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Characterization of the marine fish assemblage associated with the nearshore hardbottom of Broward County, Florida, USA

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Abstract

Some shallow (<7 m, water depth) nearshore hardbottom areas of southeast Florida have been reported to function as important juvenile fish habitat. Much of this area has been impacted by one or more local beach renourishments (sand fill to offset erosion). We characterized the nearshore fish communities and compared the fish assemblages adjacent to renourished beach to those adjacent to never-renourished beach along a 30-km stretch of coastline, primarily in Broward County, using three visual census methods. Two hundred transect-counts, 100 point-counts and 98 rover-diver counts were completed during June–August 2001. In transect- and point-counts, abundance of all fish species and their sizes were recorded; the rover-diver counts consisted of a simple species list. In total, 164 species and over 72,000 fish were recorded. The highest number of species (145) was recorded with the rover-diver counts. The transects-counts had 118 species and 109 species were recorded on the point-counts. With either all the sites adjacent to renourished beach pooled and compared to the pooled never-renourished sites or individual comparisons amongst renourished and neighboring never-renourished sites, no consistent differences were noted in fish abundance or species richness (ANOVA) or among fish assemblage structure (MDS plot of Bray–Curtis dissimilarity indices). However, although the data show no obvious distinct difference between the renourished and never-renourished sites, due to several important confounding factors (e.g., census methodology, longshore movement of sand fill) and the absence of baseline data prior to any renourishment, it would be premature to translate these results into management strategies.

The assemblage structure, in terms of percentage of juvenile fish (<5 cm) as well as percent contributions by family, was similar for the point-counts and transect-counts. However, in mean density per m^2 of substrate, greater abundance and greater species richness values were recorded with the transect-counts than with the point-counts. Newly settled and early juveniles were the dominant component (>84%) of the inshore fish community, consisting primarily (>90%) of grunts (Haemulidae). After the grunts, the wrasses (Labridae) at about 5%, and damselfish (Pomacentridae) at roughly 2% were the predominant families. It is clear from this study and others that the nearshore hardbottom of Broward County is an important juvenile fish habitat, especially for grunts. However, the nearshore hardbottom does not appear to be obligate habitat for these fishes as fishes associated with this area are, apparently, not unique to the nearshore hardbottom either in species or ontogenic stage.
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1. Introduction

Three or more major relict reef tracts and an inshore ridge complex run parallel to the coastline in sequentially deeper water offshore southeast Florida. The ridge complex is approximately 600 m wide; the most shoreward portion has a low vertical profile and is somewhat patchy with relatively few live hard corals (Goldberg, 1973; Courtenay et al., 1980; Moyer et al., 2003). This nearshore environment (commonly called hardbottom) is composed primarily of beachrock with

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low substrate topography and it is exposed to substantial wave action and turbidity from suspended sediments (Goldberg, 1973; Jordan and Gilliam, unpublished data). Therefore, at specific sites the inner reef community is ephemeral and may be periodically buried by natural sand transport processes. However, there is some added complexity due to colonies of tube-building polychaete worms, macroalgae (Goldberg, 1973; Lindeman and Snyder, 1999) and various morphological features, for example, solution holes, surge channels, flagstone formations, and ancient burrow holes which aid in the habitat's ability to support a variety of biota (Vare, 1991). Recruitment and evasion of predators by recently settled fishes are facilitated by the availability of cryptic and size-scaled shelter (Cabalerro and Shmitter-Soto, 2001). Thus, there is a speciose fish assemblage, predominately juveniles, associated with this hardbottom and many consider it to be an important nursery area for some reef fishes (Lindeman and Snyder, 1999).

In an effort to mitigate natural erosion, portions of the coastal beach throughout the area have undergone beach restoration or renourishment (beach restoration and beach renourishment are terms commonly used to indicate replacement of lost sand by dredged sand which is normally obtained from nearby offshore sites) and some of the nearshore environments have been partially buried. Over time these communities may be able to rebound and support juvenile fish assemblages (Lindeman and Snyder, 1999); however, it is not known if assemblage structure is altered. The primary goal of our study was to document the reef fish assemblage that currently exists on a 30-km stretch of nearshore hardbottom in and around Fort Lauderdale, Florida, a stretch of hardbottom that may be affected by a proposed beach renourishment. This inventory will serve as baseline data for future comparisons. A secondary goal of the study was to compare the nearshore fish assemblages on hardbottom neighboring renourished beach to areas neighboring never-renourished beach. In addition, because every census method has specific biases and, currently, there is no universally accepted standard method, we compared three differing visual census methodologies for fish in the nearshore environment.

2. Materials and methods

The study area covered the first 30 m of nearshore hardbottom along an approximately 30-km stretch of shoreline (from latitude N 25° 57.78′ to 26° 14.58′). This area is located primarily in Broward County, Florida but includes approximately 1.5 km along the northeast edge of Dade County. The beach areas between 26° 05.825′ to 26° 10.654′ and 26° 03.041′ to 26° 04.213′ (approximately 11 km total) have never been directly renourished (Fig. 1). The remaining beach area has been restored/renourished one or more times between 1970 and 1991. During June 2001, 100 transect-counts and 100 point-counts were done every 305 m (1000 ft). During July and August 2001, 100 transect and 98 rover-diver counts were made midway between the previous counts. Thus, there was a transect-count and either a point-count or rover-diver count completed every 152 m of shoreline. SCUBA divers were placed in the water at the correct latitude (determined by differential global positioning system [DGPS]) at either the nearshore (western) edge of hardbottom or 50 m from shore (seaward edge of the boating-restricted, swimming zone). In either case, the divers visually identified the nearshore hardbottom edge before beginning the fish counts. Water depth for all counts ranged from 1.8 to 6.1 m (mean 3.9 m). The divers carried buoyed "diver-down" flags, and on completion of the counts, the flags were left in place and their position recorded onboard by DGPS. Occasionally divers would have to swim the dive flags out of the boating-restricted zone. In these cases, the distance the diver had to swim the flag was estimated by fin kicks (2/m). All counts were conducted during daylight (0900–1600 h) and counts were not made if horizontal visibility was less than 8 m. The census takers consisted of eight individuals that had received both formal and informal training in fish identification and were extremely familiar with underwater fish identification from previous projects.

2.1. Transect-counts

For the transect-counts, a 30-m line was stretched out west to east, on a 90° compass heading, beginning at the nearshore (western) edge of hardbottom. The diver swam above the transect, recording all fish within 1 m of either side and 1 m above the line (an imaginary 60 m^3 tunnel). Abundances and total length (TL) (by size class: <2, 2–5, 5–10, 10–20, 20–30, 30–50 and 50+ cm) of fish species were recorded. The diver carried a 1-m "T"-rod, with the size classes marked off, to aid in transect width and fish length estimation. The transect-counts took approximately 10 min to complete but were not time delimited. On completion of the fish count, the diver followed the line from beginning to end with a fiberglass surveyor's tape, closely following the contours of the substrate. Comparison of the tape distance to the 30-m line yielded an estimate of gross rugosity (calculated as tape distance/30 m). Stretches of sand along the transect (absence of hard substrate) greater than 3 m were also recorded to get an estimate of the amount of each transect lacking hardbottom.

