

Vessel Use in the Florida Keys National Marine Sanctuary



PREPARED BY THE

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Vessel Use in the Florida Keys National Marine Sanctuary

Final Report

Prepared by:

Thomas R. Matthews
Maria Cooksey
Casey B. Butler
Gabrielle F. Renchen

Florida Fish and Wildlife Conservation Commission
Fish and Wildlife Research Institute
South Florida Regional Laboratory
2796 Overseas Hwy, Suite 119
Marathon, FL 33050
(305) 289-2330
Tom.Matthews@myFWC.com

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33 East Quay Rd
Key West, FL 33040

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Introduction

The Florida Keys National Marine Sanctuary (FKNMS or Sanctuary) encompasses 2,900 square nautical miles of the waters surrounding the islands of the Florida Keys, from Miami to the Dry Tortugas. The Sanctuary also borders three National Parks, Biscayne National Park, Everglades National Park, and Dry Tortugas National Park. Sanctuary waters include portions of the Gulf of Mexico and Atlantic Ocean, including the shallow waters of Florida Bay to 300-foot deep waters bordering the Florida Straits, and deeper waters surrounding Riley’s Hump. Within the of the Sanctuary lie nationally significant marine resources, including hundreds of uninhabited Keys, the world’s third largest barrier reef, hard-bottom habitat, seagrass beds, mangrove trees, and more than 6,000 species of marine life. The Sanctuary also protects historic shipwrecks and other archeological treasures (NOAA FKNMS home page).

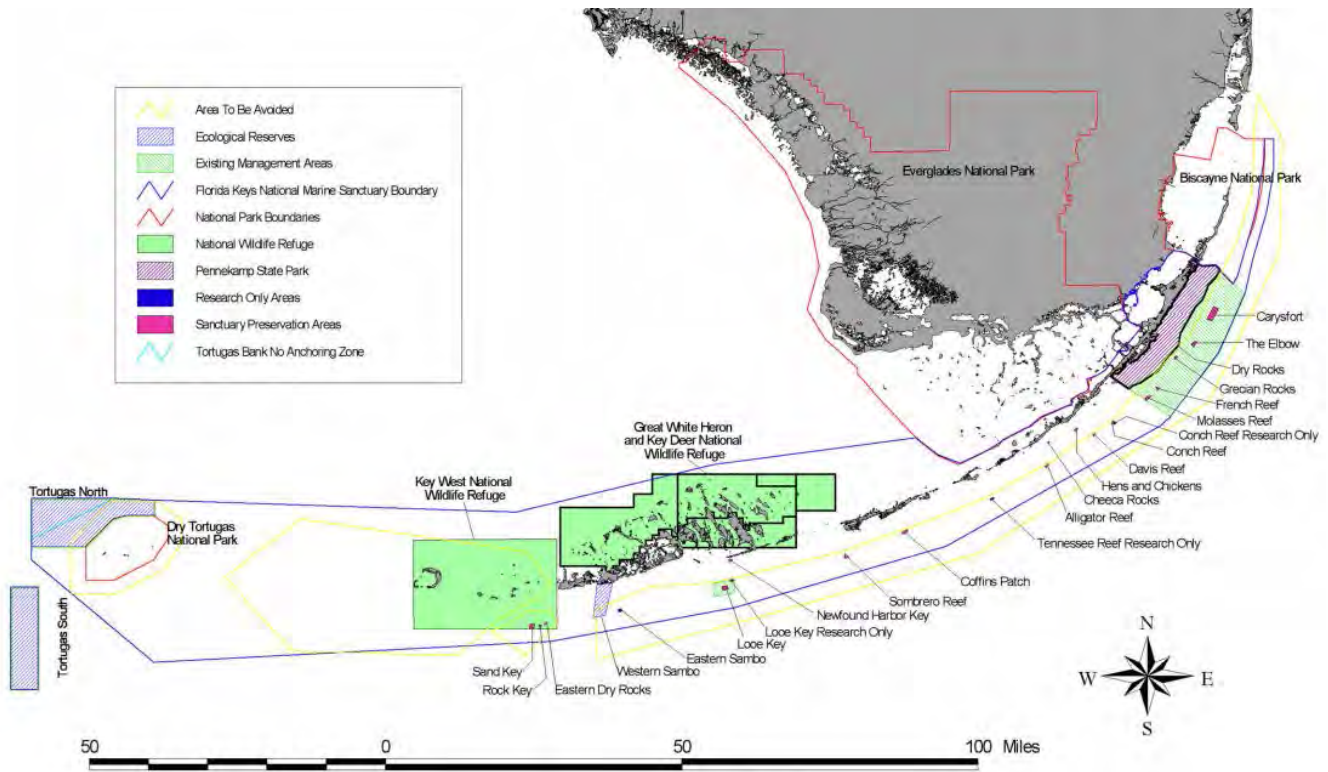


Figure 1 Florida Keys National Marine Sanctuary boundaries and its marine zones, as well as the boundaries of adjacent parks and refuges.

The Florida Keys are also home for 79,000 year-round residents and a destination for approximately 5 million visitors annually (Monroe County web page 2016). Many residents and visitors access the Sanctuary using their own vessels. For example, there are 29,106 registered vessels in Monroe County and 66,422 registered vessels in Dade County (FLHSMV web page). Boaters can access the Sanctuary at the public boats ramps (Monroe County web page 2016), abundant private boat ramps, thousands of private docks, or by navigating across the boundary. Over the last few decades, rapidly growing human populations in coastal counties have potentially increased levels of fishing, diving, habitat alterations, and disturbance of coastal waters (Ault et al., 2008). Increased boating activity is potentially, but not necessarily, linked to increased marine pollution (Markey et al., 2007), vessel groundings (Lirman and Miller, 2003), anchoring, fishing gear damage (Chiappone et al., 2005; Lewis et al., 2009), and other impacts from fishing and diving (Barker and Roberts, 2004).

Understanding the range of boat activity in the Sanctuary is vital to evaluating sustainable use of marine resources. The State of Florida and the NOAA Office of National Marine Sanctuaries jointly manage the marine resources of the Sanctuary. To that end, the State of Florida and Sanctuary entered into an agreement to survey the number, types, and locations of boats in the Sanctuary and identify the activities of those boats. A combination of NOAA, FWC, and chartered planes flew systematic survey flights from the northern reaches of the Sanctuary near Miami to the Marquesas Keys to complete those boat counts. Additional overflights west of the Marquesas Keys, including all waters near the Dry Tortugas provided some of the first boat counts for this area, but surveys were not completed during expected high boat use times.

This report provides baseline data of the types of boats, the location of boats, the abundance of boats, and the activities of the people on the boats. The report is largely descriptive, including boat count and boat densities. Basic patterns of the distribution of boats by time, location, or types are described, and statistical analysis of the differences in boating patterns are provided when appropriate. The report is divided into chapters based on a wide-range of topics relevant to boating identified during the study. For example, boating activities including hook-and-line fishing, diving, watersports, leisure activities at sandbars, and boats in transit (running) are described in separate chapters. Additional topics where sufficient data was available to discuss are included as separate chapters, including the Dry Tortugas, commercial fishing patterns, and boating patterns associated with the recreational lobster fishing.

Methods

Data collection

Aerial Census

Aerial surveys were conducted to characterize boating patterns throughout the Florida Keys National Marine Sanctuary (FKNMS or Sanctuary). Most surveys were conducted in a 4-seat fixed (high) wing Cessna 172, although occasionally, flights were conducted in NOAA Office of Marine and Aviation Operation’s high winged DHC-6 Twin Otter aircraft or the FWC Law Enforcement Division’s Cessna 182. All surveys were flown at altitudes between 500 and 1000 feet, at a speed of approximately 100 knots.

Flight Path

A single survey consisted of one “Gulfside” circuit conducted in the morning and one “Oceanside” circuit conducted in the afternoon (Figure 1). The Gulfside circuit is a 3.5-hour flight that aims to cover the Lower Keys backcountry and all Gulf of Mexico waters north of the Keys within FKNMS. The Oceanside circuit focuses on coastal Atlantic waters ranging from southeast of Miami to the Marquesas. During the 4-hour Oceanside flight, nearshore activity south of the island chain and activity over the reef tract are recorded.

During some flights, the flight path was diverted or interrupted due to inclement weather or temporary military flight restrictions. A handheld GPS was used to track each flight’s path to ensure that any diversions were accounted for in the data.

