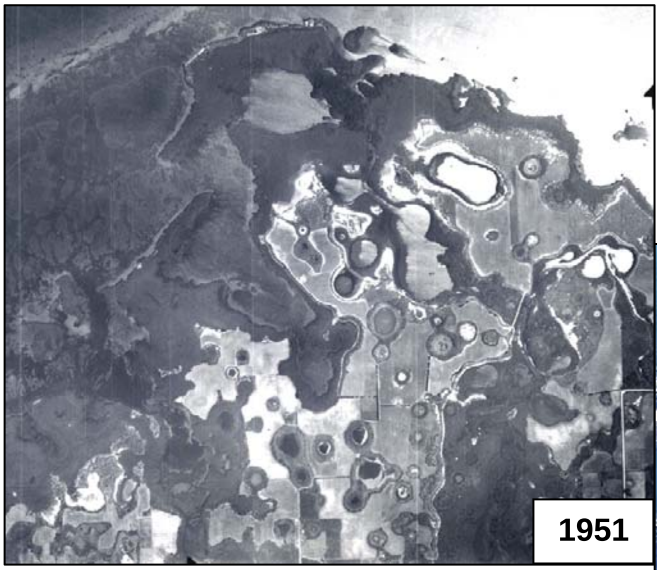
Wetland Habitat Use by the Nekton Community at Terra Ceia State Aquatic Buffer Preserve: Summary of 2004 Data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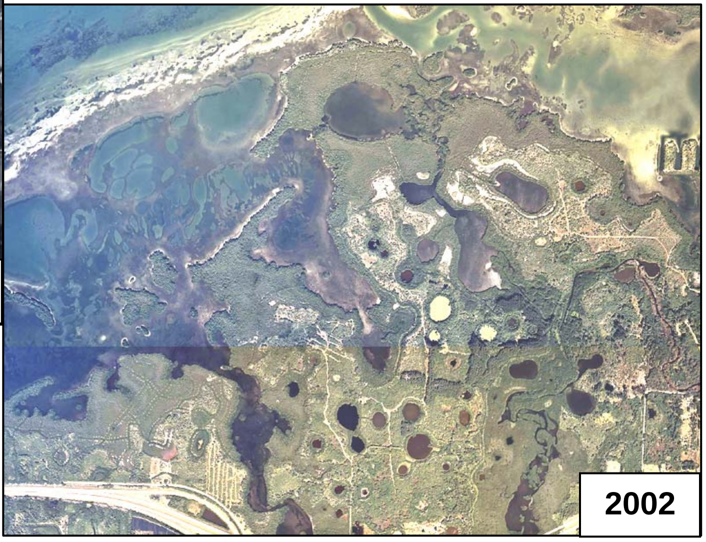
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Introduction

Coastal wetlands are defined as those vegetated lands and associated intertidal features (e.g., creeks) that are alternatively flooded and drained by lunar tides. By this definition, a wetland extends from the upland interface with terrestrial systems to the low tide interface with permanent subtidal waters (e.g., creeks, channels, tidal rivers, embayments, lagoons). For the purposes of this report, we consider those small, primarily subtidal linear (creeks, mosquito-control ditches, stormwater-conveyance ditches) and circular features (ponds) nested within the wetland landscape to be functional parts of the wetland.

Saltmarsh and mangrove wetlands provide habitat for numerous species of estuarine fishes and invertebrates, many of which are ecologically or economically valuable. Anthropogenic alteration of wetlands is visibly evident along the Gulf Coast of Florida in the form of dredged channels, spoil mounds, and water-control structures. The ecological consequences of such habitat alteration, however, are not always as apparent. Understanding the fundamental differences between natural and altered wetlands, and how faunal assemblages vary between habitats, is necessary to evaluate the effects of alteration on the ecology of the system. In an effort to repair the effects of wetland disturbance, restoration and creation of wetland habitats have become widespread management tools during the last decade. However, the creation of a functional wetland system proves to be much more of a challenge than simply creating wetland structure (i.e., tidal creeks, ponds, salt barrens). A thorough understanding of faunal ecology, including that of the nekton communities (i.e., fishes, pink shrimp, blue crabs) that utilize wetland habitats, is necessary for the successful creation of a functional wetland.

Many of Tampa Bay's wetlands have been subjected to dredge-and-fill activities since the mid-1900s. Current wetland-restoration plans in the bay seek to restore areas that have been modified for mosquito control, stormwater conveyance, and agriculture. However, hydrological changes induced by these restoration efforts may affect biotic components such as fish communities. Because little is known of the composition and structure of nekton communities in the shallow-wetland habitats of Tampa Bay, fish-community data will provide a useful baseline to assist resource managers with pre-restoration planning and post-restoration assessment.

Wetland-associated nekton communities are composed of a variety of fishes that can be grouped by their use of the wetland based on life-history strategy (Nordlie, 2003). Those fish that utilize the wetland for their entire life cycle are considered permanent residents. In contrast, those species that use the wetland only during a specific life stage are considered transients, of which there are two classes: those that use the wetland during the juvenile stage (marine nursery species), and those that use the wetland as subadults or adults (marine transients). Transient species can be distinguished as those of recreational or commercial importance (e.g., snook, *Centropomus undecimalis*, and red drum, *Sciaenops ocellatus*), and those non-recreational species that provide a forage base for larger fishes and piscivorous birds.

To assess fish-community response to habitat alteration and to provide baseline community conditions from which to plan and assess wetland-restoration projects, we initiated a three-year sampling program in Tampa Bay wetlands. Project objectives were to: 1) characterize the species composition and abundance of the wetland nekton community, 2) assess temporal trends (seasonal and annual) in the utilization of wetland habitats by nekton, and 3) determine the spatial use of natural and altered habitats by nekton. At Terra Ceia, we sampled nekton in three types of wetland habitat: 1) natural tidal creeks, 2) man-made ditches, and 3) wetland ponds with both open connections to the bay or backwaters, and others with seasonally restricted connections to the bay.

Methods

Baywide Experimental Design

Three wetland regions along a north/south axis within Tampa Bay were chosen for study (Fig. 1), within which creek, ditch, and pond sites were established. Each sample region was located within a County or State Preserve (Mobbly Bayou, Weedon Island/Feather Sound, and Terra Ceia). These particular wetland preserves were selected for study because of proposed restoration plans in the areas and thus the need for pre-restoration data. Regions were sampled seasonally (i.e., every third month; n=4 seasons) from December 2003 through November 2004. Sample sites were chosen using a combination of random and haphazard approaches. Suitable habitat types were delineated within a particular wetland, and points were randomly generated within these habitats. Fixed sites were installed as close as possible to the random point while simultaneously avoiding areas of heavy vegetative structure or inundation that would prevent efficient and standardized gear deployment and retrieval. Sample effort will continue through November 2006.

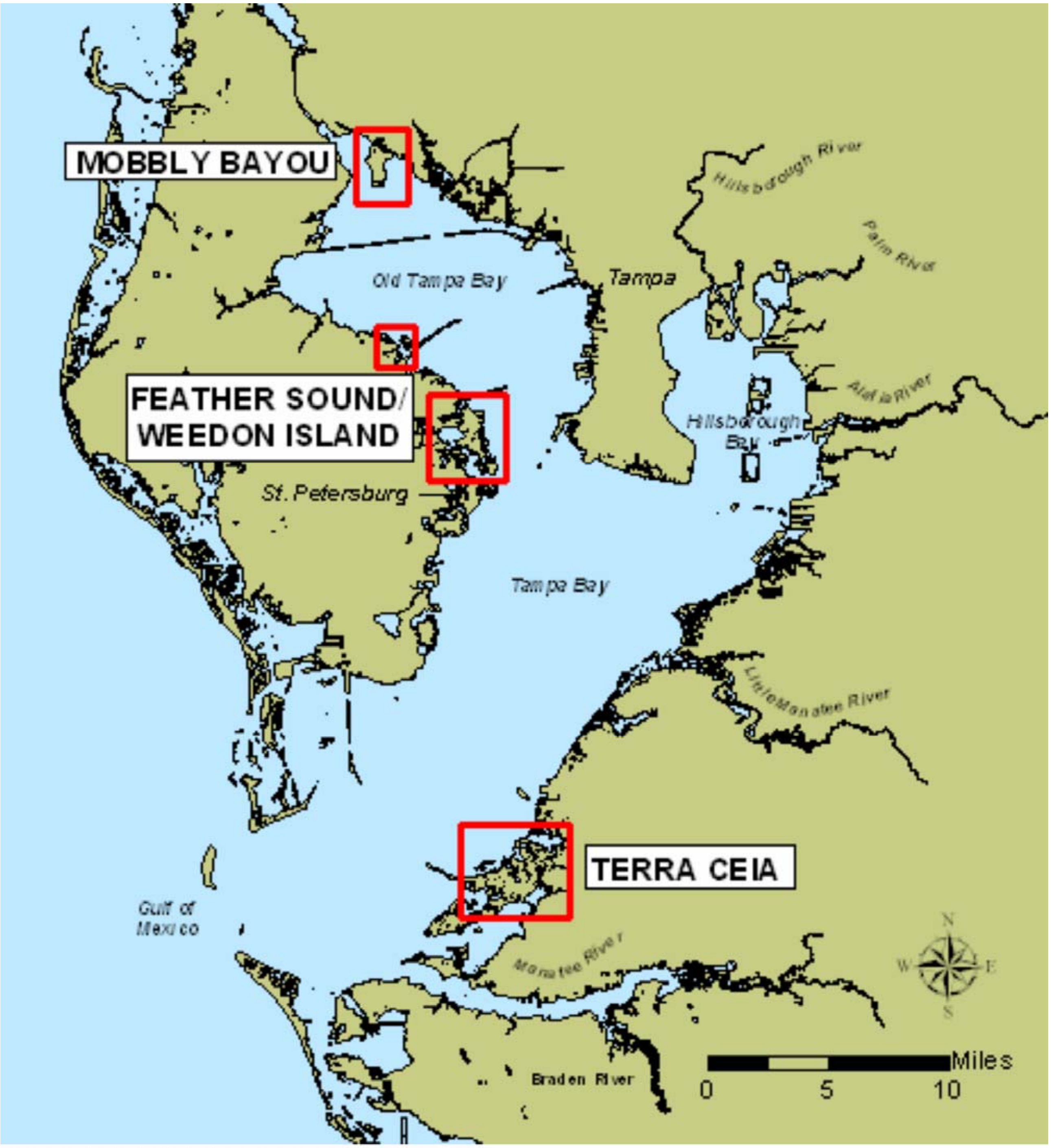

Figure 1. The three wetland regions chosen for sampling in Tampa Bay, FL.

