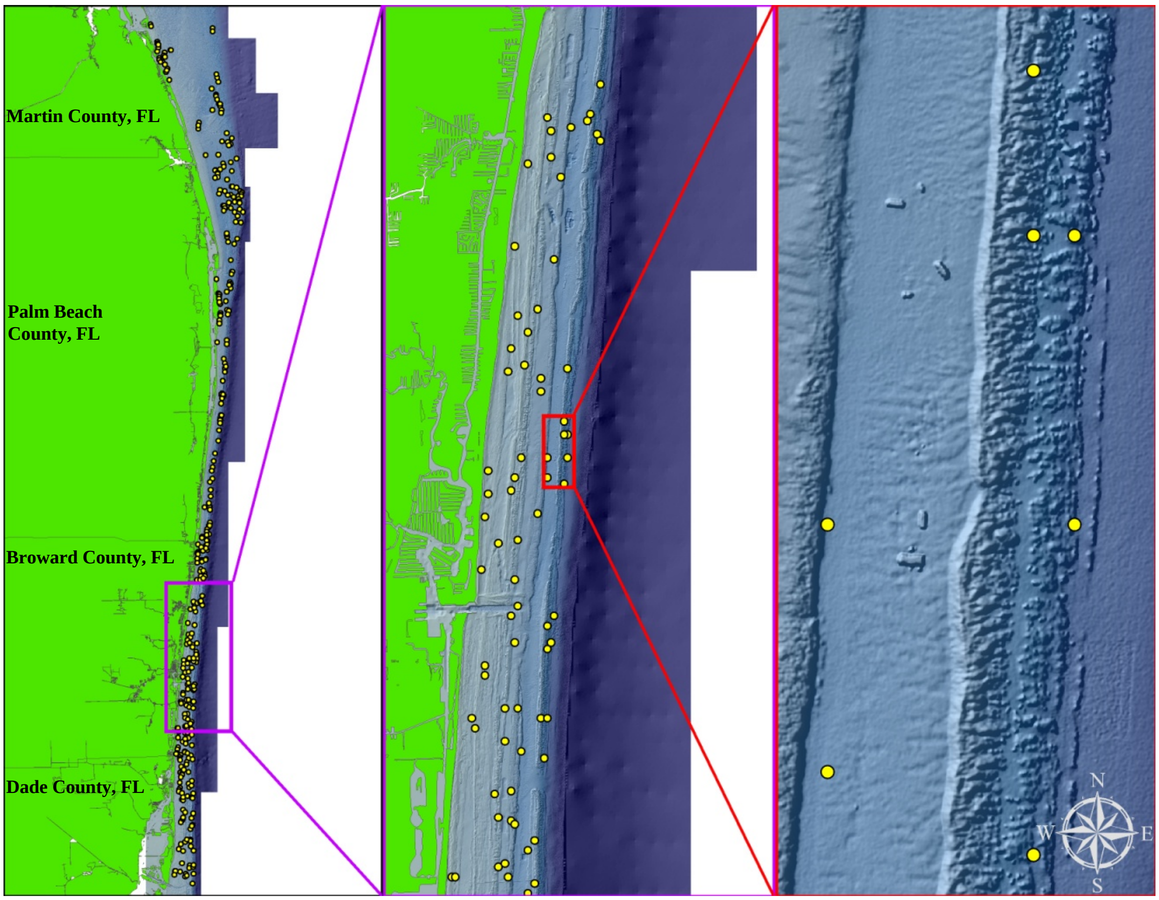
Development of a Coral Reef Fishery-Independent Assessment Protocol for the Southeast Florida Region



Florida Department of Environmental Protection
Coral Reef Conservation Program
Project 3A

Development of a Coral Reef Fishery-Independent Assessment Protocol for the Southeast Florida Region

Draft Final Report

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Table of Contents

List of Figures

List of Tables

List of Appendices

List of Acronyms

CRCP	Coral Reef Conservation Program
ERM	Department of Environmental Resources Management
FDEP	Florida Department of Environmental Protection
FWC	Florida Fish and Wildlife Conservation Commission
FKNMS	Florida Keys National Marine Sanctuary
FWRI	Fish and Wildlife Research Institute
GIS	Geographic Information System
LIDAR	Light Detection And Ranging
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
NPS	National Park Service
NSU	Nova Southeastern University
RER	Department of Regulatory and Economic Resources
PSU	Primary sample unit
REEF	Reef Environmental Education Foundation
RVC	Reef Visual Census
SAS	Statistical Analysis System
SEFSC	Southeast Fisheries Science Center
SSU	Second-Stage Unit
UTM	Universal Transverse Mercator

Acknowledgements

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Executive Summary

Reef fish populations are conspicuous and essential components of the coral reef ecosystem in the south Florida region. Recent declines in these populations are indications of habitat degradation as well as significant increases in recreational and commercial fishing (Brandt et al. 2009). In contrast to the Florida Keys, there is no comparable, spatially synoptic fisheries independent assessment program in the southeast Florida region, which encompasses the northern extent of the Florida reef tract from the northern border of Biscayne National Park to the St. Lucie Inlet (i.e., northern Miami-Dade, Broward, Palm Beach, and Martin counties). Consequently, critical data are lacking in this region to support coral reef fish resource monitoring and stock assessments. The goals of this study were to adapt the statistical sampling design developed in the Florida Keys for a diver visual survey of reef fishes inhabiting the coral reef tract in the southeast Florida region, and to create a statistically robust sampling plan for an initial region-wide survey encompassing all coral reef habitats shallower than 33 m.

Historical mapping data for bathymetry, benthic habitats, and biogeographic subregions for southeast Florida were synthesized to develop the survey sampling frame. A two-stage sampling scheme was employed to account for the disparity in area between a minimum mapping unit (10,000 m^2) for classifying reef habitats and a diver circular plot sample (177 m^2) that serves as the basic field observational unit. Biological data were synthesized from historical reef-fish sampling in the southeast Florida region. Analyses of frequency of occurrence (i.e., the proportion of diver samples that observed a given species) were used to identify six target species of both ecological and management importance: yellowtail snapper, mutton snapper, hogfish, red grouper, bluestriped grunt, and white grunt. Animal density (number per unit area) and variance of density were analyzed for these target species with respect to mapped environmental variables to partition the survey frame into subareas or strata of low, moderate, and high variance. The final stratification of the sampling frame was based on combinations of depth, habitat class, and habitat complexity within biogeographic subregions.

A statistical sampling plan for an initial region-wide survey in summer-fall 2012 was developed utilizing projections of sampling effort from a variety of participating agencies and scientists in the southeast Florida region. Sample locations were randomized based on equal probability of selection from the survey frame within each sampling stratum. Training sessions in field methods, data management, and statistical analyses were conducted to facilitate efficient execution of the summer-fall 2012 survey. Data from this initial region-wide survey will form a sound foundation for improving the statistical precision and cost-effectiveness of future surveys.

1.0 Introduction

Reef fish populations are conspicuous and essential components of the coral reef ecosystem in the south Florida region. Recent declines in these populations are indications of habitat degradation as well as significant increases in recreational and commercial fishing (Ault et al. 2005a). The sampling methodologies described in this document will enable the understanding of how natural and man-made stressors are changing reef fish populations and communities. These stressors are likely to increase over the next several decades, and understanding the responses of populations and communities will be critical for their sustainable management.

Fishery-independent monitoring of Florida Keys coral reefs began in 1979. Since then, sampling has greatly expanded in intensity and spatial coverage and now spans the Florida Coral Reef Tract some 370 km from Biscayne National Park southward to the Dry Tortugas. Results have been published widely and data are directly used for fisheries and ecosystem management by multiple state and federal agencies including the Florida Keys National Marine Sanctuary (FKNMS), NOAA National Marine Fisheries Service (NOAA NMFS), National Park Service (NPS) the South Atlantic and Gulf of Mexico Fishery Management Councils, and Florida's Department of Environmental Protection and Fish and Wildlife Conservation Commission. Recently, the program has been adopted by the State of Florida and NPS (Brandt et al. 2009), and is currently being adapted for the northwestern Hawaiian Islands (Papahanaumokuakea Marine National Monument) and the U.S. Virgin Islands.

In contrast to the Florida Keys, there is no comparable, spatially synoptic fisheries independent assessment program in the southeast Florida region, which encompasses the northern extent of the Florida Reef Tract from the northern border of Biscayne National Park to the St. Lucie Inlet (i.e., northern Miami-Dade, Broward, Palm Beach, and Martin counties). Consequently, critical data are lacking in this region to support coral reef fish resource monitoring and stock assessments. This project was designed to extend the successful fishery-independent monitoring program developed for Florida Keys corals and reef fishes (Smith et al. 2011a,b) to the southeast Florida region.

2.0 Project Goal and Objectives

The goals of this study were to adapt the statistical sampling design developed in the Florida Keys for a diver visual survey of reef fishes inhabiting the coral reef tract in the southeast Florida region, and to create a statistically robust sampling plan for an initial region-wide survey encompassing all coral reef habitats shallower than 33 m.

The objectives for accomplishing these goals were as follows:

1. Identify and assimilate all requisite physical-environmental and biological data for developing the statistical sampling design.
2. Develop the fundamental sampling frame for the visual survey from the assimilated data in a geographic information system (GIS).
3. Develop a robust statistical design and sampling plan for an initial region-wide survey of reef-fishes, based on the sampling grid GIS and historical fish sampling data for the southeast Florida region.
4. Conduct training activities for scientists in the southeast Florida region dealing with field, data management, and statistical analysis techniques for carrying out full regional-scale fish surveys now and into the future.

Our research efforts in carrying out these objectives are detailed in the following sections.

3.0 Methods & Results

3.1 Sampling Design Approach and Data Assimilation

Survey design is a long-standing, theoretically and methodologically advanced field of statistics developed for the specific purpose of estimating abundance metrics (means, proportions, totals) for a population within a finite spatial domain (Hansen et al. 1953, Cochran 1977, Särndal et al. 1992, Lohr 1999). Probabilistic survey design principles and techniques have the advantage of generating population-level metrics, as well as optimizing sampling efficiency to obtain high precision estimates at low sample sizes.

Application of survey design principles for producing accurate and precise estimates of reef fish population metrics requires certain types of fundamental physical-environmental and biological data, detailed in Smith et al. (2011a). These data include geo-referenced information for describing seafloor characteristics (e.g., depth, substrate composition, benthic habitat structure, etc.) that will enable explicit delineation of the spatial domain for the survey, as well as geo-referenced observations of animal occurrence (presence-absence), density (number of individuals per unit area), and length composition for ecologically- and economically-important reef-fish species.

During the early phase of the project, a series of meetings and discussions were held with reef-fish scientists and managers in the southeast Florida region. Participants were briefed on principles of probabilistic surveys, the successful application to Florida Keys reef-fish and stony coral populations, and the current project's goals and objectives for expanding the survey into the southeast Florida region. There were a number of important outcomes from these discussions, including identification of:

1) key scientific needs for improving resource management of reef fishes in the southeast Florida region;
2) federal, state, local, and university scientists who would likely be participating in the field sampling effort; and,
3) physical and biological data available for developing the sampling plan. These data were graciously provided to us by numerous scientists and organizations, as described in Table 1.

Table 1. Data inventory table that specifies each data set, biological and mapping, that was evaluated for inclusion in development of the survey design, whether it was utilized or not, and if not, why.

Data Inventory Table
CRCP Project 3A: 'Development of a Coral Reef Fishery-Independent Assessment Protocol for the Southeast Florida Region'

Biological Datasets

Database/Reference	Description	Years	Format	Dataset Utilized for Analysis. If no, why.	Contact
Fleur et al., 2005	Fishery Independent. Point counts are arranged on East-West transects. For each transect, there are 9 point-counts. 672 individual point counts in this dataset.	1998-2002	Excel	Yes	Kirk Kilfoyle, M.S. Research Assistant, PhD Candidate, NSU Oceanographic Center, National Coral Reef Institute, 8000 North Ocean Drive, Dania Beach, FL 33004 (954)495-6072
Baron et al., 2004	Near shore point counts in Broward.	2001	Excel	Yes	Kirk Kilfoyle, M.S. Research Assistant, PhD Candidate, NSU Oceanographic Center National Coral Reef Institute, 8000 North Ocean Drive, Dania Beach, FL 33004 (954)495-6073
Palm Beach County Natural Reef; Fishes	Fish point counts (Bohnsack method)	2000-2011	Excel	Yes	Janet J. Phipps, Ph.D. Coral Reef Ecologist Palm Beach County Dept. Environmental Resources Management, 2300 North Jog Road, 4th Floor, West Palm Beach, FL 33411-2743 Office TN: 561.233.2513 Jphipps@pbcgov.org

Table 1. Continued

Biological Datasets

Database/Reference	Description	Years	Format	Dataset Utilized for Analysis. If no, why.	Contact
St Lucie Reef (REEF)	Fish data using roving diver techniques at St Lucie Reef in Martin County as part of REEF's annual fish count in July, The Great Annual Fish Count	several years (10 or so)	REEF database and individual scantron forms	Yes	Jeff Beal FWC Marine/Estuarine Subsection, Marine Habitat Coordinator East Central Region, HBOI/FAU 5600 US 1 N Ft. Pierce FL 34946 office 772-242-2561 cell772-215-9217, Jeff.Beal@myfwc.com
Fish survey data in association with 4 beach renourishment projects (C1, C2, SIDM, and BHren)	Fish point counts (Bohnsack method)	1997-2004	Excel	Yes	Sara Thanner, Miami-Dade County Environmental Resources Project Supervisor Permitting, Environment, and Regulatory Affairs ThannS@miamidade.gov
Five-year-performance report to the U.S. Department of Interior Fish and Wildlife Service from FWC /FWRI: Southeast Florida Reef Fish Abundance and Biology Report	FWC project in Tequesta. Most of the reef fish sampling was done with chevron traps. Some point-count visual surveys were performed to study aggregating species.	2006-2007	Excel	Yes	Erick R. Ault, Research Associate/ Unit Dive Safety Officer FWC - FWRI , 19100 S. E. Federal Highway, Tequesta, FL 33469, (561)575-5407 x 29 erick.ault@myfwc.com

Map Datasets

Database	Description	Years	Format	Dataset Utilized for Analysis. If no, why.	Contact
Miami Dade, Broward, Palm Beach, Martin Counties Lidar Data (x,y,z)	Lidar (x,y,z) data for each county	2000-2011	Text	Yes	Brian K. Walker, Ph.D. Research Scientist National Coral Reef Institute, NSU, Oceanographic Center, 8000 N Ocean Drive Dania Beach, FL 33004 954-262-3675
SE FL Benthic Habitat Map	Habitat Map (Multiple Classifications), Biogeographic Regions	2000-2011	ESRI Shapefile	Yes	Brian K. Walker, Ph.D. Research Scientist National Coral Reef Institute, NSU Oceanographic Center 8000 N Ocean Drive Dania Beach, FL 33004 954-262-3675

3.2 Development of the Survey Frame

The survey domain or frame for the reef-fish visual census in the southeast Florida region was developed using digital GIS map layers for bathymetry, biogeographic subregions, benthic habitats, and reef topographical complexity (slope-rugosity). Data sources for GIS map layers are described in Table 1. These data were used to circumscribe the overall survey frame: hardbottom substrate shallower than 33 m extending northward from Government Cut to the St. Lucie Inlet (i.e., northern Miami-Dade, Broward, Palm Beach, and Martin counties). (Fig. 1). Biogeographic subregions were defined following Walker (2012). The biogeographic subregion south of Government Cut, although included in the southeast Florida region, is sampled annually during the Florida Keys RVC surveys, and so was not included in this sample design. A major aspect of the statistical efficiency (balance of survey precision and cost) of the Florida Keys reef-fish survey was the use of environmental features that correlated with the spatial distribution of reef fishes to partition the survey area into subareas (i.e., strata) of low, moderate, and high variation in abundance (Smith et al. 2011a). The mapping data acquired for the southeast Florida region (Table 1) included the variables of depth, benthic habitat type, and reef complexity that were the principal co-variates used to develop the stratification scheme for the Florida Keys (Walker 2012).

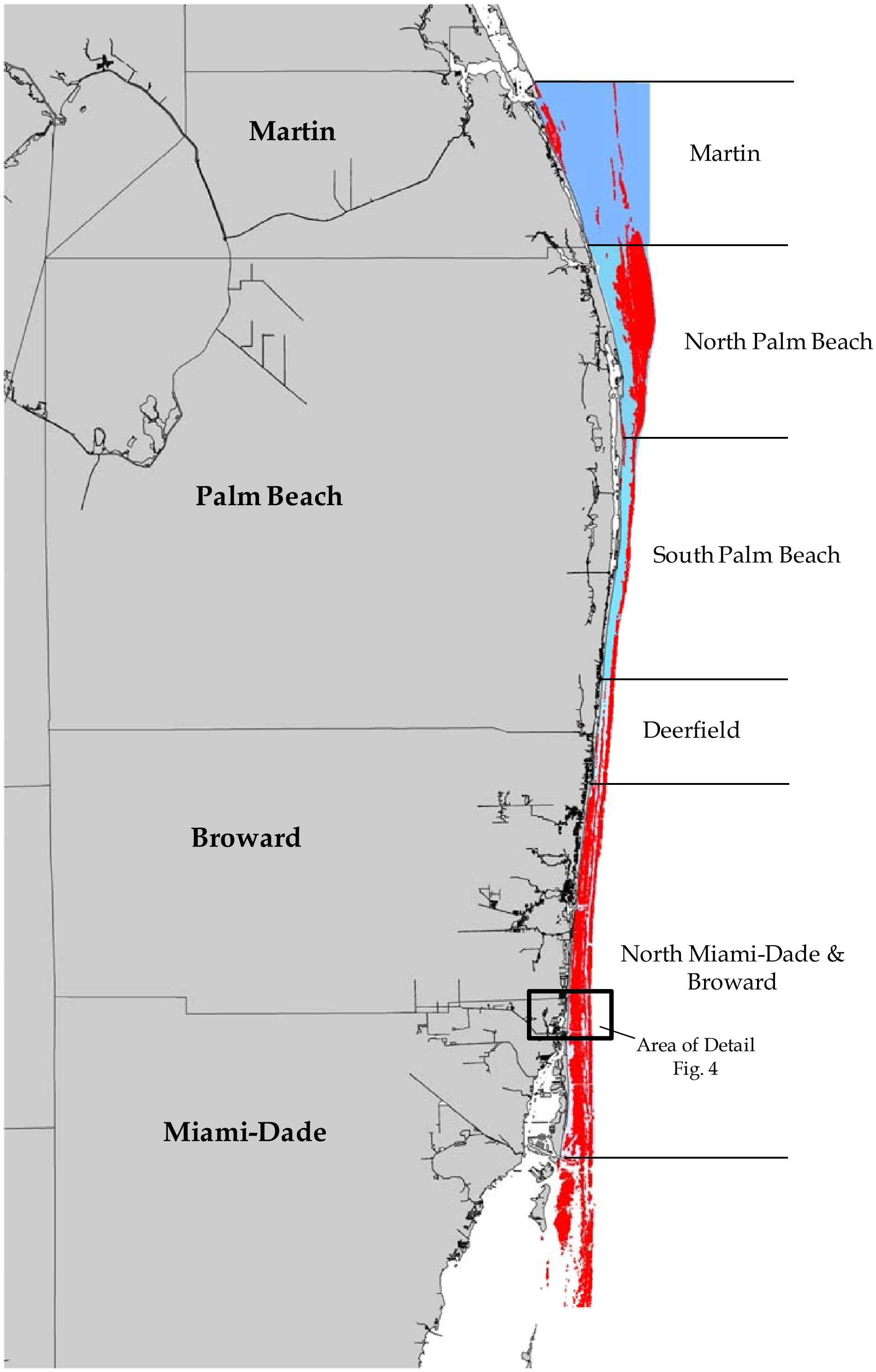

Figure 1. Map showing coral reef habitats <33 m in depth (red) and biogeographic subregions for the southeast Florida region (based on Walker, 2012). The area of detail is shown in Fig. 4.