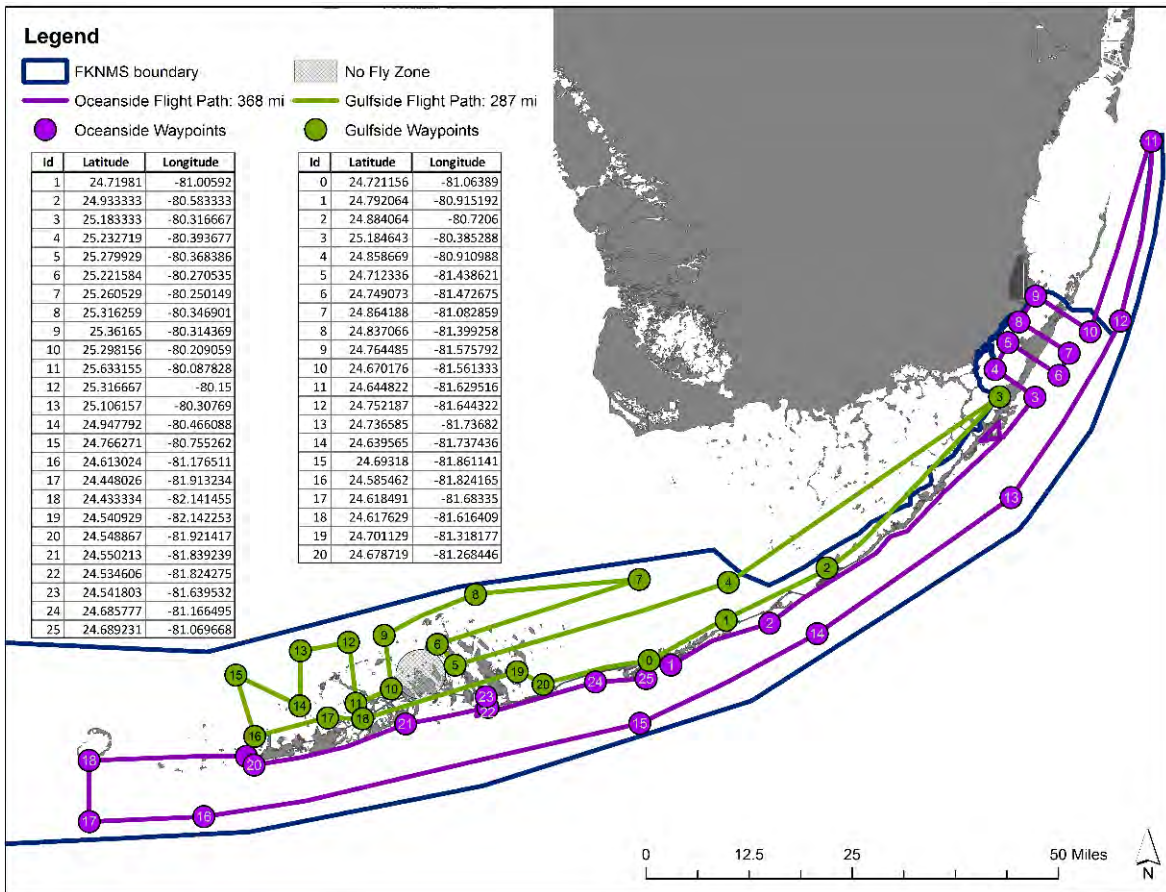


Figure 2 Gulfside (shown in green) and Oceanside (shown in purple) flight paths comprise one survey.

Flight Calendar

Twenty-nine surveys (comprised of a Gulfside and Oceanside flight) were randomly allocated by strata that varied by season (summer or winter), and day of the week (weekday or weekend) (Table 1). Summer was classified as May 1st to August 31st. Three special Holiday flight days were included to cover Memorial Day, Independence Day, and Labor Day weekends when boating activity was predisposed to be higher than other days. Two surveys were also included for the Florida Spiny Lobster Sport Season (a yearly 2-day Sport Lobster Season that occurs on the last Wednesday and Thursday of July) and for the opening day of Florida Spiny Lobster Season (August 6th of every year) (Table 1).

Table 1 Calendar of flights for the 2016-2017 aerial survey project, which comprised of 29 Gulfside and Oceanside flights. Note: For some surveys, the Gulfside and Oceanside flights are split amongst two days (e.g. April 4th/5th).

Date	Day Type	Flight path
02/02/16	Winter Weekday	Gulf AM, Ocean PM
02/06/16	Winter Weekend	Gulf AM, Ocean PM
03/12/16	Winter Weekend	Gulf AM, Ocean PM
03/26/16	Winter Weekend	Gulf AM, Ocean PM
03/30/16	Winter Weekday	Gulf AM, Ocean PM
04/02/16	Winter Weekend	Gulf AM, Ocean PM
04/04/16	Winter Weekday	Gulf AM
04/05/16	Winter Weekday	Ocean PM
04/09/16	Winter Weekend	Gulf AM, Ocean PM
05/12/16	Summer Weekday	Gulf AM, Ocean PM
05/14/16	Summer Weekend	Gulf AM, Ocean PM
05/29/16	Holiday	Gulf AM, Ocean PM
06/04/16	Summer Weekend	Gulf AM, Ocean PM
06/10/16	Summer Weekday	Gulf AM, Ocean PM
06/20/16	Summer Weekday	Gulf AM, Ocean PM
07/02/16	Holiday	Gulf AM, Ocean PM
07/09/16	Summer Weekend	Gulf AM, Ocean PM
07/27/16	Lobster Sport Season	Gulf AM
07/28/16	Lobster Sport Season	Ocean AM
07/31/16	Summer Weekend	Gulf AM, Ocean PM
08/06/16	Lobster Season Opening Day	Gulf AM, Ocean PM
08/20/16	Summer Weekend	Gulf AM, Ocean PM
08/23/16	Summer Weekday	Gulf AM, Ocean PM
09/03/16	Holiday	Gulf AM, Ocean PM
09/11/16	Winter Weekend	Gulf AM, Ocean PM
09/29/16	Winter Weekday	Gulf AM, Ocean PM
11/04/16	Winter Weekday	Gulf AM, Ocean PM
11/05/16	Winter Weekend	Gulf AM, Ocean PM
12/01/16	Winter Weekday	Gulf AM, Ocean PM
12/29/16	Winter Weekday	Gulf AM, Ocean PM
01/21/17	Winter Weekend	Gulf AM, Ocean PM

Special Flights

A set of 6 flights over the Lower Keys were flown on June 17, 2017 to learn how the time of day may affect the number of boats in the Lower Keys (Table 2). This flight mirrored the second half of our general flight path, covering the reef tract and nearshore waters of the Lower Keys (Figure 2). Each circuit was approximately an hour and 10 minutes and circuits were spread throughout the day to include times both before and after our typical survey flight times.

Table 2 Flight times of the Lower Keys flight circuits.

Circuit	Time of Flight
1	8:41 – 9:44 AM
2	10:40 – 11:52 AM
3	12:33 – 1:51 PM
4	1:51 – 3:00 PM
5	4:08 – 5:21 PM
6	5:46 – 6:49 PM

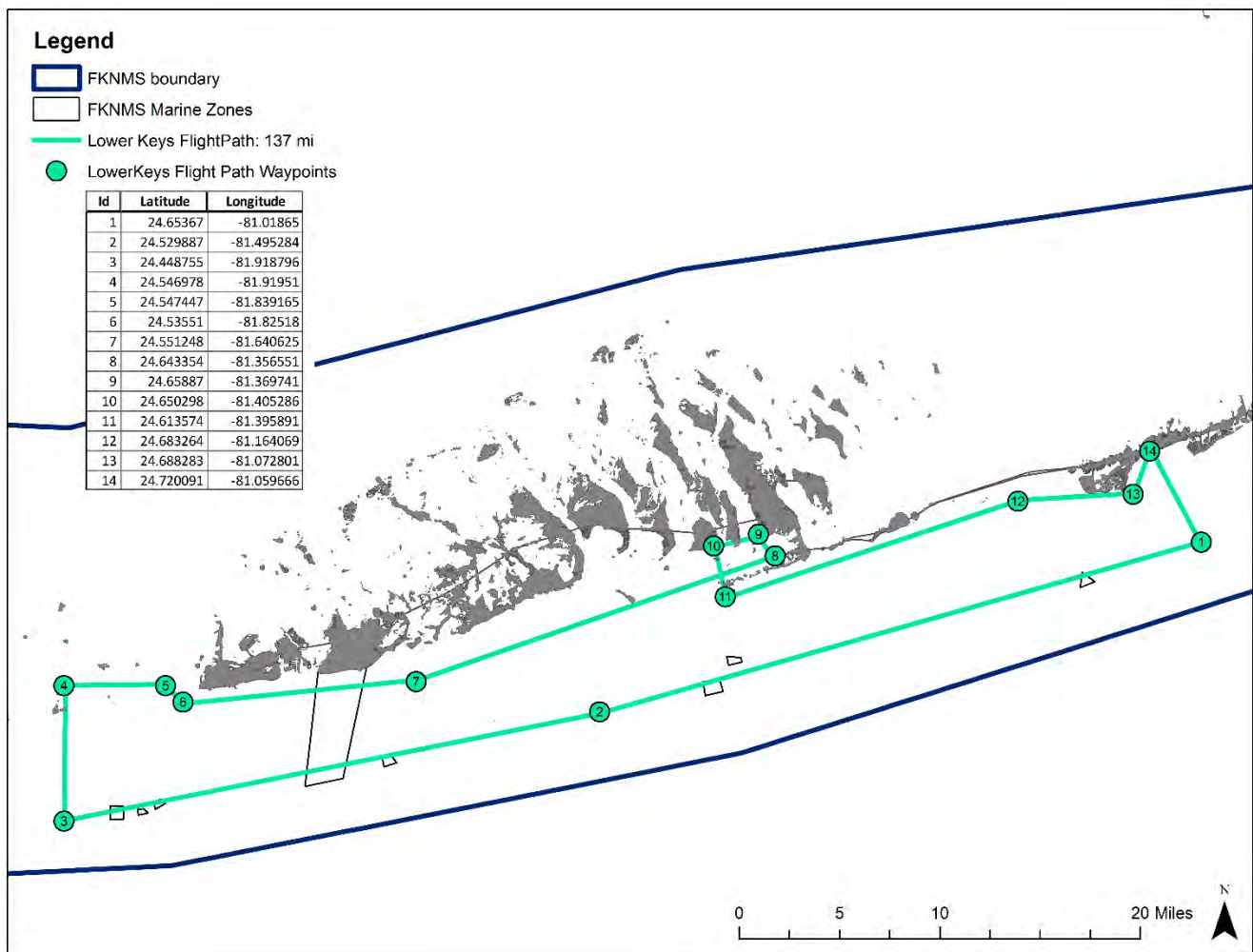


Figure 3 Flight path of the time survey on June 17, 2017.

Mapping Grids

Vessel data and position was recorded directly onto a map of the study area with a grid system with borders on the one-minute longitudinal and latitudinal lines. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile. The one square minute grid defines the accuracy of boats' locations in the survey, with the exception of boats that are found inside of marked FKNMS marine zones. FKNMS marine zones refer to Sanctuary Preservation Areas (SPAs), Ecological Reserves (ERs), and Research Only Areas (ROAs). Boats were marked as being either inside or outside of the yellow 30" buoys that delineate the boundaries of a marine zone.

Vessel Classification

Trained observers were seated at either side of the plane and used binoculars to locate every vessel that was within a 3-mile radius of the plane. The observers categorized each boat by boat class and size class (less than or greater than 30 feet in length) and determined the boaters' main activities (see Table 3 for boating categories). Using a handheld GPS and visible landmarks, the observers established the position of each vessel into the one square minute latitude-longitude grids.

Table 3 The description of boat categories used to classify vessels throughout the survey.