Sampling Methodology

Sample sites in creeks, ditches, and ponds within the preserves were characterized by measuring substrate type, substrate depth, water depth, shoreline vegetation, and bottom vegetation. Additionally, channel width, bottom profile, and current velocity at time of sampling were recorded for creek and ditch sites. Water-quality measurements of temperature, salinity, dissolved oxygen, and pH were also taken at each site during each sample using a YSI 556 MPS unit. Creeks and ditches were sampled by isolating a 9-m long section of the habitat using two block nets (3-mm mesh) and then seining through the site using a center-bag haul seine (5 m x 1.2 m, 10 m x 1.2 m, or 15 m x 1.2 m, with 3-mm mesh) stretched from bank to bank (Fig. 2). Three hauls were made at each site, and each haul processed individually in order to use the depletion method (Zippin, 1958) to examine species-specific gear-avoidance tendencies and to estimate the percentage of nekton collected at each site. Sizes of block nets (5 m, 6 m, 10 m, 12 m, or 15 m) and haul seines were dependent on the width of the creek or ditch being sampled.

Unlike creeks and ditches, wetland ponds lack the stream banks that facilitate the use of block nets to isolate the sample site, so they were sampled using the State of Florida Fisheries-Independent Monitoring Program offshore seine technique (Fisheries-Independent Monitoring Program Procedure Manual, 2004). Each sample (regardless of collection method) was processed in the field by identifying and enumerating fishes and decapod-crustacean species collected in replicate seine samples. As many as 20 individuals of each species were measured to the nearest 1-mm standard length (fishes), carapace width (blue crabs), or post-orbital carapace length (pink shrimp) and released alive when possible.

Sample Design at Terra Ceia State Aquatic Buffer Preserve

To address the study objectives, sample sites were established in three sample areas within the Terra Ceia State Aquatic Buffer Preserve: 1) Frog Creek, 2) wetland ponds in three areas, and 3) creeks and ditches at the mouth of Bishop Harbor (Fig. 3). Six fixed sample sites along Frog Creek were chosen randomly within an approximately 1 nmi stretch from the tidal freshwater portion upstream to the mouth of the creek where it enters Terra Ceia Bay. Four wetland ponds with a direct connection to Frog Creek (Frog Creek Ponds) were selected for study, and three randomly selected replicate sites were

Figure 2. Nekton sampling method used in the wetland creek and ditch habitats, at Terra Ceia, Tampa Bay, FL. Notice the densely structured vegetation associated with this mosquito-ditch site at Weedon Island.

Figure 3. Location of sample areas in wetland creek, pond, and ditch habitats at Terra Ceia Aquatic Buffer Preserve, Tampa Bay, Florida, 2004.

sampled within each pond every season. Similarly, three wetland ponds with a “less direct”, occasionally tidal connection to Tampa Bay (i.e., connected to the bay or to another wetland pond intermittently via a single ditch) were also selected for study due to proposed restoration activities in these ponds (Restoration Ponds). Three “Control Ponds” approximately 1km to the northeast of the Restoration Ponds were selected as a reference for the Restoration Ponds, but were not sampled during 2004. Several sites were also chosen at the mouth of Bishop Harbor, which included a large well-connected karst pond (Moses Hole), a natural creek habitat (Moses Creeks; 2 sites), and two mosquito ditches (Moses Ditches; 2 sites). As a result of the differences in sample methods, pond samples could not be directly compared with creek and ditch samples and were treated separately.

Data Analysis

A variety of methods was used to calculate measures of nekton community structure. Nekton density was calculated as number of individuals per 100 m^2 in order to standardize catch data from sample sites of different sizes. Species richness was calculated using Margalef’s index of richness represented by the formula $d = (S-1)/\log N$, where S equals the number of species present and N represents the total number of individuals collected. Simpson’s diversity index was calculated as $1-D = 1-[\Sigma(n/N)^2]$, where n equals the number of individuals of a certain species and N equals the total number of individuals for all species combined. Non-metric multidimensional scaling (MDS) from PRIMER v5 (Clarke and Warwick, 2001) was used to examine the association of nekton assemblages (species densities averaged by site) with sampled habitat types. Sample similarity (based on species density) was also plotted by site and season using MDS to assess seasonal trends in the wetland-associated nekton assemblages in both Frog Creek and in the ponds. Using MDS, samples with nekton assemblages having similar species composition and abundances were considered more similar and were grouped more closely in two-dimensional space than those samples that were less similar. Relegating a multidimensional dataset to two-dimensional space imposes a “stress”, which typically distorts the true multidimensional relationships between samples (i.e., two samples appear to be similar based on spatial proximity, when in fact they are not). Stress values (included with each MDS plot) are deemed acceptable at a level of ≤ 0.2. Differences in community structure between 1) seasons in Frog Creek samples and 2) wetland ponds were tested using the Analysis of Similarity (ANOSIM) routine from PRIMER, a non-parametric test analogous to

Analysis of Variance (ANOVA). Analyses for Moses Hole and its constituent creek and ditch sites were limited due to low sample effort in these areas.

Results and Discussion

Wetland Habitat Characterization

Physical characteristics for each of the three sample areas are summarized in Table 1. Total area sampled varied in all areas based on mean site widths and the number of sites sampled. Due to the relative width of Frog Creek in its downstream reach, our block-net methodology was inadequate (i.e., bank-to-bank distance was too wide) and thus that area was not sampled, leaving a potential gap in our understanding of nekton use in the creek habitat. Both water depth and substrate depth varied between the different habitats, based on tidal stage and current regime, respectively.

The ponds sampled at Terra Ceia can be classified based on the degree of connectivity and proximity to Tampa Bay. Moses Hole had the most direct connection through a series of ditches and creeks that connect the pond both to Bishop Harbor and directly to Tampa Bay (Fig. 3). The close proximity (~100 m) and clear connection to the bay facilitates good water exchange, a factor which likely affects substrate depth, seagrass growth, and the species composition of the nekton assemblage. A large portion of Moses Hole could not be sampled because of gear limitations imposed by water depths greater than 1.2 m. Therefore, interpretation can only extend to the shallow-water portion of Moses Hole, primarily its northeast quadrant. An intermediate connection linked the Frog Creek Ponds to Tampa Bay most directly through Frog Creek and Terra Ceia Bay (Fig. 3). This was assumed to be a persistent connection during all times of the year maintained by tidal and freshwater inputs. The three Restoration Ponds had the most limited connection to the bay since Ponds 47 and 49 were indirectly connected to the bay through single, shallow, pneumatophore-choked ditches into Pond 48 (Fig. 3). Pond 48 had only a seasonally affected tidal connection through a shallow, diffuse mosquito ditch into Williams Bayou and into Tampa Bay. The connection between Pond 48 and Williams Bayou became constricted closer to the bayou since black mangrove (*Avicennia germinans*) pneumatophores had mostly closed off the mosquito ditch. The seasonal nature of this connection has been directly verified during the winter (dry) season and indirectly through the collection of transient species during other times of the year. Despite differences in connectivity, the Restoration Ponds and the Frog Creek Ponds were similar in terms of mean water depth and mean substrate depth (Table 1). Pond 49 dried down during the summer sampling season (water depth <0.1 m near the pond center), and water temperature and salinity were exceptionally high (40.6 ºC and 58.2 ppt, respectively). No fish were observed in Pond 49 during the dry period. Sample sites in Moses Creek and Moses Ditch habitats at the mouth of Bishop Harbor differed only slightly in their physical description. Moses Ditch sites that connect Moses Hole to Bishop Harbor were narrower than Moses Creek sites and thus smaller in area. Steeper banks, typical of dredged channels, contributed to deeper water depths in the ditch sites, as compared to creek sites. One of the two creek sample sites had a firmer, sandy oyster substrate typical of habitats having better tidal circulation, although the current velocities between the habitats were similar when the sites were sampled.

Water Quality Characterization

Salinities at Frog Creek and the adjacent Frog Creek Ponds were affected by seasonal freshwater input to the creek and were much lower than the other habitats (Table 2). A trend of decreasing salinity was observed from the mouth of Frog Creek to the upstream sites (Fig. 4). Higher than expected salinities were recorded for the two most upstream sites during the summer, which may have resulted from a tidal connection that enters Frog Creek via Embryo Lake, just upstream of these sites.

Water quality in the ponds was related to connectivity to the bay and to freshwater input. Frog Creek Ponds received relatively greater amounts of freshwater inflow from the creek, and therefore the water quality was more similar to that of the creek than that of the other ponds (Tables 2 & 3). Mean salinity during summer sampling in the Restoration Ponds was high, caused by limited tidal connection to the bay and by evaporative “dry down”. Despite high summer water temperatures, dissolved oxygen was high in the Restoration Ponds, probably due to diurnal photosynthetic oxygen production by abundant submerged aquatic vegetation (*Ruppia maritima*) and algal biomass during that time of the year.

Water quality in Moses Hole was more similar to that of the creek and mosquito-ditch sites at the mouth of Bishop Harbor than to waters in the other ponds. An exception was the substantially lower salinity observed in Moses Hole during the summer (possibly from a freshwater seep) and the elevated salinity measured during the fall. Water quality in the creek and ditch sites around Moses Hole was very similar.

Table 1. Physical characteristics of wetland sample sites at Terra Ceia at time of sampling. Sample size (n) is equal to the number of samples taken each season. Ranges are in parentheses below mean values. Substrate depth is defined as the depth to which the observer's foot penetrates the substrate.

	Site type					
	Creek	**Ponds**			**Mouth of Bishop's Harbor**	
Measure	**Frog Creek (n=6)**	**Frog Creek Ponds (n=12)**	**Restoration Ponds (n=9)**	**Moses Hole (n=3)**	**Moses Creek (n=2)**	**Moses Ditches (n=2)**
Mean area (m^2)	83.5 (57.3-110.4)	101.8	101.8	101.8	75.9 (75.0-76.9)	58.0 (49.1-66.8)
Mean width (m)	9.2 (6.3-12.2)	-	-	-	8.3 (8.3-8.4)	6.4 (5.4-7.4)
Mean water depth (m)	0.46 (0.1-0.9)	0.57 (0.3-1.0)	0.47 (0.1-0.9)	0.82 (0.5-1.2)	0.44 (0.3-0.6)	0.60 (0.3-0.8)
Mean current velocity (m/s)	0.08 (0.0-0.3)	-	-	-	0.07 (0.0-0.2)	0.06 (0.0-0.2)
Mean substrate depth (m)	0.09 (0.0-0.3)	0.16 (0.05-0.3)	0.18 (0.0-0.5)	0.0	0.04 (0.0-0.1)	0.08 (0.0-0.1)

Table 2. Mean seasonal water quality by sample area at Terra Ceia, Tampa Bay, FL (2004). Values are averaged across sites within each sample area. Ranges are in parentheses. Sample size is denoted as number of samples per season. Estimates are representative of conditions during sampling events but may not represent seasonal means.