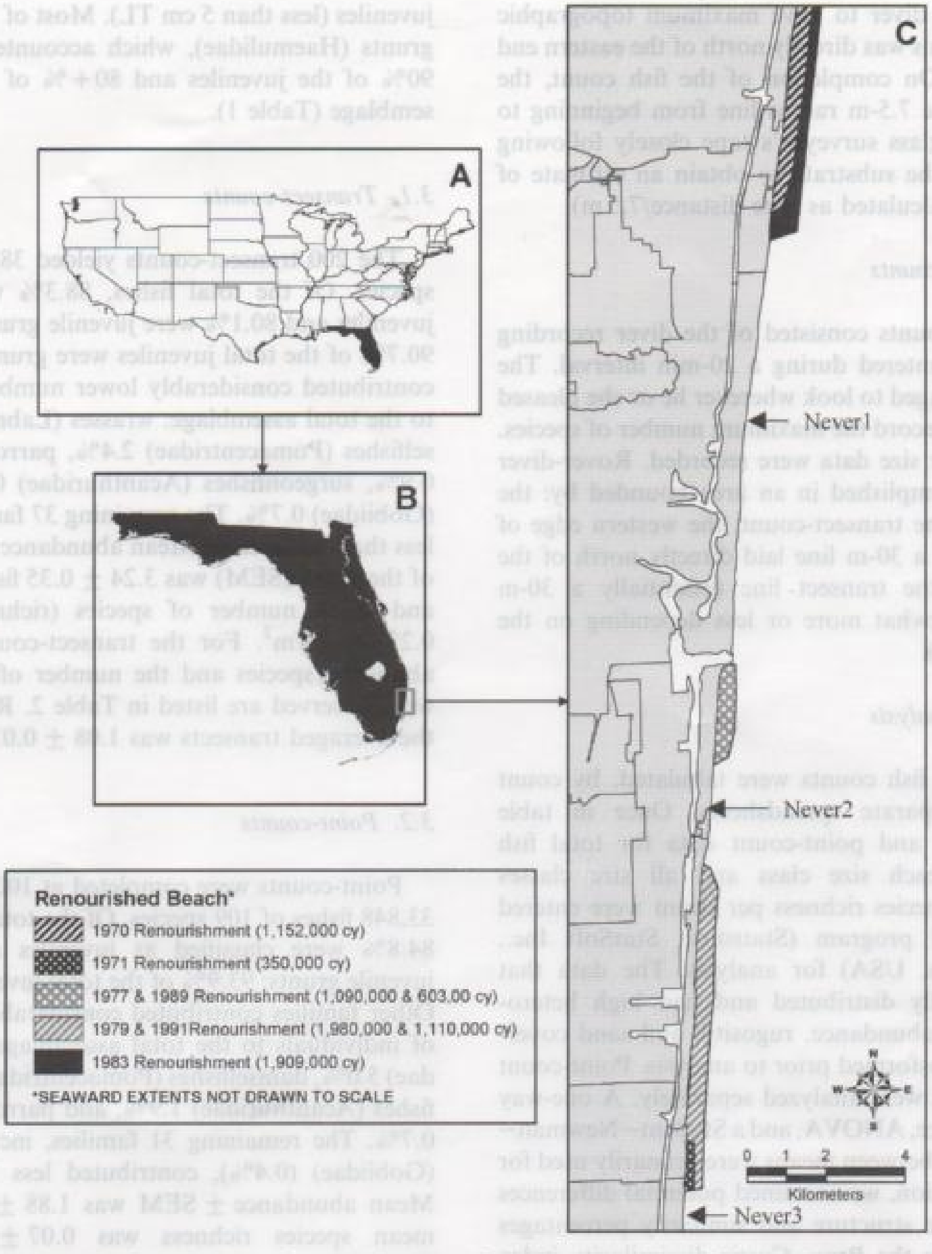

Fig. 1. Study site in southeast Florida, USA. Map C covers the range of the fish count sites and illustrates sections of renourished and never-renourished beach.

2.2. Point-counts

The point-count was a modified Bohnsack and Bannerot (1986) method in which all fishes were counted in an imaginary cylinder, 15 m in diameter, from the substrate to the water surface. A 7.5-m radius line was laid out prior to the count as an aid in estimating the cylinder boundary. For the first 5 min, only the species were recorded. After the 5-min species-count was completed, abundance of each species and the minimum, maximum, and estimated mean total length of each species were recorded along with depth and bottom features. The diver carried a 1-m rod with a ruler attached at one end of the rod in a T-configuration to aid in length estimation. In accordance with the published methodology (Bohnsack and Bannerot, 1986), actual sizes rather than size classes were recorded. However, in the published methodology the diver accomplishes the count by staying in the center of the cylinder and rotating 360° to record species and length. This was modified in our study to allow the diver to move around the cylinder because most of the fish were small juveniles that often stayed in depressions close to the substrate and were therefore hidden from the counter. Point-counts were accomplished 20 m north of, and on a line parallel to, the transect line at a position estimated by the diver to have maximum topographic relief; normally this was directly north of the eastern end of the transect. On completion of the fish count, the diver followed the 7.5-m radius line from beginning to end with a fiberglass surveyor's tape closely following the contours of the substrate to obtain an estimate of gross rugosity (calculated as tape distance/7.5 m).

2.3. Rover-diver counts

Rover-diver counts consisted of the diver recording the species encountered during a 20-min interval. The diver was encouraged to look wherever he or she pleased in an attempt to record the maximum number of species. No abundance or size data were recorded. Rover-diver counts were accomplished in an area bounded by: the transect line of the transect-count, the western edge of hardbottom, and a 30-m line laid directly north of the eastern end of the transect line (essentially a 30-m square, but somewhat more or less depending on the hardbottom edge).

2.4. Statistical analysis

Data from all fish counts were tabulated, by count method, into separate spreadsheets. Once in table format, transect- and point-count data for total fish abundance (of each size class and all size classes combined) and species richness per count were entered into a statistical program (Statistica, StatSoft Inc., Tulsa, Oklahoma, USA) for analysis. The data that were not normally distributed and had high heteroscedasticity (i.e., abundance, rugosity, and sand coverage) were log transformed prior to analysis. Point-count and transect data were analyzed separately. A one-way analysis of variance, ANOVA, and a Student–Newman–Keuls (SNK) test between means were primarily used for analyses. In addition, we examined potential differences in fish-assemblage structure and similarity percentages among sites using the Bray–Curtis dissimilarity index with multidimensional scaling (MDS) ordination and SIMPER (Field et al., 1982). For these tests we used the Plymouth Routines in Multivariate Ecological Research statistical package (PRIMER v5). We also used regression techniques to examine possible latitudinal gradients in fish richness and abundance. A P-value <0.05 in both ANOVA and SNK was accepted as a significant difference.

3. Results

With all census methodologies combined a total of 72,724 fishes from 48 families was observed. The nearshore hardbottom fish assemblages consisted of at least 164 species, of which the majority (>84%) were juveniles (less than 5 cm TL). Most of the juveniles were grunts (Haemulidae), which accounted for more than 90% of the juveniles and 80+% of the total fish assemblage (Table 1).

3.1. Transect-counts

The 200 transect-counts yielded 38,876 fishes of 118 species. Of the total fishes, 88.3% were classified as juveniles and 80.1% were juvenile grunts (Haemulidae); 90.7% of the total juveniles were grunts. Other families contributed considerably lower numbers of individuals to the total assemblage: wrasses (Labridae) 5.4%, damselfishes (Pomacentridae) 2.4%, parrotfishes (Scaridae) 0.9%, surgeonfishes (Acanthuridae) 0.8%, and gobies (Gobiidae) 0.7%. The remaining 37 families contributed less than 0.5% each. Mean abundance ± standard error of the mean (SEM) was 3.24 ± 0.35 fish/m^2 of substrate and mean number of species (richness) was 0.19 ± 0.23 species/m^2. For the transect-counts, the 15 most abundant species and the number of sites where they were observed are listed in Table 2. Rugosity index for the averaged transects was 1.08 ± 0.01.

