Bay and four sites in Santa Rosa Sound, no juvenile ladyfish were collected during 1992 through 1995. It is difficult to explain why juvenile ladyfish were not captured in Choctawhatchee Bay during the four year study period; however, one reason is perhaps the sampling locations. Distinct from all the other estuaries that were surveyed, sampling stations in this bay were not located at, or adjacent to, any freshwater input locations (i.e., rivers). As illustrated by this investigation and previous work [5], juvenile ladyfish prefer backwater low salinity creeks and rivers. In Choctawhatchee Bay, most of the sampling stations were located in more open bay habitats, and only six sites were sampled with seine gear, which was shown by this study to be the premier gear for capturing juvenile ladyfish (< 100 mm). Similar to the other estuaries with stations located in seagrass and nearshore sandy areas, the numerical dominate juvenile fish in Choctawhatchee Bay (1992–1995) were pinfish (Lagodon rhomboides), spot (Leiostomus xanthurus), pigfish (Orthopristis chrysoptera), and tidewater silverside (Menidia spp.) Although juvenile ladyfish were not captured in Choctawhatchee Bay, adult ladyfish are found in Choctawhatchee Bay; thus, it is presumable that if sampling stations were located within or near the protected bayous or creeks surrounding the northern sections of Choctawhatchee Bay, instead of the open bay areas, then juvenile ladyfish could possibly have been located and collected. This theory is highly probable since Zilberberg et al. [28] was able to collect juvenile ladyfish in creek waters of Apalachicola Bay, which is just east (~ 160 km or 100 miles) of Choctawhatchee Bay.

Low numbers of juvenile ladyfish were also collected in Charlotte Harbor (n = 44) and Florida Bay (n = 9). Similar to Choctawhatchee Bay, site locations in these estuaries were located in open-bay locations. Thus, since most juvenile ladyfish were exclusively found in protected (e.g., mangrove habitats) freshwater influenced sites in the other estuaries, it is probable that site locations in Charlotte Harbor and Florida Bay were located in unsuitable habitat for collecting large numbers of juvenile ladyfish. Also, although seines were used in Florida Bay, only offshore deployment methods were used, which may have influenced juvenile ladyfish catches. For this study, seine deployment methods were not analyzed separately or compared (i.e., assumed to be equal), which probably should be evaluated in future studies.

The only researchers that have ever investigated ladyfish habitats in any detail were McBride et al. [5]. Agreeing with their study in many ways, the results from this current study showed that juvenile ladyfish were primarily collected in large numbers at specific locations within Tampa Bay and Indian River Lagoon. However, although low numbers were collected at the other estuaries, early life-history patterns appeared similar. Various studies have investigated the early life-history of other important juvenile finfish in Florida waters and yielded similar results [18]. This study reports that juvenile ladyfish relative abundance and frequency of occurrence are comparable to findings by McMichael et al. [29] for snook (Centropomus undecimalis), Peters and McMichael [16] for larval and juvenile red drum (Sciaenops ocellatus), and juvenile spotted trout (Cynoscion nebulosus) in Tampa Bay [30]. In general, juvenile ladyfish were common in Florida estuaries and depending on the location and month; ladyfish were the prevailing species in seine hauls.
Parallel to other studies for spot (Leiostomus xanthurus) [31, 32], striped mullet (Mugil cephalus) [33], and ladyfish [5], juvenile ladyfish recruitment and abundance in the present study varied seasonally and annually. Overall, the present study demonstrated an alternating annual juvenile ladyfish abundance pattern, but annual abundance rates appeared to have increased in Tampa Bay and in the Indian River Lagoon during 1987 through 1995. It should be noted that these findings should be viewed with caution considering annual recruitment patterns were highly variable and the data (i.e., fixed station) used for these analyses were somewhat limited and restrictive. Results demonstrated that juvenile ladyfish recruited into secluded freshwater sites from late-winter (February or March) to summer (June or July) depending on the estuary, which was similar to previous studies reported for ladyfish [5, 23, 34], but an opposite pattern reported for juvenile snook [29], juvenile spotted trout [30], and juvenile red drum [16] in Tampa Bay. Juvenile ladyfish recruitment in Tampa Bay and the Indian River Lagoon occurred from April to June and January to June, respectively. Ladyfish peak recruitment in Tampa Bay and Charlotte Harbor was in May and in June for Indian River Lagoon. In Volusia County waters and the Little Manatee River, peak recruitment was in April and January, respectively. The difference in annual recruitment patterns within and among estuaries was probably associated with differences in annual water temperatures. In Tampa Bay and the Indian River Lagoon some recruitment occurred during the fall for a couple of years, which might have been associated with an influx or pulse of ladyfish leptocephali recruitment occurring earlier in some years than others, which could have been related to water temperature.