Boat Class and Activity	Description
Motorboat Hook-and-line Fishing	Any vessel with fishing rods that is primarily driven with a motor, excluding other categorized boat types. Recorded as less than or greater than 30 ft.
Motorboat Diving	Any vessel displaying a dive flag or with swimmers in the water that is primarily driven with a motor, excluding other categorized boat types. Recorded as less than or greater than 30 ft.
Motorboat Running	Any vessel that is primarily driven with a motor, excluding other categorized boat types, that is underway, not obviously participating in any other activity. Recorded as less than or greater than 30 ft.
Motorboat Anchored	Any vessel that is primarily driven with a motor, excluding other categorized boat types, that is anchored or on a mooring ball but not participating in another activity. Recorded as less than or greater than 30 ft.
Motorboat Adventure Sports	Any vessel that is primarily driven with a motor, excluding other categorized boat types, that has a parasail, tube, water-skier, or banana boat.
Motorboat Sandbar/Party	Any vessel that is primarily driven with a motor, excluding other categorized boat types, that is in shallow water or at sandbars, usually characterized by people standing in the water near the vessel
Sailboat Hook-and-line Fishing	Any vessel with a mast, whether it is under sail or under power, that has fishing rods on board. Recorded as less than or greater than 30 ft.
Sailboat Diving	Any vessel with a mast, whether it is under sail or under power, that is displaying a dive flag or has swimmers in the water. Recorded as less than or greater than 30 ft.
Sailboat Running	Any vessel with a mast that is underway, not obviously participating in any other activity, whether it is under sail or under power. Recorded as less than or greater than 30 ft.
Sailboat Anchored	Any vessel with a mast that is anchored or on a mooring ball that are not obviously participating in any other activity.
Sailboat Sandbar/Party	Any vessel with a mast in shallow water or at sandbars usually characterized by people standing in water near the vessel
Personal Watercraft (PWC) Hook-and-line Fishing	Jet driven vessel under 13 ft with fishing rods
Personal Watercraft (PWC) Diving	Jet driven vessel under 13 ft displaying a dive flag or with swimmers in the water
Personal Watercraft (PWC) Running	Jet driven vessel under 13 ft that is either running or not moving, but not participating in any other activity

Personal Watercraft (PWC) Sandbar/Party	Jet driven vessel under 13 ft in shallow water or at sandbars usually characterized by people standing in water near the vessel
Personal Watercraft (PWC) Adventure Sports	Jet driven vessel under 13 ft with a parasail, tube, water-skier, or banana boat.
Paddlecraft Hook-and-line Fishing	Kayak, paddleboards, canoes, or other small human-powered watercraft that have fishing rods
Paddlecraft Diving	Kayak, paddleboards, canoes, or other small human-powered watercraft that are displaying a dive flag or have swimmers in the water
Paddlecraft Running	Kayak, paddleboards, canoes, or other small human-powered watercraft that is running or not moving, but not participating in another activity
Paddlecraft Sandbar/Party	Kayak, paddleboards, canoes, or other small human-powered watercraft in shallow water or at sandbars usually characterized by people standing in water near the vessel
Commercial Fishing	Vessels with commercial trap markings, head boats, and sponge fishers. This category does not include charter fishing boats (Ex. Flats boats and sport fishing boats). Recorded as less than or greater than 30 ft.
Commercial Fishing Running	Vessels with commercial trap markings, head boats, and sponge fishing that are underway, and not actively fishing. This category does not include charter fishing boats (Ex. Flats boats and sport fishing boats). Recorded as less than or greater than 30 ft.
Charter Diving Diving	Vessels that are marked by dive shop logos that are displaying dive flags or have swimmers in the water. Recorded as less than or greater than 30 ft.
Charter Diving Running	Vessels that are marked by dive shop logos that are underway, and not actively diving. Recorded as less than or greater than 30 ft.
Charter Adventure Sports	Vessels that are marked with logos of water adventure companies, with a parasail, tube, water-skier, or banana boat.
Charter Sports Running	Vessels that are marked with logos of water adventure companies, which are not actively pulling a parasail, tube, water-skier, banana boat, etc.
Cargo Running	Vessels greater than 50 ft whose primary function is for shipping that are underway
Sightseeing Diving	Vessels recognizable for education or entertainment purposes (<i>i.e.</i> Boy Scout or Seacamp Vessels, Glassbottom boats) that are displaying dive flags or have swimmers in the water. Recorded as less than or greater than 30 ft.
Sightseeing Running	Vessels recognizable for education or entertainment purposes (<i>i.e.</i> Boy Scout or Seacamp Vessels, Glassbottom boats) that are underway, not obviously participating in any other activity. Recorded as less than or greater than 30 ft.
Sightseeing Anchored	Vessels recognizable for education or entertainment purposes (<i>i.e.</i> Boy Scout or Seacamp Vessels, Glassbottom boats) that are anchored or on a mooring ball that are not obviously participating in any other activity. Recorded as less than or greater than 30 ft.
Construction Anchored	Vessels used for construction and repair that are anchored or on a mooring ball that are not obviously participating in any other activity.
Construction Running	Vessels used for construction and repair that are underway, not obviously participating in any other activity.
Military/Law Enforcement Running	Any vessel clearly marked with a Military or Law Enforcement logo that is underway, not obviously participating in any other activity. Recorded as less than or greater than 30 ft.
Cruise Ships	Passenger vessels greater than 300 ft; only counted when underway (and not at port)

Weather

All wind data was collected from the National Weather Service National Data Buoy Center's quality controlled archive of marine weather observations at three weather stations representing the Upper Keys (Molasses Reef), Middle Keys (Long Key), and Lower Keys (Sand Key). Molasses Reef Weather Station is located at 25°0'42" N 80°22'35" W. Long Key Weather Station is located at 24°50'38" N 80°51'49" W. Sand Key is located at 24°27'21" N 81°52'38" W. The daily average wind speed was calculated for each of the three weather stations by taking the average of all wind speed measurements observed between 9 AM and 5 PM Eastern Standard Time. The wind speed assigned to each flight survey was calculated as the average of the daily average wind speeds from each of the three weather stations.

Tropical Storms and Hurricanes

No tropical storms or hurricanes appeared to affect boating patterns during the study. A tropical storm warning for Hurricane Matthew was in effect for the Upper and Middle Keys on October 5th, 2016 but the Keys never registered tropical storm force winds, nor were there any known impacts from the storm. No surveys were scheduled near this time and the project was not disrupted by this storm, or any other hurricanes during the 2016 season. However, it is outside the scope of this study to understand how tropical weather watches and warnings affect boating, even by those storms that do not ultimately affect the waters of the Sanctuary.

Boat Locations and Times

Vessel data was recorded directly onto a paper map of the study area with each latitude and longitude grid delineated. Flight path and plane locations were recorded using the handheld GPS. Ground truthing experiments determined that the observers' ability to discern the activity and type of boats decreased when boats were more than 3 miles from the plane. Therefore, grids that were within 3 miles of the flight path were compiled into a list that documented the survey area of each individual flight survey. Grids further than 3 miles from the flight path were not included in calculations of boat density. With a list of grids that were observed throughout every flight, it is possible to discern the difference between grids that were observed but do not have any boats (true zeroes), and grids that were not observed at all during a particular flight due to diversions in the flight path. Some areas, specifically the Biscayne region and Marquesas region, were not surveyed every flight due to thunder storms or military closed airspace.

The handheld GPS also recorded time along the flight path, which can be used to determine the time that each grid was observed. All UTC times were converted to Local time, which is either Eastern Daylight Time (for flights from March 13-November 6, 2016 or March 12-November 5, 2017), or Eastern Standard time. For flights without a GPS flight track, a standard flight track was used, and no time was applied to the grids that were observed.

Habitat Data

The Florida Unified Reef Map 2.0 (release date January 2017) was used to describe the benthic habitat throughout the survey area. The Florida Unified Reef Map 2.0 characterizes the dominant biological cover and geological formations found on the seafloor between Martin County and the Dry Tortugas and extends to the 20-m depth contour. The map was created by compiling individual regional maps from multiple sources, and the accuracy and resolution of each individual map may differ. Overall, the Florida Unified Reef Map 2.0 is estimated to have 85.6% to 98.0% accuracy for the broadest categories among the individual source maps (FWC-FWRI 2016). For this study, "Unified Class Level 1", the second broadest set of classes within Florida Unified Reef Map 2.0, best represent the scale of our surveys and was used to distinguish between habitat types in this study. "Unified Class Level 1" classifies the benthic habitat as aggregate reef, patch reefs, pavement, reef rubble, reef ridge, continuous seagrass, discontinuous seagrass, artificial habitat, dredged/excavated area, scattered coral/rock in unconsolidated sediment, or unconsolidated sediment. Aggregate reef habitats were reclassified as 'Continuous Reef' and patch reefs, reef rubble, reef ridge, scattered coral/rock habitats were merged to form "Other Reef". Continuous and discontinuous seagrass were merged to form an inclusive "Seagrass" category. The one-minute grid system was overlaid onto the benthic habitat maps to calculate the percent cover of each category for each grid. A single habitat category was

chosen to represent each grid. This habitat category was determined by establishing a hierarchy of the habitats that were considered to be the most relevant to fishing and diving activities. Bridges held the highest rank in the hierarchy – any grid with a bridge within it was classified as a bridge, regardless of other habitats present in the grid. Grids with any amount of continuous reef were classified as such, followed by grids that contained other reef, pavement, or seagrass, and lastly, unconsolidated sediment (Figure 3). There were no grids labeled as artificial habitat or dredged/excavated area. Any grids within our study area that are beyond the 20-m contour line, where habitat data is not available, were labeled as “Not Classified” (Figure 3).