3.2. Point-counts

Point-counts were completed at 100 sites and yielded 33,848 fishes of 109 species. Of the total fish abundance, 84.8% were classified as juveniles and 79.6% were juvenile grunts; 93.9% of the total juveniles were grunts. Other families contributed considerably lower numbers of individuals to the total assemblage: wrasses (Labridae) 5.0%, damselfishes (Pomacentridae) 1.9%, surgeonfishes (Acanthuridae) 1.9%, and parrotfishes (Scaridae) 0.7%. The remaining 31 families, including the gobies (Gobiidae) (0.4%), contributed less than 0.5% each. Mean abundance ± SEM was 1.88 ± 0.06 fish/m^2 and mean species richness was 0.07 ± 0.003 species/m^2. The fishes most often present at a site were juvenile *Haemulon* spp. (recorded at 83 sites), *Halichoeres bivittatus* (82), *Haemulon plumieri* (53), *Stegastes variabilis* (51), and *Stegastes leucostictus* (39). Rugosity averaged 1.12 ± 0.01 for the point-counts.

3.3. Rover-diver counts

Rover-diver counts were completed at 98 sites and yielded 145 species of 42 families. Similar to the most abundant, and most often present, fishes in transect- and point-counts, the species present most often with rover-diver counts were: *Halichoeres bivittatus* (recorded at 98 sites), *Haemulon plumieri* (82), *Stegastes variabilis* (79), *Acanthurus bahianus* (79), *Stegastes leucostictus* (74), and other *Haemulon* spp. (69).

Table 1
Nearshore hardbottom species list, compiled from transect-count, point-count, and rover-diver surveys (species presence is indicated by an **X**: species restricted to the nearshore (RN) (not found on offshore reef tracts in previous research); neighboring renourished beach (R); neighboring never-renourished beach (NR); and fish counted and approximate mean total length and range in cm for R and NR combined (*n*/mean/minimum–maximum))[a]

Common name	Scientific name	RN	R	NR	Transect-count	Point-count
Nurse sharks	Orectolobidae					
Nurse shark	*Ginglymostoma cirratum*		**X**	**X**	2/45.0/40–50+	–
Stingrays	Dasyatidae					
Southern stingray	*Dasyatis americana*		**X**	**X**	1/50.0	–
Round stingrays	Urolophidae					
Yellow stingray	*Urobatis jamaicensis*		**X**	**X**	19/29.7/15–40	8/30.9/17–36
Eagle rays	Myliobatidae					
Spotted Eagle ray	*Aetobatus narinari*		**X**		–	1/150.0
Manta rays	Mobulidae					
Giant Manta	*Manta birostris*		**X**	**X**	–	1/210
Tarpons	Megalopidae					
Tarpon	*Megalops atlanticus*	**X**	**X**	**X**	14/50.0/50+	1/165.0
Moray eels	Muraenidae					
Spotted Moray	*Gymnothorax moringa*			**X**	1/40.0	–
Purplemouth Moray	*Gymnothorax vicinus*		**X**	**X**	5/36.0/25–50+	2/69.5/40–99
Goldentail Moray	*Muraena miliaris*	**X**	**X**	**X**	–	1/30.0
Snake eels	Ophichthidae					
Sharptail eel	*Myrichthys breviceps*	**X**	**X**	**X**	–	1/40.0
Lizardfishes	Synodontidae					
Inshore lizardfish	*Synodus foetens*		**X**	**X**	1/15.0	–
Sand diver	*Synodus intermedius*		**X**	**X**	–	1/7.0
Squirrelfishes	Holocentridae					
Squirrelfish	*Holocentrus adscensionis*		**X**	**X**	7/15.8/7–25	4/20.3/18–23
Blackbar soldierfish	*Myripristis jacobus*		**X**		4/11.0/7–15	–
Pipefish/seahorses	Syngnathidae					
Whitenose pipefish	*Cosmocampus albirostris*	**RD**		**RD**	–	–
Shortfin pipefish	*Cosmocampus elucens*	**RD**		**RD**	–	–
Cornetfishes	Fistulariidae					
Bluespotted cornetfish	*Fistularia tabacaria*		**X**	**X**	1/50+	–
Flying gurnards	Dactylopteridae					
Flying gurnard	*Dactylopterus volitans*	**RD**	**RD**		–	–
Scorpionfishes	Scorpaenidae					
Spotted scorpionfish	*Scorpaena plumieri*		**X**	**X**	4/13.5/7–25	–
Searobins	Triglidae					
Leopard searobin	*Prionotus scitulus*			**RD**	–	–
Sea basses	Serranidae					
Sand perch	*Diplectum formosum*		**X**	**X**	101/6.5/3–15	27/7.9/3–14
Rock hind	*Epinephelus adscensionis*		**RD**	**RD**	–	–
Graysby	*Epinephelus cruentatus*		**RD**	**RD**	–	–
Red grouper	*Epinephelus morio*		**X**	**X**	4/31.2/25–50+	13/34.9/18–50
Barred hamlet	*Hypoplectrus puella*		**X**	**X**	4/4.0/3–7	–
Butter hamlet	*Hypoplectrus unicolor*		**X**	**X**	3/2.7/2–3	2/3.5/3–4
Scamp	*Mycteroperca phenax*		**X**	**X**	2/7.0/7–7	–
Lantern bass	*Serranus baldwini*		**X**	**X**	4/5.0/3–7	7/5.8/4–9
Harlequin bass	*Serranus tigrinus*		**RD**		–	–
Soapfishes	Grammistidae					
Greater soapfish	*Rypticus saponaceus*		**X**		1/15.0	2/14.0/13–15
Jawfishes	Opistognathidae					
Banded jawfish	*Opistognathus macrognathus*		**X**	**X**	4/7.0/7–7	–
Dusky jawfish	*Opistognathus whitehursti*		**X**	**X**	45/4.5/3–7	2/6.5/6–7
Cardinalfishes	Apogonidae					
Barred cardinalfish	*Apogon binotatus*		**X**	**X**	1/7.0	–
Flamefish	*Apogon maculatus*		**X**	**X**	8/3.5/3–7	–
Twospot cardinalfish	*Apogon pseudomaculatus*		**X**	**X**	9/3.9/3–7	17/4.9/2–6
Belted cardinalfish	*Apogon townsendi*	**RD**		**RD**	–	–
Blackfin cardinalfish	*Astrapogon puncticulatus*	**X**	**X**	**X**	1/2.0	–
Conchfish	*Astrapogon stellatus*	**X**	**X**	**X**	–	1/1.0
Tilefishes	Malacanthidae					

(continued on next page)

Table 1 (*continued*)