		Season								Annual
Sample area	**Mean**	**Winter**		**Spring**		**Summer**		**Fall**		**2004**
Creek										
Frog Creek	Temperature (°C)	**16.0**	(14.2-17.7)	**19.6**	(17.3-21.6)	**30.2**	(28.8-32.8)	**27.1**	(25.6-28.2)	**23.2**
(n=6)	Salinity (ppt)	**10.3**	(6.8-21.1)	**3.1**	(1.6-8.7)	**14.7**	(10.8-21.2)	**1.8**	(0.6-5.2)	**7.5**
	Dissolved oxygen (mg/L)	**6.83**	(6.14-7.89)	**7.78**	(6.85-9.24)	**4.86**	(1.88-8.45)	**2.67**	(2.44-3.02)	**5.53**
Ponds										
Frog Creek Ponds	Temperature (°C)	**19.8**	(17.7-20.9)	**24.5**	(23.1-25.6)	**29.8**	(26.9-32.8)	**26.0**	(25.2-27.5)	**25.0**
(n=12)	Salinity (ppt)	**13.8**	(5.6-23.5)	**6.4**	(2.2-18.2)	**10.2**	(1.6-21.9)	**3.0**	(0.6-5.7)	**8.4**
	Dissolved oxygen (mg/L)	**6.16**	(3.52-9.50)	**8.48**	(5.94-11.95)	**6.59**	(3.20-15.75)	**5.53**	(2.12-8.24)	**6.69**
Restoration Ponds	Temperature (°C)	**15.3**	(13.4-16.9)	**25.7**	(21.7-29.2)	**34.0**	(29.2-40.6)	**27.3**	(24.8-29.3)	**25.6**
(n=9)	Salinity (ppt)	**25.0**	(21.3-28.5)	**26.4**	(22.1-29.5)	**49.2**	(42.4-58.2)	**14.7**	(11.4-17.3)	**28.8**
	Dissolved oxygen (mg/L)	**10.44**	(7.46-13.70)	**6.77**	(5.51-8.40)	**7.35**	(2.83-11.55)	**4.86**	(0.66-11.84)	**7.36**
Moses Hole	Temperature (°C)	**13.5**	(12.9-13.8)	**24.5**	(24.1-25.2)	**31.2**	(30.9-31.4)	**30.9**	(30.4-31.3)	**25.0**
(n=3)	Salinity (ppt)	**27.7**	(27.6-27.7)	**29.8**	(29.8-29.8)	**19.4**	(9.6-32.0)	**20.6**	(19.4-22.4)	**24.4**
	Dissolved oxygen (mg/L)	**7.68**	(7.50-8.03)	**9.60**	(8.65-10.45)	**3.20**	(3.10-3.28)	**6.86**	(6.01-7.52)	**6.83**
Moses Hole area										
Moses Creek	Temperature (°C)	**14.0**	(13.4-14.6)	**22.3**	(21.4-23.1)	**32.0**	(31.9-32.1)	**28.8**	(27.4-30.2)	**24.3**
(n=2)	Salinity (ppt)	**27.4**	(27.2-27.7)	**29.0**	(28.8-29.3)	**31.8**	(31.2-32.5)	**10.4**	(2.9-17.9)	**24.7**
	Dissolved oxygen (mg/L)	**7.46**	(6.57-8.34)	**7.60**	(7.40-7.80)	**2.79**	(2.56-3.02)	**3.34**	(3.24-3.44)	**5.30**
Moses Ditch	Temperature (°C)	**14.5**	(13.8-15.2)	**20.5**	(20.3-20.7)	**31.5**	(31.4-31.6)	**27.8**	(27.7-27.9)	**23.6**
(n=2)	Salinity (ppt)	**27.5**	(27.4-27.6)	**30.1**	(30.0-30.2)	**32.3**	(32.1-32.4)	**11.0**	(3.5-18.4)	**25.2**
	Dissolved oxygen (mg/L)	**7.48**	(7.35-7.62)	**7.20**	(5.86-8.54)	**2.77**	(2.48-3.06)	**2.92**	(2.21-3.63)	**5.10**

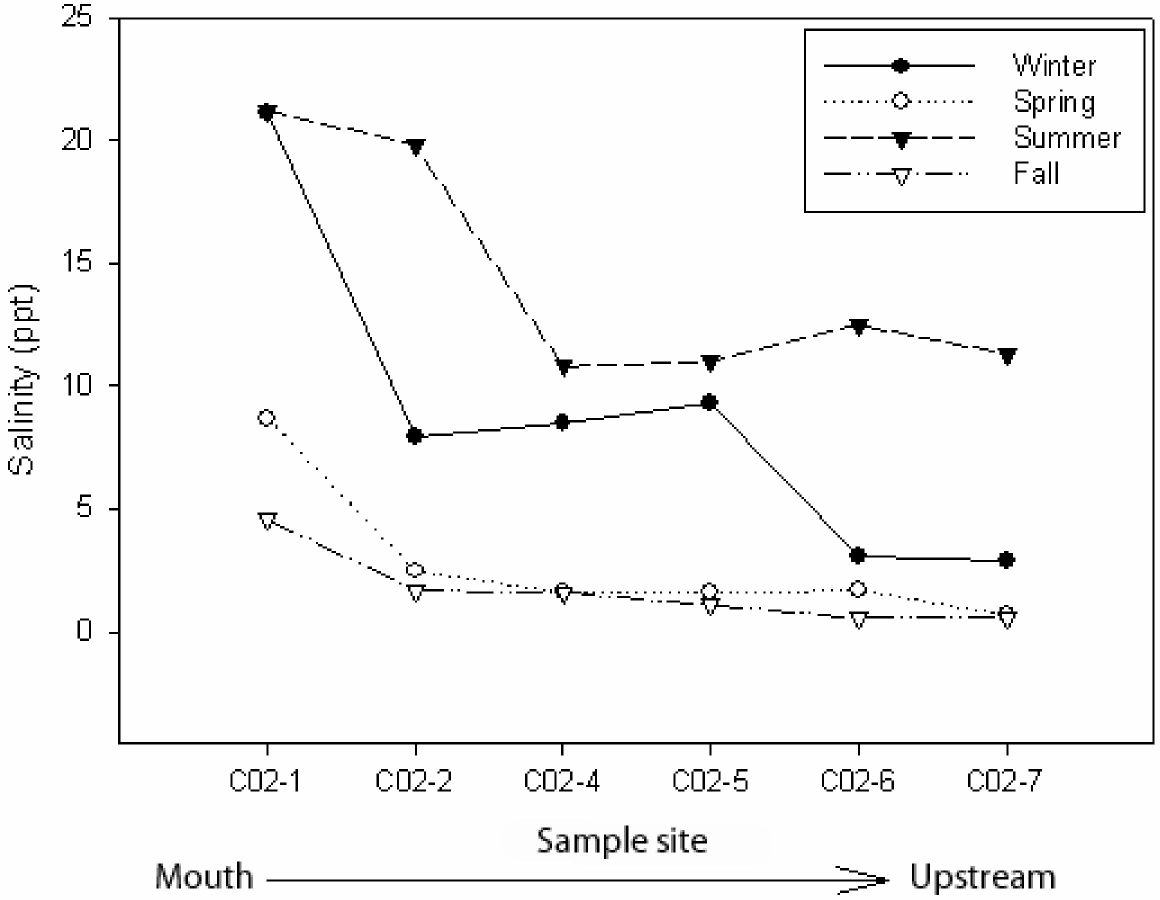

Figure 4. Seasonal salinities from the mouth of Frog Creek to the most upstream sample site during the 2004 wetland sampling year.

Table 3. Water quality in karst ponds at Terra Ceia, Tampa Bay, FL (2004). Values are annual averages across sites (n=12) within each pond. Ranges are in parentheses.

Site	Mean Temperature (°C)		Mean Salinity (ppt)		Mean Dissolved oxygen (mg/L)	
Frog Creek Ponds						
Pond 101	**24.3**	(17.7-28.8)	**3.3**	(0.6-9.2)	**7.39**	(3.53-11.95)
Pond 106	**24.4**	(20.8-27.8)	**5.5**	(2.2-13.0)	**6.03**	(3.20-7.99)
Pond 107	**25.8**	(20.4-32.4)	**8.7**	(4.0-15.7)	**7.40**	(5.25-9.51)
Pond 117	**25.6**	(19.5-32.8)	**15.9**	(4.8-23.5)	**5.95**	(2.12-15.75)
Restoration Ponds						
Pond 47	**22.7**	(13.4-29.9)	**28.6**	(14.8-47.0)	**4.39**	(0.66-7.46)
Pond 48	**25.5**	(15.9-32.9)	**29.4**	(17.3-42.4)	**7.61**	(4.96-11.5)
Pond 49	**28.6**	(14.8-40.6)	**28.4**	(11.4-58.2)	**10.07**	(6.84-13.7)
Moses Hole						
Pond 01	**25.0**	(12.9-31.4)	**24.4**	(9.6-32.0)	**6.83**	(3.10-10.45)

Nekton Assemblages at Terra Ceia

During 2004, wetland-associated nekton were sampled during four seasons (winter-December, spring-March, summer-June, and fall-September). Year-one sampling yielded data from 24 Frog Creek samples, 96 pond samples, and eight samples each from two creek sites and two ditch sites at the perimeter of Moses Hole. In all, 42,511 individuals were collected from 79 different taxa. The 10 most abundant species accounted for 88% of the total number of fishes collected. Abundant residents were primarily species in the families Poeciliidae (livebearers) and Gobiidae (gobies), whereas the abundant non-recreational transients consisted mainly of the families Engraulidae (anchovies), Gerreidae (mojarras), and Atherinidae (silversides). In addition, 22 transient species of recreational or commercial importance were collected, contributing 12% of the total catch. Seven species contributed the largest proportion of the recreational assemblage (88%), including two species of Sciaenidae (spot, *Leiostomus xanthurus*; and red drum, *Sciaenops ocellatus*), two species of decapod crustacean (pink shrimp, *Farfantepenaeus duorarum*; and blue crab, *Callinectes sapidus*), and members of the family Mugilidae (striped mullet, *Mugil cephalus;* fantail mullet, *M. gyrans*; and white mullet, *M. curema*). Several other important recreational species were also collected, including (in order of decreasing abundance) common snook, *Centropomus undecimalis*; sheepshead, *Archosargus probatocephalus*; spotted seatrout, *Cynoscion nebulosus;* tarpon, *Megalops atlanticus*; gray snapper, *Lutjanus griseus*; and black drum, *Pogonias cromis*. However, these latter species contributed a lesser combined percentage (6%) of the overall recreational assemblage.