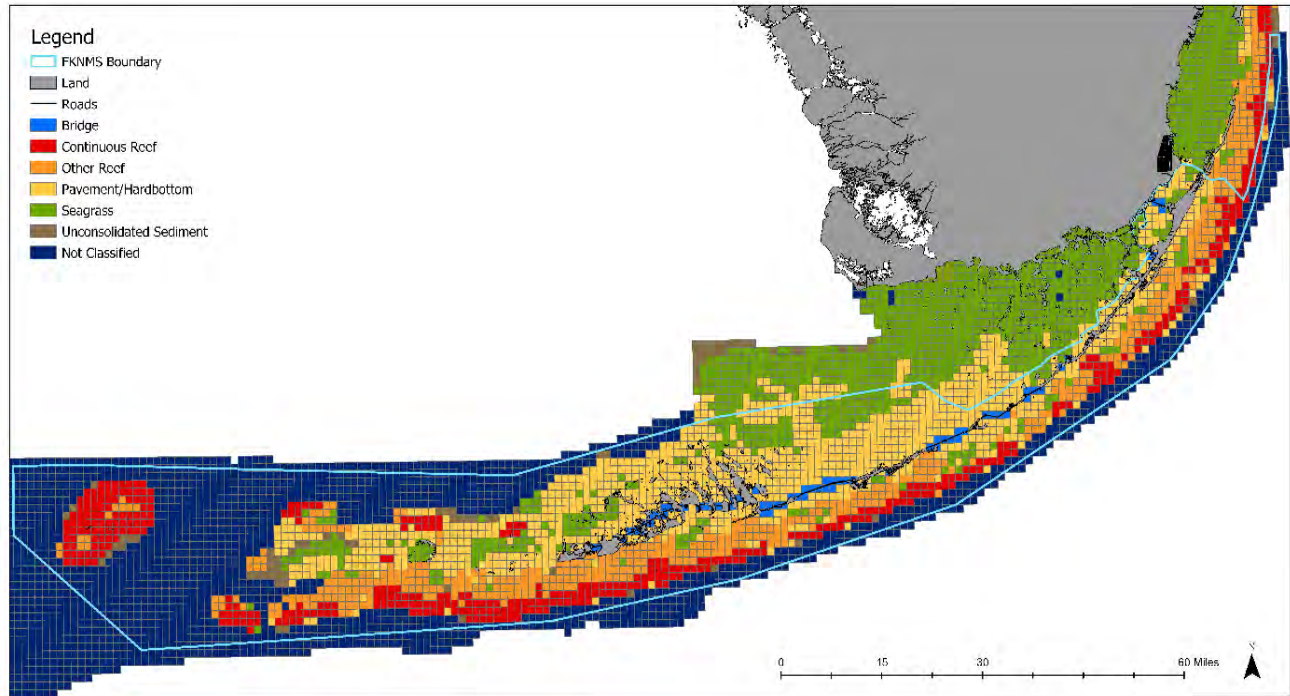


Figure 4 Single habitat categories for each grid based on a hierarchy of habitats that are the most relevant to fishing and diving boats. Hierarchical order is Bridge, Continuous Reef, Other Reef, Pavement/Hardbottom, Seagrass, then unconsolidated sediment. Any grids that lacked habitat data were listed as not classified. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile. All habitat data is based on the Florida Unified Reef Tract Map 2.0 (FWC-FWRI 2016).

Regions

The Florida Keys and surrounding waters are often divided into regions (e.g. Upper Keys, Middle Keys, Lower Keys) that help to describe the locations and habitats of the Keys. A map was created to divide the one-minute grids into regions that are commonly used by the Sanctuary, and to further divide those regions by Gulfside and Oceanside sections (Figure 4). Areas surrounding the Marquesas Keys and the Dry Tortugas National Park were designated as North/Gulfside or South/Oceanside. If a grid was bisected by the boundary of two regions, the entire grid was designated as being part of the region in which the grid centroid was located. Grids that are bisected by bridges or other Gulf and Oceanside boundaries were designated as Gulfside grids since boater activity at bridges tends to be more aligned with that of other Gulfside activities). It is also important to note that the Biscayne region of the Florida Keys National Marine Sanctuary is adjacent to, but not part of, Biscayne National Park.

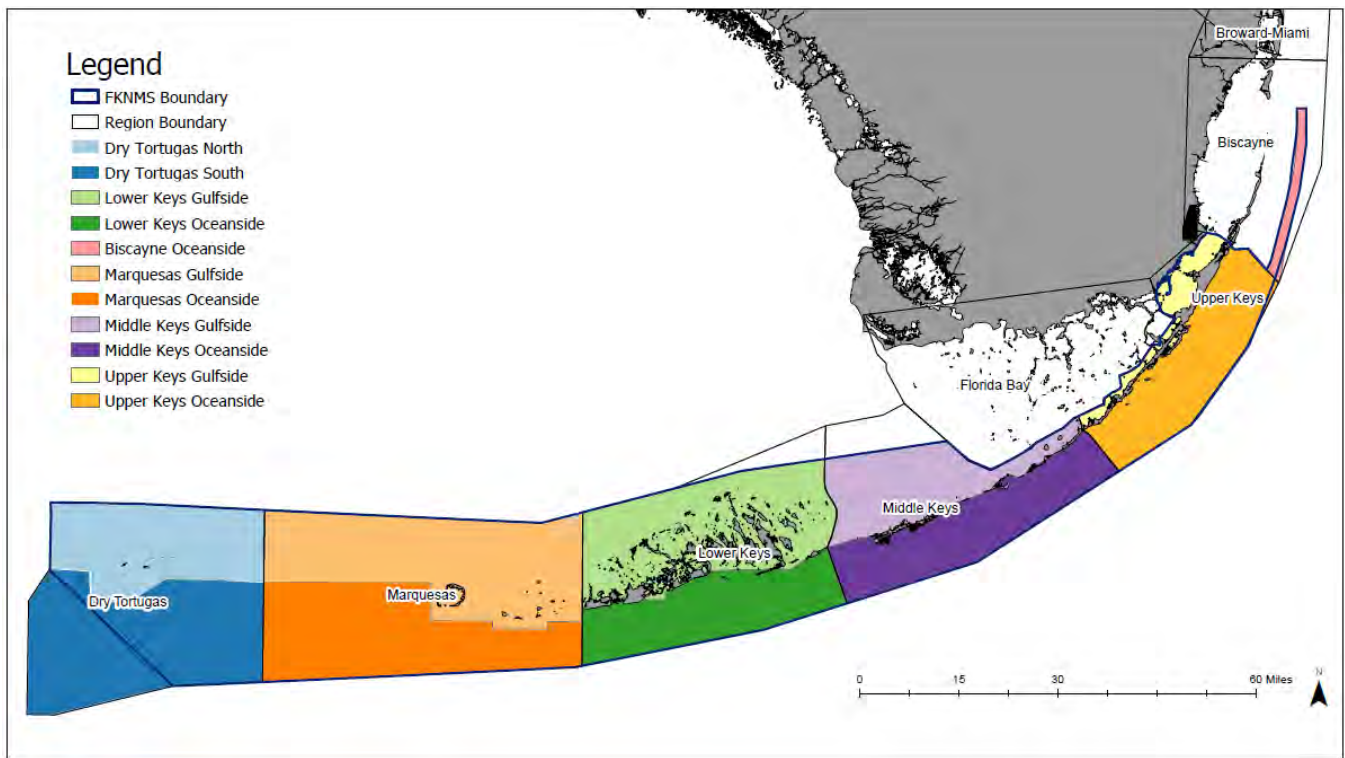


Figure 5 The Florida Keys are divided into regions that help to describe differences in boating activity.

Data Analysis

Data were analyzed to look for patterns spatially, temporally (throughout the day and throughout day types), and categorically (e.g. types of boats, boat activities). Data were queried to select only the type of boat, boat activity, day types, etc. that were relevant to the desired analysis.

Spatial Analysis

Density patterns were analyzed averaging the number of (a type of) boats per one-minute grid, or by region.

Occupancy maps were created to compare how frequently a site was visited throughout the survey, and if the frequency of use changed when boat activity, wind conditions, or day type (i.e. season or day or the week) changed. The occupancy rates were measured by comparing the proportion of times a boat was seen in a grid to the number of times a grid was surveyed (within a day type or wind condition). All spatial analyses were completed using ArcGIS (v. 10.5, Environmental Systems Research Institute, Redlands, CA, USA).

Average density and occupancy maps were created for each activity and day type, and are included in Appendix A, regardless of whether they are referenced in the chapters of this report.

Statistical and Descriptive Analysis

Temporal analyses compared the counts of boats per survey (comprised of a Gulfside and Oceanside paired flight). When comparing the average number of boats seen per day type (*i.e.* summer weekday, summer weekend, winter weekday, winter weekend, holiday, and lobster holiday) the average was weighted to account for differences in the number of surveys that were completed for each day type of each day type (Table 4).

Table 4 The number of surveys (Gulfside/Oceanside paired flights) per day type. Refer to Table 1 for specific flight days.

Day Type	Number of Surveys
Holiday	3
Lobster Season Opening Day	2
Summer Weekday	4
Summer Weekend	5
Winter Weekday	7
Winter Weekend	8

Statistical analyses were used to determine differences among day types of different activities. Negative binomial regressions with a log link function within generalized linear models (GLMs) were used to analyze boat count data, and gamma distributions with a log link function within GLMs were used to analyze the density (continuous) data. Homogeneous subsets for each category (*i.e.*, season, day type, location, etc.) were identified via a priori pairwise contrasts. All statistical analyses were completed using SPSS (v 21, IBM Corp., Armonk, NY, USA) or R (R Core Team, Vienna, Austria).

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Overall Results

Section at a glance

- ❖ *52,107 boats were observed during 29 flights over the Sanctuary from February 2, 2016 – January 21, 2017, with an average of 1796 ± 1047 boats per day.*
- ❖ *High-use areas of the Sanctuary were along the reef tract, nearshore, and near bridges.*
- ❖ *Diving and hook-and-line fishing each represented approximately 19% of boating activities. Sandbar and watersports activities each made up approximately 9%. Boats that were running (29%) when counted were likely also participating in other activities, just not at the time and location when they were counted.*
- ❖ *Diving (presumably for lobster) is the dominant boat activity for a few weeks at the beginning of Lobster Season with 4,818 boats counted on the first day of the Lobster Sport Season (7/27/2016) and 4,096 boats counted on Opening Day of Lobster Season (8/6/2016).*
- ❖ *On average, 65% of all boats were observed on the Oceanside during the survey.*
- ❖ *Many of the boats observed in the Middle and Lower Keys Gulfside areas (36-38%) were observed during Lobster Season Opening Days.*
- ❖ *Holiday weekends were the second highest boat use times, with an average of $2,875 \pm 818$ boats per day. Peak boat use was on Memorial Day weekend (5/29/2016, 4,019 boats).*
- ❖ *The highest counts of boats were observed during days with an average wind speed of less than 15 mph; winds greater than 15 mph tended to reduce the number of boats observed.*
- ❖ *On windy days, more boats were concentrated nearshore, around bridges, and on the Gulfside than on calm days, when boats were more abundant Oceanside, particularly along the reef tract.*

Introduction

Sanctuary waters host many boaters throughout the year. Patterns of use depend upon many variables, including time of year, boater activity, geographic region, and weather. Here we provide an overview of the boat count data collected from 29 aerial survey flights over the Florida Keys National Marine Sanctuary from February 2, 2016 to January 21, 2017, and provide analyses and descriptions of how these boating patterns change with these variables.