Common name	Scientific name	RN	R	NR	Transect-count	Point-count
Sand tilefish	*Malacanthus plumieri*		**X**	**X**	1/7.0	–
Remoras	Echeneididae					
Sharksucker	*Echeneis naucrates*		**RD**	**RD**	–	–
Jacks	Carangidae					
Yellow jack	*Caranx bartholomaei*		**X**	**X**	8/15.3/7–25	28/17.3/8–26
Blue runner	*Caranx crysos*		**X**	**X**	23/13.6/7–15	11/26.3/20–45
Bar jack	*Caranx ruber*		**X**	**X**	88/8.4/3–25	28/18.8/5–40
Round scad	*Decapterus punctatus*		**RD**		–	–
Rainbow runner	*Elagatis bipinnulata*			**RD**	–	–
Lookdown	*Selene vomer*		**RD**		–	–
Greater amberjack	*Seriola dumerili*		**X**	**X**	4/17.5/15–25	–
Snappers	Lutjanidae					
Mutton snapper	*Lutjanus analis*		**X**	**X**	3/26.7/15–40	3/27.0/12–38
Schoolmaster	*Lutjanus apodus*		**RD**		–	–
Gray snapper	*Lutjanus griseus*		**X**	**X**	–	2/22.0
Dog snapper	*Lutjanus jocu*		**RD**		–	–
Lane snapper	*Lutjanus synagris*		**X**	**X**	23/5.1/3–7	6/22.8/16–30
Yellowtail snapper	*Ocyurus chrysurus*		**X**	**X**	65/3.8/2–15	16/3.5/2–6
Mojarras	Gerreidae					
Slender mojarra	*Eucinostomus jonesi*	**X**	**X**		2/2.0/2–2	–
Mottled mojarra	*Eucinostomus lefroyi*	**X**	**X**		4/7.0/7–7	–
Yellowfin mojarra	*Gerres cinereus*		**X**	**X**	5/17.4/7–25	1/69.0
Grunts	Haemulidae					
Black margate	*Anisotremus surinamensis*		**X**	**X**	1/25.0	–
Porkfish	*Anisotremus virginicus*		**X**	**X**	90/7.2/2–25	75/9.4/2–25
Margate	*Haemulon album*		**X**	**X**	7/17.4/7–25	1/26.0
Tomtates	*Haemulon aurolineatum*		**X**	**X**	1023/3.7/2–15	1401/8.2/2–26
Caesar grunt	*Haemulon carbonarium*		**X**	**X**	1/7.0	1/28.0
Smallmouth grunt	*Haemulon chrysargyreum*		**RD**		–	–
French grunt	*Haemulon flavolineatum*		**X**	**X**	357/7.5/2–25	120/12.4/6–20
Spanish grunt	*Haemulon macrostomum*		**X**		–	1/13.0
Cottonwick	*Haemulon melanurum*		**X**		1/7.0	–
Sailors choice	*Haemulon parra*		**X**	**X**	17/14.9/3–25	26/17.5/14–24
White grunt	*Haemulon plumieri*		**X**	**X**	877/4.0/2–25	509/10.5/2–38
Bluestripe grunt	*Haemulon sciurus*		**X**	**X**	75/20.2/3–25	61/22.8/10–30
Striped grunt	*Haemulon striatum*		**X**	**X**	38/7.0/7–7	50/18.0/16–22
Unident. juvenile grunts	*Haemulon* spp.		**X**	**X**	31194/2.6/2–7	26899/2.9/1–7
Porgies	Sparidae					
Sea bream	*Archosargus rhomboidalis*	**X**	**X**	**X**	–	6/21/20–22
Jolthead porgy	*Calamus bajonado*		**X**	**X**	–	1/30.0
Saucereye porgy	*Calamus calamus*		**X**	**X**	3/15.0/15–15	4/19.5/14–25
Sheepshead porgy	*Calamus penna*		**X**	**X**	4/15.0/15–15	–
Silver porgy	*Diplodus argenteus*		**X**	**X**	3/12.3/7–15	10/18.0/18–24
Spottail pinfish	*Diplodus holbrooki*		**X**	**X**	20/9.8/7–15	33/16.1/7–25
Drums	Sciaenidae					
Highhat	*Equetus acuminatus*		**X**	**X**	152/3.6/2–15	144/4.2/1–25
Reef croaker	*Odontoscion dentex*		**X**	**X**	8/3.0/3–3	–
Goatfishes	Mullidae					
Yellow goatfish	*Mulloidichthys martinicus*		**X**		7/7.0/7–7	–
Spotted goatfish	*Pseudupeneus maculatus*		**X**	**X**	29/7.2/3–25	47/9.1/4–22
Sweepers	Pempheridae					
Glassy sweeper	*Pempheris schomburgki*		**X**	**X**	52/4.2/3–7	471/2.8/2–7
Butterflyfishes	Chaetodontidae					
Spotfin butterflyfish	*Chaetodon ocellatus*		**X**		–	1/6.0
Reef butterflyfish	*Chaetodon sedentarius*		**X**	**X**	2/4.0/2–7	2/6.0
Angelfishes	Pomacanthidae					
Blue angelfish	*Holocanthus bermudensis*		**X**		1/7.0	1/34.0
Queen angelfish	*Holocanthus ciliaris*		**X**	**X**	2/7.0/7–7	2/20.0/10–30
Gray angelfish	*Pomacanthus arcuatus*		**X**	**X**	13/13.5/3–40	12/28.7/2–50
French angelfish	*Pomacanthus paru*		**X**	**X**	23/8.0/3–25	28/7.4/2–49
Sea chubs	Kyphosidae					
Bermuda chub	*Kyphosus sectatrix*		**X**		1/15.0	67/20.3/13–40
Damselfishes	Pomacentridae					
Sergeant major	*Abudefduf saxatilis*		**X**	**X**	128/2.9/2–7	156/5.1/2–17

Table 1 (*continued*)