A probabilistic survey approach requires description of the survey frame as a finite number of sample units from which random sampling locations are drawn (Ault et al. 1999, Smith et al. 2011a,b). To accomplish this we used the GIS to grid the digital map layers for bathymetry, benthic habitats, and reef complexity into an appropriate cell size (sample unit) for delineating hardbottom habitats shallower than 33 m from the complete range of habitat types and depths. Ideally, the minimum grid size for a cell would be the 15 m diameter circular plot used in the reef-fish visual sampling protocol (Bohnsack and Bannerot 1986; Brandt et al. 2009). However, the minimum mapping unit for accurately defining a specific benthic habitat class is generally somewhat larger than 15 x 15 m. For example, the current survey frame for the Florida Keys reef-fish census uses a minimum mapping unit of 200 x 200 m (Smith et al. 2011a). Through evaluation of the GIS layers and subsequent discussions with Dr. Brian Walker (Nova Southeastern University, NSU), it was determined that the quality of the GIS layers for bathymetry and benthic habitats in the southeast Florida region was significantly higher compared to the Florida Keys mapping data. The minimum mapping unit was estimated to be between 50 x 50 m and 100 x 100 m. To be conservative, the minimum mapping unit was defined as a 100 x 100 m grid cell for the initial full-scale survey of the southeast Florida region.

Following the approach used for the Florida Keys (Smith et al. 2011a,b), a two-stage sampling scheme was employed to account for the disparity in area between a minimum mapping unit (10,000 m^2) for classifying reef habitats and a Bohnsack-Bannerot circular plot sample (177 m^2) that serves as the basic field observational unit. The primary sample unit (PSU) was defined as a 100 x 100 m map grid cell and the second-stage unit (SSU) was defined as a 15 m diameter visual plot (Fig. 2). A 50 x 50 m GIS sampling grid that nested within the 100 x 100 m grid was also developed to facilitate (1) random selection of SSUs within selected PSUs, and (2) to enable post-survey analyses comparing the statistical efficiency of single-stage designs based on a 50 x 50 m minimum mapping unit vs. two-stage designs utilizing a 100 x 100 m minimum mapping unit.

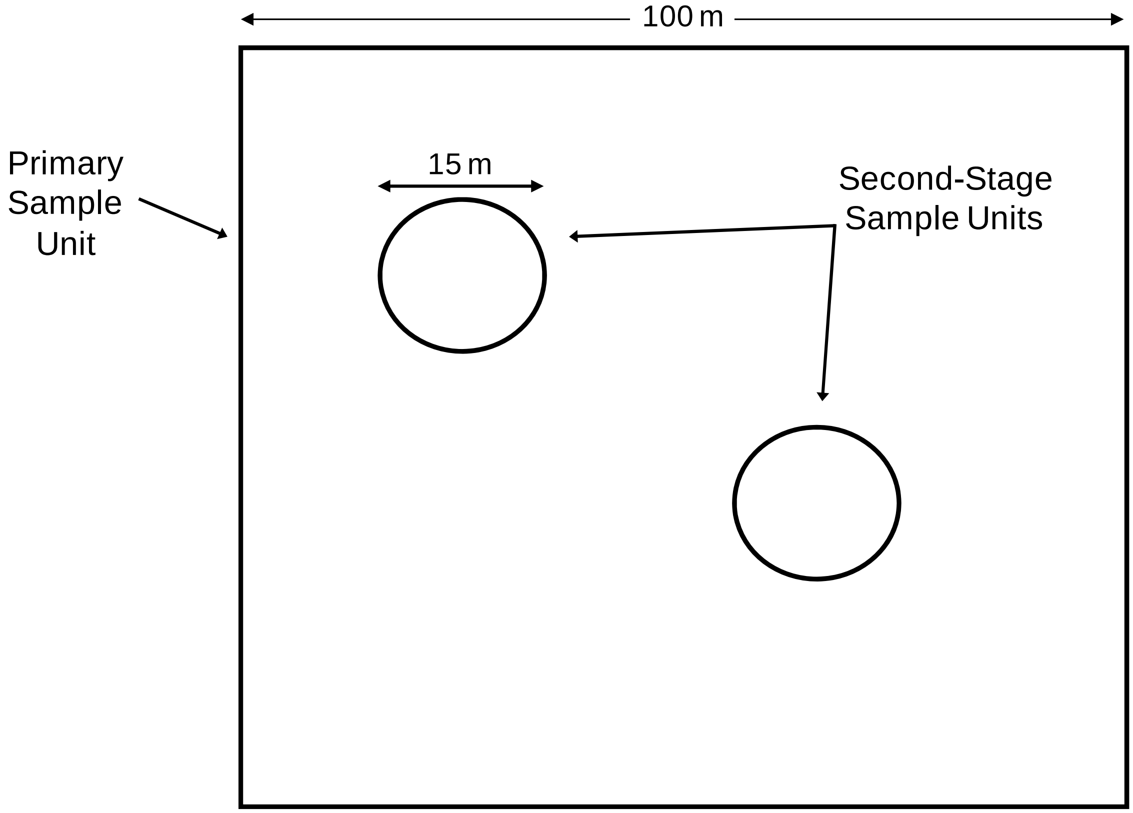

Figure 2. Diagram of the primary sample unit (PSU, 100 x 100 m grid cell) and second-stage unit (SSU, 15 m diameter circular plot sample) for the two-stage sampling design for the visual survey of reef fishes in the southeast Florida region.

Procedures were developed using ArcGIS (ESRI, 2011) and SAS (SAS Institute, 2009) software to synthesize the various mapping layers to the spatial resolution of the minimum mapping unit (Fig. 3). Average depth was estimated for each grid cell from high-resolution Light Detection And Ranging (LIDAR) bathymetry data (1-4 m spacing between point values, yielding >1000 observations per grid cell).

Mapped benthic habitat classes (provided by B. Walker, NSU) are described in Table 2. As illustrated in Fig. 4, the classification scheme for hardbottom habitats incorporated both cross-shelf position (inshore to offshore) and depth (shallow to deep) as well as general reef morphology (e.g., spur-groove, pavement, etc.). Procedures were developed in ArcGIS and SAS for designating a unique habitat class for each minimum mapping unit (Fig. 3), many of which contained multiple types of habitats. The algorithm grouped specific habitat classes into major categories (Table 2), and then based the designation on a combination of (i) area per category within a cell and (ii) a hierarchical scheme in which more complex habitats (e.g., spur-groove, linear-ridge) were given precedence over less complex types (e.g., pavement). SAS program code detailing this algorithm is listed in Appendix A1. Grid cells containing the 'Other' habitat class (altered natural substrates, dredge channels, artificial reefs, etc.) were excluded from the sample frame, as were cells containing only softbottom habitats (e.g., sand, seagrass, etc.).

A metric for reef complexity (high vs. low) was derived by Dr. Brian Walker (NSU) from the high-resolution bathymetry data, based on the change in depth among adjacent spatial point observations (i.e., slope). Using ArcGIS, the areas of high and low slope substrates were computed for each grid cell. These values were then analyzed using SAS procedures to evaluate criteria for designating high vs. low slope grid cells (see Appendix A2 for the SAS program code). These procedures evaluated varying threshold levels of high slope substrate area within a grid cell (e.g., 5%, 10%, and so on) for classifying the cell as high slope. For each threshold level tested, the number of grid cells classified as low and high slope were compared for each habitat class. Particular attention was given to habitat classes with known high complexity (i.e., spur-groove) vs. low complexity (i.e., pavement). These analyses suggested that a threshold level of 20% minimized the number of pavement cells classified as high slope while still classifying a majority of spur-groove cells as high slope. The final criteria thus classified high slope cells as containing 20% or more area of high slope substrate; all other cells were classified as having low slope.

Processed map grid layers for depth, slope, and habitat class were combined to create the final sampling grid GIS map. Each grid cell was assigned with a unique ID number, and also with the spatial coordinates of the center point. The procedures outlined in Fig. 3 and the associated SAS programs provided in Appendix A are specific for the 100 x 100 m minimum mapping unit. An identical set of procedures was used for the 50 x 50 m minimum mapping unit. Digital layers for the sampling grid were provided to FDEP and NOAA.

Table 2. Habitat classes (provided by B. Walker, NSU), habitat codes, and major categories for the benthic habitat map in the southeast Florida region.

Habitat Class	Habitat Code	Major Category
Deep Ridge Complex	DPRC	Linear-Ridge
Linear Reef-Inner	LIRI	Linear-Ridge
Linear Reef-Middle	LIRM	Linear-Ridge
Linear Reef-Outer	LIRO	Linear-Ridge
Ridge-Deep	RGDP	Linear-Ridge
Ridge-Shallow	RGSH	Linear-Ridge
Other Delineations	OTHR	Other-Dredged, Artificial, etc.
Aggregated Patch Reef-Deep	APRD	Patch
Aggregated Patch Reef-Shallow	APRS	Patch
Patch Reef	PTCH	Patch
Colonized Pavement-Deep	CPDP	Pavement
Colonized Pavement-Shallow	CPSH	Pavement
Unconsolidated Sediment	SAND	Sand
Scattered Coral/Rock in Sand	SCRS	Scattered Coral/Rock in Sand
Seagrass	SGRS	Seagrass
Spur and Groove	SPGR	Spur-Groove
No Map Data	UNKW	Unknown

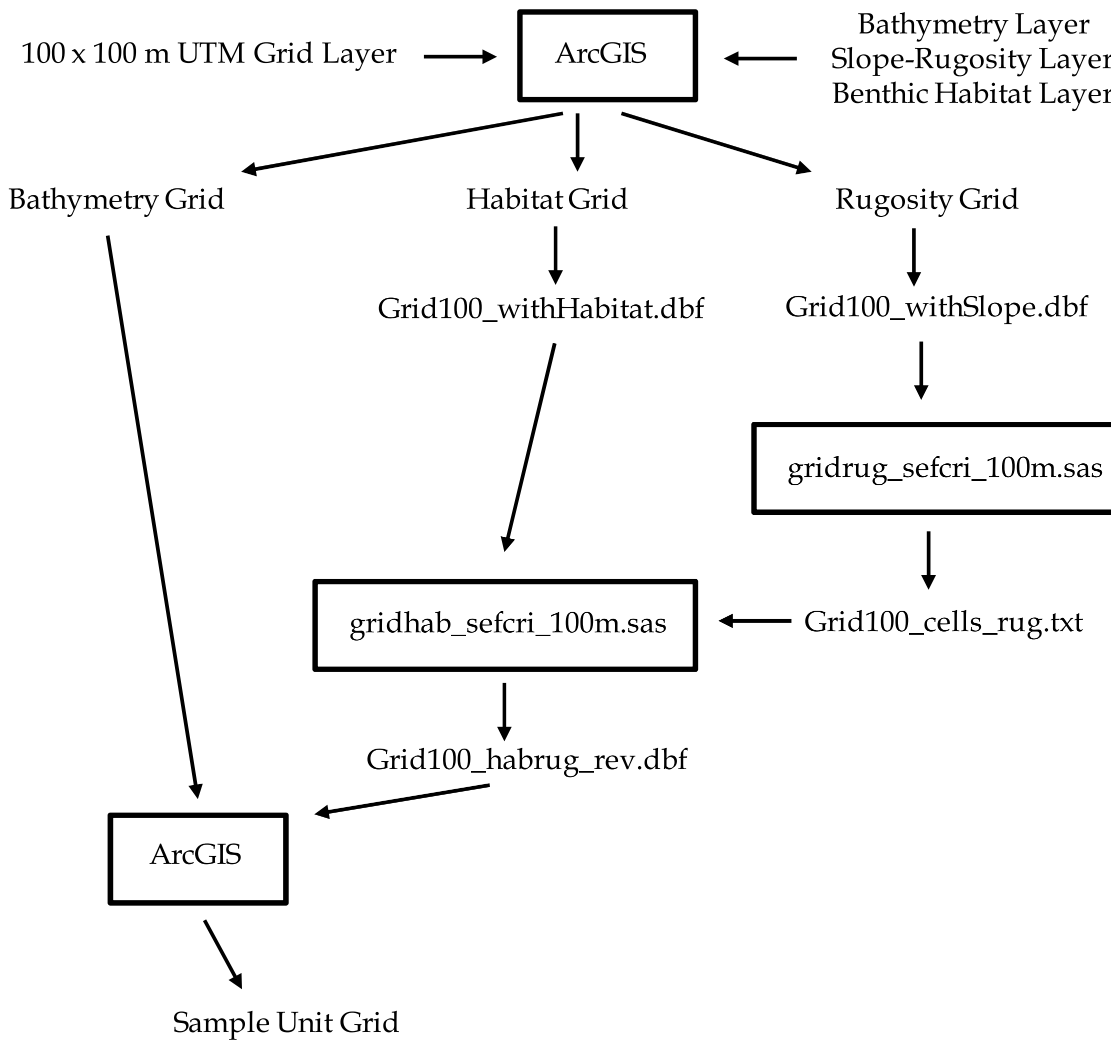

Figure 3. Process flow diagram of ArcGIS and SAS procedures used to develop the sample unit grid map incorporating depth, benthic habitats, and reef complexity (slope-rugosity) for the southeast Florida region. SAS program code is provided in Appendix A. Universal Transverse Mercator (UTM).

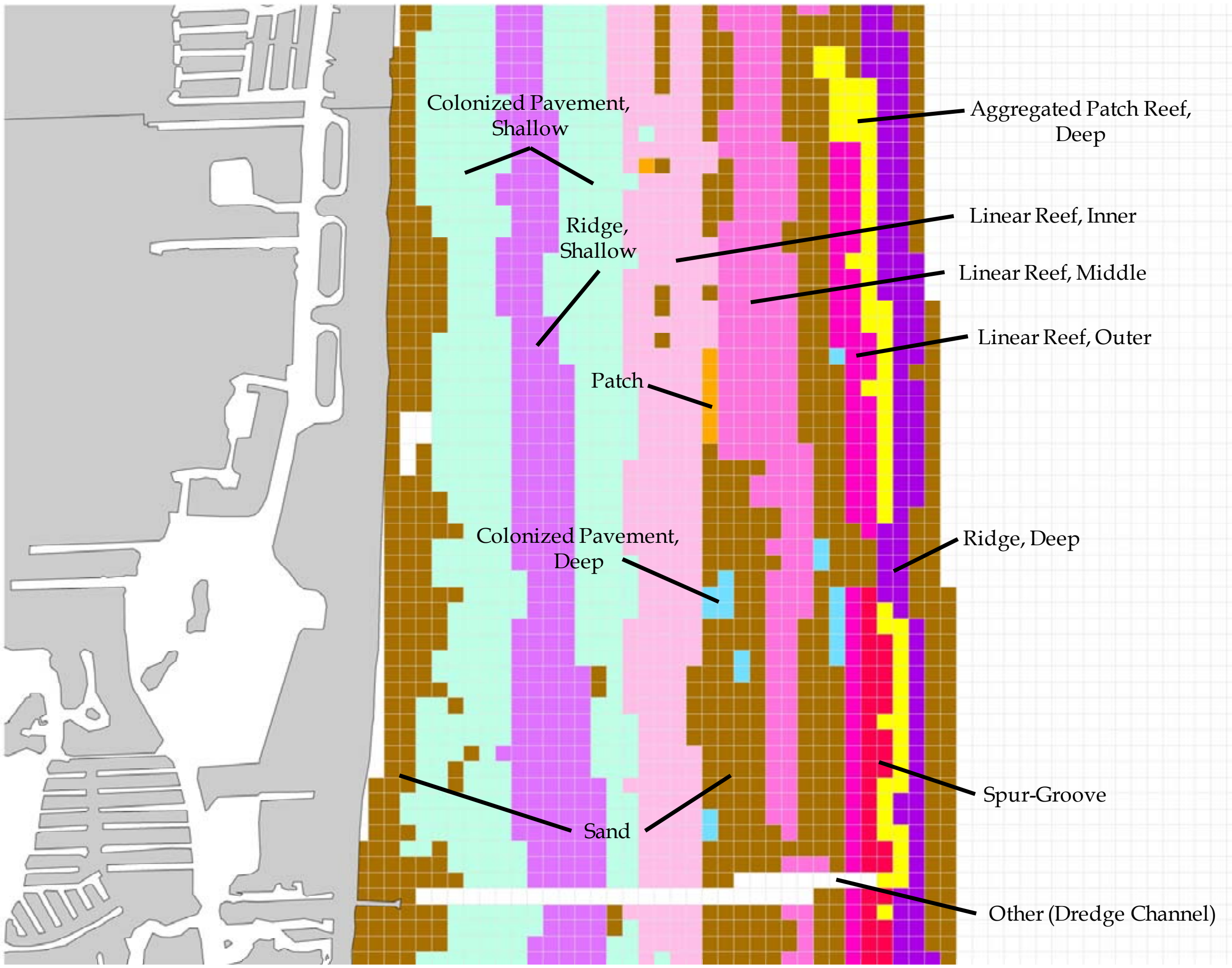

Figure 4. Map detail from Fig. 1 showing gridded benthic habitat classes for the southeast Florida region. Note that most of the hardbottom classes incorporate cross-shelf position (inshore to offshore) and depth (shallow to deep).