Methods

Statistical analyses were used to determine differences among boater activity by season and weekday, and by region. Negative binomial regressions with a log link function within generalized linear models (GLMs) were used to analyze count data, and gamma distributions with a log link function within GLMs were used to analyze the density (continuous) data. Homogeneous subsets for each category (*i.e.* boat type, region) were identified via *a priori* pairwise contrasts. All statistical analyses were completed using SPSS (v 21, IBM Corp., Armonk, NY, USA) or R (R Core Team, Vienna, Austria).

Types of Boats

A total of 52,107 vessels were observed during 29 flights over the Sanctuary from February 2, 2016 to January 21, 2017, with an average of 1796 ± 1047 (average \pm standard deviation) boats observed per day. Most (79%) of the boats observed in the Sanctuary were motorboats (1422 ± 967 motorboats observed per day), and 84% of motorboats were less than 30 feet in length. Sailboats, paddlecraft (kayaks, paddleboards, canoes), and personal watercraft (PWCs) were observed in frequencies of approximately 50-100 per day. On average, fewer than 50 of each of the other boat types (e.g. cargo, construction, cruise, etc.) were observed daily (Figure 1).

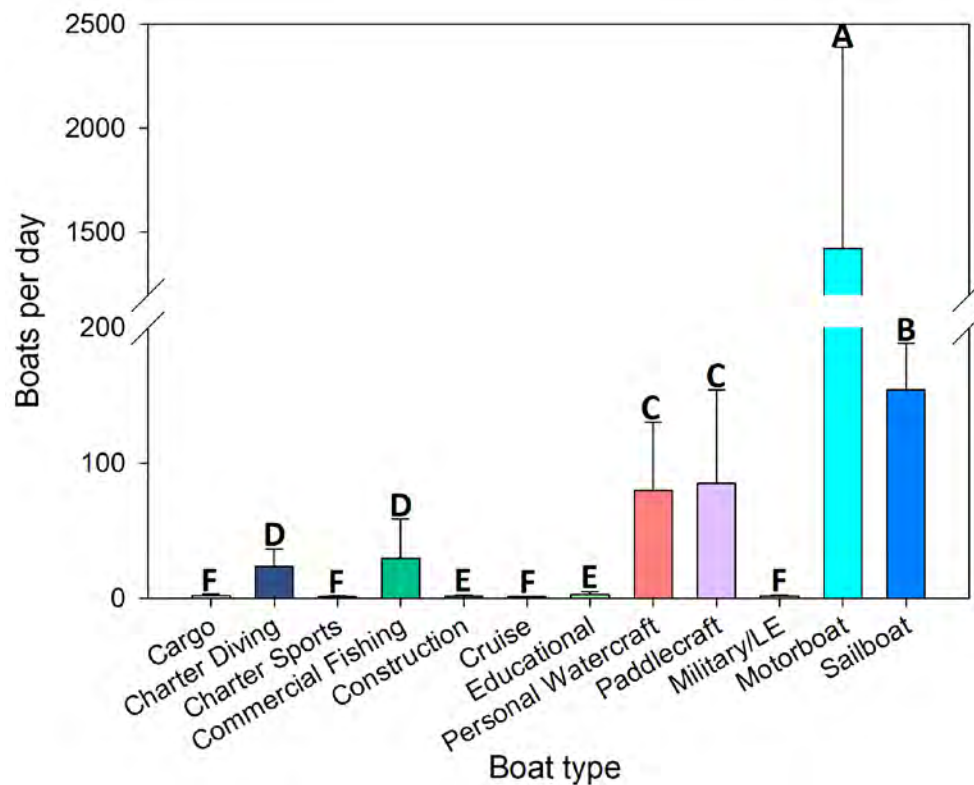


Figure 6 Average and standard deviation of the number of boats per day by boat type (Wald $\chi^2 = 3497.2$, $df = 11$, $p < 0.001$; $n = 29$ flights; total boats = 52,107). Letters indicate homogeneous subgroups ($p < 0.05$).

Boater Activity by Season

The highest counts of boats (by nearly twice as many as other flight days) were observed on lobster season opening days (7/27/2016, 4818 boats; and 8/6/2016, 4096 boats) and on Memorial Day weekend (5/29/2016, 4019 boats) (Figure 2). Greater counts were generally observed during the summer than during the winter (Figure 3). However, one particularly nice weather day with unseasonably warm temperature and low winds that occurred during the holiday break (12/29/2016, 2824) was very popular for boaters (Figure 2). Apart from lobster season opening days, there were greater numbers of boats observed on the Oceanside of the Sanctuary than on the Gulfside (Figure 2). More boats were observed on the Oceanside during the spring and summer, with a peak on Memorial Day weekend (May 29, 2016). The number of boats observed on the Oceanside was lower between October and February. The number of boats observed on the Gulfside was relatively steady, with peaks occurring on lobster season opening days (7/27/2016, 3553 boats; 8/6/2016, 2206 boats) (Figure 2).

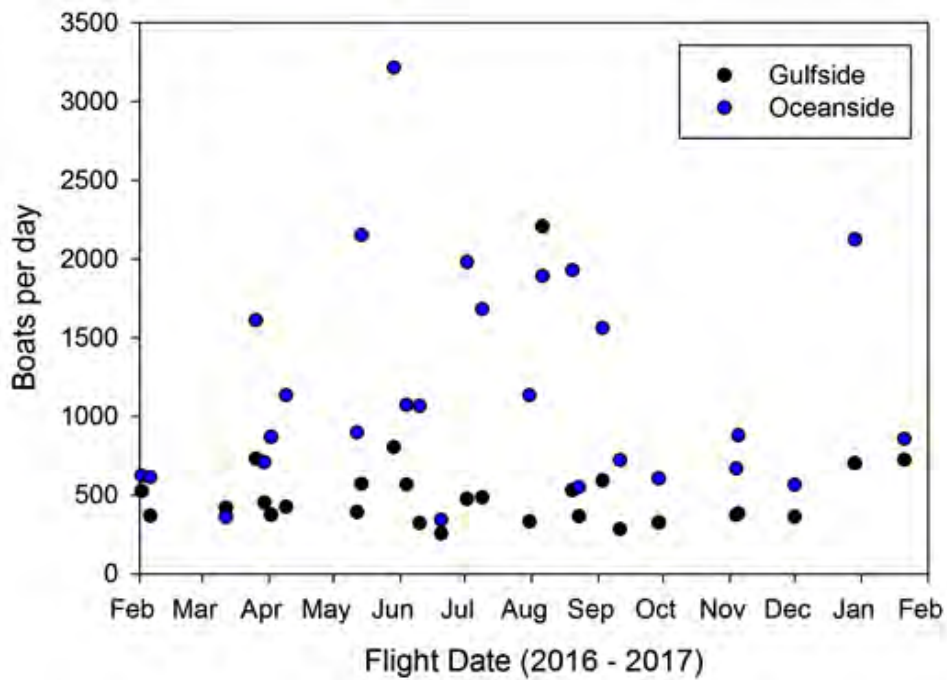


Figure 7 Total boats observed by flight date on the Gulfside and Oceanside of the Sanctuary (29 flights, total of 52,107 boats observed).

The most popular boating days were lobster season opening days (4457 ± 361 boats per day), followed by holidays (2875 ± 818 boats per day) and summer weekends (2089 ± 477 boats per day). Winter weekdays and weekends, and summer weekdays saw significantly fewer boats per day (Figure 3).

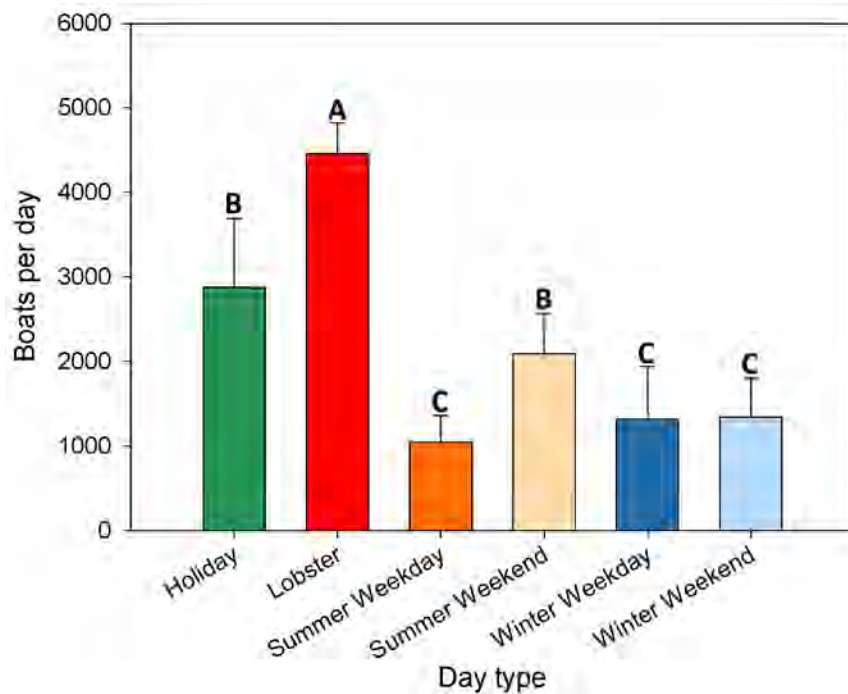


Figure 8 Average and standard deviation of the number of boats by type of day flown (Wald $\chi^2 = 171.9$, $df = 5$, $p < 0.001$; $n = 2-8$ flights per day type; total boats = 52,107). Letters indicate homogeneous subgroups ($p < 0.05$).