Common name	Scientific name	RN	R	NR	Transect-count	Point-count
Yellowtail damselfish	*Microspathadon chrysurus*		X	X	–	5/7.3/4–11
Longfin damselfish	*Stegastes diencaeus*		X	X	54/2.9/2–7	27/3.5/2–5
Dusky damselfish	*Stegastes dorsopunicans*		X	X	76/4.4/2–7	73/5.8/2–12
Beaugregory	*Stegastes leucostictus*		X	X	256/3.9/2–7	109/4.6/2–11
Bicolor damselfish	*Stegastes partitus*		X	X	42/3.5/2–7	35/4.1/2–7
Threespot damselfish	*Stegastes planifrons*		X	X	7/5.9/3–7	30/6.7/5–8
Cocoa damslefish	*Stegastes variabilis*		X	X	378/4.0/2–15	212/4.6/1–10
Wrasses	Labridae					
Spanish hogfish	*Bodianus rufus*		X	X	4/3.8/2–7	1/2.0
Slippery dick	*Halichoeres bivittatus*		X	X	1617/5.1/2–15	1202/7.3/2–20
Yellowcheek wrasse	*Halichoeres cyanocephalus*		X	X	3/5.7/3–7	–
Yellowhead wrasse	*Halichoeres garnoti*		X	X	4/5.0/3–7	–
Clown wrasse	*Halichoeres maculipinna*		X	X	183/4.4/2–15	237/6.8/3–18
Blackear wrasse	*Halichoeres poeyi*		X	X	29/6.3/3–15	14/7.9/6–12
Puddingwife	*Halichoeres radiatus*		X	X	28/2.4/2–7	29/4.4/2–8
Hogfish	*Lachnolaimus maximus*		X	X	3/31.7/15–40	1/21.0
Bluehead wrasse	*Thalassoma bifasciatum*		X	X	138/6.3/2–15	3/7.4/2–15
Rosy razorfish	*Xyrichtys martinicensis*	X	X	X	6/5.0/3–7	7/6.3/4–8
Green razorfish	*Xyrichtys splendens*		X	X	80/6.0/2–15	69/6.1/3–11
Parrotfishes	Scaridae					
Bluelip parrotfish	*Cryptotomus roseus*		X	X	–	1/3.0
Blue parrotfish	*Scarus coeruleus*		X	X	–	1/30.0
Striped parrotfish	*Scarus croicensis*		X	X	58/5.1/3–15	51/8.5/3–18
Rainbow parrotfish	*Scarus guacamaia*			RD	–	–
Princess parrotfish	*Scarus taeniopterus*		X	X	18/8.8/3–15	3/11.5/10–13
Greenblotch parrotfish	*Sparisoma atomarium*		X	X	4/4.0/3–7	1/5.0
Redband parrotfish	*Sparisoma aurofrenatum*		X	X	34/5.6/3–15	55/10.2/4–30
Redtail parrotfish	*Sparisoma chrysopterum*		X	X	5/15.0/3–25	1/20.0
Bucktooth parrotfish	*Sparisoma radians*		X	X	208/3.9/2–15	12/5.6/2–9
Redfin parrotfishfish	*Sparisoma rubripinne*		X		3/7.0/7–7	–
Stoplight parrotfish	*Sparisoma virride*		X	X	21/5.2/2–15	13/9.2/4–19
Flagblennies	Chaenopsidae					
Roughhead blenny	*Acanthemblemaria aspera*		X	X	3/3.0/3–3	–
Spinyhead blenny	*Acanthemblemaria spinosa*			X	2/3.0/3–3	1/4.0
Sailfin blenny	*Emblemaria pandionis*		X	X	20/2.5/3–7	6/3.8/2–5
Labrisomids	Labrisomidae					
Downy blenny	*Labrisomus kalisherae*	X	X	X	1/3.0	1/5.0
Hairy blenny	*Labrisomus nuchipinnis*	RD	RD		–	–
Rosy blenny	*Malacoctenus macropus*		X	X	132/3.6/2–7	42/4.6/3–8
Saddled blenny	*Malacoctenus triangulatus*		X	X	22/4.3/3–7	7/5.3/3–7
Banded blenny	*Paraclinus fasciatus*	RD	RD		–	–
Marbled blenny	*Paraclinus marmoratus*	RD		RD	–	–
Combtooth blennies	Blennidae					
Barred blenny	*Hypleurochilus bermudensis*		X	X	–	1/4.0
Redlip blenny	*Ophioblennius atlanticus*		X	X	–	1/6.0
Seaweed blenny	*Parablennius marmoreus*		X	X	83/4.2/2–7	32/5.1/2–7
Molly miller	*Scartella cristata*	X	X	X	4/7.0/7–7	–
Gobies	Gobiidae					
Colon goby	*Coryphopterus dircus*	X	X	X	3/1.7/2–3	–
Bridled goby	*Coryphopterus glaucofraenum*		X	X	198/3.2/2–7	41/4.8/2–6
Masked/glass goby	*Coryphopterus hyalinus/personatus*		X		10/1.0/0–2	–
Goldspot goby	*Gnatholepis thompsoni*		X	X	9/3.2/2–7	7/5.0/4–7
Rockcut goby	*Gobiosoma grosvenori*	RD	RD	RD	–	–
Tiger goby	*Gobiosoma macrodon*	X	X	X	5/1.8/2–3	2/2.5/2–3
Neon goby	*Gobiosoma oceanops*		X	X	34/3.2/2–7	74/3.2/1–7
Dash goby	*Gobiosoma saepepallens*		X	X	–	3/4.0/3–5
Blue goby	*Ioglossus calliurus*		X	X	2/7.0/7–7	–
Hovering goby	*Ioglossus helenae*		X	X	2/7.0/7–7	1/5.0
Seminole goby	*Microgobius carri*		X	X	12/3.7/3–7	–
Rusty goby	*Quisquilius hipoliti*	X	X	X	–	2/3.0
Spadefishes	Ephippidae					
Spadefish	*Chaetodipterus faber*		X		1/40.0	–
Surgeonfishes	Acanthuridae					

(*continued on next page*)

Table 1 (*continued*)

Common name	Scientific name	RN	R	NR	Transect-count	Point-count
Ocean surgeon	*Acanthurus bahianus*		X	X	178/10.1/3–25	414/11.1/3–28
Doctorfish	*Acanthurus chirurgus*		X	X	118/6.9/2–15	216/8.7/3–25
Blue tang	*Acanthurus coeruleus*		X	X	4/8.0/3–15	28/11.7/4–25
Barracudas	Sphyraenidae					
Great barracuda	*Sphyraena barracuda*		X	X	4/38.3/3–50+	2/87.5/75–100
Mackerels	Scombridae					
Cero	*Scomberomorous regalis*		X		1/15.0	–
Leatherjackets	Balistidae					
Gray triggerfish	*Balistes capriscus*		X	X	68/15.6/7–25	44/17.6/10–40
Queen triggerfish	*Balistes vetula*		**RD**		–	–
Filefishes	Monacanthidae					
Orange filefish	*Aluterus schoepfi*		X	X	–	4/11.5/10–12
Scrawled filefish	*Aluterus scriptus*		**RD**		–	–
Orangespotted filefish	*Cantherhines pullus*		X	X	9/6.0/3–7	–
Planehead filefish	*Monocanthus hispidus*		X	X	3/12.3/7–15	6/17.0/13–27
Boxfishes	Ostraciidae					
Spotted trunkfish	*Lactophrys bicaudalis*		**RD**	**RD**	–	–
Honeycomb cowfish	*Lactophrys polygonia*		X		–	3/29.0/15–43
Scrawled cowfish	*Lactophrys quadricornis*		X	X	7/17.9/15–25	1/17.0
Trunkfish	*Lactophrys trigonus*	X	X	X	9/12.8/7–15	1/25.0
Smooth trunkfish	*Lactrophrys triqueter*		X	X	–	6/16.6/12–20
Puffers	Tetraodontidae					
Sharpnose puffer	*Canthigaster rostrata*		X	X	40/5.2/3–7	27/5.4/2–11
Bandtail puffer	*Sphoeroides spengleri*		X	X	9/7.3/2–15	9/10.7/5–16
Spiny puffers	Diodontidae					
Striped burrfish	*Chilomycterus schoepfi*			**RD**	–	–
Balloonfish	*Diodon holocanthus*		X	X	21/13.9/3–25	14/15.3/7–25
Porcupinefish	*Diodon hystrix*		X	X	2/15.0/15–15	1/35.0

[a] In transect-counts, total length was estimated underwater by size class (<2, 2–5, 5–10, 10–20, 20–30, 30–50 and 50+ cm). With the exception of the smallest and largest size classes, the median total length per size class was used in the calculations for this table; 2 cm and 50 cm were used, respectively, for the smallest and largest size classes. **RD** indicates the species was recorded in rover-diver counts but not in transect- or point-counts.

3.4. Renourished versus never-renourished sites

The fish assemblages on hardbottom areas adjacent to renourished beach were compared to fish assemblages on hardbottom areas adjacent to never-renourished beach using all three visual census methods. We initially compared all the renourished sites combined to the combined never-renourished sites. We then attempted to examine specific renourishment areas and compare them to never-renourished sites. However, because some sites were repeatedly renourished we were unable to dissect out potential effects of the earliest renourishments.