Nekton Assemblages in Frog Creek

Forty-three taxa were collected in Frog Creek during the 2004 sampling period, totaling 8,037 individuals from 24 samples. Frog Creek was characterized by 13 taxa, which constituted 94% of the creek assemblage (Fig. 5). Gobiids (25%), two schooling taxa - *Menidia* spp. and *Anchoa* spp. (22%), gerreids (14%), and poeciliids (13%) accounted for 74% of the assemblage. Highest mean density was observed during the summer season as a result of high catches of the schooling species, anchovy, *Anchoa* spp., and the clown goby, *Microgobius gulosus*. Lowest mean fish density was observed during winter season, when many of the dominant taxa were considerably less abundant (Table 4). Species diversity was consistent throughout the year.

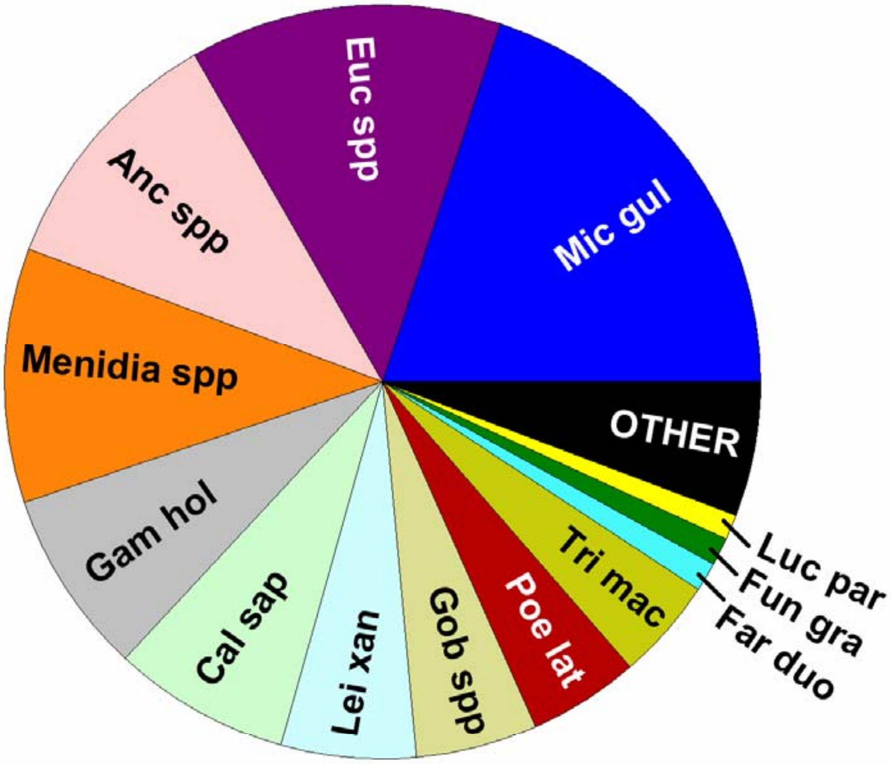

Figure 5. Species composition of the nekton assemblage in Frog Creek (2004).

Mic gul=*Microgobius gulosus*
Euc spp=*Eucinostomus* spp
Anc spp=*Anchoa* spp
Gam hol=*Gambusia holbrooki*
Cal sap=*Callinectes sapidus*
Lei xan=*Leiostomus xanthurus*
Gob spp=*Gobiosoma* spp
Poe lat=*Poecilia latipinna*
Tri mac=*Trinectes maculatus*
Far duo=*Farfantepenaeus duorarum*
Fun gra=*Fundulus grandis*
Luc par=*Lucania parva*
Other=34 taxa

Table 4. Measures of nekton community structure by season and sample area at Terra Ceia, Tampa Bay, FL (2004).

		Season				Annual
Sample area	**Measure**	**Winter**	**Spring**	**Summer**	**Fall**	**2004**
Frog Creek	Density (fish/100m^2)	35.08	75.44	106.23	76.16	**73.23**
	Richness*	7.04	6.93	8.94	8.73	**11.52**
	Diversity**	0.87	0.85	0.79	0.85	**0.90**
Frog Creek Ponds	Density	357.65	201.21	333.74	56.48	**237.27**
	Richness*	6.87	5.01	6.37	7.75	**10.83**
	Diversity**	0.82	0.77	0.37	0.86	**0.85**
Restoration Ponds	Density	308.12	622.24	617.88	289.78	**459.51**
	Richness*	1.74	2.40	1.60	2.04	**3.55**
	Diversity**	0.09	0.15	0.34	0.48	**0.29**
Moses Hole	Density	27.83	313.36	168.30	198.10	**176.90**
	Richness*	2.07	4.70	3.32	6.47	**8.40**
	Diversity**	0.28	0.64	0.35	0.75	**0.83**

*** Margalef's Index of Species Richness**

**** Simpson Diversity Index**

Table 5. Mean ± S.E. seasonal nekton abundance (nekton/100 m^2) in Frog Creek at Terra Ceia, Tampa Bay, FL (2004).

Species			Season				Annual
Family	**Scientific name**	**Common name**	**Winter**	**Spring**	**Summer**	**Fall**	**2004**
Achiridae	Achiridae	Unidentified sole	0.3±0.3	0	0	0.4±0.4	**0.2±0.1**
	Achirus lineatus	Lined sole	0	0	0	0.2±0.2	**<0.1**
	Trinectes maculatus	Hogchoker	18.2±8.9	16.6±7.3	13.2±6.4	12.6±4.2	**15.2±3.2**
Atherinidae	*Menidia* spp.	Silverside	8±4.5	80.0±67.0	22.7±6.1	39.4±21.1	**37.5±17.4**
Carangidae	*Oligoplites saurus*	Leatherjacket	0	0	0.9±0.9	0	**0.2±0.2**
Centrarchidae	*Lepomis punctatus*	Spotted sunfish	0.2±0.2	0	0	0	**<0.1**
	Lepomis spp.	Sunfish	0	0	0	0.8±0.8	**0.2±0.2**
	Micropterus salmoides	Largemouth bass	0	0	0.2±0.2	0.2±0.2	**0.1±0.1**
Centropomidae	*Centropomus undecimalis*	Common snook	0.6±0.6	0.6±0.4	0.3±0.3	6.6±2.7	**2.0±0.9**
Cichlidae	Cichlidae	Unidentified cichlid	0	0	0	0.3±0.2	**0.2±0.1**
Clupeidae	*Brevoortia* spp.	Menhaden	0	0.5±0	11.9±11.9	0	**3.0±3.0**
Cyprinodontidae	*Cyprinodon variegatus*	Sheepshead minnow	0.3±0.3	0.2±0.2	1.0±0.8	0.2±0.2	**0.4±0.2**
	Floridichthys carpio	Goldspotted killifish	0	0	3.2±3.2	4.1±4.1	**1.8±1.3**
	Fundulus confluentus	Marsh killifish	0.6±0.4	0.3±0.3	0	0	**0.2±0.1**
	Fundulus grandis	Gulf killifish	0	0.4±0.4	13.4±13.1	3.4±2.8	**4.3±3.3**
	Fundulus spp.	Killifish	0	0.5±0.5	0	0.6±0.4	**0.3±0.2**
	Lucania parva	Rainwater killifish	0	0.2±0.2	1.1±1.1	17.1±7.9	**4.6±2.4**
Dasyatidae	*Dasyatis sabina*	Atlantic stingray	0	0	0	0.3±0.3	**0.1±0.1**
Engraulidae	*Anchoa mitchilli*	Bay anchovy	0.3±0.3	7.7±6.5	146.3±145.1	0.2±0.2	**38.6±36.3**
	Anchoa spp.	Unidentified anchovy	0	0	1.8±1.8	0	**0.4±0.4**
Gerreidae	*Diapterus plumieri*	Striped mojarra	0.3±0.2	0.2±0.2	4.2±1.9	5.8±2.1	**2.6±0.8**
	Eucinostomus harengulus	Tidewater mojarra	0	1.1±1.1	0.5±0.5	11.5±2.8	**3.3±1.2**
	Eucinostomus spp.	Mojarra	12.6±11.1	27.2±10.2	34.0±33.6	116.0±68.4	**47.5±20**
	Gerreidae	Unidentified mojarra	0	0	0.5±0.5	0	**0.1±0.1**
Gobiidae	Gobiidae	Unidentified goby	0	0	2.1±2.1	0	**0.5±0.5**
	Gobiosoma bosc	Naked goby	12.4±7.1	0	0	0	**3.1±2**
	Gobiosoma spp.	Goby	11.6±3.8	24.7±7.6	30.9±11.8	15.5±8.0	**20.7±4.2**
	Microgobius gulosus	Clown goby	20.2±6.0	14.8±4.6	192.1±61.7	109.7±78.0	**84.2±27.8**
Lutjanidae	*Lutjanus griseus*	Gray snapper	0.2±0.2	0	0.3±0.3	0.8±0.6	**0.3±0.2**
Mugilidae	*Mugil* spp.	Mullet	0	0.3±0.3	0.4±0.4	0	**0.2±0.1**
	Mugil cephalus	Striped mullet	7.4±7.4	0	0	0	**1.9±1.9**
	Mugil gyrans	Fantail mullet	0.7±0.7	0	0	0	**0.2±0.2**
Myliobatidae	*Rhinoptera bonasus*	Cownose ray	0	0	0.2±0.2	0	**<0.1**
Penaeidae	*Farfantepenaeus duorarum*	Pink shrimp	3.0±1.9	1.4±1.1	0.5±0.5	14.1±13.8	**4.8±3.4**
Poeciliidae	*Gambusia holbrooki*	Eastern mosquitofish	42.5±24.8	53.3±13.4	15.8±7.1	25.8±9.9	**34.4±7.8**
	Heterandria formosa	Least killifish	0.2±0.2	0	0	0	**<0.1**
	Poecilia latipinna	Sailfin molly	13.8±12.3	13.7±4.6	23.7±7.4	24.9±11.1	**19.0±4.5**
	Poecilidae	Unidentified livebearer	0	0.3±0.3	0.3±0.3	0	**0.1±0.1**
Portunidae	*Callinectes sapidus*	Blue crab	47.5±13.3	51.2±20.4	12.8±4.5	19.0±7.1	**32.6±7**
Sciaenidae	*Cynoscion arenarius*	Sand seatrout	0	0	0	1.4±1.4	**0.4±0.4**
	Cynoscion nebulosus	Spotted seatrout	0	0	0.4±0.4	0.6±0.4	**0.2±0.1**
	Leiostomus xanthurus	Spot	0	101.7±29.0	2.0±1.7	0.3±0.3	**26.0±11.4**
	Pogonias cromis	Black drum	0	0	0.3±0.3	0	**0.1±0.1**
	Sciaenidae	Unidentified drum/croaker	0	0	0	2.6±2.5	**0.7±0.6**
	Sciaenops ocellatus	Red drum	1.8±1.0	3.6±1.4	0	0	**1.4±0.5**
Sparidae	*Archosargus probatocephalus*	Sheepshead	0.6±0.4	2.9±1.3	8.4±4.8	5.7±4.8	**4.4±1.7**
	Lagodon rhomboides	Pinfish	0	7.9±4.5	6.2±3.5	0.3±0.3	**3.6±1.5**

Species in gray are of recreational and/or commercial fishery value in Florida.