Boaters were observed participating in a variety of activities in Sanctuary waters (see Methods). These activities are discussed in depth in the following sections of this report. Of all boaters observed, diving and fishing each represented approximately 19% of activities of boaters. Sandbar and watersports activities each made up approximately 9% of activities of boaters. Many (29%) of our observations were of boats running (in-transit), and 13% of boats were observed anchored, mostly in anchorages nearshore (Figure 4).

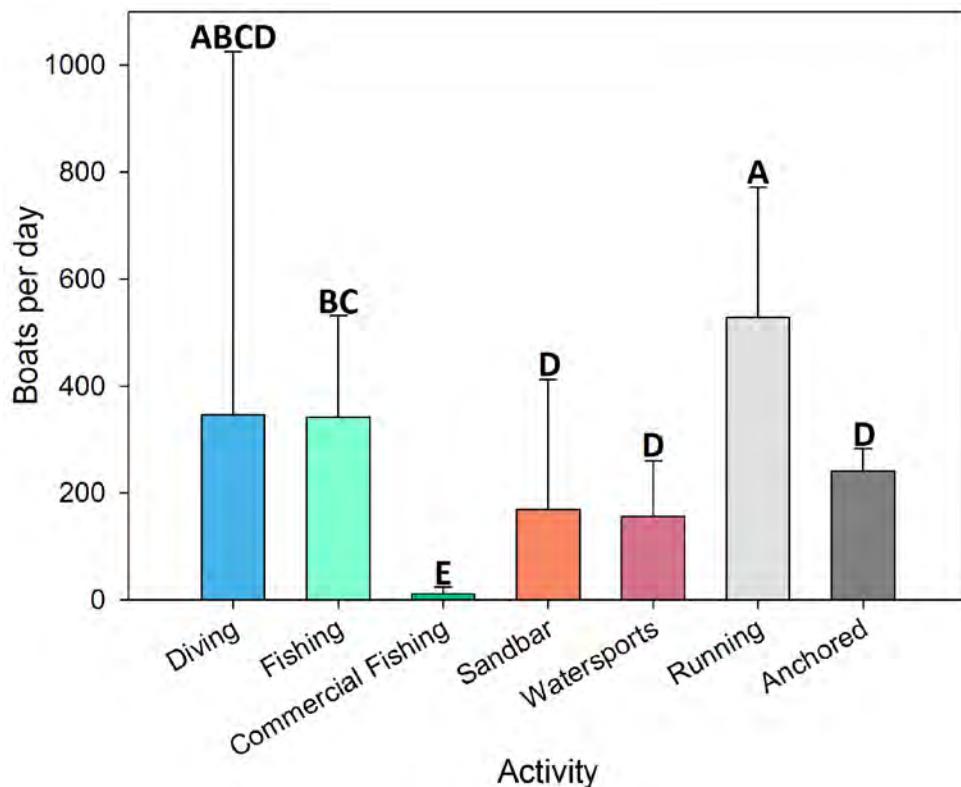


Figure 9 Average and standard deviation of the number of boats per day by boater activity type (Wald $X^2 = 372.9$, $df = 6$, $p < 0.001$; $n = 29$ flights per activity; total boats = 52,107). Letters indicate homogeneous subgroups ($p < 0.05$).

Boater activity varied by day type and season (Figure 5, Appendix B). Most notably, the increase in the number of boats observed on lobster season opening days was driven by the increase in the number of boats diving (presumably diving for lobster). The increase in the number of boats on holidays, however, was spread out over all the various activities, with sandbar and watersports activities having larger shares of boaters than on other days. Additionally, the lowest numbers of hook-and-line fishing boats were observed on lobster season opening days.

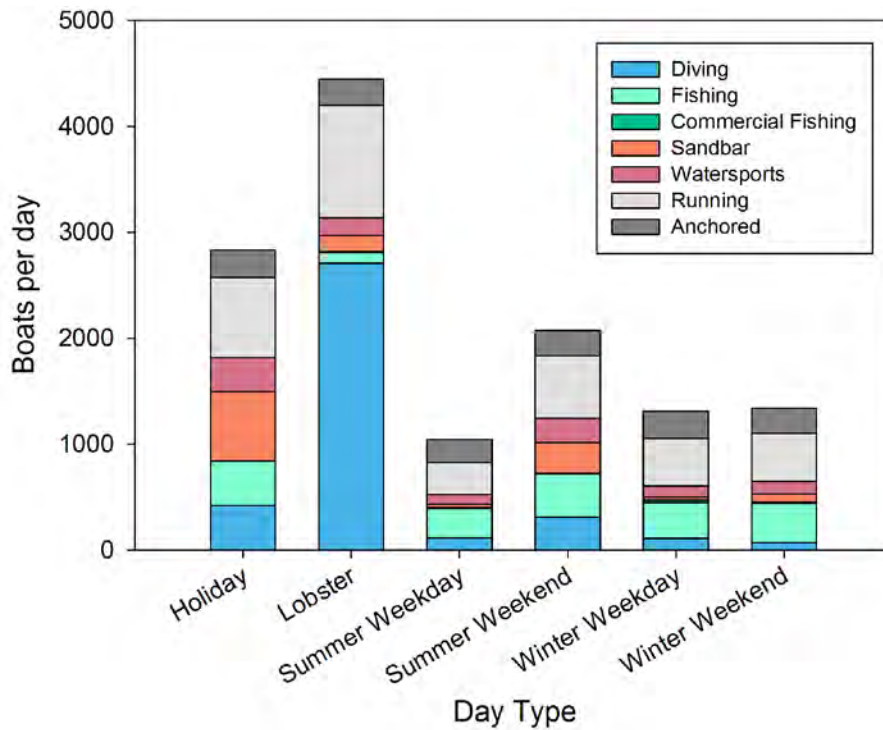


Figure 10 Average number of boats by boater activity and type of day flown (n=29 flights, total boats =52,107)

Region Use by Boaters

Boaters were observed throughout the Sanctuary, and the likelihood of a given area being occupied by boats (*i.e.*, the percentage of time a boat was observed within a grid) varied by location (Figure 6) and region (Table 1). Frequent-use areas of the Sanctuary (grids with >50% occupancy; 16% of all grids surveyed) were located along the reef tract, nearshore, and near bridges. Medium-use areas (grids with 25-50% occupancy; 23% of all grids surveyed) were found in areas like Hawk Channel and around islands in the backcountry. Low-use areas (grids with 0-25% occupancy; 61% of all grids surveyed) appeared to be situated further from land and reef structure, and not in the main channels or transit areas.

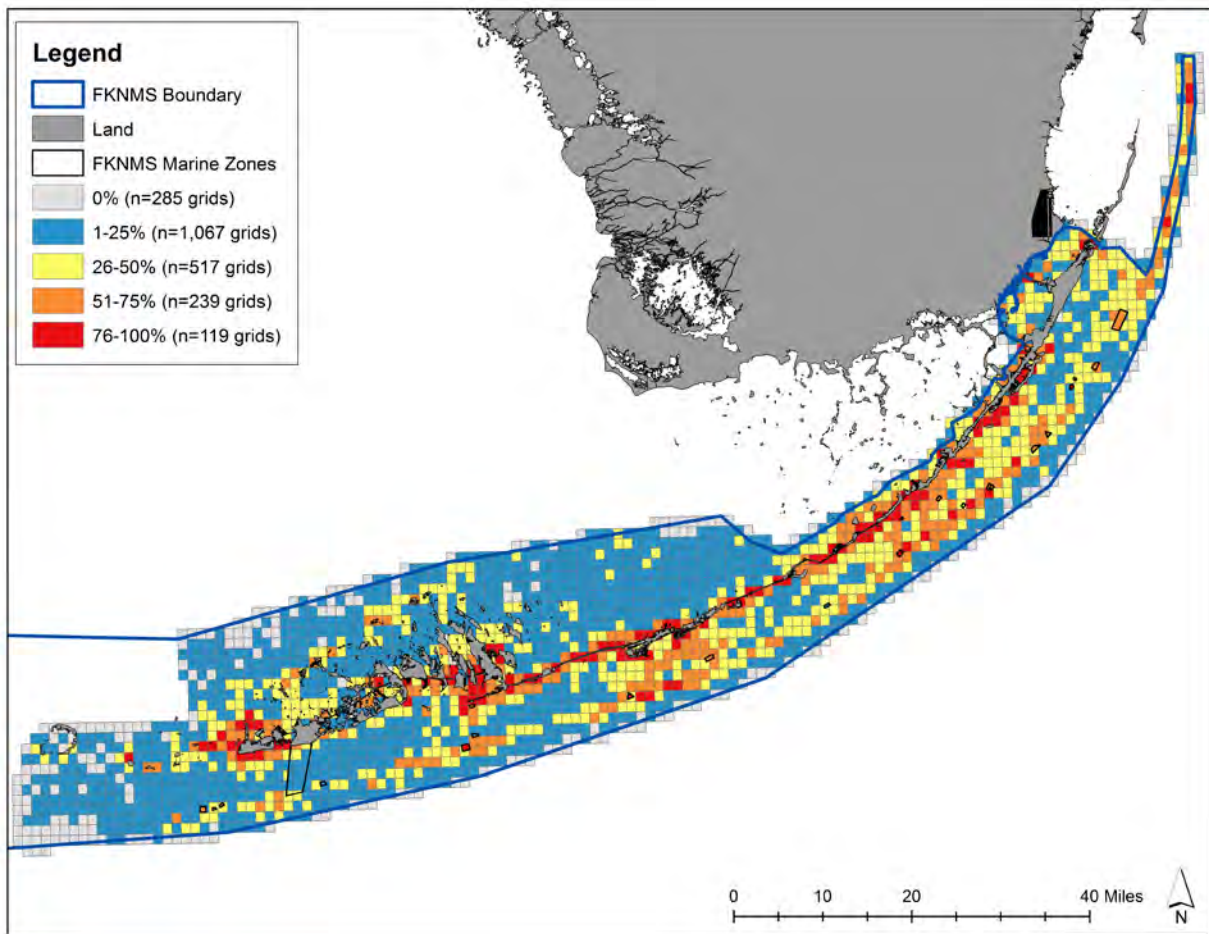


Figure 11 Map depicting the percent of time grids were occupied by boats (n = 29 flights, total boat count = 52,107, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

The Florida Keys and surrounding waters are often divided into regions (e.g. Upper Keys, Middle Keys, Lower Keys) to help describe the locations and habitats of the Keys (see Methods). Grids that included bridges or any portion of the Gulf were designated as Gulfside grids, since boater activity at bridges tends to be more aligned with that of other Gulfside boaters. We further designated areas surrounding the Marquesas Keys if a grid was north or south of those Keys. It is also important to note that the Biscayne region of the Florida Keys National Marine Sanctuary is adjacent to, but not part of, Biscayne National Park.