Juvenile ladyfish recruitment patterns in the current study were consistent with some geographical areas and inconsistent with others. The findings from the present study were unlike the recruitment pattern for juvenile ladyfish (Elops hawaiensis) in a Northern Taiwan estuary, which occurred in two pronounced specific recruitment periods, one during spring months and another during summer months [35]. However, findings agreed with the peak juvenile ladyfish (Elops machnata) abundance timing in South Africa, which occurred in the month of May. Unlike the present study, no seasonal pattern was evident with recruitment occurring throughout the year [36]. Ladyfish (Elops machnata) recruitment in the Philippines occurred in May and October [37], but in India, ladyfish (Elops saurus) leptocephali (20–25 mm) recruitment occurred in September and October [38] and then again from October to December for larval/juvenile sizes (30–240 mm TL) [6]. While some juvenile fish, such as permit, recruit throughout the year because of an extended spawning season [39], many fish that inhabit temperate and tropical waters only recruit one time per year, such as striped mullet [33]. Interestingly, the findings from this present study indicate that ladyfish recruitment occurs only during late-winter through early summer in many locations, which suggests one prolonged spawning period. Overall, juvenile ladyfish recruitment patterns found in the present study was not only comparable and common to other juvenile fish, but patterns were similar to other Elops species in various world-wide locations. Findings showed that juvenile ladyfish recruitment patterns were predictable through time and similar among geographical locations (i.e., estuaries).

Presently, ladyfish spawning information is lacking; however, spawning is presumed to occur in late-summer and offshore [10-12]; possibly peaking in the fall [40]. This current study supports the late-summer or early-fall spawning period theory. Hence, if spawning occurs in late-summer or early-fall, then it is probable that it would take approximately 3 to 5 months for ladyfish leptocephali larvae to migrate from offshore waters to protected low salinity nearshore estuaries (i.e. Alafia and Little Manatee Rivers in Tampa Bay). Also, if the distance from offshore waters to low salinity waters is between 20 and 40 km, then a conservative transport rate would be around 6 to 8 km per month (1.5 to 2.0 km per week), which is reasonable and comparable to other leptocephali larvae transport rates [41].

5. Conclusion
Results from the present study demonstrated that juvenile ladyfish were unevenly distributed throughout Florida estuaries; juvenile ladyfish distribution was skewed toward a limited number of locations. Thus, it is evident that juvenile ladyfish do not recruit to a wide-variety of habitats, but require specific micro-habitats. Overall, spatial distribution findings from the study were analogous to previous studies for other juvenile fish, such as snook [29] and red drum [16]. In Tampa Bay, McMichael et al. [29] found that most juvenile snook were only collected at 5 of the 23 stations sampled, and Peters and McMichael [16] found that majority of juvenile red drum were collected in backwater stations. In Alamitos Bay, California, Valle et al. [42] found that 11 of 13 common juvenile fish preferred specific habitats. In Delaware Bay and adjacent marshes, Miller et al. [43] found that Atlantic croaker (Micropogonias undulatus) also recruited to specific habitats. Specific juvenile ladyfish micro-habitat recruitment in the present study was also similar to those reported for bluefish (Pomatomus saltatrix) [44]; it obvious that many
juvenile fish recruit to specific habitats [29-32, 44, 45]. In summary, juvenile ladyfish were collected primarily at specific stations located near, or adjacent to, freshwater input or protected bayou areas during the late-winter through early summer months. Moreover, juvenile ladyfish recruitment is annually variable and unstable. Thus, this study demonstrates how important specific geographical areas and possibly environmental conditions are in influencing annual and temporal juvenile ladyfish population dynamics.

Presently, urban sprawl is impacting various ecologically sensitive areas throughout the United States [46]. In Florida, urban sprawl is encroaching on many back-country freshwater bayou areas surrounding Florida estuaries, which may have consequential negative influences on local fisheries due to deteriorating water quality conditions associated with various factors (e.g., storm-water run-off). As demonstrated by this study, many important species use back-country bayous as nursery grounds. Given that many anthropogenic activities have already impacted many fish populations in Florida [47], it is essential that environmental planners, regulators, and environmental consultants evaluate the potential impacts of urban development in back-country areas so that irreversible anthropogenic activities are either avoided, minimized, or mitigated.

Competing Interests
The author declares there are no competing interests.

Acknowledgement
A great debt of gratitude is owed to all the Fisheries Independent Monitoring (FIM) staff at the Florida Fish and Wildlife Research Institute. I thank the many FIM program personnel whom have worked for the program throughout the years for all their dedicated field sampling, sorting, identifying, assuring data quality, and boat and gear maintenance efforts. More importantly, I thank the FIM staff for all the wonderful memories and experience I gained during my time as a staff biologist. In addition, I thank R. Matheson, J. Colvocoresses, and D. Adams for providing assistance with ensuring data coordinates corresponded to appropriate sampling locations for the Little Manatee River, Florida Bay, and the Indian River Lagoon, respectively. I especially thank R. Wells and three other anonymous reviewers for providing valuable comments and edits that significantly improved the quality of the manuscript. Lastly, I thank K. Knight and P. Gehring for GIS graphics support. This study would not have been possible were it not for B. McMichael and T. McDonald for kindly providing access to the FIM data. The field-work was supported in part by funding from Florida saltwater fishing license sales and the Department of Interior, U.S. Fish and Wildlife Service, Federal Aid for Sportfish Restoration Project Number F-43 to the Florida Fish and Wildlife Conservation Commission. Sampling in the Little Manatee River was made available through grants CM-254 and CM-280 from the Department of Environmental Regulation, Office of Coastal Management, with funds made available through the National Oceanic and Atmospheric Administration under the Coastal Zone Management Act of 1972, as amended.

References

http://astonjournals.com/faj

Co-Publisher: OMICS Group, www.omicsonline.org

How to cite this article