Eighteen taxa of recreational importance were collected in Frog Creek. *Callinectes sapidus*, *L. xanthurus*, and *F. duorarum* were among the most abundant (Table 5). Seasonal recruitment was observed for several of the most abundant recreational species. Juvenile *F. duorarum*, *A. probatocephalus*, *C. undecimalis*, and striped mojarra, *Diapterus plumieri*, were most abundant during summer and/or fall, whereas *L. xanthurus*, *C. sapidus*, *M. cephalus*, and *S. ocellatus* were most abundant during winter and/or spring (Table 5).

Species composition and abundance of Frog Creek assemblages differed seasonally (ANOSIM; p=0.001; Fig. 6). Furthermore, nekton assemblages in Frog Creek differed between the dry season (December and March) and the wet season (June and September; ANOSIM; p=0.001; Fig. 6).

Nekton Assemblages in Terra Ceia Ponds

Sixty taxa were collected in ponds from three geographic areas of Terra Ceia, including 20 taxa of recreational importance (Table 6). Mean nekton density was greatest in the Restoration Ponds (Table 5) as a result of high abundance of *Gambusia holbrooki*. However, only 16 taxa were collected in the Restoration Ponds, with only four species occurring in notable abundance. The low richness and diversity of the Restoration Ponds were probably a result of the limited tidal connection in these ponds. Nekton densities in Frog Creek Ponds and Moses Hole (i.e., those with more persistent tidal connections) were similar to one another, as were species richness and diversity, even though sampling was limited to the shallow-water perimeter of Moses Hole. Seasonal species diversity in the Restoration Ponds was lowest during the winter and spring dry season (Table 4), probably a result of limited connectivity between these ponds and the bay during low dry-season tides. Seasonal diversity trends were similar in Frog Creek Ponds and Moses Hole during most of the year (i.e., lowest during summer and highest during fall), although diversity was always lower in Moses Hole, even during winter, despite its close proximity to Tampa Bay. Although Moses Hole is connected to Tampa Bay and Bishop Harbor on all four sides, these connections are constrained in places by shallow expanses of oyster habitat, which may prevent nekton from utilizing this habitat during low-water conditions.

Species composition of the ponds was drastically different among sample areas - Frog Creek Ponds, Moses Hole, and Restoration Ponds (Fig. 7). The assemblage in the Frog Creek Ponds was

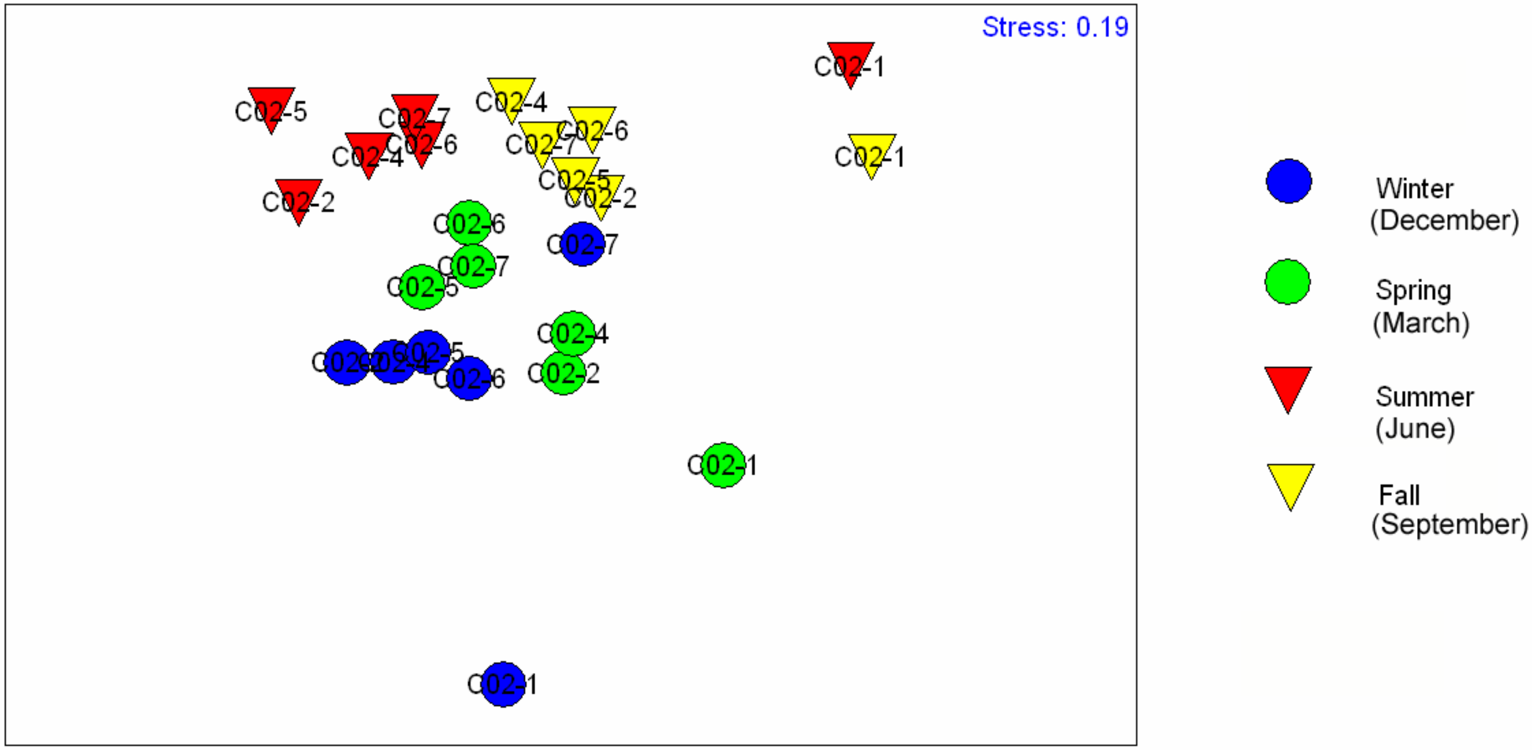

Figure 6. Non-metric multidimensional scaling plot representing the similarity of seasonal composition of wetland nekton assemblages in Frog Creek, 2004. Note that site C02-1 (mouth of Frog Creek) is considerably more dissimilar than the other sites.

Table 6. Mean ± S.E. nekton abundance (nekton/100 m^2) in wetland ponds at Terra Ceia, Tampa Bay, FL (2004). Abundances were calculated as the mean density of each species in three replicate samples from all ponds in a sample area during the course of four sampling seasons.

Species			Habitat		
Family	**Scientific name**	**Common name**	**Frog Creek ponds**	**Moses Hole**	**Restoration ponds**
			(Ponds = 4)	**(Ponds = 1)**	**(Ponds = 3)**
Achiridae	*Trinectes maculatus*	Hogchoker	2.6±0.6	0	0
Atherinidae	*Membras martinica*	Rough silverside	0	0.1±0.1	0
	Menidia spp.	Silverside	16.9±4.3	5.1±4.7	9.5±5.5
Belonidae	*Stongylura timucu*	Timucu	0	0.1±0.1	0
Carangidae	*Oligoplites saurus*	Leatherjacket	0	1.1±0.5	0
Centrarchidae	*Lepomis* spp.	Sunfish	0.1±0	0	0
Centropomidae	*Centropomus undecimalis*	Common snook	1.6±0.6	0.2±0.2	0.1±0
Cichlidae	Cichlidae	Unidentified cichlid	<0.1	0	0.4±0.2
	Oreochromis aureus	Blue tilapia	0	0	0.2±0.4
Clupeidae	*Brevoortia* spp.	Menhaden	4.5±3.1	0	0
	Clupeidae	Herring	2.4±1.7	0	0
	Harengula jaguana	Scaled sardine	<0.1	4.2±4.1	0
	Opisthonema olginum	Atlantic threadfin herring	0.2±0.2	0	0
Cyprinodontidae	*Adinia xenica*	Diamond killifish	0	0	<0.1
	Cyprinodon variegatus	Sheepshead minnow	0.9±0.6	0	24.2±10.4
	Floridichthys carpio	Goldspotted killifish	0.7±0.5	0	0
	Fundulus grandis	Gulf killifish	1.4±0.9	0	0
	Fundulus majalis	Longnose killifish	0	0	0.1±0.1
	Lucania parva	Rainwater killifish	1.3±0.9	6.6±5.5	0.1±0.1
Dasyatidae	*Dasyatis sabina*	Atlantic stingray	0.1±0	0.2±0.1	0
Elopidae	*Elops saurus*	Ladyfish	0.2±0.1	0	0
Engraulidae	*Anchoa hepsetus*	Striped anchovy	0	0.1±0.1	0
	Anchoa mitchilli	Bay anchovy	43.9±13.1	1.1±0.7	0
	Anchoa spp.	Unidentified anchovy	65.6±43.7	0	0
Exocoetidae	*Hyporhamphus meeki*	False silverstripe halfbeak	0	0.4±0.4	0
Gerreidae	*Diapterus plumieri*	Striped mojarra	3.4±0.6	0	0
	Eucinostomus gula	Silver jenny	0	3.1±1.8	0
	Eucinostomus harengulus	Tidewater mojarra	0.6±0.2	1.5±1.0	0
	Eucinostomus spp.	Mojarra	30.2±13.0	38.4±12.4	0
Gobiidae	*Gobionellus smaragdus*	Emerald goby	<0.1	0	0
	Gobiosoma bosc	Naked goby	<0.1	0	0
	Gobiosoma robustum	Code goby	0	0.1±0.1	0
	Gobiosoma spp.	Goby	0.1±0	4.9±2.7	0
	Microgobius gulosus	Clown goby	16.3±3.1	37.8±23.1	0.1±0.1
Haemulidae	*Haemulon* spp.	Unidentified grunt	0	0.2±0.2	0
Lutjanidae	*Lutjanus griseus*	Gray snapper	<0.1	0	0
Megalopidae	*Megalops atlanticus*	Tarpon	0	0	0.5±0.3
Mugilidae	*Mugil* spp.	Mullet	6.3±5.7	0	0
	Mugil cephalus	Striped mullet	1.6±0.7	0	0.4±0.4
	Mugil curema	White mullet	0.1±0	0	0
	Mugil gyrans	Fantail mullet	2.1±1.9	0	0
Myliobatidae	*Rhinoptera bonasus*	Cownose ray	<0.1	0	0
Ophichthidae	*Myrophis* spp.	Unidentified eel	<0.1	0	0
Penaeidae	*Farfantepenaeus duorarum*	Pink shrimp	0.6±0.2	1.9±1.1	0
Poeciliidae	*Gambusia holbrooki*	Eastern mosquitofish	0.1±0.1	0	384.8±83.1
	Poecilia latipinna	Sailfin molly	0	0	38.3±19.1
Portunidae	*Callinectes sapidus*	Blue crab	5.6±1.6	0.1±0.1	0.7±0.2
Sciaenidae	*Bairdiella chrysoura*	Silver perch	0	0.8±0.6	0
	Cynoscion arenarius	Sand seatrout	0.1±0	0	0
	Cynoscion nebulosus	Spotted seatrout	<0.1	1±0.5	0
	Leiostomus xanthurus	Spot	13.8±6.0	31.6±18.4	0.1±0.1
	Micropogonias undulatus	Atlantic croaker	<0.1	0	0
	Pogonias cromis	Black drum	0.2±0.1	0	0.1±0.1
	Sciaenidae	Unidentified drum/croaker	0.1±0.1	0.3±0.3	0
	Sciaenops ocellatus	Red drum	13.3±9.4	0.3±0.3	0
Sparidae	*Archosargus probatocephalus*	Sheepshead	0.2±0.1	0	0
	Lagodon rhomboides	Pinfish	0.1±0.1	35.4±21.4	0
Syngnathidae	*Syngnathus scovelli*	Gulf pipefish	0	0.2±0.2	0
Synodontidae	*Synodus foetens*	Inshore lizardfish	0	0.1±0.1	0
Tetraodontidae	*Sphoeroides nephelus*	Southern puffer	0	0.2±0.2	0