The number of boats observed varied by region of the Sanctuary (Table 1, Figure 7). Approximately 60.6% more boats were observed on the Oceanside (n=33,957 boats) than on the Gulfside (n=18,150 boats) of the Sanctuary. The greatest numbers of boats were observed on the Oceanside of the Upper and Middle Keys, followed by Lower Keys Gulfside and Oceanside. Lower average boat counts were observed on the Gulfside of the Middle Keys and Upper Keys. The fewest average boat counts were seen in the Marquesas and in the Biscayne Reef portions of the Sanctuary. Since the number of boats observed in these regions likely reflects the size of these regions, we also analyzed the densities (boat counts per nmi²) by region of the Sanctuary (Table 1, Figure 8). The densities of boats varied less than the counts did, and there were similar densities of boats in the Upper Keys (Gulfside and Oceanside), Middle Keys Oceanside, and Biscayne Reef regions. Densities were slightly lower for Lower Keys Oceanside, Middle Keys Gulfside, and Lower Keys Gulfside. Marquesas regions had the lowest densities of boats observed in the study.

Table 5 Descriptive statistics [averages, standard deviations (st. dev.), and percentages] of counts and densities of boats in the Sanctuary by region. Gulfside (GS), Oceanside (OS); (29 flights, total of 52,107 boats observed).

	Area (nmi ²)	Total Boats			Density of Boats	
		Avg. Boats per day	St. Dev. Boats per day	% boats per day	Avg. Boats per nmi ²	St. Dev. Boats per nmi ²
Biscayne Reef	29	42.1	38.3	2	1.43	1.30
Upper Keys GS	81	121.6	60.2	7	1.50	0.74
Upper Keys OS	273	417.3	321.8	23	1.53	1.18
Middle Keys GS	227	182.3	236.2	10	0.80	1.04
Middle Keys OS	279	383.0	211.3	21	1.37	0.76
Lower Keys GS	419	285.6	378.3	16	0.68	0.90
Lower Keys OS	267	279.2	127.8	16	1.05	0.48
Marquesas North	473	36.5	22.9	2	0.08	0.05
Marquesas South	399	52.3	32.6	3	0.13	0.08
Grand Total	2447					

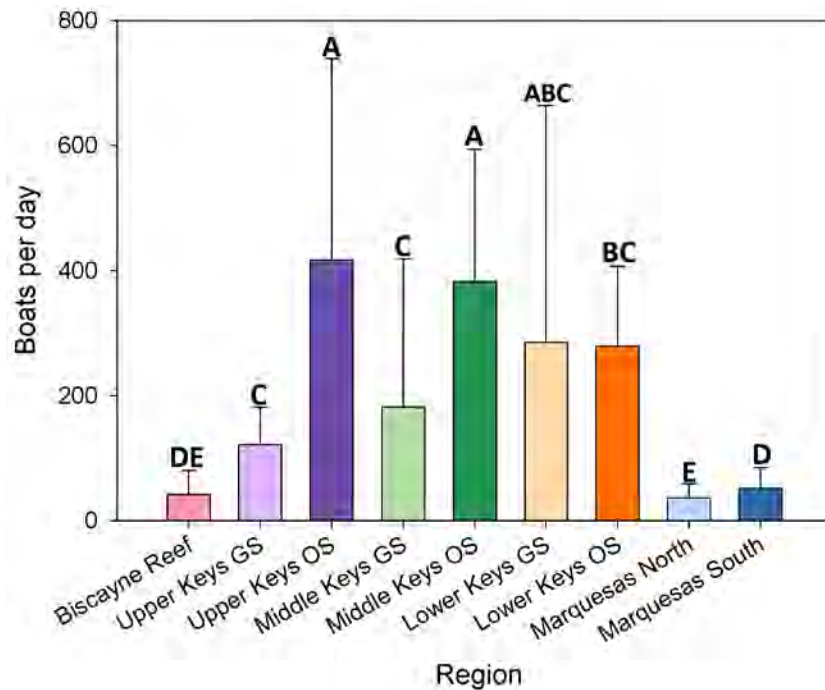


Figure 12 Average and standard deviation of the number of boats by general region of the Sanctuary. Letters indicate regions with similar density of boats. (Wald $X^2 = 500.4$, $df = 8$, $p < 0.001$; $n=27-29$ flights per region; total boats = 52,107). Letters indicate homogeneous subgroups ($p < 0.05$).

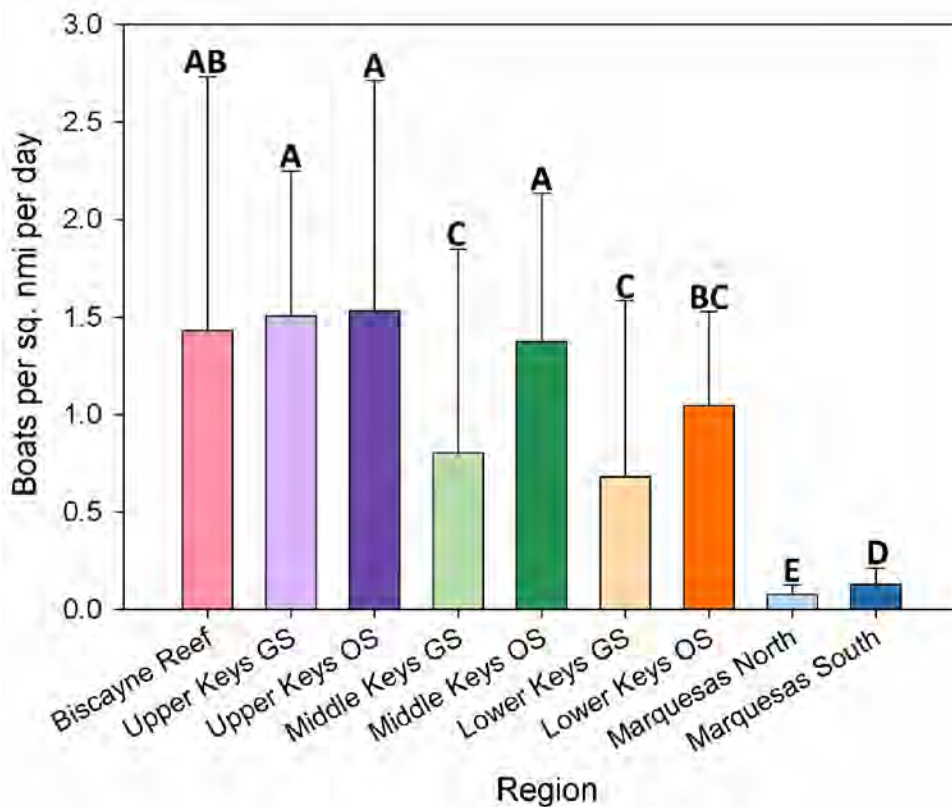


Figure 13 Average and standard deviation of the number of boats per square nautical mile (nmi²) by general region of the Sanctuary. Letters indicate regions with similar density boats. (Wald $\chi^2 = 1123.4$, $df = 8$, $p < 0.001$; $n=27-29$ flights per region; total boats =52,107). Letters indicate homogeneous subgroups ($p < 0.05$).

Boater Activity Patterns by Region

Boater activity patterns in the Sanctuary also varied by region (Figure 9). For example, hook-and-line fishing was the most popular activity among boaters in the Biscayne reef region of the Sanctuary (63% of Biscayne reef boaters). This may be a reflection of the small size of the Biscayne region, and its location which included predominately coral habitat (see Hook-and-Line Fishing for more information). Hook-and-line fishing (17-23% of boaters for each region) and diving (13-20% of boaters for each region) are important activities for boaters throughout the Oceanside of the Keys (Figure 6). Greater proportions of boaters on the Oceanside of the Keys and the Marquesas South participated in sandbar activities (9-16% of boaters per region) than on the Gulfside of the Keys and Marquesas North. Boaters engaged in watersports (34%) represented a higher proportion of boaters in the Marquesas North region than did other activities; most watersports in the Marquesas region were observed in the immediate vicinity of Key West (See Watersports). Importantly, the assessment of boat activity using all 29 flights from the entire year of surveys includes only waters east of the Marquesas Keys. Descriptions of boating activity in the entire Marquesas region are available in the report section (see Boat use near the Marquesas and Dry Tortugas) albeit results for the entire Marquesas region were based on 6 surveys. Other notable differences in the regional composition of boaters by activities include the high proportion of boaters diving on the Gulfside of the Middle (26%) and Lower Keys (31%, Figure 9). Divers target these areas during lobster season; however, throughout the rest of the year, these areas are generally not popular for diving, and when lobster season opening days were removed from this analysis, diving represented 2-3% of all activities on the Gulfside of the Middle and Lower Keys. Throughout most of

the year, the Gulfside of the Florida Keys is most regularly used by boaters for hook-and-line fishing (9-33% of all boaters per region).