3.3 Development of the Reef-fish Sampling Plan

The following sections document the three principal analysis steps for developing the reef-fish sampling plan for the southeast Florida region:
(1) identify target species of management importance for analysis;
(2) develop a stratification scheme that partitions the variance of animal density of target species into subareas of low, medium, and high variance; and,
(3) allocate the total projected number of samples for the survey among strata.
Statistical estimation procedures and formulae for all analyses in this section are detailed in Smith et al. (2011a).

3.3.1 Species for Optimization

As described above, an effective stratification scheme uses environmental features that correspond with reef-fish spatial distribution patterns to partition the variance of density or abundance into subareas of low, medium, and high variance. However, many species and even life-stages of the same species (e.g., juveniles, adults) may have spatial distribution patterns that differ from one another (Ault et el. 2005a). It follows that a stratification scheme that is effective for one species or taxa group may be suboptimal for other species or taxa groups. A key step in the development of an efficient statistical sampling design is thus the choice of principal species of high management or scientific interest to serve as the basis for the stratification scheme (Smith et al. 2011a). In the Florida Keys, a group of 8 economically important species were chosen for optimization (white grunt, bluestriped grunt, hogfish, mutton snapper, gray snapper, yellowtail snapper, red grouper, and black grouper) (Brandt et al. 2009; Smith et al. 2011a). These are the principal exploited species in both the commercial and sport reef fisheries in the Florida Keys, and are relatively abundant in diver visual surveys, with frequency of occurrence at or above 10% (i.e., the proportion of diver point count samples in which at least one individual was sighted). These same criteria—relatively abundant species under fishery exploitation—were used to guide selection of target species for developing the survey design in the southeast Florida region.

The biological datasets in Table 1 were first used to evaluate which species were seen in diver visual samples in the southeast Florida region compared to species observed in the Florida Keys and Dry Tortugas. With few exceptions, all species observed in the southeast Florida region have also been observed in the Florida Keys-Dry Tortugas region. Quantitative species abundance data were used from three data sets to analyze the frequency of occurrence of reef fish species in Broward, Palm Beach, and Martin counties (Tables 3-5, respectively). SAS program code for frequency of occurrence analyses is provided in Appendices A3-A5. Methods for data collection varied among programs; thus, values are not directly comparable from one county to another. Data from Miami-Dade County were used to qualitatively compare species occurrences to other counties. The dataset from Broward County included the widest range of habitat types (Table 6), and was the primary information used to develop the stratification scheme (see below). Therefore frequency of occurrence data from that region were given a higher priority for selecting optimization species.

Six target species were chosen for the southeast Florida region; yellowtail snapper (*Ocyurus chrysurus*), mutton snapper (*Lutjanus analis*), hogfish (*Lachnolaimus maximus),* red grouper (*Epinephelus morio*), bluestriped grunt (*Haemulon sciurus*), and white grunt (*Haemulon plumieri*). These species were the principal exploited reef fishes with frequency of occurrence greater than 9% in Broward County (Table 3). In addition, three of the six species (yellowtail snapper, bluestriped and white grunt) had frequency of occurrence above 10% in Palm Beach (Table 4) and Martin (Table 5) counties.

Table 3. Frequency of occurrence of reef fish in Broward County with greater than 10% frequency of occurrence. (Nova Southeastern University Oceanographic Center data, 628 sites, 1999-2002). Optimization species are shown in bold and those with less than 10% frequency occurrence are shown below the dotted line.

Species	Frequency of Occurrence
Bluehead wrasse	0.826
Ocean surgeonfish	0.796
Redband parrotfish	0.711
Bicolor damselfish	0.692
Slippery dick	0.627
Yellowhead wrasse	0.548
Sharpnose puffer	0.482
White grunt	**0.444**
Doctorfish	0.407
Reef butterflyfish	0.398
Tobaccofish	0.362
Harlequin bass	0.344
Princess parrotfish	0.327
Cocoa damselfish	0.322
Spotted goatfish	0.306
Stoplight parrotfish	0.301
Gray triggerfish	0.296
Striped parrotfish	0.294
Blue tang	0.284
Butter hamlet	0.275
French grunt	0.241
Bridled goby	0.233
Gray angelfish	0.227
Porkfish	0.224
Red grouper	**0.207**
Bluestriped grunt	**0.204**
Clown wrasse	0.203
Rock beauty	0.199
Squirrelfish	0.191
Beaugregory	0.172
Bar jack	0.165
Hogfish	**0.150**
Spotfin butterflyfish	0.145
Masked goby	0.137
French angelfish	0.126
Graysby	0.118
Spanish hogfish	0.115
Blue chromis	0.114
Chalk bass	0.113
Saucereye porgy	0.110
Blue angelfish	0.108
Yellowhead jawfish	0.108
Greenblotch parrotfish	0.106
Yellowtail snapper	**0.094**
Mutton snapper	**0.090**

Table 4. Frequency of occurrence of reef fish in Palm Beach County with greater than 10% frequency of occurrence. (Palm Beach ERM data, 34 locations, 484 dives, 2000-2011). Optimization species are shown in bold and those with less than 10% frequency occurrence are shown below the dotted line.

Species	Frequency of Occurrence
Bluehead wrasse	0.781
Bicolor damselfish	0.704
Porkfish	0.611
Ocean surgeonfish	0.583
Redband parrotfish	0.515
Cocoa damselfish	0.480
Yellowhead wrasse	0.477
Sergeant major	0.455
Sharpnose puffer	0.445
Spanish hogfish	0.422
Reef butterflyfish	0.422
French grunt	0.420
Doctorfish	0.420
Blue tang	0.409
Spotted goatfish	0.388
Slippery dick	0.386
White grunt	**0.369**
Harlequin bass	0.368
Tomtate	0.368
Beaugregory	0.358
Sailors choice	0.326
Black margate	0.320
Bluestriped grunt	**0.300**
Purple reeffish	0.276
Clown wrasse	0.274
Rock beauty	0.255
Puddingwife	0.243
Highhat	0.242
Brown chromis	0.240
Blue angelfish	0.228
Princess parrotfish	0.226
Graysby	0.222
Bridled goby	0.220
Blackbar soldierfish	0.216
Stoplight parrotfish	0.214
Creole wrasse	0.214
Gray snapper	0.209
Spotfin butterflyfish	0.206
Blue chromis	0.206
Smallmouth grunt	0.200
Silver progy	0.190
Bar jack	0.189
Squirelfish	0.183
Yellowtail parrotfish	0.182
Sunshine fish	0.181
Yellowtail snapper	**0.180**
Butter hamlet	0.179
Striped parrotfish	0.165
Trumpetfish	0.158

Table 4. Continued.

Species	**Frequency of Occurrence**
Bermuda chub	0.151
Caesar grunt	0.150
Foureye butterflyfish	0.149
French angelfish	0.149
Masked goby	0.147
Gray angelfish	0.142
Hairy blenny	0.127
Greenblotch parrotfish	0.122
Goldspot goby	0.117
Lane snapper	0.113
Scrawled cowfish	0.112
Seaweed blenny	0.110
Barracuda	0.107
Yellow jack	0.107
Queen angelfish	0.106
Hogfish	**0.077**
Mutton snapper	**0.034**
Red Grouper	**0.013**

Table 5. Frequency of occurrence of reef fish in Martin County with greater than 10% frequency of occurrence. (FWC Tequesta data, 6 locations, 2006-2007). Optimization species are shown in bold and those with less than 10% frequency occurrence are shown below the dotted line.

Species	Frequency of Occurrence
Gray snapper	0.755
Porkfish	0.710
Lane snapper	0.561
Tomtate	0.544
Doctorfish	0.460
Black margate	0.439
Spanish hogfish	0.435
White grunt	**0.433**
Bluestriped grunt	**0.301**
Yellowtail snapper	**0.270**
Blue angelfish	0.263
Ocean surgeonfish	0.255
Chubbyu	0.252
Gray triggerfish	0.243
Spotted goatfish	0.222
Sheepshead	0.189
Atlantic spadefish	0.187
Calamus species	0.177
Blue tang	0.166
Common snook	0.164
Reef butterflyfish	0.160
Squirrelfish	0.152
French grunt	0.148
Blue runner	0.135
Vermilion snapper	0.132
Cottonwick	0.118
Graysby	0.100
Red grouper	**0.023**
Mutton snapper	**0.021**
Hogfish	**0.006**

3.3.2 Stratification Scheme

Fish density and variance of density for optimization species from Broward County were used to evaluate potential stratification schemes. Density data for all life stages of mutton snapper, hogfish, and red grouper were used. Only data for the adult life stage were used for white grunt (≥ 17.7 cm), bluestriped grunt (≥ 20.5 cm), and yellowtail snapper (≥ 19.9 cm) (Ault et al. 2005b). Spatial coordinates of fish sample locations were used to assign habitat and slope-rugosity classes from the sampling grid map to each biological observation.

Depth, habitat, and slope-rugosity were investigated as potential factors for a stratification scheme (see SAS program code in Appendix A6). The variance of fish density was effectively partitioned into low, medium, and high categories by both depth (Fig. 5) and habitat type (Fig. 6). These results were used to guide further grouping of both depth and habitat into four different "reefzones" that represent three cross-shelf reef formations moving from inshore to offshore, and a fourth category for patch reefs (Table 6, Fig. 4). A measure of complexity-rugosity (i.e., slope) was used to subdivide each reefzone into low and high categories. This reefzone-complexity stratification scheme was effective in partitioning variance of density into spatial subareas of low to high variance for each of the six target species (Figs. 7 & 8). Because comparable, spatially-synoptic fish density data were not available for Palm Beach and Martin counties, reefzone-complexity strata developed for Broward County data were applied to the other four biogeographic subregions (Fig. 1, Table 7).

Table 6. Habitat classes, the associated number of grid cells in the sample frame, the number of sites selected for each habitat class (from Broward County data), and the reefzone categories for grouping habitat classes.

Habitat Class	Number of Grid Cells	Sites Sampled	Reefzone
Aggregated Patch-Deep	1263	31	Patch
Aggregated Patch-Shallow	395	0	Patch
Colonized Pavement-Deep	819	36	Offshore
Colonized Pavement-Shallow	5607	79	Inshore
Deep Ridge Complex	9208	0	Offshore
Linear Reef-Inner	2867	53	Middle
Linear Reef-Middle	2295	95	Middle
Linear Reef-Outer	1577	75	Offshore
Other	270	0	n/a
Patch Reef	340	0	Patch
Ridge-Deep	2347	13	Offshore
Ridge-Shallow	3528	154	Inshore
Sand	24451	14	n/a
Scattered Coral/Rock in Sand	94	0	Patch
Seagrass	6019	0	n/a
Spur-Groove	1092	49	Offshore
Unknown	167572	1	n/a

Table 7. Definition of sampling strata by combining habitat classes and/or slope categories within biogeographic subregions. Habitat codes are defined in Table 2; slope categories are low=0, high=1; grid cells are the number of 100 x 100 minimum mapping units available for sampling.

Stratum *h*	Subregion	Habitat Code	Slope Category	Grid Cells
1	Broward-North Miami	APRD	0	198
1	Broward-North Miami	APRS	0	1
1	Broward-North Miami	PTCH	0	17
1	Broward-North Miami	SCRS	0	36
2	Broward-North Miami	APRD	1	272
2	Broward-North Miami	PTCH	1	2
3	Broward-North Miami	CPSH	0	2551
3	Broward-North Miami	RGSH	0	3032
4	Broward-North Miami	CPSH	1	36
4	Broward-North Miami	RGSH	1	141
5	Broward-North Miami	LIRI	0	1216
5	Broward-North Miami	LIRM	0	1346
6	Broward-North Miami	LIRI	1	633
6	Broward-North Miami	LIRM	1	519
7	Broward-North Miami	CPDP	0	458
7	Broward-North Miami	LIRO	0	113
7	Broward-North Miami	RGDP	0	283
7	Broward-North Miami	SPGR	0	7
8	Broward-North Miami	CPDP	1	128
8	Broward-North Miami	LIRO	1	476
8	Broward-North Miami	RGDP	1	265
8	Broward-North Miami	SPGR	1	548
9	Deerfield	APRD	0	79
9	Deerfield	PTCH	0	2
10	Deerfield	APRD	1	172
11	Deerfield	CPSH	0	60
11	Deerfield	RGSH	0	52
11	Deerfield	RGSH	1	2
12	Deerfield	LIRM	0	242
13	Deerfield	LIRM	1	103
14	Deerfield	CPDP	0	49
14	Deerfield	LIRO	0	25
14	Deerfield	RGDP	0	55
14	Deerfield	SPGR	0	1
15	Deerfield	CPDP	1	21
15	Deerfield	LIRO	1	128

Table 7. Continued

Stratum *h*	Subregion	Habitat Code	Slope Category	Grid Cells
15	Deerfield	RGDP	1	39
15	Deerfield	SPGR	1	163
16	South Palm Beach	APRD	0	178
16	South Palm Beach	PTCH	0	24
17	South Palm Beach	APRD	1	175
17	South Palm Beach	PTCH	1	3
18	South Palm Beach	CPSH	0	47
18	South Palm Beach	RGSH	0	85
19	South Palm Beach	CPDP	0	69
19	South Palm Beach	DPRC	0	12
19	South Palm Beach	LIRO	0	136
19	South Palm Beach	RGDP	0	248
19	South Palm Beach	SPGR	0	15
20	South Palm Beach	CPDP	1	20
20	South Palm Beach	LIRO	1	288
20	South Palm Beach	RGDP	1	192
20	South Palm Beach	SPGR	1	257
21	North Palm Beach	APRD	0	10
21	North Palm Beach	PTCH	0	40
21	North Palm Beach	APRD	1	1
21	North Palm Beach	PTCH	1	6
22	North Palm Beach	CPSH	0	25
22	North Palm Beach	RGSH	0	85
23	North Palm Beach	CPDP	0	20
23	North Palm Beach	DPRC	0	7748
23	North Palm Beach	LIRO	0	2
24	North Palm Beach	CPDP	1	3
24	North Palm Beach	DPRC	1	389
25	Martin	APRD	0	14
25	Martin	APRS	0	12
26	Martin	CPSH	0	345
26	Martin	RGSH	0	416
27	Martin	CPSH	1	79
27	Martin	RGSH	1	123
28	Martin	DPRC	0	379
28	Martin	RGDP	0	619
29	Martin	DPRC	1	9
29	Martin	RGDP	1	128

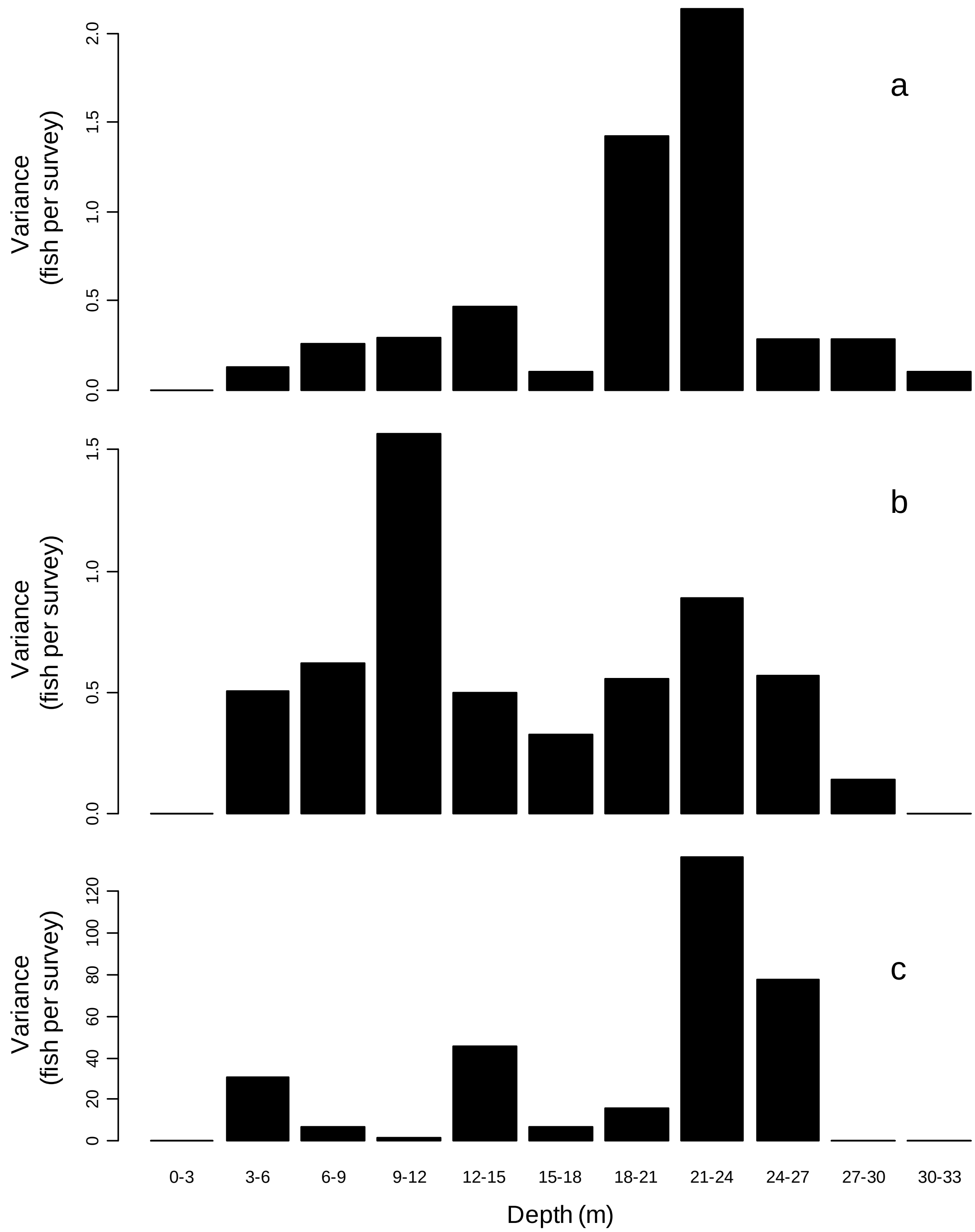

Figure 5. Variance of density by 3 m depth categories for (a) hogfish, (b) red grouper, and (c) bluestriped grunt in Broward County.