Species in gray are of recreational and/or commercial fishery value in Florida.

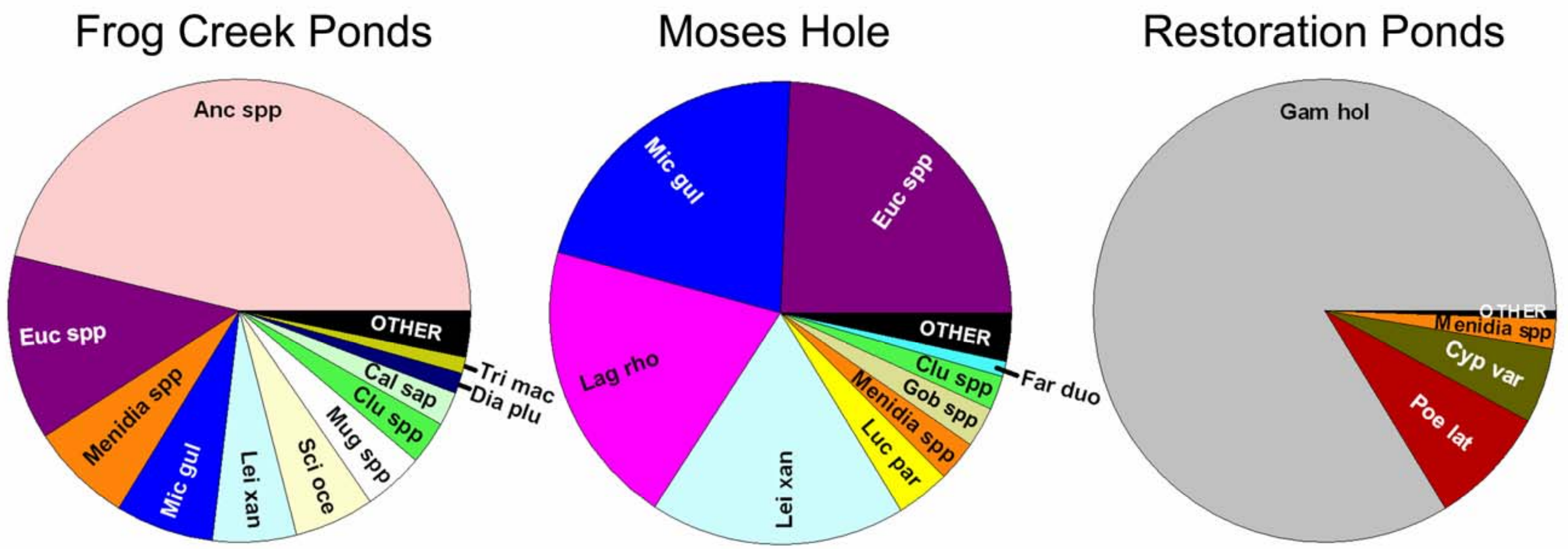

Figure 7. Species composition of nekton assemblages in Terra Ceia karst ponds with varying degrees of connectivity to Tampa Bay. Moses Hole (n=1) is directly connected, Frog Creek ponds (n=4) are connected via Frog Creek to Terra Ceia Bay, and Restoration ponds (n=3) are connected via seasonally inundated mosquito ditches to Williams Bayou.

Anc spp=*Anchoa* spp
Euc spp=*Eucinostomus* spp
Mic gul=*Microgobius gulosus*
Lei xan=*Leiostomus xanthurus*
Sci oce=*Sciaenops ocellatus*

Mug spp=*Mugil* spp
Clu spp=Clupeidae spp
Cal sap=*Callinectes sapidus*
Dia plu=*Diapterus plumieri*
Tri mac=*Trinectes maculatus*

Lag rho=*Lagodon rhomboides*
Luc par=*Lucania parva*
Gob spp=*Gobiosoma* spp.
Far duo=*Farfantepenaeus duorarum*
Gam hol=*Gambusia holbrooki*

Poe lat=*Poecilia latipinna*
Cyp var=*Cyprinodon variegatus*
Other=35, 20, 12 taxa

Table 7. Mean ± S.E. seasonal nekton abundance (nekton/100 m^2) in Frog Creek karst ponds at Terra Ceia, Tampa Bay, FL (2004). Three random samples were collected from each pond every season.

Species			Season				Annual
Family	**Scientific name**	**Common name**	**Winter (n=12)**	**Spring (n=12)**	**Summer (n=12)**	**Fall (n=12)**	**Frog Ponds (Ponds = 4)**
Achiridae	Achiridae	Sole	0	0	0.1±0.1	0	<0.1
	Trinectes maculatus	Hogchoker	3.7±1.6	3.1±1.3	1.6±0.6	2.1±0.6	2.6±0.6
Atherinidae	*Menidia* spp.	Silverside	15.0±5.4	9.3±2.9	26.9±15.4	16.5±5.6	16.9±4.3
Centrarchidae	*Lepomis* spp.	Sunfish	0	0	0	0.3±0.2	0.1±0
Centropomidae	*Centropomus undecimalis*	Common snook	2.5±1.4	0.5±0.2	0.2±0.2	3.3±1.7	1.6±0.6
Cichlidae	Cichlidae	Cichlid	0	0.1±0.1	0	0	<0.1
Clupeidae	*Brevoortia* spp.	Menhaden	0	16.4±12.0	1.6±1.4	0	4.5±3.1
	Clupeidae	Herring	0	6.3±6.1	0	3.1±3.0	2.3±1.7
	Harengula jaguana	Scaled sardine	0	0	0	0.2±0.1	<0.1
	Opisthonema olginum	Atlantic threadfin herring	0	0	0	0.9±0.9	0.2±0.2
Cyprinodontidae	*Cyprinodon variegatus*	Sheepshead minnow	3.6±2.3	0	0	0	0.9±0.6
	Floridichthys carpio	Goldspotted killifish	0.1±0.1	0	2.1±1.8	0.4±0.4	0.7±0.5
	Fundulus grandis	Gulf killifish	5.4±3.5	0	0	0	1.4±0.9
	Lucania parva	Rainwater killifish	4.6±3.4	0	0.7±0.6	0	1.3±0.9
Dasyatidae	*Dasyatis sabina*	Atlantic stingray	0	0	0.2±0.2	0	0.1±0
Elopidae	*Elops saurus*	Ladyfish	0	0	0.7±0.5	0	0.2±0.1
Engraulidae	*Anchoa mitchilli*	Bay anchovy	88.7±42.4	77.6±23.2	6.6±5.9	2.5±2.5	43.9±13.1
	Anchoa spp.	Anchovy	0.7±0.7	0	261.5±167.4	0	65.6±43.7
Gerreidae	*Diapterus plumieri*	Striped mojarra	4±1.4	4.2±1.1	0.8±0.4	4.7±1.6	3.4±0.6
	Eucinostomus harengulus	Tidewater mojarra	0	0.3±0.3	0	1.9±0.8	0.6±0.2
	Eucinostomus spp.	Mojarra	105.2±46.8	7.3±4.0	0	8.3±3.3	30.2±13
	Gerreidae	Mojarra	0	0	0.2±0.2	0	0.1±0.1
Gobiidae	*Gobionellus smaragdus*	Emerald goby	0.1±0.1	0	0	0	<0.1
	Gobiosoma bosc	Naked goby	0.1±0.1	0	0	0.1±0.1	<0.1
	Gobiosoma spp.	Goby	0.1±0.1	0	0	0.2±0.1	0.1±0
	Microgobius gulosus	Clown goby	21.2±6.1	9.2±2.3	27.4±9.7	7.3±1.9	16.3±3.1
Lutjanidae	*Lutjanus griseus*	Gray snapper	0	0	0	0.1±0.1	<0.1
Mugilidae	*Mugil* spp.	Mullet	22.8±22.8	2.2±1.8	0	0	6.3±5.7
	Mugil cephalus	Striped mullet	2.2±1.1	4.2±2.4	0	0.1±0.1	1.6±0.7
	Mugil curema	White mullet	0.3±0.2	0	0	0	0.1±0
	Mugil gyrans	Fantail mullet	8.3±7.6	0	0	0	2.1±1.9
Myliobatidae	*Rhinoptera bonasus*	Cownose ray	0	0	0.1±0.1	0	<0.1
Ophichthidae	*Myrophis* spp.	Eel	0	0	0.1±0.1	0	<0.1
Penaeidae	*Farfantepenaeus duorarum*	Pink shrimp	0.7±0.4	0	0	1.6±0.9	0.6±0.2
Poeciliidae	*Gambusia holbrooki*	Eastern mosquitofish	0	0	0.2±0.2	0.2±0.2	0.1±0.1
Portunidae	*Callinectes sapidus*	Blue crab	11.5±4.8	8.8±3.4	0	2.3±1.6	5.6±1.6
Sciaenidae	*Cynoscion arenarius*	Sand seatrout	0.2±0.1	0	0	0	0.1±0
	Cynoscion nebulosus	Spotted seatrout	0	0	0.1±0.1	0.1±0.1	<0.1
	Leiostomus xanthurus	Spot	3.4±1.3	51.3±20.9	0.7±0.4	0	13.8±6
	Micropogonias undulatus	Atlantic croaker	0	0.2±0.1	0	0	<0.1
	Pogonias cromis	Black drum	0.1±0.1	0	0.7±0.5	0	0.2±0.1
	Sciaenidae	Drum/croaker	0	0	0.1±0.1	0.3±0.3	0.1±0.1
	Sciaenops ocellatus	Red drum	52.8±36.1	0.1±0.1	0.2±0.2	0	13.3±9.4
Sparidae	*Archosargus probatocephalus*	Sheepshead	0.3±0.2	0	0.2±0.1	0.2±0.1	0.2±0.1
	Lagodon rhomboides	Pinfish	0	0.2±0.2	0.3±0.2	0	0.1±0.1