Table 2
List of 15 most abundant species, or species group (i.e., *Haemulon* spp.), recorded in 200 transect-counts by size class and number of sites where counted (none of the fishes in this list were over 30 cm in total length (TL))

Species	Size class in cm (TL)					Counts
	0–2	2–5	5–10	10–20	20–30	
Haemulon spp.[a]	20,044	9287	1860	3	0	167
Halichoeres bivittatus	156	816	508	137	0	185
Haemulon aurolineatum	1	841	180	1	0	23
Haemulon plumieri	49	696	87	38	7	112
Stegastes variabilis	34	249	91	4	0	123
Haemulon flavolineatum	2	232	101	21	1	40
Stegastes leucostictus	29	158	65	0	0	93
Sparisoma radians	6	157	44	1	0	78
Coryphopterus glaucofraenum	14	169	15	0	0	71
Halichoeres maculipinna	14	107	58	4	0	63
Acanthurus bahianus	0	31	74	64	9	69
Equetus acuminatus	46	78	24	4	0	69
Thalassoma bifasciatum	1	54	67	16	0	48
Malacoctenus macropus	2	109	21	0	0	76

[a] Mixed haemulids not identified to species, include *H. aurolineatum*, *H. plumieri*, *H. flavolineatum* and others.

Thus, the 1970 renourishment site is included in the 1983 renourishment; the 1977 renourishment site is included in 1989; and the 1971 and 1979 renourishment sites are included in the 1991 renourishment (Fig. 1). Looking at all the pooled renourished sites versus all never-renourished: the transect data yielded significantly greater mean abundance for the never-renourished hardbottom sites (mean ± SEM: 278.86 ± 45.21 fish/transect) than the renourished hardbottom (144.93 ± 18.38 mean fish/transect; ANOVA, $F_{1,198} = 9.9$, $P < 0.05$) (Table 3). Species richness was the opposite resulting in higher values, albeit not statistically significant, on the renourished sites than on the never-renourished sites (11.81 ± 0.5 versus 10.5 ± 0.44 mean species/transect; ANOVA, $F_{1,198} = 3.15$, $P < 0.078$). The amount of sand coverage over the hardbottom was greater for the renourished sites (mean sand coverage m/transect: 3.41 ± 0.52 versus 1.61 ± 0.5; ANOVA, $F_{1,198} = 6.27$, $P < 0.05$). The rugosity was not significantly different between the transect sites (ANOVA, $F_{1,198} = 1.2$ $P > 0.27$). With point-count data, abundance, species richness, and rugosity values did not differ statistically between combined renourished and never-renourished sites (ANOVA, $P > 0.05$) (Table 4). The rover-diver counts yielded a total of 112 species at the pooled never-renourished sites and 124 species on the renourished sites.

On the 64 sites that have been renourished 27 species were recorded that were not recorded on the renourished sites (Table 1). Twenty of these species were recorded at a single site, three species noted at two sites, three species at three sites, and one species at six sites. On the 36 never-renourished sites, there were 10 species not observed on renourished sites, all 10 species were recorded at a single site (Table 1). MDS plots of Bray–Curtis dissimilarity indices did not show separated grouping of renourished and never-renourished sites (Figs. 2, 3).

With the transect-count data, there were differences among individual renourished and never-renourished sites when separated by year of most recent renourishment (Table 3). The 1983 renourished sites had significantly higher abundance than the southernmost never-renourished area (Never3) and higher species richness than any other site, renourished or never-renourished.

Measurements of the distance from shoreline at mean low tide to the western edge of hardbottom using Laser Airborne Depth Sounding (LADS) images (obtained from Broward County Department of Planning and Environmental Protection and which provided a detailed image of the hardbottom edge) indicated that distances were significantly greater in pooled renourished areas compared to never renourished areas (Table 3). When the sites were separated by year of most recent renourishment, there were some significant differences between renourished sites and adjacent never-renourished sites. However, the differences were not consistent among never-renourished and renourished sites or renourishment dates ($P < 0.05$; ANOVA, SNK) (Table 3).

With transect data, there was a weak regression in both abundance ($r^2 = 0.04$) and species richness ($r^2 = 0.21$) with increasing fish abundance from south to north with renourished and never-renourished sites combined. The r^2 value decreased to 0.02 for abundance and 0.02 for species richness if renourished sites were excluded from the analysis. With point-count data, exclusion of renourished sites changed r^2 values from 0.15 to 0.00 for species richness but abundance remained at 0.03.

4. Discussion

4.1. The inshore fish assemblages

This study provides a two-month, summer "snapshot" of the inshore, hardbottom fish assemblage of Broward County and thus misses a temporal characterization of the community from either an inter- or intra-annual perspective. However, the summer months are typically the period of highest fish abundance and

Table 3
Mean ± 1SEM of 30 m transect-count: depth (m), rugosity index, distance of western edge to shore (m), total abundance, and species richness for total sites and sites adjacent to combined renourished (R) and combined never-renourished beach (NR), or individual renourished sites (by date of last renourishment) or individual never-renourished sites (within a column, sites with differing subscript numbers or letters are significantly different ($P < 0.05$, ANOVA, SNK))

Site	N	Depth	Rugosity	Distance to shore	Abundance	Richness
Total	200	4.13 ± 0.07	1.08 ± 0.00	535.8 ± 16.4	194.49 ± 20.79	11.33 ± 0.36
R	126	4.10 ± 0.09	1.09 ± 0.01	$576.4 \pm 24.4_1$	$144.93 \pm 18.38_2$	$11.81 \pm 0.50_1$
NR	74	4.19 ± 0.10	1.08 ± 0.00	$468.5 \pm 13.3_2$	$278.86 \pm 45.20_1$	$10.50 \pm 0.44_2$
1983	40	$3.97 \pm 0.12_{BC}$	$1.13 \pm 0.01_A$	$423.8 \pm 37.3_C$	$206.45 \pm 35.77_A$	$16.68 \pm 0.69_A$
1989	17	$2.83 \pm 0.18_D$	$1.08 \pm 0.01_B$	$362.6 \pm 69.2_D$	$122.41 \pm 45.11_{AB}$	$7.47 \pm 0.96_B$
1991	56	$4.34 \pm 0.12_B$	$1.05 \pm 0.00_B$	$709.0 \pm 22.1_B$	$121.14 \pm 29.49_{AB}$	$9.70 \pm 0.63_B$
Never1	68	$4.40 \pm 0.09_B$	$1.09 \pm 0.01_B$	$458.0 \pm 14.0_C$	$292.44 \pm 48.10_A$	$10.94 \pm 0.51_B$
Never2	14	$3.51 \pm 0.24_C$	$1.06 \pm 0.00_B$	$517.5 \pm 24.3_C$	$116.71 \pm 32.04_{AB}$	$9.86 \pm 0.58_B$
Never3	5	$5.61 \pm 0.21_A$	$1.05 \pm 0.02_B$	$1087.5 \pm 131.1_A$	$50.80 \pm 17.08_B$	$9.20 \pm 1.39_B$

Table 4
Mean ± 1SEM of point-count: depth (m), rugosity index, abundance, and species richness for total sites and sites adjacent to combined renourished (R) and combined never-renourished beach (NR), or individual renourished sites (by date of last renourishment) or individual never-renourished sites (within a column, sites with differing subscript letters are significantly different ($P < 0.05$, ANOVA, SNK))