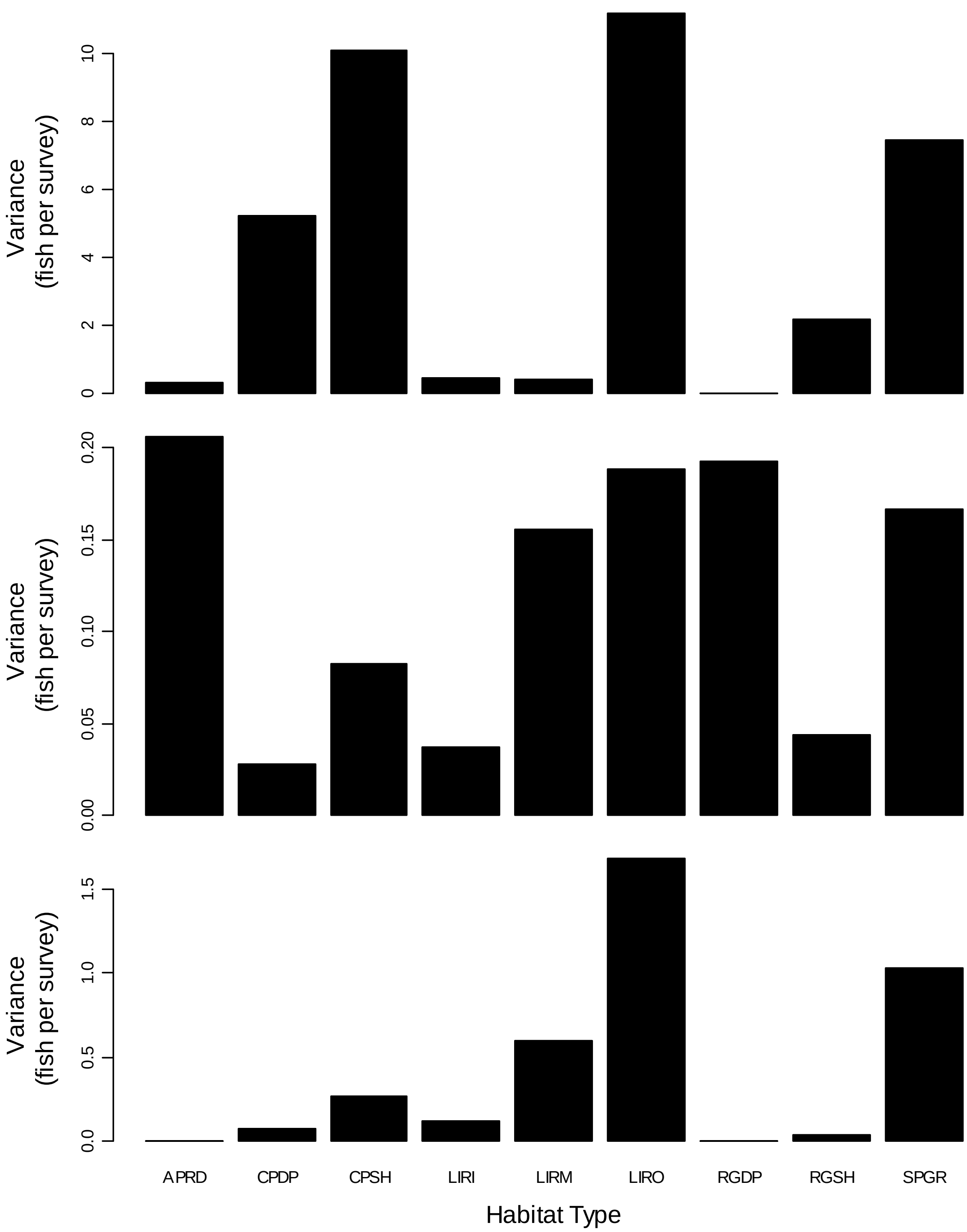

Figure 6. Variance of density by habitat type for (a) white grunt, (b) mutton snapper, and (c) yellowtail snapper in Broward County. Habitat types include: APRD (aggregate patch, deep), CPDP (colonized pavement, deep), CPSH (colonized pavement, shallow), LIRI (linear reef inner), LIRM (linear reef middle), LIRO (linear reef outer), RGDP (ridge deep), RGSH (ridge shallow), and SPGR (spur and groove).

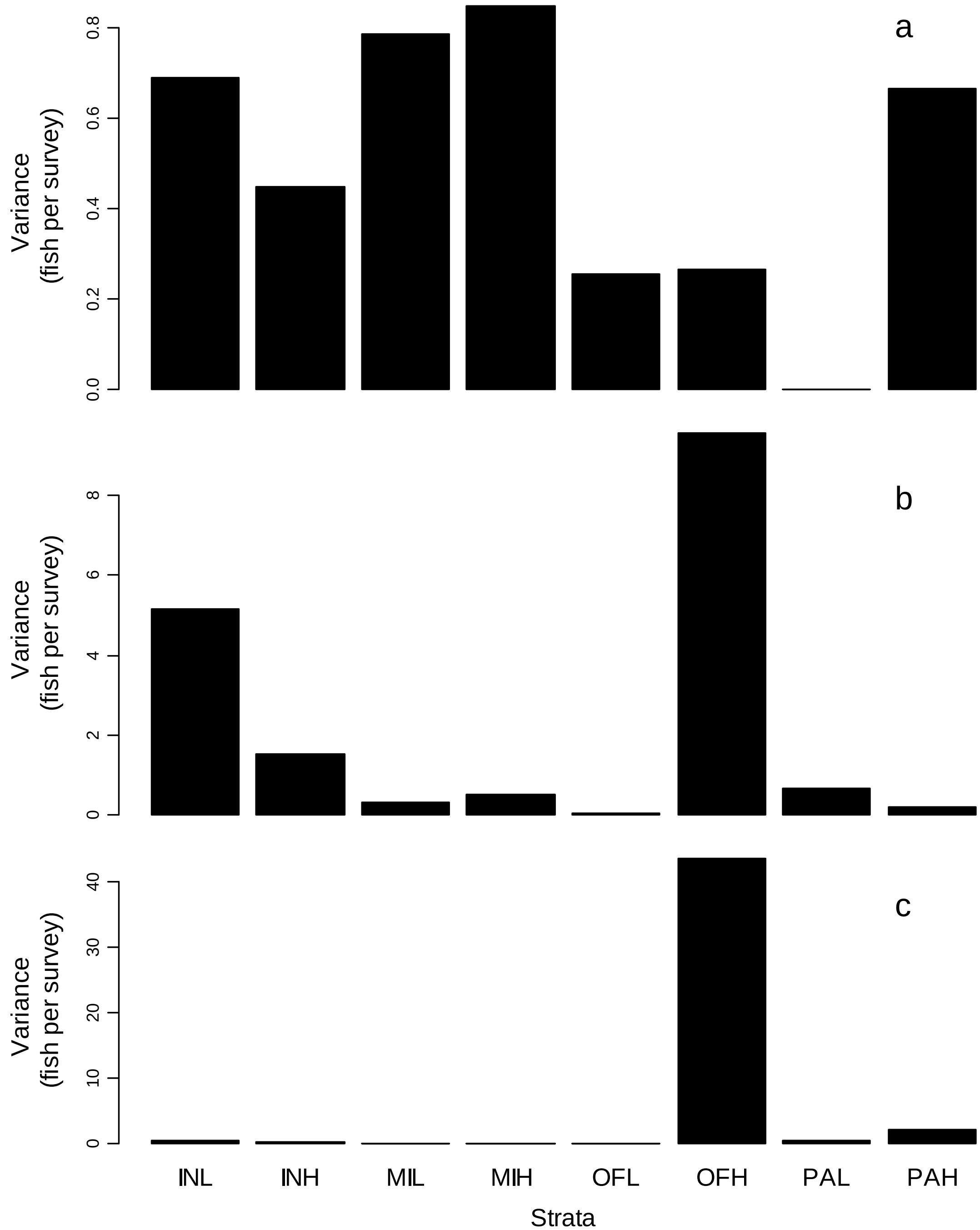

Figure 7. Variance of density for (a) red grouper, (b) white grunt, and (c) bluestriped grunt by reefzone-rugosity strata. Strata include: INL (inshore low rugosity), INH (inshore high rugosity), MIL (middle low rugosity), MIH (middle high rugosity), OFL (offshore low rugosity), OFH (offshore high rugosity), PAL (patch reef low rugosity), and PAH (patch reef high rugosity).

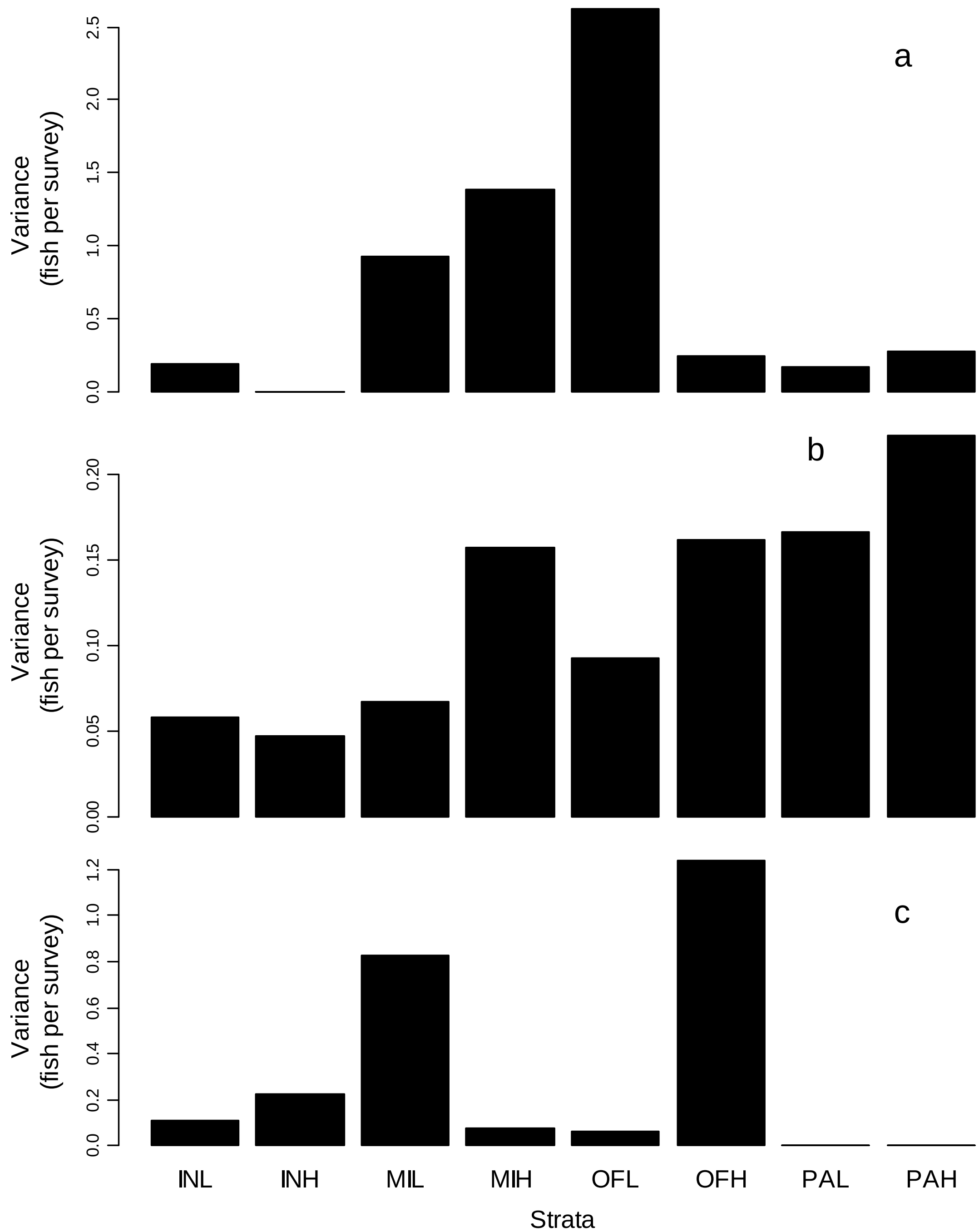

Figure 8. Variance of density for (a) hogfish, (b) mutton snapper, and (c) yellowtail snapper by reefzone-rugosity strata. Strata include: INL (inshore low rugosity), INH (inshore high rugosity), MIL (middle low rugosity), MIH (middle high rugosity), OFL (offshore low rugosity), OFH (offshore high rugosity), PAL (patch reef low rugosity), and PAH (patch reef high rugosity).

3.3.3 Sample Allocation and Randomized Sites

Sample allocation of primary sample units (PSUs) for the 2012 survey in the southeast Florida region entailed two steps: (1) estimation of the total sampling effort in terms of PSUs for the overall survey; and (2) allocation of the total projected PSUs among strata defined by biogeographic subregion, reefzone, and complexity. For the two-stage stratified random design, two SSUs are sampled within each PSU (Brandt et al. 2009; Smith et al. 2011a); thus, diver counts by two buddy pairs are conducted at each PSU (or alternatively, two SSUs are sampled by the same buddy pair, i.e., two point counts per diver). These basic requirements for field sampling were provided to a wide variety of agencies-groups that expressed interest in participating in the 2012 survey. Each group in turn provided an estimate of PSUs per day and the number of total vessel-days that they could contribute to the field effort. A total of 360 PSUs were estimated as the sampling effort for 2012 (Table 8).

Table 8. Sampling effort projections by agencies and groups participating in the summer-fall 2012 reef-fish survey in the southeast Florida region.

Agency/Group	Vessel days	PSUs per day	Total PSUs
Nova Southeastern	40	5	200
NOAA SEFSC	3	6	18
Miami-Dade RER	4	4	16
FWC Tequesta	3	4	12
Palm Beach DERM	6	3	18
Broward County	6	4	24
FDEP SE District	4	3	12
FDEP Park Service	6	4	24
FDEP Coral Program	6	4	24
Martin County	3	4	12
Total			**360**

The most efficient survey designs (e.g., Ault et al. 1999; Smith et al. 2011a,b) employ a Neyman or optimal allocation strategy for determining sample sizes for each stratum from the total projected sample size. This strategy allocates samples according to both stratum size (i.e., area) and stratum variance, with larger, higher variance strata receiving more sampling effort, and smaller, lower variance strata receiving less sampling effort. Use of optimal allocation in practice requires prior estimates of sample variance for each stratum. At present, reliable estimates of strata variance are only available for Broward County. To be prudent, a more basic proportional allocation scheme was adopted, which allocates samples according to stratum size only. The emphasis for the initial region-wide 2012 survey is thus to obtain complete spatial coverage of reef habitats and depths in each of the five subregions.

Allocation of n=360 PSUs among strata for the 2012 survey in the southeast Florida region is shown in Table 9. The number of PSUs (target n_h) to be sampled in each stratum (*h*) was based on the PSUs proportional (prop. n_h) to the number of 100 x 100 m grids that occur in each stratum (N_h, w_h), adjusted for minimum (n_h=5) and maximum (n_h=50) levels per stratum. Note that all reefzone and slope categories do not occur in each biogeographic subregion.

Random selection of PSUs to be sampled within a stratum *h* from the complete list of N_h units was carried out using the discrete uniform distribution to ensure equal probability of selection (Law, 2007). The list of PSUs selected for sampling is provided in Appendix B. For the selected PSUs, the same procedure was used to randomly select two SSUs using the 50 x 50 m sampling grid that is nested within the 100 x 100 m grid.

Table 9. Allocation of sampling effort (target n_h, number of PSUs) among strata for the initial full-scale visual survey of reef-fishes in the southeastern Florida region. N_h is the total PSUs (100 x 100 m grid cells) available for sampling in a stratum; w_h is the proportion of total sample frame PSUs in a stratum; prop. n_h is the sampling effort per stratum (number of PSUs) based on the proportion of sample units in a stratum (i.e., w_h).