Species in gray are of recreational and/or commercial fishery value in Florida.

characterized by 11 species, which constituted 97% of the assemblage. Two species of *Anchoa* spp. and *Eucinostomus* spp. constituted greater than 50% of the assemblage, though the abundance of these taxa varied seasonally and was not consistently high (Table 7). *Anchoa* spp., *Menidia* spp., *M. gulosus*, *D. plumieri*, *Trinectes maculatus,* and *C. undecimalis* were the only species of the 46 collected taxa that were consistently present in the Frog Creek Ponds during all four seasons. Four species of recreational importance (*L. xanthurus*, *S. ocellatus*, *Mugil* spp., and *C. sapidus*) were in notable abundance during the winter and spring recruitment periods. Moses Hole was characterized by 12 taxa, which constituted 96% of the overall assemblage. The four most abundant taxa were present in similar proportions (Fig. 7). With the exception of *M. gulosus*, these species were only seasonally abundant and contributed to the Moses Hole assemblage during their respective recruitment periods. Seven species of recreational importance were collected in Moses Hole (Table 6), but only two species were of notable abundance, *L. xanthurus* and *F. duorarum*. The Restoration Ponds had lower species richness and diversity (Fig. 7) than the other ponds. Only four species represented 99% of the entire assemblage. The remaining 12 taxa were collected infrequently and in low abundance. Six species of recreational importance were collected in the Restoration Ponds, including *C. sapidus*; juvenile tarpon, *M. atlanticus*; juvenile mullet, *Mugil* spp; *L. xanthurus*; *P. cromis*; and *C. undecimalis*.

Species composition and abundance of nekton assemblages in Terra Ceia ponds were more similar within sample areas than between sample areas (Fig. 8). The Moses Hole assemblage differed from all other assemblages (p=0.03) with the exception of Pond 117 at the mouth of Frog Creek (p=0.06), probably a result of the close proximity of both ponds to Tampa Bay, and thus more open access for nekton migration between bay and pond habitats. Nekton assemblages in the ponds on Frog Creek were similar to one another (p>0.05) with the exception of the two most distant ponds: Pond 101 farthest upstream and P117 at the mouth (p=0.03). Restoration Pond assemblages were similar among ponds (p>0.05) but differed from Frog Creek Ponds and Moses Hole (p=0.03). The similarities/differences among ponds at Terra Ceia may be attributed to their degree of tidal connectivity with Tampa Bay and its backwater habitats (as described earlier in the habitat results). The ponds with the least tidal connection to Tampa Bay (Restoration Ponds) are most dissimilar to the ponds with the closest proximity and greatest tidal connection (Moses Hole and downstream Frog Creek Ponds; Fig. 8). This trend is also apparent within a

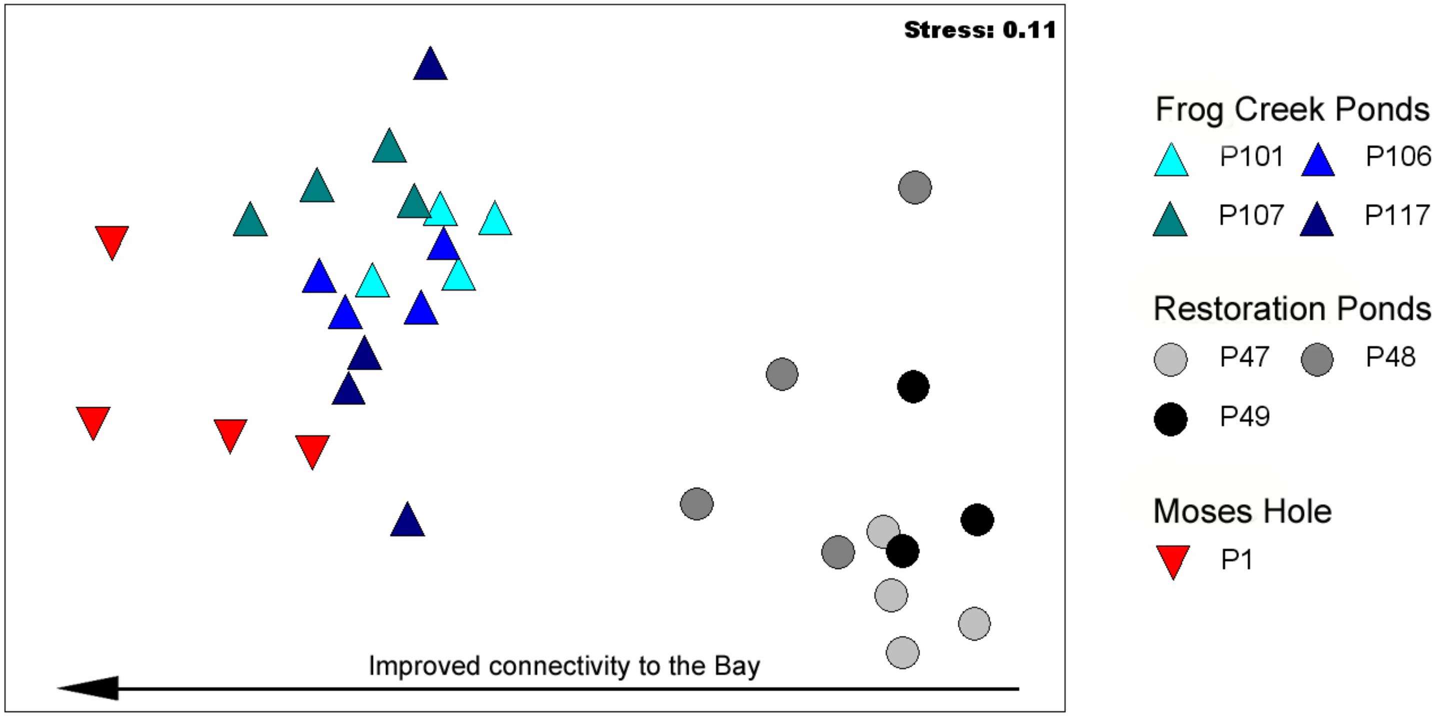

Figure 8. Non-metric multidimensional scaling plot of nekton assemblages in Terra Ceia karst ponds during 2004. Each point represents the mean species abundance from three replicate seine hauls within a pond during one season. Pond 49 was not sampled during the summer season because of a dry-down.

pond sample area. For example, within the Restoration Ponds, Ponds 47 and 49 are most tidally isolated from Tampa Bay, and therefore their fish assemblages are more similar to one another than to those of Pond 48. Within the Frog Pond sample area, the most upstream pond (i.e., furthest from the bay) - Pond 101 - on Frog Creek is most similar among Frog Creek Ponds to the least well-connected Restoration Ponds, while the downstream Frog Creek Ponds 107 and 117 are most similar to the most well-connected Moses Hole, sharing a closer proximity and higher degree of connectivity to the bay (Fig. 8).

Restoration plans for the Restoration Ponds entail completely blocking the tidal connection to Tampa Bay in an effort to restore oligohaline conditions in these historically freshwater ponds. During the fall (September) 2004 sample collection, following the passage of Hurricane Jeanne, several juvenile tarpon (n=20) under 200 mm standard length were collected in the Restoration Ponds. We hypothesize that the storm surge observed during the passage of the storm facilitated access to the otherwise isolated ponds. Due to the recreational importance of this species and the extremely limited information on juvenile tarpon habitat use on the Gulf Coast of Florida, we continued monthly sampling of the Restoration Ponds through January 2005. Juvenile tarpon persisted in the ponds until a cold front in mid-December caused water temperatures to drop below 14ºC. Only one tarpon was collected from the Restoration Ponds during January 2005. We suggest that decreasing abundance was caused by juvenile mortality and was most likely the direct result of lethal water temperatures during the cold front. We have recommended that restoration be delayed until 2004 data can be validated following fall 2005 data collection.

Nekton Assemblages in Moses Creek and Ditches

Forty-seven taxa were collected from four sites in creek and ditch habitats in the northeast area adjacent to Moses Hole (Table 8). The majority of these (30 of 47 taxa) was collected at all creek and ditch sites. Those species that were unique to a site were in low abundance and were uncommonly encountered, or were schooling species that were typically collected in high abundance but with low frequency (e.g., *Anchoa mitchilli*). Twelve of the 13 most abundant taxa were collected at both creek and ditch habitats, although most of those taxa were more abundant in the ditch habitats. The observed differences in mean species density between creek and ditch sites were probably a result of habitat differences between the two creek sites. One of the creek sites was similar to the ditch sites in that it had a muddy substrate; the other creek site had an oyster bottom and greater water flow. The nekton assemblage in Moses Hole creek and ditch habitats consisted of taxa from four abundant families including two taxa each from Poeciliidae (*Poecilia latipinna, G. holbrooki*), Gobiidae (*Gobiosoma* spp., *M. gulosus*), Cyprinodontidae (*Fundulus grandis*, *Floridichthys carpio*), and Gerreidae (*Eucinostomus* spp., *Eucinostomus. harengulus*). Three species of recreational importance, *L. xanthurus*, *F. duorarum,* and *C. sapidus* were also among the most abundant nekton. Species composition and abundance were more similar within than between habitat types, with the exception of the muddier creek site which was more similar to the ditch sites than to the other, oyster-bottom creek site (Fig. 9), indicating a habitat-related difference.

Conclusions

Fish assemblages in Terra Ceia sample sites are related to connectivity and freshwater input. Frog Creek, with an upstream source of fresh water and a good connection to Tampa Bay, had the most diverse nekton assemblage, which included 43 taxa, 18 of fishery importance. Seasonal differences in the Frog Creek nekton assemblage were observed and can be explained by seasonal recruitment of juveniles from the bay and later emigration back into bay habitats. Differential use of pond habitats also seemed to be determined by connectivity and proximity of the ponds to Tampa Bay. Frog Creek Ponds were similar to Frog Creek mainstream habitats in terms of salinity and connectivity to the bay and had comparable species richness (n=45 taxa) and diversity, despite greater nekton densities in the more open water pond habitat. Moses Hole, which was well-connected to the bay and had more saline waters, was similar to the Frog Creek Ponds in terms of nekton diversity but had a slightly lower species richness and contained fewer taxa (n=29), many of which were unique to Moses Hole (n=13) and more typical of higher salinity bay habitats. The poorly connected Restoration Ponds, which experienced high temperatures and greatly increased salinities during summer evaporative “dry downs”, exhibited the lowest diversity and most depauperate fish assemblages of those sampled at Terra Ceia. A dense population of *G. holbrooki* and only three other wetland-associated species composed 99% of the overall assemblage.