Site	N	Depth	Rugosity	Abundance	Richness
Total	101	4.10 ± 0.09	1.12 ± 0.01	340.91 ± 43.74	12.66 ± 0.53
R	63	4.04 ± 0.12	1.13 ± 0.02	316.18 ± 53.04	13.32 ± 0.73
NR	38	4.19 ± 0.12	1.11 ± 0.01	379.39 ± 75.92	11.64 ± 0.70
1983	20	$3.91 \pm 0.15_B$	1.19 ± 0.02	$375.68 \pm 58.11_A$	$17.00 \pm 1.15_A$
1989	9	$3.48 \pm 0.39_B$	1.10 ± 0.04	$290.71 \pm 112.87_{AB}$	$11.43 \pm 0.78_{AB}$
1991	28	$4.31 \pm 0.19_B$	1.08 ± 0.02	$299.88 \pm 102.19_{AB}$	$10.77 \pm 0.94_{AB}$
Never1	34	$4.17 \pm 0.14_B$	1.14 ± 0.03	$414.87 \pm 86.17_A$	$12.26 \pm 0.80_{AB}$
Never2	7	$3.75 \pm 0.21_B$	1.10 ± 0.01	$204.00 \pm 43.31_{AB}$	$12.43 \pm 1.54_{AB}$
Never3	3	$5.33 \pm 0.15_A$	1.07 ± 0.07	$52.50 \pm 10.50_B$	$7.50 \pm 4.50_B$

species richness in the area as well as the period of highest population densities of juvenile grunts (Gilliam, 1999; Sherman, 2000; Walker et al., 2002; Jordan et al., 2003) and a single attempt to examine year-to-year variation in this area did not find significant differences in fish assemblage structure (Ettinger et al., 2001). Thus, although our survey may have missed some migratory species residing in or moving through the area during colder months and may overemphasize the proportion of juveniles to adults, it nonetheless provides a relatively thorough inventory that can be used for comparisons with future surveys taken during the same seasonal timeframe. Taken as a whole, the census data of this study indicate the inshore fish assemblage is composed of at least 164 species. More than 85% of the total fish are juveniles. The weak north–south regressions for both abundance and species richness noted in this study, and another (Ferro and Spieler, in preparation), imply a relatively homogeneous assemblage of fishes throughout the nearshore hardbottom of Broward County. Juvenile grunts (Haemulidae) comprised more than 90% of the juvenile population and more than 80% of the total fish assemblage. The remaining families contributed to the assemblage in much lower numbers and the predominant species were primarily juveniles. Because of the difficulty in identifying newly settled and early juveniles, most of the juvenile grunts were not recorded to species level. However, based on the results of other studies in Broward County, we suspect that tomtate, *Haemulon aurolineatum*, and French grunt, *Haemulon flavolineatum*, were the predominant species in the juvenile grunt counts (Jordan et al., 2003).

Courtenay and co-authors (1980) recorded 67 fish species of 26 families on the nearshore hardbottom (first reef) offshore of Hallandale, Florida, an area included in our study. All of the 67 species noted in Hallandale were recorded in this study with the exception of four rare or occasional species (polka-dot batfish, *Ogcocephalus radiatus*; freckled cardinalfish, *Phaeoptyx conklini*; spotfin mojarra, *Eucinostomus argenteus*; ocean triggerfish, *Canthidermis sufflamen*), whose presence may have been detected due to the use of an ichthyocide, which was not utilized in this study.

From April 1994 to June 1996 a study was done in Jupiter, Florida (approximately 80 km north of the northernmost site of our study) where 394, 15-m transects were sampled over a 27-month period (Lindeman and Snyder, 1999). The authors noted 86 species with

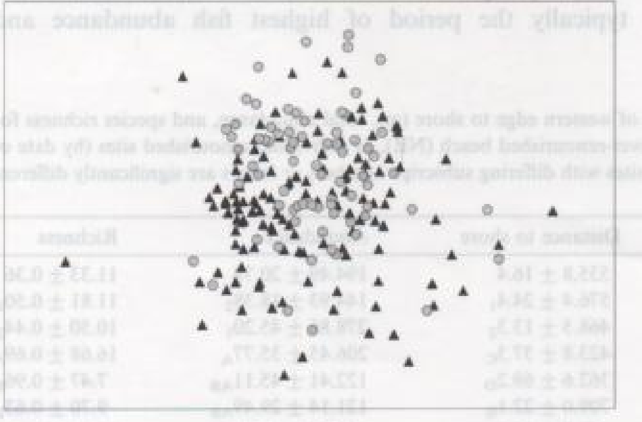

Fig. 2. MDS plot of Bray–Curtis dissimilarity indices of sites neighboring renourished beach (all renourished sites combined) (triangles) and sites neighboring never-renourished beach (circles).

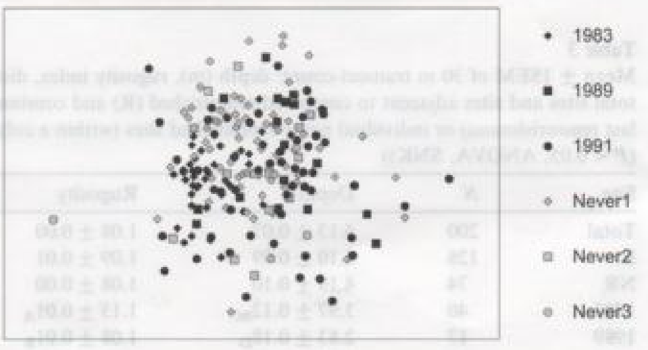

Fig. 3. MDS plot of Bray–Curtis dissimilarity indices of individual hardbottom sites neighboring renourished beach by date of last renourishment (1983, 1989, 1991) and three areas adjacent to never-renourished beach (Never1, 2, 3).

juveniles representing 80+%. Similar to this study, they found grunts (Haemulidae) comprised the biggest percentage of fishes with six of the 11 most abundant species. Likewise, two of the remaining five most abundant species in the Jupiter study, the cocoa damselfish (*Stegastes variabilis*) and the slippery dick (*Halichoeres bivittatus*) were also among the five most abundant fishes in our study. In contrast, the sergeant major (*Abudefduf saxatilis*), although relatively abundant, was not in the 10 most abundant species in our study. The two most abundant fishes recorded in the Jupiter study, sailors choice (*Haemulon parra*) and the silver porgy (*Diplodus argenteus*), were poorly represented in Broward County. Also, the presence of hairy blenny (*Labrisomus nuchipinnis*), which was among the top five species in the Jupiter study, was only noted once in our counts. The reason(s) for this difference in distribution between the two studies is unclear but may, in part, be due to differences in habitat. All three species, sailors choice, silver porgy and the hairy blenny, are often found in association with seagrass beds (Froese and Pauly, 2003) that are plentiful in the Jupiter area but sparse in offshore Broward County.