Stratum *h*	**Subregion**	**Reefzone**	**Slope Category**	**N_h**	**w_h**	**Prop. n_h**	**Target n_h**
1	Broward-North Miami	Patch	Low	252	0.0098	3.5	5
2	Broward-North Miami	Patch	High	274	0.0107	3.8	7
3	Broward-North Miami	Inshore	Low	5583	0.2175	78.3	50
4	Broward-North Miami	Inshore	High	177	0.0069	2.5	7
5	Broward-North Miami	Middle	Low	2562	0.0998	35.9	36
6	Broward-North Miami	Middle	High	1152	0.0449	16.2	18
7	Broward-North Miami	Offshore	Low	861	0.0335	12.1	13
8	Broward-North Miami	Offshore	High	1417	0.0552	19.9	22
9	Deerfield	Patch	Low	81	0.0032	1.1	5
10	Deerfield	Patch	High	172	0.0067	2.4	7
11	Deerfield	Inshore	n/d	114	0.0044	1.6	7
12	Deerfield	Middle	Low	242	0.0094	3.4	5
13	Deerfield	Middle	High	103	0.0040	1.4	7
14	Deerfield	Offshore	Low	130	0.0051	1.8	5
15	Deerfield	Offshore	High	351	0.0137	4.9	8

Table 9. Continued

Stratum *h*	Subregion	Reefzone	Slope Category	N_h	w_h	Prop. n_h	Target n_h
16	South Palm Beach	Patch	Low	202	0.0079	2.8	5
17	South Palm Beach	Patch	High	178	0.0069	2.5	7
18	South Palm Beach	Inshore	n/d	132	0.0051	1.9	7
19	South Palm Beach	Offshore	Low	480	0.0187	6.7	8
20	South Palm Beach	Offshore	High	757	0.0295	10.6	14
21	North Palm Beach	Patch	n/d	57	0.0022	0.8	5
22	North Palm Beach	Inshore	n/d	110	0.0043	1.5	7
23	North Palm Beach	Offshore	Low	7770	0.3027	109.0	50
24	North Palm Beach	Offshore	High	392	0.0153	5.5	9
25	Martin	Patch	n/d	26	0.0010	0.4	5
26	Martin	Inshore	Low	761	0.0296	10.7	12
27	Martin	Inshore	High	202	0.0079	2.8	7
28	Martin	Offshore	Low	998	0.0389	14.0	15
29	Martin	Offshore	High	137	0.0053	1.9	7
Total				**25673**	**1.0000**	**360**	**360**

3.4 Meetings & Training Activities

Training is a critical component of reef fish monitoring program, and should incorporate both initial and annual refresher training components. All participants of all agencies in the southeast Florida region should be capable of accurately identifying and estimating sizes of reef fish that are encountered on the Florida Coral Reef Tract. Participants should also be familiar with the habitat assessment techniques and benthic categories that are included in the method. Out-of-water training meetings and in-water training activities should be held each year before sampling commences. In-water training should be organized and executed by each agency independently, although exchange of personnel among agencies is encouraged.

Prior to the start of sampling in the southeast Florida region, all fish counters, including those who had previously participated in reef fish surveys, attended an out-of-water training session on April 13, 2012. This session covered the sampling design, logistics, reef fish census (RVC) methods, habitat characteristics, and data entry and proofing methods to familiarize participants with all steps of the monitoring program. The presentation given at this training meeting is posted online (http://femar.rsmas.miami.edu/fknms_multiagency_rvc.htm) so that it is accessible to all participants throughout the field season. Also available is the

RVC protocol document entitled *A Cooperative Multi-agency Reef Fish Monitoring Protocol for the Florida Keys Coral Reef Ecosystem* by Brandt et al. (2009).

In-water training was organized independently by all agencies involved with the field work (i.e., FDEP CRCP, NOAA NMFS, and NSU) and focused on RVC method execution, proper equipment handling, species identification and size estimation, and proper habitat characterization. Participants were also encouraged to independently use computer programs and books to practice species identification.

In April 2012, a 3-day course on the principles and application of statistical survey design to coral reef ecosystems was held in the Miami-Dade County. Participants included data analysts from the Florida Keys-Dry Tortugas region as well as analysts from (NSU) who will be leading the effort to analyze the 2012 survey data and develop future sampling plans for the southeast Florida region.

Data management meetings were held on two different occasions (July 2 & 23, 2012) to ensure that all designated data managers were trained. These sessions included the steps involved in collating the data and creating the boat log. At the end of the field season, designated agency-specific data managers will be responsible for assuring that all data collected has been entered and proofed.

On November 14, 2012, after the sampling season ended, a data proofing and a results meeting was held with all the partners who were involved in sampling season. This meeting focused on the steps involved in collating the data, producing proofing reports for individual divers to check their data, and for submitting final data files for data verification, as well as any issues that may have arisen during the sampling season, including in-water work as well as with data entry.

4.0 Conclusions

This study adapted the statistical sampling design developed in the Florida Keys for a diver visual survey of reef fishes inhabiting the coral reef tract in the southeast Florida region. A variety of historical mapping and biological data were used to create a statistically robust sampling plan for an initial region-wide survey in summer-fall 2012 encompassing all coral reef habitats shallower than 33 m.

Data from this initial region-wide survey will form a sound foundation for improving the precision of future surveys via refined stratification and allocation schemes. Efficient sampling surveys are not developed overnight, but rather evolve via an iterative learning process in which data from current surveys are used to improve performance of future surveys (Ault et al. 2005a). It usually takes at least 2-3 iterations of this process to obtain a well-performing sampling design (Ault et al. 1999; Smith et al. 2011a).

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Appendix A: SAS Program Code

Appendix A1: SAS program gridhab_sefcri_100m.sas

```
/*program gridhab_sefcri_100m.sas*/
/*programmer: S.G. Smith, RSMAS*/
/*processes 100m hab sampling grid*/
/*composite hierarchy-majority area algorithm*/
/*incorporates rug info*/
/*top hierarchy=other*/
options nodate nonumber;
proc import datafile="C:\sgs\SEFCRI_RVC\SEFCRI_GIS\Grid100_withHabitat.dbf"
   out=g1a replace;
quit;
/*proc contents data=g1a;
quit;*/
data g1b;
  set g1a;
  if habclass='Aggregated Patch Reef-Dee' then habcode='APRD';
  else if habclass='Aggregated Patch Reef-Sha' then habcode='APRS';
  else if habclass='Colonized Pavement-Deep' then habcode='CPDP';
  else if habclass='Colonized Pavement-Shallo' then habcode='CPSH';
  else if habclass='Deep Ridge Complex' then habcode='DPRC';
  else if habclass='Linear Reef-Inner' then habcode='LIRI';
  else if habclass='Linear Reef-Middle' then habcode='LIRM';
  else if habclass='Linear Reef-Outer' then habcode='LIRO';
  else if habclass='No Map Data' then habcode='UNKW';
  else if habclass='Other Delineations' then habcode='OTHR';
  else if habclass='Patch Reef' then habcode='PTCH';
  else if habclass='Ridge-Deep' then habcode='RGDP';
  else if habclass='Ridge-Shallow' then habcode='RGSH';
  else if habclass='Scattered Coral/Rock in S' then habcode='SCRS';
  else if habclass='Seagrass' then habcode='SGRS';
  else if habclass='Spur and Groove' then habcode='SPGR';
  else if habclass='Unconsolidated Sediment' then habcode='SAND';
  else habcode='-999';
  if habcode='OTHR' then othr=1;
  else othr=0;
  if habcode='UNKW' or habcode='OTHR' or habcode='SGRS' or habcode='SAND'
    then hard=0;
  else hard=1;
run;
/*proc freq;
  tables habclass*habcode;
quit;*/
/*proc univariate plot;
  var area;
```

```
quit;*/
proc means data=g1b nway noprint;
 class habclass habcode;
 var area;
 output out=table1 (drop=_type_ _freq_) n=n;
quit;
proc print;
quit;
proc means data=g1b nway noprint;
 class cellid habcode;
 var area;
 id othr hard;
 output out=g2 (drop=_type_ _freq_) sum=habarea;
quit;
proc means nway noprint;
 class cellid;
 var habarea othr hard;
 output out=g3 (drop=_type_ _freq_) n=ntypes sum=totarea n_othr n_hard;
quit;
/*proc univariate plot;
 var totarea;
quit;*/
/*proc freq;
 tables n_othr ntypes n_hard ntypes*n_hard;
quit;*/
data g4;
 merge g2 g3;
 by cellid;
run;
/*subset grid cells with other hab type*/
data o1;
 set g4;
 if n_othr>0;
 if habcode='OTHR';
 hab=habcode;
 keep cellid hab;
run;
/*proc print;
quit;*/
/*subset grid cells with 1 hab type*/
data h1;
 set g4;
 if n_othr>0 then delete;
 if ntypes=1;
 hab=habcode;
 keep cellid hab;
run;
```

```
/*proc freq;
 tables hab;
quit;*/
/*subset grid cells with >1 hab type*/
data g5;
 set g4;
 if n_othr>0 then delete;
 if ntypes>1;
run;
/*proc print;
quit;*/
/*isolate grid cells with 1 hard hab type*/
data h2;
 set g5;
 if n_hard=1 and hard=1;
 hab=habcode;
 keep cellid hab;
run;
/*proc print;
quit;*/
/*isolate remaining cells*/
data f1;
 set g5;
 if n_hard=1 and hard=1;
 flag_1=1;
 keep cellid flag_1;
run;
data g6;
 merge g5 f1;
 by cellid;
 if flag_1=1 then delete;
 drop flag_1;
run;
/*proc print;
quit;*/
/*proc freq;
 tables ntypes n_hard ntypes*n_hard;
quit;*/
/*hierarchical classification for non-reef habitat cells*/
data s1;
 set g6;
 if n_hard=0;
run;
proc transpose out=s2;
 by cellid;
 var habarea;
 id habcode;
```

```
quit;
/*proc contents data=s2;
quit;*/
/*proc print;
quit;*/
data s3;
 set s2;
 if SAND=. then SAND=0.0;
 else SAND=SAND;
 if UNKW=. then UNKW=0.0;
 else UNKW=UNKW;
 if SGRS=. then SGRS=0.0;
 else SGRS=SGRS;
 if SGRS>0.0 then hab='SGRS';
 else if SGRS=0.0 and SAND>0.0 then hab='SAND';
 else hab='-999';
run;
/*proc print;
quit;*/
/*proc freq;
 tables hab;
quit;*/
data h3;
 set s3;
 keep cellid hab;
run;
/*isolate remaining cells with >1 hard habitat*/
data g7;
 set g6;
 if n_hard=0 then delete;
 if hard=1;
run;
/*proc print;
quit;*/
/*analysis of habitats occurring together within a cell*/
/*data rh1a;
 set g7;
 if habcode='SPGR';
 flag_2=1;
 keep cellid flag_2;
run;
data rh1b;
 merge g7 rh1a;
 by cellid;
 if flag_2=. then delete;
run;*/
/*proc print;
```

```
quit;*/
/*proc freq;
 tables habcode;
quit;*/
/*consolidation of like habitats within cells*/
proc transpose data=g7 out=c1;
 by cellid;
 var habarea;
 id habcode;
quit;
/*proc print;
quit;*/
data c2a;
 set c1;
 if DPRC>0.0 and RGDP>0.0;
 if DPRC>=RGDP then ridge=1;
 else ridge=2;
 keep cellid ridge;
run;
data c2b;
 set c1;
 if LIRI>0.0 and LIRM>0.0;
 if LIRI>=LIRM then lin1=1;
 else lin1=2;
 keep cellid lin1;
run;
data c2c;
 set c1;
 if LIRI>0.0 and LIRO>0.0;
 if LIRI>=LIRO then lin2=1;
 else lin2=2;
 keep cellid lin2;
run;
data c2d;
 set c1;
 if APRS>0.0 and PTCH>0.0;
 if APRS>=PTCH then patch1=1;
 else patch1=2;
 keep cellid patch1;
run;
data c2e;
 set c1;
 if APRD>0.0 and PTCH>0.0;
 if APRD>=PTCH then patch2=1;
 else patch2=2;
 keep cellid patch2;
run;
```

```
/*proc print;
quit;*/
data g8;
  merge g7 c2a c2b c2c c2d c2e;
  by cellid;
  if ridge=1 and habcode='RGDP' then habcode='DPRC';
  else if ridge=2 and habcode='DPRC' then habcode='RGDP';
  else if lin1=1 and habcode='LIRM' then habcode='LIRI';
  else if lin1=2 and habcode='LIRI' then habcode='LIRM';
  else if lin2=1 and habcode='LIRO' then habcode='LIRI';
  else if lin2=2 and habcode='LIRI' then habcode='LIRO';
  else if patch1=1 and habcode='PTCH' then habcode='APRS';
  else if patch1=2 and habcode='APRS' then habcode='PTCH';
  else if patch2=1 and habcode='PTCH' then habcode='APRD';
  else if patch2=2 and habcode='APRD' then habcode='PTCH';
  else habcode=habcode;
run;
/*proc print;
quit;*/
proc means nway noprint;
  class cellid habcode;
  var habarea;
  output out=g9 (drop=_type_ _freq_) sum=habarea;
quit;
/*proc print;
quit;*/
/*analyze major hab categories*/
data g10;
  set g9;
  if habcode='SPGR' then maj_cat='SPGR';
  else if habcode='LIRI' or habcode='LIRM' or habcode='LIRO'
    or habcode='DPRC' or habcode='RGDP' or habcode='RGSH'
           then maj_cat='LNRG';
  else if habcode='APRS' or habcode='APRD' or habcode='PTCH'
    then maj_cat='PTCH';
  else if habcode='CPDP' or habcode='CPSH' then maj_cat='PVMT';
  else if habcode='SCRS' then maj_cat='SCRS';
  else maj_cat='-999';
run;
/*proc freq;
  tables maj_cat;
quit;*/
proc means nway noprint;
  class cellid maj_cat;
  var habarea;
  output out=mc1 (drop=_type_ _freq_) sum=habarea;
quit;
```

```
/*proc print;
quit;*/
/*proc sort;
 by maj_cat;
quit;
proc chart;
 by maj_cat;
 hbar habarea/midpoints=250 to 9750 by 500;
quit;*/
proc transpose data=mc1 out=mc2;
 by cellid;
 var habarea;
 id maj_cat;
quit;
/*proc print;
quit;*/
/*hierarchical scheme, 10% area threshold*/
/*data mc3_10;
 set mc2;
 if LNRG=. then LNRG=0.0;
 else LNRG=LNRG;
 if PTCH=. then PTCH=0.0;
 else PTCH=PTCH;
 if PVMT=. then PVMT=0.0;
 else PVMT=PVMT;
 if SPGR=. then SPGR=0.0;
 else SPGR=SPGR;
 if SCRS=. then SCRS=0.0;
 else SCRS=SCRS;
 if SPGR>=1000.0 then maj_hab='SPGR';
 else if SPGR<1000.0 and LNRG>=1000.0 then maj_hab='LNRG';
 else if (SPGR<1000.0 and LNRG<1000.0) and PTCH>=1000.0 then maj_hab='PTCH';
 else if (SPGR<1000.0 and LNRG<1000.0 and PTCH<1000.0) and PVMT>=1000.0 then
maj_hab='PVMT';
 else if (SPGR<1000.0 and LNRG<1000.0 and PTCH<1000.0 and PVMT<1000.0) and
  SCRS>=1000.0 then maj_hab='SCRS';
 else maj_hab='NONE';
 keep cellid maj_hab;
run;
/*hierarchical scheme, 20% area threshold*/
data mc3_20;
 set mc2;
 if LNRG=. then LNRG=0.0;
 else LNRG=LNRG;
 if PTCH=. then PTCH=0.0;
 else PTCH=PTCH;
 if PVMT=. then PVMT=0.0;
```

```
  else PVMT=PVMT;
  if SPGR=. then SPGR=0.0;
  else SPGR=SPGR;
  if SCRS=. then SCRS=0.0;
  else SCRS=SCRS;
  if SPGR>=2000.0 then maj_hab='SPGR';
  else if SPGR<2000.0 and LNRG>=2000.0 then maj_hab='LNRG';
  else if (SPGR<2000.0 and LNRG<2000.0) and PTCH>=2000.0 then maj_hab='PTCH';
  else if (SPGR<2000.0 and LNRG<2000.0 and PTCH<2000.0) and PVMT>=2000.0 then
maj_hab='PVMT';
  else if (SPGR<2000.0 and LNRG<2000.0 and PTCH<2000.0 and PVMT<2000.0) and
   SCRS>=2000.0 then maj_hab='SCRS';
  else maj_hab='NONE';
  keep cellid maj_hab;
run;
/*proc print;
quit;*/
/*proc freq;
  tables maj_hab;
quit;*/
data g11;
  merge g10 mc3_20;
  by cellid;
  if maj_hab=maj_cat or maj_hab='NONE';
run;
/*proc print;
quit;*/
proc means nway noprint;
  class cellid;
  var habarea;
  output out=mc4 (drop=_type_ _freq_) max=maxarea;
quit;
data h4;
  merge g11 mc4;
  by cellid;
  if habarea=maxarea;
  hab=habcode;
  keep cellid hab;
run;
/*proc print;
quit;*/
/*proc freq;
  tables hab;
quit;*/
data h5;
  set o1 h1 h2 h3 h4;
run;
```

```
proc sort;
 by cellid;
quit;
/*proc freq;
 tables hab;
quit;*/
data rg1;
 infile 'c:\sgs\SEFCRI_RVC\SEFCRI_GIS\Grid100_cells_rug.txt';
 input cellid 1-7 rug$ 9;
run;
proc sort;
 by cellid;
quit;
data hr1;
 merge h5 rg1;
 by cellid;
 if rug='H' then rug_cat=1;
 else rug_cat=0;
run;
/*proc freq;
 tables hab*rug hab*rug_cat;
quit;*/
data hr2;
 set hr1;
 keep cellid hab rug_cat;
run;
/*dbf export file*/
/*proc export data=hr2
 outfile="c:\sgs\SEFCRI_RVC\SEFCRI_GIS\Grid100_habrug_rev.dbf"
 dbms=dbf replace;
quit;*/
```

Appendix A2: SAS program gridrug_sefcri_100m.sas

```
/*program gridrug_sefcri_100m.sas*/
/*programmer: S.G. Smith, RSMAS
/*processes 100m complexity sampling grid*/
/*composite hierarchy-majority area algorithm*/
options nodate nonumber;
proc import datafile="C:\sgs\SEFCRI_RVC\SEFCRI_GIS\Grid100_withSlope.dbf"
   out=g1 replace;
quit;
/*proc contents data=g1a;
quit;*/
/*proc freq;
  tables gridcode;
quit;
proc univariate plot;
  var area;
quit;*/
proc means nway noprint;
  class cellid gridcode;
  var area;
  output out=g2 (drop=_type_ _freq_) sum=rugarea;
quit;
/*proc means nway noprint;
  class cellid;
  var habarea hard;
  output out=g3 (drop=_type_ _freq_) n=ntypes sum=totarea n_hard;
quit;*/
/*proc sort;
  by gridcode;
quit;*/
/*proc univariate plot nobyplot;
  by gridcode;
  var rugarea;
quit;*/
/*proc chart;
  by gridcode;
  hbar rugarea/midpoints=25 to 9975 by 50;
quit;*/
proc transpose data=g2 out=g3;
  by cellid;
  var rugarea;
  id gridcode;
quit;
/*proc univariate plot;
  var cellid;
quit;*/
```

```
/*data ck1;
  set g3;
  if cellid<20000;
run;
proc print;
quit;*/
data g4;
  set g3;
  if _0=. then _0=0.0;
  else _0=_0;
  if _5=. then _5=0.0;
  else _5=_5;
  if _5=0.0 then rug='N';
  else if 0.0<_5<=100.0 then rug='L';
  else if 100.0<_5<=1000.0 then rug='M';
  else if _5>1000.0 then rug='H';
run;
/*proc freq;
  tables rug;
quit;*/
data rg1;
  set g4;
  file 'c:\sgs\SEFCRI_RVC\SEFCRI_GIS\Grid100_cells_rug.txt';
  put cellid 1-7 rug$ 9;
run;
```