Among the factors that govern habitat use by wetland nekton, salinity regime and habitat accessibility (or connectivity) seem to regulate assemblage structure and presence/absence of species. Three critical requirements seem to be important for moderating salinity regime in the areas sampled: 1) volume of freshwater input, 2) degree of tidal connectivity, and 3) rate of evaporative processes. Habitat accessibility is likely determined by the degree of water flow, sedimentation, elevation, and obstruction of habitat linkages by vegetation. Salinity regime and connectivity to bay habitats (as observed at Terra Ceia) should be considered when planning and assessing habitat restoration projects.

Table 8. Comparison of ranked mean density (±S.E.) by habitat type at Moses Hole, Terra Ceia, Tampa Bay, FL. Sample size (n) is equal to the number of samples taken during 2004.

Creek (n=8)			Ditch (n=8)		
Scientific name	**Common name**	**Density**	**Scientific name**	**Common name**	**Density**
Eucinostomus spp.	Mojarra	64.9±28.0	*Eucinostomus* spp.	Mojarra	113.8±51.6
Lagodon rhomboides	Pinfish	40.8±19.9	*Menidia* spp.	Silverside	78.0±42.7
Poecilia latipinna	Sailfin molly	21.2±15.9	*Leiostomus xanthurus*	Spot	58.7±43.0
Farfantepenaeus duorarum	Pink shrimp	12.2±10.9	*Lagodon rhomboides*	Pinfish	45.7±20.7
Leiostomus xanthurus	Spot	10.8±7.6	*Callinectes sapidus*	Blue crab	36.7±10.6
Eucinostomus harengulus	Tidewater mojarra	9.7±3.5	*Microgobius gulosus*	Clown goby	33.7±7.9
Gobiosoma spp.	Goby	9.6±4.0	*Fundulus grandis*	Gulf killifish	31.9±19.3
Fundulus grandis	Gulf killifish	6.8±3.8	*Harengula jaguana*	Scaled sardine	21.0±21.0
Menidia spp.	Silverside	5.6±2.8	*Gobiosoma* spp.	Goby	20.9±3.6
Floridichthys carpio	Goldspotted killifish	5.5±2.8	*Farfantepenaeus duorarum*	Pink shrimp	20.6±5.9
Gambusia holbrooki	Eastern mosquitofish	4.7±3.9	*Floridichthys carpio*	Goldspotted killifish	19.4±10.9
Callinectes sapidus	Blue crab	4.2±2.1	*Eucinostomus harengulus*	Tidewater mojarra	10.9±4.1
Microgobius gulosus	Clown goby	3.4±2.9	*Poecilia latipinna*	Sailfin molly	8.6±4.9
Cyprinodon variegatus	Sheepshead minnow	3.1±2.6	*Eucinostomus gula*	Silver jenny	6.5±3.0
Eucinostomus gula	Silver jenny	2.5±1.5	*Achirus lineatus*	Lined sole	6.4±2.5
Gobiosoma bosc	Naked goby	2.1±1.8	*Gambusia holbrooki*	Eastern mosquitofish	5.4±2.9
Bathygobius soporator	Frillfin goby	1.6±0.5	*Anchoa mitchilli*	Bay anchovy	3.9±3.9
Penaeidae	Unidentified shrimp	1.6±1.6	*Fundulus* spp.	Killifish	3.6±2.7
Fundulus confluentus	Marsh killifish	1.5±1.5	*Diapterus plumieri*	Striped mojarra	2.2±1.5
Achirus lineatus	Lined sole	1.3±1.1	*Cynoscion nebulosus*	Spotted seatrout	1.7±1.5
Fundulus spp.	Killifish	1.3±0.8	*Lucania parva*	Rainwater killifish	1.7±1.0
Cynoscion nebulosus	Spotted seatrout	1.1±0.8	*Gobiosoma robustum*	Code goby	1.5±1.5
Adinia xenica	Diamond killifish	1.1±1.0	*Lutjanus griseus*	Gray snapper	1.4±0.6
Diapterus plumieri	Striped mojarra	0.8±0.8	*Adinia xenica*	Diamond killifish	1.0±0.6
Lucania parva	Rainwater killifish	0.8±0.5	*Strongylura notata*	Redfin needlefish	0.9±0.3
Lutjanus griseus	Gray snapper	0.7±0.7	*Cyprinodon variegatus*	Sheepshead minnow	0.8±0.4
Cyprinodon spp.		0.7±0.5	*Syngnathus scovelli*	Gulf pipefish	0.8±0.5
Achiridae	Unidentified sole	0.7±0.4	*Opsanus beta*	Gulf toadfish	0.7±0.4
Archosargus probatocephalus	Sheepshead	0.5±0.3	*Sphoeroides nephelus*	Southern puffer	0.4±0.3
Mugil spp.	Mullet	0.5±0.2	*Mugil gyrans*	Fantail mullet	0.4±0.4
Symphurus plagiusa	Blackcheek tonguefish	0.5±0.3	*Synodus foetens*	Inshore lizardfish	0.4±0.2
Centropomus undecimalis	Common snook	0.3±0.2	*Fundulus confluentus*	Marsh killifish	0.3±0.3
Chasmodes saburrae	Florida blenny	0.3±0.2	*Paralichthys albigutta*	Gulf flounder	0.3±0.3
Fundulus majalis	Longnose killifish	0.3±0.3	*Sciaenops ocellatus*	Red drum	0.3±0.3
Gobiosoma robustum	Code goby	0.3±0.3	*Archosargus probatocephalus*	Sheepshead	0.2±0.2
Lupinoblennius nicholsi	Highfin blenny	0.2±0.2	*Bathygobius soporator*	Frillfin goby	0.2±0.2
Mugil gyrans	Fantail mullet	0.2±0.2	*Chasmodes saburrae*	Florida blenny	0.2±0.2
Blenniidae	Unidentified blenny	0.2±0.2	*Hippocampus zosterae*	Dwarf seahorse	0.2±0.2
Hoplosternum littorale	Brown hoplo	0.2±0.2	*Opisthonema oglinum*	Atlantic threadfin herring	0.2±0.2
Sciaenops ocellatus	Red drum	0.2±0.2	*Syngnathus louisianae*	Chain pipefish	0.2±0.2

Species in gray are of recreational or commercial importance.

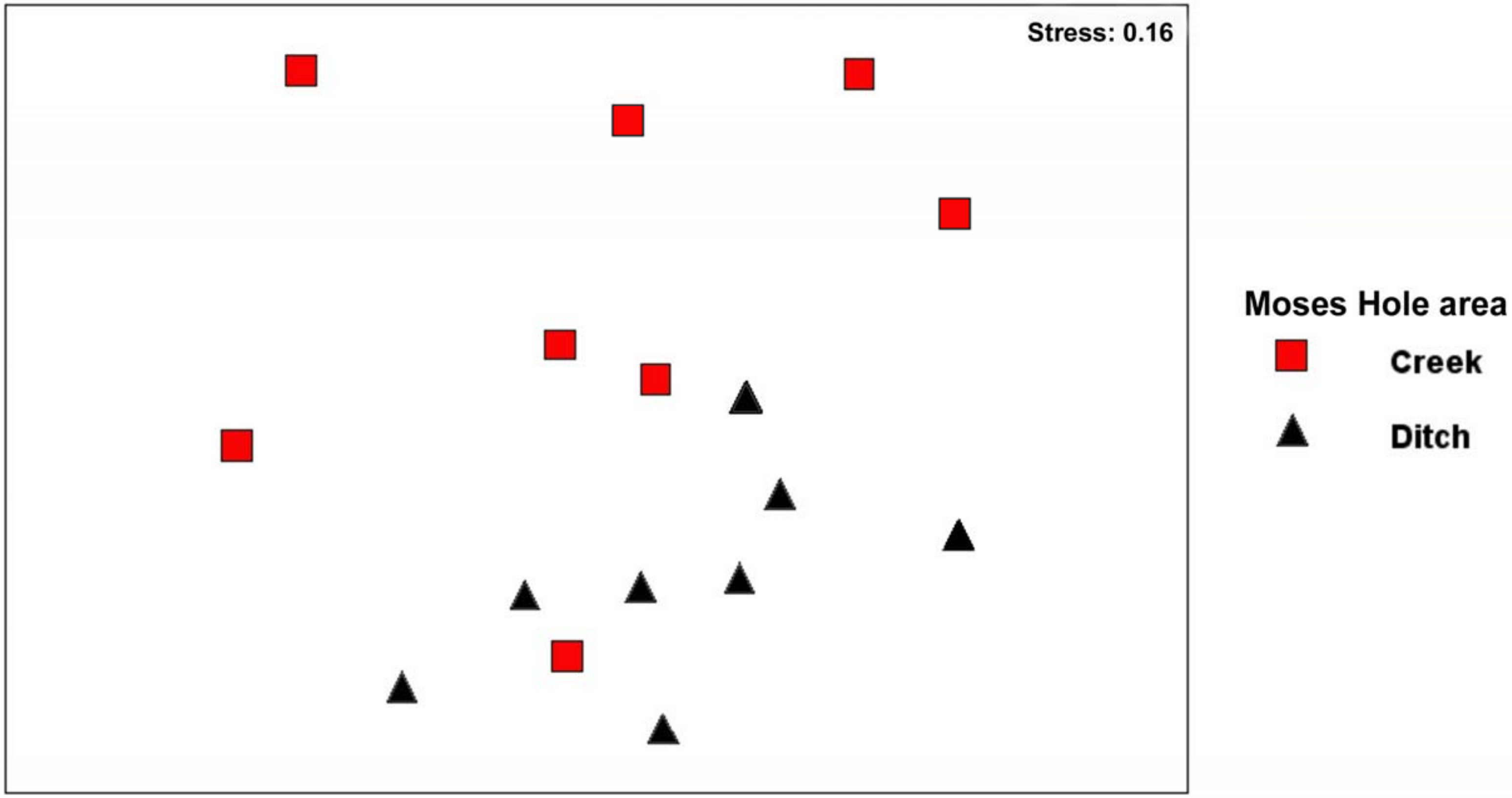

Figure 9. Non-metric multidimensional scaling plot of wetland creek and ditch habitats at Moses Hole, Terra Ceia during 2004. Each point represents a single sample. Samples were taken during four seasons at four sites throughout the year.

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