The nearshore hardbottom (ridge complex) off the coast of Broward County is difficult to differentiate from the inshore reef in some areas and is commonly considered the first reef [recent research has found additional reef tracts and the current terminology, including the numbering of the reef tracts, is under revision, (Moyer et al., 2003; Moyer and Riegl personal communication)]. Based on past studies, Broward County's nearshore hardbottom/inshore reef tract has significantly lower species richness and abundance in density/m^2 than the two offshore reefs; however, juvenile grunts are more abundant on the inshore reef (Ettinger et al., 2001; Jordan et al., 2003; Ferro and Spieler, in preparation). Twenty-three species from this study were found to be unique to fish counts of the nearshore hardbottom. These species have not been recorded from past studies on offshore natural or artificial substrate in Broward County (Gilliam, 1999; Sherman, 2000; Ettinger et al., 2001; Ferro and Spieler, in preparation) (Table 1). However, 18 of these species were only observed at one site and may have been a chance occurrence or a difference based on methodology as extensive rover-diver counts have not been done on the middle and offshore reef tracts. The remaining five species (molly miller, *Scartella cristata*; rosy razorfish, *Xyrichtys martinicensis*; tiger goby, *Gobiosoma macrodon*; banded blenny, *Paraclinus fasciatus*; and sea bream *Archosargus rhomboidalis*) are not rare and, except for the banded blenny, have a published depth distribution greater than that of the nearshore hardbottom (Humann, 2002). In this study more than 80% of the fishes were juvenile grunts on the nearshore hardbottom at about 4 m water depth. However, in artificial reef studies in Broward County, juvenile grunts made up 84% of the fish assemblage on artificial reefs in 7 m of water (Gilliam, 1999) and 52% on artificial reefs at a depth of 21 m (Sherman, 2000). Further, 667 point-counts on natural reef, also in Broward County, found 71% of the total fishes of the inshore reef tract (1.8–9.1 m depth) and 41% of the middle reef tract fishes (1.8–22.1 m depth) were juvenile grunts (Ferro and Spieler, in preparation). As a result, the nearshore hardbottom of Broward County is undeniably an important juvenile fish habitat, especially for grunts. However, based on presence data, the nearshore hardbottom does not appear to be obligate habitat for these fishes as fishes associated with this area are, apparently, not unique to the nearshore hardbottom either by species or ontogenic stage. Further, although the simplest explanation remains that the inshore hardbottom is an important nursery area, there is no conclusive evidence, at this point, that these fishes form the post-juvenile populations seen further offshore.

4.2. Census methodologies

In this study the use of destructive sampling methods (i.e., rotenone, explosives) was avoided. Nondestructive methods are commonly used to avoid damaging or disturbing coral reefs or reef associated biota (Sale and Douglas, 1981). Visual census methods can provide rapid estimates of relative abundance, biomass, and length frequency distributions of reef fish, and are considered the most practical and accepted means for monitoring the populations of coral reef fishes in shallow waters (Cheal and Thompson, 1997; Thompson and Mapstone, 1997; Connell et al., 1998; Kulbicki and Sarramegna, 1999; Samoilys and Carlos, 2000). However, only diurnally exposed fish species can be censused accurately using visual census techniques and, even then, visual census often misses cryptic species (Jones and Thompson, 1978; Brock, 1982; Willis, 2001). Three different visual census techniques were used in this study: transect-counts, point-counts, and rover-diver counts. The transect-count and point-count methods are quantitative and can be statistically analyzed. They are also less susceptible to bias based on different experience levels of the fish counters. The rover-diver method, as used here, is less suitable for quantitative comparisons because it is more dependent on the experience level of the diver (to recognize and search differing microhabitats) and water clarity (as the visual search distance from the diver is not restricted), and because determining the area already covered during the random swim is not easy. However, a more complete species list is often obtained with the rover-diver counts than with the other methods because the counter can freely search an area moving among different habitats.

As anticipated, the 98 rover-diver counts recorded the highest number of species (145). The 200 transect-counts had 118 species and the 100 point-counts recorded only 109 species. The percentage of juvenile fish (<5 cm TL) was similar for the point-counts and transect-counts (84.8% and 88.3%, respectively). However, there were significantly greater abundance (3.24 ± 0.35 versus 1.88 ± 0.06; ANOVA, $F_{1,200} = 18.30$, $P < 0.001$) and species richness values (0.19 ± 0.23 versus 0.07 ± 0.003; ANOVA, $F_{1,200} = 159.54$, $P < 0.001$) on the transect-counts than the neighboring point-counts when the counts were standardized by substrate area covered by each count type. This is interesting because the rugosity was significantly higher on the point-counts than the adjacent transects (1.12 ± 0.01 versus 1.08 ± 0.01; ANOVA, $F_{1,192} = 8.18$, $P < 0.05$). The higher point-count rugosity was expected because the counter selected the most complex area 20 m north of the transect line to perform the point-count. Since there was greater abundance and species richness on the transects, and given the difference in rugosity, it appears that the point-count is a less effective census method in the nearshore environment. The point-counts cover a greater area (176.7 m^2) than the transect-counts (60 m^2) so it may have been more difficult to see juvenile fishes, which commonly remain close to the substrate, in the larger area covered by the point-count method.

4.3. *Renourished versus never-renourished beaches*

Courtenay et al. (1980) found an absence of the previously recorded dusky jawfish (*Opistognathus whitehursti*) along the inshore hardbottom seven years after renourishment of Hallandale Beach. The absence was thought to have been from the addition of fine sediment from eroded beach fill. In contrast, this study noted the presence of dusky jawfish in 13 rover-diver counts on the nearshore hardbottom adjacent to renourished beach at least 10 years after renourishment and they were recorded at only eight sites in the counts adjacent to never-renourished beach.

Lindeman and Snyder (1999) censused transects randomly established over a 5 ha nearshore hardbottom area at Carlin Park, Jupiter, Florida prior to and after the area was buried by a renourishment project. They found a dramatic decrease in fish abundance and species richness within one year of hardbottom burial. A direct comparison cannot be made between the Lindeman and Snyder (1999) study and this one because the amount of time between renourishment and fish counts (<1 year and >10 years, respectively) is so different. In addition, the short-term effects and the original nearshore edge of hardbottom are not known in Broward County. Thus, a conclusion cannot be made that Broward nearshore hardbottom has returned to a pre-renourishment fish assemblage from the conditions noted at Carlin Park.

In this study, with all the renourished sites pooled and compared to the pooled never-renourished sites, the transect-count data showed greater total abundance but no significant difference in species richness for never-renourished sites whereas, point-count data showed no differences between abundance or richness. There were some differences in the species noted between the two areas with the rover-diver counts, but the majority of these differences (81%) were from single sightings. No difference was observed between the two areas in an MDS plot of Bray–Curtis dissimilarity indices. Individual comparisons amongst renourished and non-renourished sites for abundance, species richness, or the distance from the western edge of hardbottom to the shoreline are not consistent, in that there is no consistent change with date of renourishment or latitudinal gradient, such as might be expected with longshore sand movement from one site to another. Likewise, no consistent difference was observed between the individual renourished and never-renourished sites in an MDS plot of the Bray–Curtis dissimilarity indices. Thus, taken as a whole, the data show no obvious distinct difference among the fish assemblages between the renourished and never-renourished sites. However, due to several confounding factors, we caution it would be premature to translate these results into management strategies. Because we used a non-temporally replicated visual census some cryptic or migratory species may have been overlooked. Longshore movement of sand fill may have impacted the entire shoreline and reduced any differences in habitat, and associated fish assemblages, between renourished and never-renourished sites. Further, the absence of baseline data, prior to any renourishment, is a major impediment to a full determination of renourishment effects. Until these factors have been adequately addressed, a "risk-averse approach should be taken to hardbottom burial" (Lindeman and Snyder, 1999).

4.4. *Summary*

The 398 fish counts were completed from June to August 2001 resulting in a total of 72,724 fish from 48 families. The nearshore hardbottom fish assemblages consisted of at least 164 species. By far the major component of the inshore fish assemblages was juvenile grunts (Haemulidae). Based on comparisons to the offshore reefs, and with the caveat that visual census can miss many cryptic species, the nearshore hardbottom of our study area, although obviously important juvenile habitat, does not appear to provide unique or obligatory habitat for any of the fish species (or ontogenic stages of those species) we observed. A full understanding of the role of nearshore hardbottom in the ontogeny of some fishes and in reefal ecosystem dynamics remains to be elucidated.

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