Appendix A3: SAS program prp_broward.sas

```
/*program prp_broward.sas*/
/* Calculate frequency of occurrence for NSU Broward 1999-2002 fish surveys */
/*programmers: D. Bryan & S.G. Smith, RSMAS*/
/*proc import datafile='c:\users\david\documents\sefcri\Fleur_fish(no ar).csv'
   out=ff1 replace;
quit;
data ff2;
  set ff1;
  file 'c:\users\david\documents\sefcri\fffish_temp.txt';
  put samp$ 1-4 year 6-9 species$ 11-19 n 21-25 mean 27-29 min 31-33 max 35-37;
run;*/
data ff3;
  infile 'c:\users\david\documents\sefcri\fffish_temp.txt';
  input samp$ 1-4 year 6-9 species$ 11-19 n 21-25 mean 27-29 min 31-33 max 35-37;
run;
/*add-in zero obs per species*/
 proc means nway noprint;
  class samp species;
  var n;
  id year ;
  output out=z1 (drop=_type_ _freq_) sum=abund;
quit;
proc sort;
  by samp year species;
quit;
proc transpose data=z1 out=z2;
  by samp year;
  var abund;
  id species;
quit;
proc transpose out=z3;
  by samp year ;
quit;
data z4;
  set z3;
  sci_name=_name_;
  if abund=. then abund=0;
  else abund=abund;
  drop _name_;
run;
/* Get average percent occurrence for each year */
data fffish;
  set z4;
  if abund>0 then pres=1;
  else pres=0;
```

```
run;
proc means data=fffish noprint nway;
  class year sci_name;
  var pres;
  output out=fffish1 (drop=_type_ _freq_) n=n mean=avgpresyr;
quit;
/*proc print;
quit;*/
/* percent occurrence by species */
proc means data=fffish1 noprint nway;
  class sci_name;
  var avgpresyr;
  output out=fffish2 (drop=_type_ _freq_) n=n1 mean=avgpres min=minpres
max=maxpres
quit;
/*proc print;
quit;*/
```

Appendix A4: SAS program prp_wpalm.sas

```
/*program prp_wpalm.sas*/
/* Calculate frequency of occurrence for WP_DERM  fish surveys */
/*programmers: D. Bryan & S.G. Smith, RSMAS */
proc import datafile='c:\users\david\documents\sefcri\wpderm.csv'
   out=f1 replace;
quit;
/*proc contents data=f1;
quit;*/
data f2;
  set f1;
  file 'c:\users\david\documents\sefcri\wpderm_temp.txt';
  put location_name$ 1-20 year 22-25 site$ 27-51 last_name$ 53-61 sci_name$ 63-102
fish_count 104-108;
run;
data f3;
  infile 'c:\users\david\documents\sefcri\wpderm_temp.txt';
  input location_name$ 1-20 year 22-25 site$ 27-51 last_name$ 53-61 sci_name$ 63-102
fish_count 104-108;
run;
/*add-in zero obs per species*/
 proc means nway noprint;
  class site last_name sci_name;
  var fish_count;
  id location_name year ;
  output out=z1 (drop=_type_ _freq_) sum=abund;
quit;
proc sort;
  by site location_name year last_name;
quit;
proc transpose data=z1 out=z2;
  by site location_name year last_name;
  var abund;
  id sci_name;
quit;
proc transpose out=z3;
  by site location_name year last_name;
quit;
data z4;
  set z3;
  sci_name=_name_;
  if abund=. then abund=0;
  else abund=abund;
  drop _name_;
run;
/*proc print;
```

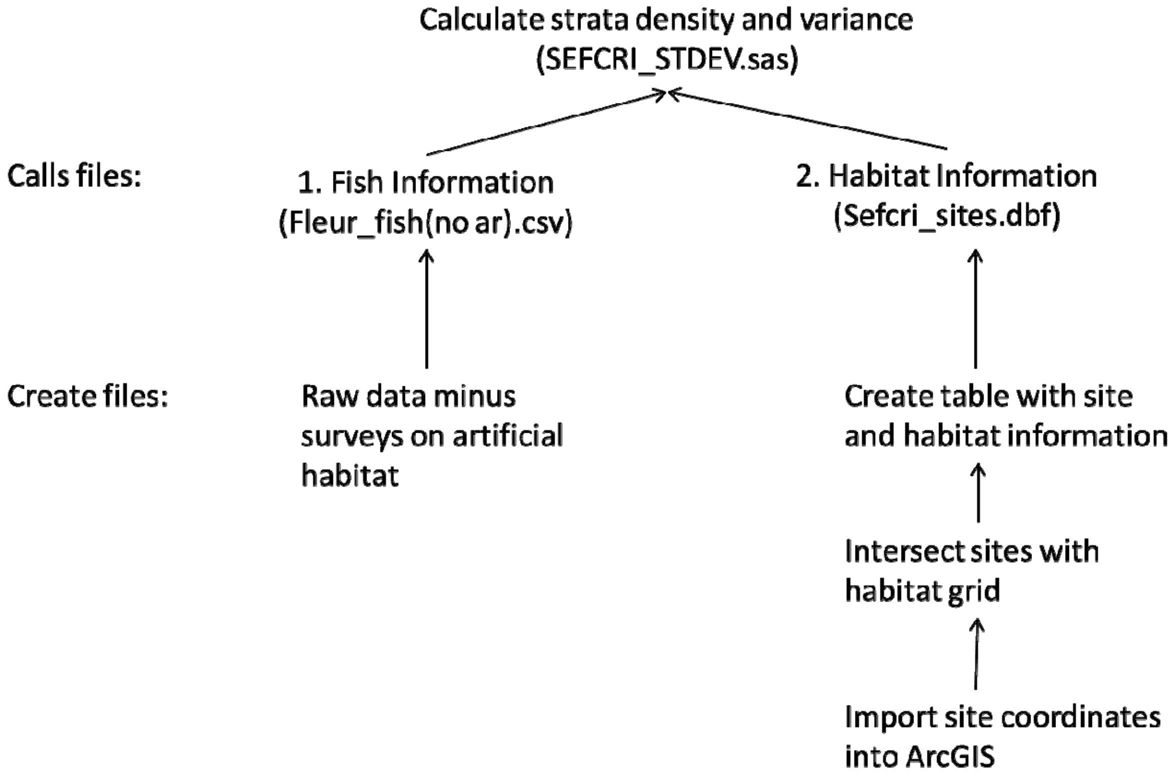
```
quit;*/
/* Get average percent occurence for each year at each site */
data derm;
 set z4;
 if abund>0 then pres=1;
 else pres=0;
run;
proc means data=derm noprint nway;
 class location_name year sci_name;
 var pres;
 output out=derm1 (drop=_type_ _freq_) n=n mean=avgpres;
quit;
/* Mean occurence per year */
proc means data=derm1 noprint nway;
 class year sci_name;
 var avgpres n;
 output out=derm2 (drop=_type_ _freq_) n=locn xy mean=avgpresyr xz sum=xx
divesum;
quit;
data derm3;
 set derm2;
 drop xy xz xx;
run;
/* percent occurence by species */
proc means data=derm2 noprint nway;
 class sci_name;
 var avgpresyr;
 output out=derm3 (drop=_type_ _freq_) n=n1 mean=avgpresderm min=minavgpres
max=maxavgpres
quit;
proc print;
quit;
```

Appendix A5: SAS program prp_martin.sas

```
/*program prp_martin.sas*/
/* Calculate frequency of occurrence for Martin fish surveys */
/*programmers: D. Bryan & S.G. Smith, RSMAS*/
/*proc import datafile='c:\users\david\documents\sefcri\martin.csv'
   out=ff1 replace;
quit;
data ff2;
  set ff1;
  file 'c:\users\david\documents\sefcri\martin_temp.txt';
  put samp$ 1-4 year 6-9 species$ 11-19 n 21-25 mean 27-29 min 31-33 max 35-37;
run;*/
data ff3;
  infile 'c:\users\david\documents\sefcri\martin_temp.txt';
  input samp$ 1-4 year 6-9 species$ 11-19 n 21-25 mean 27-29 min 31-33 max 35-37;
run;
/*add-in zero obs per species*/
 proc means nway noprint;
  class samp species;
  var n;
  id year ;
  output out=z1 (drop=_type_ _freq_) sum=abund;
quit;
proc sort;
  by samp year species;
quit;
proc transpose data=z1 out=z2;
  by samp year;
  var abund;
  id species;
quit;
proc transpose out=z3;
  by samp year ;
quit;
data z4;
  set z3;
  sci_name=_name_;
  if abund=. then abund=0;
  else abund=abund;
  drop _name_;
run;
/* Get average percent occurrence for each year */
data fffish;
  set z4;
  if abund>0 then pres=1;
  else pres=0;
```

```
run;
proc means data=fffish noprint nway;
  class year sci_name;
  var pres;
  output out=fffish1 (drop=_type_ _freq_) n=n mean=avgpresyr;
quit;
/*proc print;
quit;*/
/* percent occurrence by species */
proc means data=fffish1 noprint nway;
  class sci_name;
  var avgpresyr;
  output out=fffish2 (drop=_type_ _freq_) n=n1 mean=avgpres min=minpres
max=maxpres
quit;
/*proc print;
quit;*/
```

Appendix A6: Flow chart and SAS routines used during stratification scheme analysis.




```
/*program broward_dns.sas*/
/*calculate density and variance by strata for NSU Broward data 1999-2002*/
/* programmers: D. Bryan and S.G. Smith, RSMAS*/
/*proc import datafile='c:\users\david\documents\sefcri\Fleur_fish(no ar).csv'
   out=ff1 replace;
quit;
data ff2;
  set ff1;
  file 'c:\users\david\documents\sefcri\fffish_temp.txt';
  put samp$ 1-4 year 6-9 species$ 11-19 n 21-25 mean 27-29 min 31-33 max 35-37;
run;*/
data ff3;
  infile 'c:\users\david\documents\sefcri\fffish_temp.txt';
  input samp$ 1-4 year 6-9 species$ 11-19 n 21-25 mean 27-29 min 31-33 max 35-37;
run;
/* adding in length */
data ff4;
  set ff3;
  mastersampcd=samp;
  specnum=species;
  catch=n;
```

```
  meanlen=mean;
  minlen=min;
  maxlen=max;
  if catch=. then catch=0;
  else catch=catch;
  if meanlen=. then meanlen=0;
  else meanlen=meanlen;
  keep mastersampcd specnum catch meanlen minlen maxlen;
run;
data r1;
  set ff4;
  if meanlen=0;
  L3=-9;
  A3=catch;
  L1=.;
  A1=.;
  L2=.;
  A2=.;
  L4=.;
  A4=.;
  L5=.;
  A5=.;
  drop catch minlen meanlen maxlen;
run;
data r2;
  set ff4;
  if meanlen=0 then delete;
run;
data r3a;
  set r2;
  if catch=1;
  L3=meanlen;
  A3=catch;
  L1=.;
  A1=.;
  L2=.;
  A2=.;
  L4=.;
  A4=.;
  L5=.;
  A5=.;
  drop catch minlen meanlen maxlen;
run;
data r3b;
  set r2;
  if catch=2;
  L1=minlen;
```

```
  A1=1;
  L5=maxlen;
  A5=1;
  L2=.;
  A2=.;
  L4=.;
  A4=.;
  L3=.;
  A3=.;
  drop catch minlen meanlen maxlen;
run;
data r3c;
  set r2;
  if catch=3;
  L1=minlen;
  A1=1;
  L3=meanlen;
  A3=1;
  L5=maxlen;
  A5=1;
  L2=.;
  A2=.;
  L4=.;
  A4=.;
  drop catch minlen meanlen maxlen;
run;
data r3d;
  set r2;
  if catch=4;
  L1=minlen;
  A1=1;
  L3=meanlen;
  A3=2;
  L5=maxlen;
  A5=1;
  L2=.;
  A2=.;
  L4=.;
  A4=.;
  drop catch minlen meanlen maxlen;
run;
data r3e;
  set r2;
  if 5<=catch<=99;
  L1=minlen;
  A1=1;
  L3=meanlen;
```

```
  A3=0.5*catch;
  L5=maxlen;
  A5=1;
  L2=(L3+L1)/2;
  A2=(catch-(A1+A3+A5))/2;
  L4=(L3+L5)/2;
  A4=A2;
  drop catch minlen meanlen maxlen;
run;
data r3f;
  set r2;
  if catch>99;
  L1=minlen;
  A1=0.01*catch;
  L3=meanlen;
  A3=0.5*catch;
  L5=maxlen;
  A5=0.01*catch;
  L2=(L3+L1)/2;
  A2=(catch-(A1+A3+A5))/2;
  L4=(L3+L5)/2;
  A4=A2;
  drop catch minlen meanlen maxlen;
run;
/*proc print;
quit;*/
data r4;
  set r1 r3a r3b r3c r3d r3e r3f;
run;
/*proc print;
quit;*/
data r5a;
  set r4;
  if L1=. then delete;
  len=L1;
  abund=A1;
  keep mastersampcd specnum len abund;
run;
data r5b;
  set r4;
  if L2=. then delete;
  len=L2;
  abund=A2;
  keep mastersampcd specnum len abund;
run;
data r5c;
  set r4;
```

```
 if L3=. then delete;
 len=L3;
 abund=A3;
 keep mastersampcd specnum len abund;
run;
data r5d;
 set r4;
 if L4=. then delete;
 len=L4;
 abund=A4;
 keep mastersampcd specnum len abund;
run;
data r5e;
 set r4;
 if L5=. then delete;
 len=L5;
 abund=A5;
 keep mastersampcd specnum len abund;
run;
data r6;
 set r5a r5b r5c r5d r5e;
 abundance=abund;
 drop abund;
run;
proc sort;
 by mastersampcd specnum;
quit;
/*add-in zero obs per species*/
 proc means nway noprint;
 class mastersampcd specnum;
 var abundance;
 output out=z1 (drop=_type_ _freq_) sum=abund;
quit;
proc sort;
 by mastersampcd specnum;
quit;
proc transpose data=z1 out=z2;
 by mastersampcd;
 var abund;
 id specnum;
quit;
proc transpose out=z3;
 by mastersampcd ;
quit;
data z4;
 set z3;
 specnum=_NAME_;
```

```
  if abund=. then abund=0;
  else abund=abund;
  abundance=abund;
  if abundance=0;
  len=0;
  drop _NAME_ abund;
run;
data b5;
  set r6 z4;
  samp=mastersampcd;
  drop mastersampcd;
  sci_name=specnum;
  drop specnum;
run;
proc sort;
  by samp;
quit;
/* add in habitat data from GIS */
/*proc import datafile="c:\users\david\documents\sefcri\shapefiles\sefcri_sites.dbf"
  dbms=dbf out=h1 replace;
quit;
data h2;
  set h1;
  format depth 5.2;
  file 'c:\users\david\documents\sefcri\ffhab_temp.txt';
  put site$ 1-9 program$ 11-20 region$ 22-31 @33 depth hab$ 40-43 rug_cat 45-46;
run;*/
data h3;
  infile 'c:\users\david\documents\sefcri\ffhab_temp.txt';
  input site$ 1-9 program$ 11-20 region$ 22-31 depth 33-38 hab$ 40-43 rug_cat 45-46;
run;
data h4;
  set h3;
  samp=site;
  drop site;
run;
proc sort data=h4;
  by samp;
quit;
/* Merge fish data which habitat */
data a1;
  merge b5 h4;
  if len=. then delete;
  by samp;
run;
/* Key species and add juvenile and adult stages */
/* lengths at maturity from Ault et al 2005*/
```

```
data a2;
  set a1;
  if program='Nova_FLR';
  if sci_name='HAE_PLUM' or sci_name='EPI_MORI' or sci_name='HAE_SCIU' or
sci_name='LUT_ANAL' or sci_name='LAC_MAXI' or sci_name='OCY_CHRY';
  drop program;
 run;
data a3;
  set a2;
  if sci_name='HAE_PLUM' then LM=17.7;
  else if sci_name='EPI_MORI' then LM=43.7;
  else if sci_name='HAE_SCIU' then LM=20.5;
  else if sci_name='LUT_ANAL' then LM=27.9;
  else if sci_name='LAC_MAXI' then LM=16.6;
  else if sci_name='OCY_CHRY' then LM=19.9;
  else LM=100.0;
  if len<LM then jnum=abundance;
  else jnum=0;
  if len=0 or len>=LM then anum=abundance;
  else anum=0;
run;
/*proc print;
quit;*/
 proc means data=a3 noprint nway;
  class sci_name samp;
  var jnum anum;
  id Depth hab rug_cat;
  output out=a4 (drop=_type_ _freq_) sum=jabund aabund;
quit;
data a5;
  set a4;
  if sci_name='HAE_PLUM' then abund=aabund;
  else if sci_name='OCY_CHRY' then abund=aabund;
  else if sci_name='HAE_SCIU' then abund=aabund;
  else abund=aabund+jabund;
run;
/* Setting up some depth categories */
/*proc means data =a5 noprint nway;
  class samp;
  var abund;
  id Depth hab rug_cat;
  output out=d1 (drop=_type_ _freq_) n=num;
quit;*/
data d2;
  set a5;
  if -3.0<depth<=0.0 then depcat='D01';
  else if -6.0<depth<=-3.0 then depcat='D02';
```

```
  else if -9.0<depth<=-6.0 then depcat='D03';
  else if -12.0<depth<=-9.0 then depcat='D04';
  else if -15.0<depth<=-12.0 then depcat='D05';
  else if -18.0<depth<=-15.0 then depcat='D06';
  else if -21.0<depth<=-18.0 then depcat='D07';
  else if -24.0<depth<=-21.0 then depcat='D08';
  else if -27.0<depth<=-24.0 then depcat='D09';
  else if -30.0<depth<=-27.0 then depcat='D10';
  else if -33.0<depth<=-30.0 then depcat='D11';
  else depcat='U';
run;
data d3;
  set d2;
  if hab='DPRC' or hab='RGDP' or hab='SPGR' or hab='LIRO' or hab='CPDP' then
tract='OFF';
  else if hab='LIRM' or hab='LIRI' then tract='MID';
  else if hab='RGSH' or hab='CPSH' then tract='INS';
  else if hab='APRD' or hab='APRS' then tract='PAT';
  else tract='UNKN';
run;
data d4;
  set d3;
  if tract='OFF' and rug_cat=1 then strat='OFF1';
  else if tract='OFF' and rug_cat=0 then strat='OFF0';
  else if tract='MID' and rug_cat=1 then strat='MID1';
  else if tract='MID' and rug_cat=0 then strat='MID0';
  else if tract='INS' and rug_cat=1 then strat='INS1';
  else if tract='INS' and rug_cat=0 then strat='INS0';
  else if tract='PAT' and rug_cat=0 then strat='PAT0';
  else if tract='PAT' and rug_cat=1 then strat='PAT1';
  else strat='UNKN';
run;
/*proc freq;
  table depcat hab hab*depcat rug_cat*hab;
quit;*/
/* look at different strata options */
 proc means data=d4 noprint nway;
  class sci_name tract;
  var abund;
  output out=s (drop=_type_ _freq_) n=n mean=avdns var=svar;
quit;
data s1;
  set s;
  std=sqrt(svar);
run;
/*proc print;
quit;*/
```

Appendix B. List of PSUs selected for sampling for the 2012 reef-fish survey in the southeast Florida region.

siteid	strat	Subregion	hab	rug_ cat	Depth	CELLID _100m	lat_deg	lon_deg
001	1	Broward-Miami	SCRS	0	-8.7	351378	26.2243088	-80.0814848
002	1	Broward-Miami	APRD	0	-13.9	375975	26.1566145	-80.0850170
003	1	Broward-Miami	APRD	0	-14.0	377287	26.1530031	-80.0850452
004	1	Broward-Miami	APRD	0	-20.6	441900	25.9751580	-80.0894226
005	1	Broward-Miami	APRD	0	-17.1	518327	25.7647664	-80.0880425
006	2	Broward-Miami	APRD	1	-27.0	351720	26.2233157	-80.0674780
007	2	Broward-Miami	APRD	1	-28.0	381559	26.1412149	-80.0771343
008	2	Broward-Miami	APRD	1	-29.4	383855	26.1348950	-80.0771840
009	2	Broward-Miami	APRD	1	-27.8	386478	26.1276786	-80.0782409
010	2	Broward-Miami	APRD	1	-24.8	402873	26.0825676	-80.0835938
011	2	Broward-Miami	APRD	1	-24.6	456990	25.9336131	-80.0877451
012	2	Broward-Miami	APRD	1	-26.1	512425	25.7810061	-80.0859237
013	3	Broward-Miami	RGSH	0	-5.6	354651	26.2153250	-80.0885622
014	3	Broward-Miami	RGSH	0	-4.3	362847	26.1927791	-80.0927409
015	3	Broward-Miami	RGSH	0	-5.6	369736	26.1738130	-80.0918871
016	3	Broward-Miami	CPSH	0	-7.9	375309	26.1584834	-80.0950073
017	3	Broward-Miami	CPSH	0	-5.5	385143	26.1314353	-80.1012175
018	3	Broward-Miami	RGSH	0	-7.1	385807	26.1295795	-80.0932297
019	3	Broward-Miami	CPSH	0	-4.6	387439	26.1251153	-80.1012659
020	3	Broward-Miami	CPSH	0	-4.9	389734	26.1188015	-80.1023143
021	3	Broward-Miami	CPSH	0	-7.5	392362	26.1115537	-80.0983693
022	3	Broward-Miami	CPSH	0	-4.1	394981	26.1043620	-80.1034246
023	3	Broward-Miami	CPSH	0	-5.9	404494	26.0781727	-80.1026244
024	3	Broward-Miami	CPSH	0	-6.7	405478	26.0754641	-80.1026451
025	3	Broward-Miami	CPSH	0	-6.0	409738	26.0637516	-80.1067331
026	3	Broward-Miami	CPSH	0	-2.7	425476	26.0204508	-80.1130571
027	3	Broward-Miami	CPSH	0	-5.0	425477	26.0204446	-80.1120578
028	3	Broward-Miami	CPSH	0	-7.4	427774	26.0141184	-80.1111061
029	3	Broward-Miami	CPSH	0	-6.0	431053	26.0050957	-80.1121733
030	3	Broward-Miami	CPSH	0	-9.0	433685	25.9978234	-80.1042349
031	3	Broward-Miami	CPSH	0	-7.0	436957	25.9888439	-80.1122954
032	3	Broward-Miami	CPSH	0	-6.8	438268	25.9852386	-80.1133215
033	3	Broward-Miami	CPSH	0	-6.5	440235	25.9798274	-80.1143611
034	3	Broward-Miami	CPSH	0	-3.4	440889	25.9780338	-80.1163724
035	3	Broward-Miami	CPSH	0	-9.5	441554	25.9761729	-80.1073958
036	3	Broward-Miami	RGSH	0	-6.3	442864	25.9725737	-80.1094208
037	3	Broward-Miami	RGSH	0	-6.2	443848	25.9698651	-80.1094412
038	3	Broward-Miami	RGSH	0	-8.3	444505	25.9680531	-80.1084560
039	3	Broward-Miami	CPSH	0	-9.3	448443	25.9572063	-80.1065402

040	3	Broward-Miami	RGSH	0	-5.2	452049	25.9472869	-80.1086124
041	3	Broward-Miami	CPSH	0	-10.3	452708	25.9454626	-80.1056301
042	3	Broward-Miami	CPSH	0	-10.8	453364	25.9436569	-80.1056438
043	3	Broward-Miami	RGSH	0	-7.5	454674	25.9400577	-80.1076682
044	3	Broward-Miami	RGSH	0	-6.1	457952	25.9310411	-80.1097333
045	3	Broward-Miami	RGSH	0	-5.8	461233	25.9220061	-80.1088027
046	3	Broward-Miami	CPSH	0	-6.9	462215	25.9193097	-80.1108199
047	3	Broward-Miami	CPSH	0	-6.6	463198	25.9166072	-80.1118386
048	3	Broward-Miami	RGSH	0	-7.5	468124	25.9030270	-80.1059503
049	3	Broward-Miami	CPSH	0	-10.0	468454	25.9021118	-80.1039606
050	3	Broward-Miami	RGSH	0	-9.5	474358	25.8858598	-80.1040833
051	3	Broward-Miami	RGSH	0	-7.1	480588	25.8687172	-80.1062087
052	3	Broward-Miami	RGSH	0	-5.8	481570	25.8660208	-80.1082250
053	3	Broward-Miami	RGSH	0	-6.8	494690	25.8299050	-80.1084959
054	3	Broward-Miami	RGSH	0	-5.8	497638	25.8218034	-80.1125471
055	3	Broward-Miami	RGSH	0	-7.1	498958	25.8181428	-80.1045935
056	3	Broward-Miami	RGSH	0	-6.5	506172	25.7982913	-80.1067376
057	3	Broward-Miami	RGSH	0	-5.4	510751	25.7857297	-80.1197972
058	3	Broward-Miami	RGSH	0	-5.6	510752	25.7857237	-80.1187999
059	3	Broward-Miami	CPSH	0	-8.5	511089	25.7847661	-80.1098310
060	3	Broward-Miami	RGSH	0	-8.9	512411	25.7810931	-80.0998853
061	3	Broward-Miami	RGSH	0	-7.0	513046	25.7794154	-80.1208411
062	3	Broward-Miami	RGSH	0	-8.1	514050	25.7765848	-80.1009166
063	4	Broward-Miami	RGSH	1	-7.2	350065	26.2279266	-80.0824574
064	4	Broward-Miami	RGSH	1	-5.0	371379	26.1692798	-80.0889205
065	4	Broward-Miami	RGSH	1	-7.6	373014	26.1647971	-80.0939581
066	4	Broward-Miami	RGSH	1	-5.2	374658	26.1602576	-80.0899911
067	4	Broward-Miami	RGSH	1	-6.8	387118	26.1259743	-80.0942578
068	4	Broward-Miami	RGSH	1	-5.9	410723	26.0610368	-80.1057540
069	4	Broward-Miami	RGSH	1	-7.9	464188	25.9138617	-80.1058686
070	5	Broward-Miami	LIRM	0	-13.2	355973	26.2116498	-80.0785813
071	5	Broward-Miami	LIRM	0	-14.0	364171	26.1890915	-80.0807604
072	5	Broward-Miami	LIRI	0	-10.7	369086	26.1755807	-80.0858696
073	5	Broward-Miami	LIRM	0	-22.5	385817	26.1295162	-80.0832277
074	5	Broward-Miami	LIRM	0	-16.0	389422	26.1196038	-80.0863056
075	5	Broward-Miami	LIRI	0	-11.4	392040	26.1124189	-80.0923621
076	5	Broward-Miami	LIRI	0	-10.5	395975	26.1015909	-80.0934457
077	5	Broward-Miami	LIRI	0	-12.4	399582	26.0916657	-80.0945221
078	5	Broward-Miami	LIRI	0	-13.8	402207	26.0844365	-80.0935779
079	5	Broward-Miami	LIRI	0	-12.0	412044	26.0573694	-80.0967852
080	5	Broward-Miami	LIRM	0	-12.7	416966	26.0438139	-80.0948900
081	5	Broward-Miami	LIRI	0	-8.8	417289	26.0429422	-80.0998943
082	5	Broward-Miami	LIRM	0	-13.0	419918	26.0356880	-80.0949524

083	5	Broward-Miami	LIRM	0	-12.7	425493	26.0203455	-80.0960694
084	5	Broward-Miami	LIRI	0	-12.6	428442	26.0122384	-80.0991293
085	5	Broward-Miami	LIRM	0	-18.9	429102	26.0104077	-80.0951463
086	5	Broward-Miami	LIRM	0	-14.4	432053	26.0022881	-80.0962077
087	5	Broward-Miami	LIRM	0	-12.0	433035	25.9995919	-80.0982266
088	5	Broward-Miami	LIRM	0	-12.4	434675	25.9950776	-80.0982611
089	5	Broward-Miami	LIRI	0	-10.8	439593	25.9815469	-80.1003623
090	5	Broward-Miami	LIRI	0	-10.6	439921	25.9806440	-80.1003692
091	5	Broward-Miami	LIRM	0	-15.6	440582	25.9788071	-80.0953883
092	5	Broward-Miami	LIRM	0	-18.2	443536	25.9706687	-80.0934528
093	5	Broward-Miami	LIRM	0	-13.9	445829	25.9643673	-80.0964976
094	5	Broward-Miami	LIRM	0	-13.4	447140	25.9607620	-80.0975240
095	5	Broward-Miami	LIRI	0	-8.2	450415	25.9517643	-80.1025863
096	5	Broward-Miami	LIRM	0	-15.8	458624	25.9291363	-80.0937708
097	5	Broward-Miami	LIRM	0	-15.6	466166	25.9083825	-80.0959262
098	5	Broward-Miami	LIRI	0	-9.3	466814	25.9066263	-80.1039265
099	5	Broward-Miami	LIRI	0	-6.7	479605	25.8714197	-80.1051903
100	5	Broward-Miami	LIRM	0	-19.7	485851	25.8541780	-80.0913493
101	5	Broward-Miami	LIRI	0	-10.6	493386	25.8334674	-80.1004872
102	5	Broward-Miami	LIRM	0	-17.6	496020	25.8261821	-80.0905654
103	5	Broward-Miami	LIRM	0	-14.9	507498	25.7945933	-80.0928015
104	5	Broward-Miami	LIRM	0	-13.8	508809	25.7909879	-80.0938263
105	5	Broward-Miami	LIRI	0	-9.5	513397	25.7783721	-80.0979113
106	6	Broward-Miami	LIRM	1	-18.8	351056	26.2251731	-80.0754716
107	6	Broward-Miami	LIRI	1	-9.2	354002	26.2170861	-80.0815415
108	6	Broward-Miami	LIRI	1	-7.4	383841	26.1349840	-80.0911874
109	6	Broward-Miami	LIRM	1	-20.2	383849	26.1349333	-80.0831854
110	6	Broward-Miami	LIRM	1	-13.9	398600	26.0943617	-80.0925015
111	6	Broward-Miami	LIRI	1	-9.6	408764	26.0663980	-80.0967159
112	6	Broward-Miami	LIRM	1	-14.3	408768	26.0663730	-80.0927173
113	6	Broward-Miami	LIRM	1	-20.3	413033	26.0546294	-80.0918081
114	6	Broward-Miami	LIRI	1	-9.1	419586	26.0366159	-80.0989431
115	6	Broward-Miami	LIRM	1	-15.9	420247	26.0347789	-80.0939599
116	6	Broward-Miami	LIRI	1	-9.7	424506	26.0230728	-80.0990466
117	6	Broward-Miami	LIRM	1	-16.1	428118	26.0131163	-80.0951255
118	6	Broward-Miami	LIRM	1	-17.8	451736	25.9480968	-80.0936257
119	6	Broward-Miami	LIRM	1	-17.6	460921	25.9228099	-80.0928207
120	6	Broward-Miami	LIRI	1	-11.8	475674	25.8822236	-80.1001181
121	6	Broward-Miami	LIRI	1	-7.5	478950	25.8732194	-80.1041787
122	6	Broward-Miami	LIRM	1	-24.9	492083	25.8370231	-80.0914804
123	6	Broward-Miami	LIRM	1	-20.7	492739	25.8352173	-80.0914942
124	7	Broward-Miami	CPDP	0	-20.2	350405	26.2269465	-80.0704522
125	7	Broward-Miami	RGDP	0	-31.7	352377	26.2215036	-80.0664914

126	7	Broward-Miami	RGDP	0	-29.4	399595	26.0915835	-80.0815238
127	7	Broward-Miami	RGDP	0	-28.6	402218	26.0843670	-80.0825800
128	7	Broward-Miami	CPDP	0	-12.8	424180	26.0239632	-80.0970411
129	7	Broward-Miami	CPDP	0	-18.5	427139	26.0157936	-80.0901086
130	7	Broward-Miami	CPDP	0	-20.1	431400	26.0040751	-80.0931965
131	7	Broward-Miami	CPDP	0	-12.2	432050	26.0023068	-80.0992050
132	7	Broward-Miami	RGDP	0	-25.7	435670	25.9923000	-80.0872924
133	7	Broward-Miami	RGDP	0	-29.3	464536	25.9128343	-80.0859082
134	7	Broward-Miami	RGDP	0	-32.4	476344	25.8803305	-80.0861586
135	7	Broward-Miami	CPDP	0	-16.8	492077	25.8370604	-80.0974667
136	7	Broward-Miami	LIRO	0	-18.8	508160	25.7927500	-80.0868311
137	8	Broward-Miami	SPGR	1	-22.7	346801	26.2368518	-80.0663688
138	8	Broward-Miami	LIRO	1	-16.8	349750	26.2287457	-80.0694368
139	8	Broward-Miami	SPGR	1	-19.2	374999	26.1592719	-80.0769923
140	8	Broward-Miami	SPGR	1	-21.1	380246	26.1448328	-80.0781062
141	8	Broward-Miami	SPGR	1	-22.6	381558	26.1412214	-80.0781346
142	8	Broward-Miami	SPGR	1	-19.7	400577	26.0888876	-80.0835446
143	8	Broward-Miami	SPGR	1	-17.6	409759	26.0636202	-80.0857407
144	8	Broward-Miami	RGDP	1	-30.0	409761	26.0636075	-80.0837414
145	8	Broward-Miami	SPGR	1	-26.8	413696	26.0527795	-80.0848252
146	8	Broward-Miami	LIRO	1	-15.4	421893	26.0302269	-80.0879985
147	8	Broward-Miami	CPDP	1	-19.1	422875	26.0275308	-80.0900181
148	8	Broward-Miami	LIRO	1	-16.6	426157	26.0184896	-80.0880892
149	8	Broward-Miami	SPGR	1	-19.4	429438	26.0094546	-80.0871598
150	8	Broward-Miami	RGDP	1	-31.5	444199	25.9688190	-80.0864748
151	8	Broward-Miami	SPGR	1	-17.7	459941	25.9254935	-80.0888061
152	8	Broward-Miami	CPDP	1	-18.9	466829	25.9065329	-80.0889518
153	8	Broward-Miami	SPGR	1	-22.8	467487	25.9047146	-80.0869691
154	8	Broward-Miami	LIRO	1	-20.2	479293	25.8722233	-80.0892152
155	8	Broward-Miami	SPGR	1	-25.1	483231	25.8613761	-80.0873024
156	8	Broward-Miami	LIRO	1	-17.4	483886	25.8595766	-80.0883141
157	8	Broward-Miami	RGDP	1	-31.4	498649	25.8189277	-80.0856328
158	8	Broward-Miami	LIRO	1	-23.8	507177	25.7954524	-80.0858129
159	9	Deerfield	APRD	0	-24.0	293678	26.3830240	-80.0521652
160	9	Deerfield	APRD	0	-28.4	304829	26.3523349	-80.0534177
161	9	Deerfield	APRD	0	-29.3	305813	26.3496264	-80.0534397
162	9	Deerfield	APRD	0	-22.3	316632	26.3198663	-80.0586911
163	9	Deerfield	APRD	0	-25.5	333357	26.2738419	-80.0620671
164	10	Deerfield	APRD	1	-24.2	294006	26.3821212	-80.0521726
165	10	Deerfield	APRD	1	-28.9	314011	26.3270692	-80.0556271
166	10	Deerfield	APRD	1	-30.5	314995	26.3243607	-80.0556490
167	10	Deerfield	APRD	1	-27.5	315978	26.3216588	-80.0566728
168	10	Deerfield	APRD	1	-30.5	319586	26.3117278	-80.0567533

169	10	Deerfield	APRD	1	-27.8	324832	26.2972957	-80.0588735
170	10	Deerfield	APRD	1	-30.7	334998	26.2693212	-80.0611020
171	11	Deerfield	CPSH	0	-1.7	315961	26.3217699	-80.0737040
172	11	Deerfield	RGSH	0	-4.3	320553	26.3091303	-80.0738046
173	11	Deerfield	CPSH	0	-2.7	321208	26.3073311	-80.0748206
174	11	Deerfield	RGSH	0	-5.0	321865	26.3055190	-80.0738333
175	11	Deerfield	RGSH	0	-4.6	324488	26.2983028	-80.0748923
176	11	Deerfield	CPSH	0	-5.8	327112	26.2910801	-80.0749496
177	11	Deerfield	CPSH	0	-8.4	337279	26.2630988	-80.0761728
178	12	Deerfield	LIRM	0	-9.5	293997	26.3821807	-80.0611938
179	12	Deerfield	LIRM	0	-10.2	311377	26.3343574	-80.0655879
180	12	Deerfield	LIRM	0	-8.9	312360	26.3316555	-80.0666116
181	12	Deerfield	LIRM	0	-11.7	317607	26.3172168	-80.0677292
182	12	Deerfield	LIRM	0	-22.7	334990	26.2693733	-80.0691131
183	13	Deerfield	LIRM	1	-21.6	319906	26.3108774	-80.0647745
184	13	Deerfield	LIRM	1	-21.9	325480	26.2955424	-80.0669009
185	13	Deerfield	LIRM	1	-22.7	326136	26.2937367	-80.0669154
186	13	Deerfield	LIRM	1	-22.6	326464	26.2928339	-80.0669226
187	13	Deerfield	LIRM	1	-20.4	330726	26.2811101	-80.0690195
188	13	Deerfield	LIRM	1	-15.2	332365	26.2766025	-80.0700569
189	13	Deerfield	LIRM	1	-20.8	337285	26.2630600	-80.0701648
190	14	Deerfield	RGDP	0	-28.5	295319	26.3785033	-80.0511997
191	14	Deerfield	RGDP	0	-32.0	303191	26.3568357	-80.0513767
192	14	Deerfield	RGDP	0	-31.3	304830	26.3523283	-80.0524156
193	14	Deerfield	RGDP	0	-32.6	310077	26.3378898	-80.0535352
194	14	Deerfield	LIRO	0	-20.1	331715	26.2783691	-80.0640338
195	15	Deerfield	LIRO	1	-16.9	291381	26.3893503	-80.0531160
196	15	Deerfield	LIRO	1	-16.6	307122	26.3460350	-80.0564752
197	15	Deerfield	LIRO	1	-18.9	308433	26.3424303	-80.0575065
198	15	Deerfield	LIRO	1	-17.1	310401	26.3370134	-80.0575504
199	15	Deerfield	SPGR	1	-21.1	313681	26.3279852	-80.0576235
200	15	Deerfield	SPGR	1	-20.3	318272	26.3153522	-80.0587276
201	15	Deerfield	SPGR	1	-24.1	325159	26.2963995	-80.0598824
202	15	Deerfield	LIRO	1	-16.8	336307	26.2657294	-80.0641351
203	16	South Palm Beach	APRD	0	-23.1	194325	26.6563597	-80.0187696
204	16	South Palm Beach	APRD	0	-14.6	227116	26.5661440	-80.0285753
205	16	South Palm Beach	APRD	0	-28.0	227448	26.5652137	-80.0245672
206	16	South Palm Beach	PTCH	0	-18.8	232035	26.5526090	-80.0296933
207	16	South Palm Beach	APRD	0	-24.8	266462	26.4579037	-80.0435283
208	17	South Palm Beach	APRD	1	-22.6	196621	26.6500403	-80.0188237
209	17	South Palm Beach	APRD	1	-14.3	226133	26.5688455	-80.0275485
210	17	South Palm Beach	APRD	1	-19.6	226790	26.5670330	-80.0265598
211	17	South Palm Beach	APRD	1	-19.0	229085	26.5607204	-80.0276171

212	17	South Palm Beach	APRD	1	-30.5	254334	26.4912533	-80.0352257
213	17	South Palm Beach	APRD	1	-27.0	276955	26.4290340	-80.0467752
214	17	South Palm Beach	APRD	1	-26.9	287448	26.4001642	-80.0500201
215	18	South Palm Beach	RGSH	0	-3.7	172993	26.7151224	-80.0303300
216	18	South Palm Beach	RGSH	0	-4.9	178242	26.7006713	-80.0294472
217	18	South Palm Beach	RGSH	0	-3.4	179225	26.6979699	-80.0304752
218	18	South Palm Beach	RGSH	0	-5.1	179882	26.6961575	-80.0294854
219	18	South Palm Beach	RGSH	0	-3.1	182504	26.6889490	-80.0315566
220	18	South Palm Beach	RGSH	0	-4.7	184472	26.6835324	-80.0316024
221	18	South Palm Beach	CPSH	0	-3.4	195620	26.6528655	-80.0358804
222	19	South Palm Beach	CPDP	0	-17.8	176286	26.7060049	-80.0173393
223	19	South Palm Beach	LIRO	0	-15.7	205472	26.6257000	-80.0240542
224	19	South Palm Beach	RGDP	0	-22.5	211050	26.6103390	-80.0221759
225	19	South Palm Beach	RGDP	0	-24.5	213346	26.6040195	-80.0222296
226	19	South Palm Beach	LIRO	0	-12.9	218590	26.5896026	-80.0263689
227	19	South Palm Beach	CPDP	0	-14.1	226460	26.5679495	-80.0285601
228	19	South Palm Beach	RGDP	0	-21.8	240562	26.5291433	-80.0308944
229	19	South Palm Beach	LIRO	0	-19.7	278919	26.4236439	-80.0508306
230	20	South Palm Beach	RGDP	1	-26.2	176945	26.7041785	-80.0143394
231	20	South Palm Beach	SPGR	1	-19.6	178911	26.6987758	-80.0163962
232	20	South Palm Beach	LIRO	1	-18.6	208098	26.6184640	-80.0221068
233	20	South Palm Beach	RGDP	1	-30.3	210068	26.6130335	-80.0201441
234	20	South Palm Beach	RGDP	1	-23.7	226791	26.5670262	-80.0255558
235	20	South Palm Beach	LIRO	1	-21.3	238923	26.5336505	-80.0298528
236	20	South Palm Beach	RGDP	1	-25.7	239252	26.5327408	-80.0288567
237	20	South Palm Beach	LIRO	1	-18.8	242201	26.5246362	-80.0319359
238	20	South Palm Beach	LIRO	1	-15.3	243841	26.5201223	-80.0319737
239	20	South Palm Beach	LIRO	1	-18.7	248103	26.5083996	-80.0340790
240	20	South Palm Beach	SPGR	1	-25.1	261872	26.4705294	-80.0414176
241	20	South Palm Beach	SPGR	1	-21.4	270068	26.4479863	-80.0456162
242	20	South Palm Beach	LIRO	1	-16.8	272362	26.4416800	-80.0476740
243	20	South Palm Beach	SPGR	1	-22.4	283512	26.4109979	-80.0499314
244	21	North Palm Beach	PTCH	0	-16.9	84079	26.9599458	-80.0544365
245	21	North Palm Beach	PTCH	0	-26.2	132662	26.8260715	-80.0163056
246	21	North Palm Beach	PTCH	0	-25.5	132990	26.8251687	-80.0163134
247	21	North Palm Beach	PTCH	0	-22.0	165461	26.7358030	-80.0180888
248	21	North Palm Beach	PTCH	0	-18.4	171036	26.7204630	-80.0192259
249	22	North Palm Beach	RGSH	0	-1.4	157899	26.7566907	-80.0360114
250	22	North Palm Beach	RGSH	0	-2.8	166430	26.7331983	-80.0331931
251	22	North Palm Beach	RGSH	0	-2.5	166758	26.7322956	-80.0332007
252	22	North Palm Beach	CPSH	0	-7.2	167088	26.7313791	-80.0311976
253	22	North Palm Beach	RGSH	0	-3.6	168399	26.7277749	-80.0322335
254	22	North Palm Beach	RGSH	0	-3.1	169711	26.7241638	-80.0322641

255	22	North Palm Beach	RGSH	0	-3.5	171680	26.7187404	-80.0313046
256	23	North Palm Beach	DPRC	0	-20.7	83774	26.9606913	-80.0312583
257	23	North Palm Beach	DPRC	0	-31.6	86103	26.9541399	-79.9980697
258	23	North Palm Beach	DPRC	0	-24.7	88389	26.9478920	-80.0081986
259	23	North Palm Beach	DPRC	0	-20.6	90016	26.9434698	-80.0213324
260	23	North Palm Beach	DPRC	0	-21.6	92633	26.9362966	-80.0284451
261	23	North Palm Beach	DPRC	0	-22.4	92953	26.9354491	-80.0365104
262	23	North Palm Beach	DPRC	0	-22.3	93280	26.9345533	-80.0375253
263	23	North Palm Beach	DPRC	0	-25.0	93639	26.9334341	-80.0063106
264	23	North Palm Beach	DPRC	0	-23.2	94597	26.9309079	-80.0325202
265	23	North Palm Beach	DPRC	0	-23.2	95253	26.9291024	-80.0325356
266	23	North Palm Beach	DPRC	0	-23.0	97221	26.9236860	-80.0325818
267	23	North Palm Beach	DPRC	0	-21.8	97544	26.9228176	-80.0376249
268	23	North Palm Beach	DPRC	0	-22.6	98550	26.9199566	-80.0154927
269	23	North Palm Beach	DPRC	0	-24.8	102822	26.9081647	-80.0075390
270	23	North Palm Beach	DPRC	0	-25.1	102824	26.9081505	-80.0055251
271	23	North Palm Beach	DPRC	0	-29.0	103487	26.9062952	-79.9984924
272	23	North Palm Beach	DPRC	0	-23.0	104769	26.9028953	-80.0287312
273	23	North Palm Beach	DPRC	0	-32.7	105462	26.9008287	-79.9914921
274	23	North Palm Beach	DPRC	0	-32.3	106449	26.8980989	-79.9884956
275	23	North Palm Beach	DPRC	0	-22.6	107063	26.8965899	-80.0307989
276	23	North Palm Beach	DPRC	0	-32.3	107432	26.8953979	-79.9895266
277	23	North Palm Beach	DPRC	0	-23.8	107740	26.8946378	-80.0096710
278	23	North Palm Beach	DPRC	0	-21.8	108063	26.8937702	-80.0147129
279	23	North Palm Beach	DPRC	0	-30.1	108411	26.8927256	-79.9945847
280	23	North Palm Beach	DPRC	0	-31.5	108744	26.8917869	-79.9895587
281	23	North Palm Beach	DPRC	0	-26.6	109058	26.8909843	-80.0036617
282	23	North Palm Beach	DPRC	0	-29.6	110379	26.8873092	-79.9946326
283	23	North Palm Beach	DPRC	0	-30.0	111692	26.8836911	-79.9936579
284	23	North Palm Beach	DPRC	0	-25.2	112012	26.8828455	-80.0017196
285	23	North Palm Beach	DPRC	0	-23.2	112329	26.8820206	-80.0128013
286	23	North Palm Beach	DPRC	0	-30.5	112677	26.8809757	-79.9926752
287	23	North Palm Beach	DPRC	0	-27.2	114287	26.8766741	-80.0229150
288	23	North Palm Beach	DPRC	0	-24.1	115613	26.8729650	-80.0088532
289	23	North Palm Beach	DPRC	0	-23.0	115931	26.8721325	-80.0189273
290	23	North Palm Beach	DPRC	0	-30.9	116285	26.8710456	-79.9927632
291	23	North Palm Beach	DPRC	0	-25.7	117916	26.8665962	-80.0018623
292	23	North Palm Beach	DPRC	0	-32.9	117931	26.8664888	-79.9867638
293	23	North Palm Beach	DPRC	0	-29.1	120545	26.8593387	-79.9968931
294	23	North Palm Beach	DPRC	0	-26.5	123822	26.8503327	-79.9999920
295	23	North Palm Beach	DPRC	0	-32.9	124159	26.8493656	-79.9909422
296	23	North Palm Beach	DPRC	0	-24.4	131349	26.8296894	-80.0172806
297	23	North Palm Beach	DPRC	0	-31.5	133992	26.8223334	-79.9982255

298	23	North Palm Beach	DPRC	0	-23.8	135944	26.8170300	-80.0143712
299	23	North Palm Beach	DPRC	0	-25.5	146773	26.7872041	-80.0095994
300	23	North Palm Beach	DPRC	0	-27.1	153663	26.7682322	-80.0077525
301	23	North Palm Beach	DPRC	0	-27.8	153664	26.7682252	-80.0067467
302	23	North Palm Beach	DPRC	0	-26.4	154974	26.7646283	-80.0087895
303	23	North Palm Beach	DPRC	0	-22.8	159891	26.7511080	-80.0119237
304	23	North Palm Beach	DPRC	0	-26.0	160876	26.7483927	-80.0109415
305	23	North Palm Beach	DPRC	0	-28.8	163501	26.7411637	-80.0099986
306	24	North Palm Beach	DPRC	1	-20.6	89031	26.9461850	-80.0223163
307	24	North Palm Beach	DPRC	1	-21.7	91000	26.9407616	-80.0213558
308	24	North Palm Beach	DPRC	1	-24.8	105434	26.9010272	-80.0196847
309	24	North Palm Beach	DPRC	1	-25.6	114289	26.8766601	-80.0209017
310	24	North Palm Beach	DPRC	1	-23.8	115602	26.8730422	-80.0199262
311	24	North Palm Beach	DPRC	1	-26.4	117240	26.8685424	-80.0219783
312	24	North Palm Beach	DPRC	1	-24.6	130693	26.8314949	-80.0172650
313	24	North Palm Beach	DPRC	1	-31.4	136939	26.8142442	-80.0033274
314	24	North Palm Beach	DPRC	1	-23.8	161530	26.7466012	-80.0129682
315	25	Martin	APRS	0	-5.6	20033	27.1365366	-80.1397341
316	25	Martin	APRS	0	-5.9	34479	27.0967288	-80.1259166
317	25	Martin	APRD	0	-23.6	37852	27.0870869	-80.0321906
318	25	Martin	APRD	0	-18.1	64715	27.0132881	-80.0660859
319	25	Martin	APRD	0	-17.2	68322	27.0033646	-80.0671757
320	26	Martin	RGSH	0	-2.9	5915	27.1754403	-80.1535678
321	26	Martin	RGSH	0	-4.1	7228	27.1718233	-80.1525857
322	26	Martin	RGSH	0	-5.0	16423	27.1464791	-80.1416763
323	26	Martin	RGSH	0	-4.8	17407	27.1437709	-80.1416970
324	26	Martin	RGSH	0	-13.4	21367	27.1327879	-80.1175642
325	26	Martin	RGSH	0	-13.6	21368	27.1327816	-80.1165552
326	26	Martin	CPSH	0	-5.2	22327	27.1302298	-80.1418004
327	26	Martin	RGSH	0	-9.5	22996	27.1283435	-80.1286979
328	26	Martin	CPSH	0	-8.4	28569	27.1130157	-80.1318432
329	26	Martin	CPSH	0	-7.4	29885	27.1093798	-80.1278360
330	26	Martin	CPSH	0	-9.8	32513	27.1021327	-80.1238572
331	26	Martin	RGSH	0	-5.2	39077	27.0840527	-80.1199635
332	27	Martin	RGSH	1	-5.6	18065	27.1419531	-80.1396927
333	27	Martin	RGSH	1	-6.2	24635	27.1238361	-80.1297418
334	27	Martin	RGSH	1	-11.7	25293	27.1220181	-80.1277380
335	27	Martin	CPSH	1	-7.0	25939	27.1202749	-80.1378407
336	27	Martin	CPSH	1	-5.1	27251	27.1166640	-80.1378684
337	27	Martin	CPSH	1	-5.3	28565	27.1130406	-80.1358785
338	27	Martin	CPSH	1	-9.7	33496	27.0994308	-80.1248869
339	28	Martin	RGDP	0	-24.5	8324	27.1683867	-80.0395651
340	28	Martin	RGDP	0	-24.7	10292	27.1629704	-80.0396115

341	28	Martin	RGDP	0	-23.1	40478	27.0798513	-80.0302357
342	28	Martin	RGDP	0	-22.3	44402	27.0691015	-80.0424296
343	28	Martin	RGDP	0	-23.7	53599	27.0437355	-80.0295381
344	28	Martin	RGDP	0	-23.7	54913	27.0401106	-80.0275529
345	28	Martin	RGDP	0	-20.2	57195	27.0338884	-80.0417203
346	28	Martin	RGDP	0	-24.6	57212	27.0337706	-80.0245832
347	28	Martin	RGDP	0	-22.8	58851	27.0292640	-80.0256302
348	28	Martin	RGDP	0	-18.3	66354	27.0087811	-80.0671310
349	28	Martin	DPRC	0	-31.5	73959	26.9875978	-80.0058352
350	28	Martin	DPRC	0	-19.6	75909	26.9823082	-80.0240196
351	28	Martin	DPRC	0	-22.8	76247	26.9813354	-80.0139515
352	28	Martin	DPRC	0	-26.8	77565	26.9776820	-80.0079376
353	28	Martin	DPRC	0	-23.9	78217	26.9759049	-80.0119836
354	29	Martin	RGDP	1	-23.1	35883	27.0925102	-80.0331527
355	29	Martin	RGDP	1	-24.2	48018	27.0591164	-80.0344475
356	29	Martin	RGDP	1	-24.3	48674	27.0573110	-80.0344630
357	29	Martin	RGDP	1	-24.9	49002	27.0564083	-80.0344707
358	29	Martin	RGDP	1	-23.1	50972	27.0509781	-80.0325007
359	29	Martin	RGDP	1	-25.1	53601	27.0437215	-80.0275218
360	29	Martin	DPRC	1	-22.7	70997	26.9957931	-80.0158410