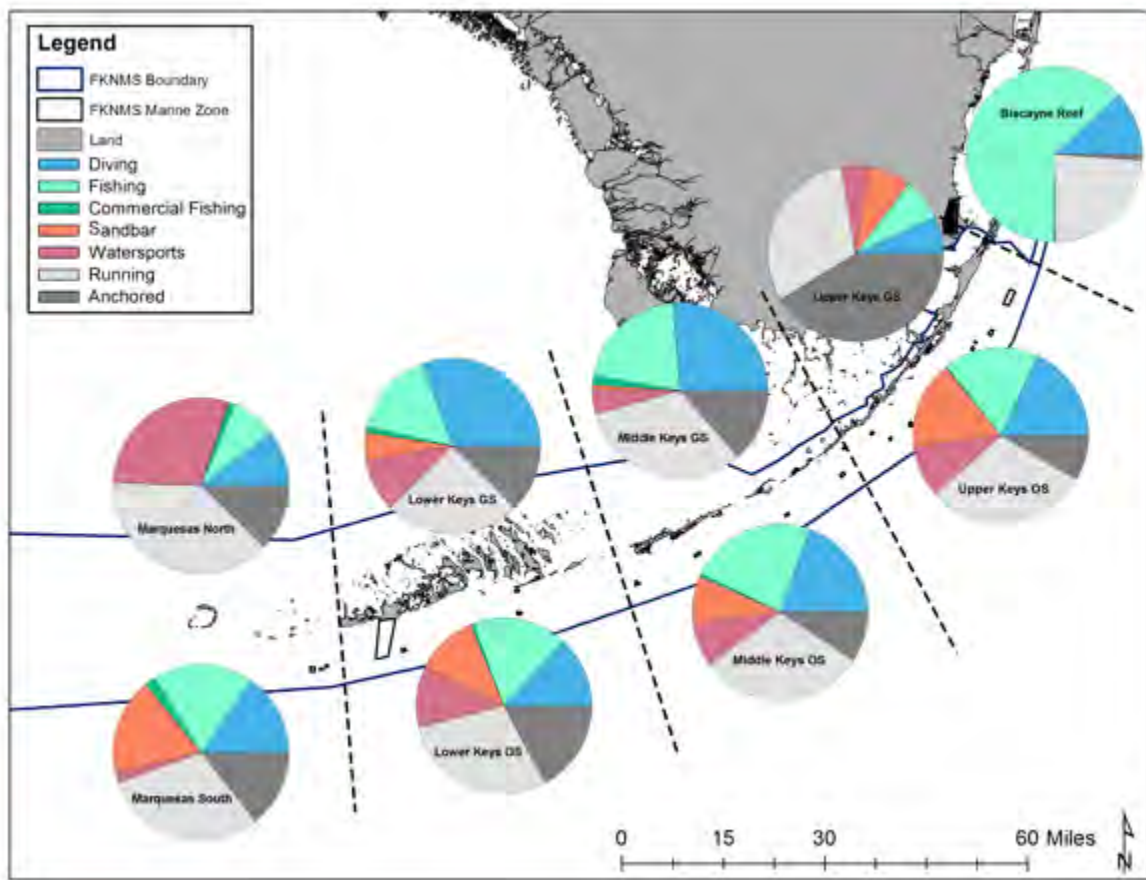


Figure 14 Activity (percentages) of boats observed in each region of the Sanctuary for the total year (n=29 flights, total boats =52,107).

Activity in SPAs

Boaters were observed participating in a variety of activities in FKNMS Sanctuary Preservation Areas (SPAs), and boater activity varied by day type and season (Figure 10). By far, the greatest proportion of boaters (85%) were diving or snorkeling in SPAs. Some boaters in SPAs were observed participating in sandbar/party activities (9%) and watersports (7%). Other activities made up less than 5% of boater activities in SPAs. Though many boat types were observed in SPAs, 73% were <30 ft. in length, and most (79%) were motorboats and charter dive boats (12%).

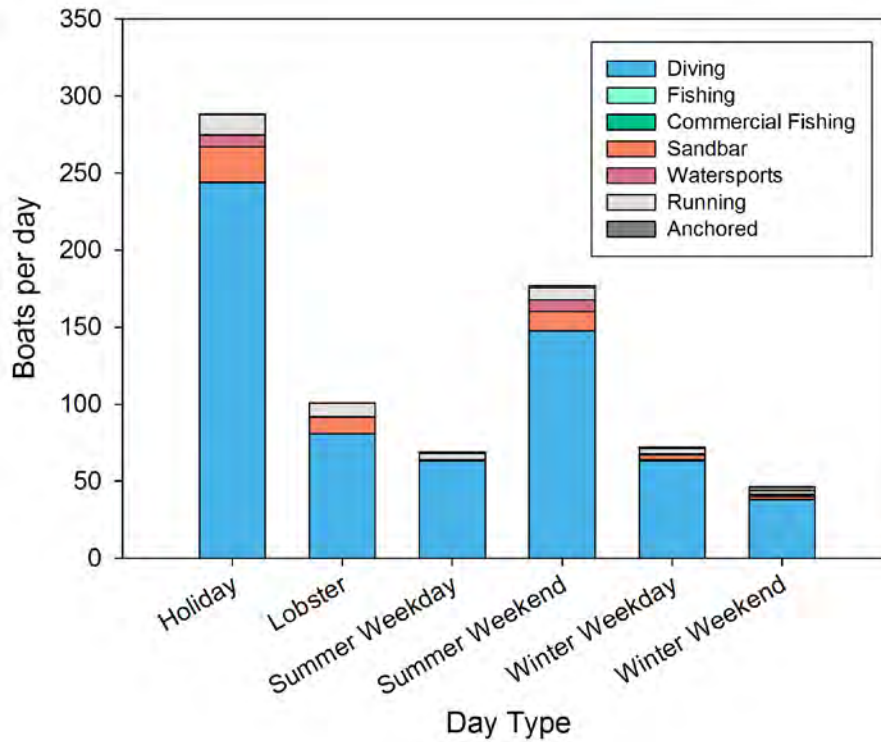


Figure 15 Average number of boats in FKNMS Sanctuary Preservation Areas by boater activity and type of day flown (n = 29 flights per activity; total boats =3,102).

Wind

Weather has a great effect on boating, with more favorable weather allowing more boats to participate in more activities. The highest counts of boats were observed during days with an average wind speed of less than 15 mph (Figure 11a). Winds greater than 15 mph tended to reduce the number of boats observed and although we intentionally did not fly on days with winds over 20 mph, it was clear that winds over 20 mph greatly reduced the number of boats (Figure 11a). Overall, the number of boats on the Gulfside remained fairly constant regardless of wind speed ($r^2 = 0.000$, $p = 0.97$), which is a result of the greater protection from the wind for boats near land (Figure 11b). The number of hook-and-line fishing boats on the Oceanside declined as wind speed increased ($r^2 = 0.26$, $p = 0.002$), indicating that boating drops off at greater wind speeds. Of those boats that were observed during high winds (greater than 15mph), the proportion of boats on the Gulfside increased slightly (Figures 11a,b).

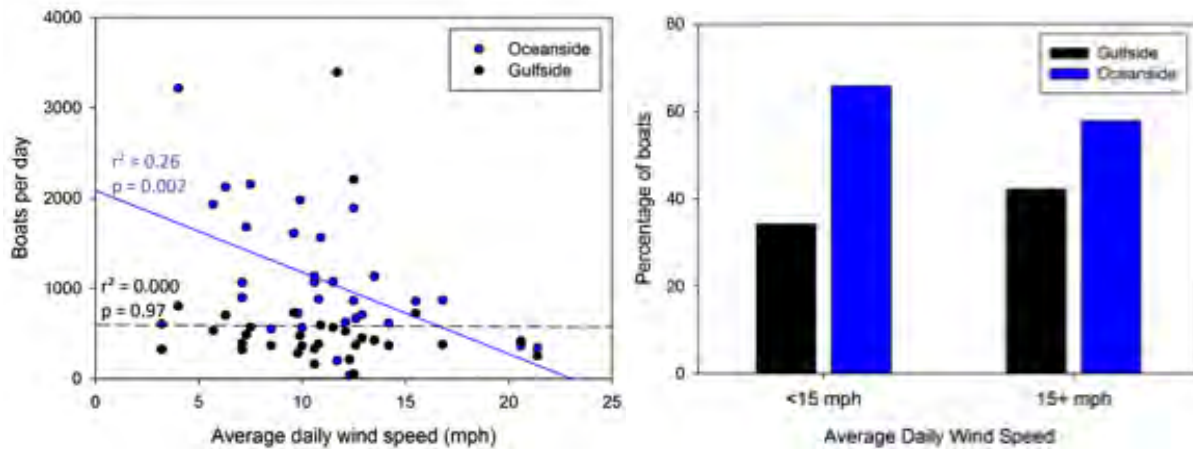


Figure 16 (a) Number of boats per day observed on the Gulfside vs the Oceanside of the Sanctuary by average daily wind speed; lines, r^2 , and p-values represent results of linear regressions. **(b)** Proportion of boats observed on the Gulfside vs. the Oceanside on calm (<15 mph) days vs. on windy (15+ mph) days.

Wind not only affected the quantity of boats using the Sanctuary, but it also influenced where boats were. For example, on windier days, more boats were concentrated nearshore, around bridges, and on the Gulfside than on calm days, when boats were more concentrated Oceanside, particularly along the reef tract (Figures 12, 13). Though we only flew on four windy days (*i.e.*, Figure 13 is based on 4 flights), there was clearly reduced boating along the Oceanside during our high wind flights, particularly in the Lower and Middle Keys. Only a small portion of all observed grids (46%) was occupied on windy days, whereas 76% of all observed grids were occupied on calm days (Figures 12, 13). On calm days the 132 grids (33%) that were occupied more than 50% of the time were located offshore, along the reef tract; on windy days, only 21 grids (11%) along the reef tract were occupied (Figures 12, 13). Rather, the grids that were occupied more than 50% of the time on windy days were located nearshore. Grids along the Biscayne reef and parts of the Upper Keys were often occupied despite high wind speed. This is likely because wind direction is also a determining factor of boating conditions. For example, a West to North wind associated with cold fronts would not produce as high seas leeward of and in close proximity to land (*i.e.*, fetch) in these areas. Wind direction was not investigated as a factor of fishing location in this study due to the low number of days flown at each wind speed and direction combination.

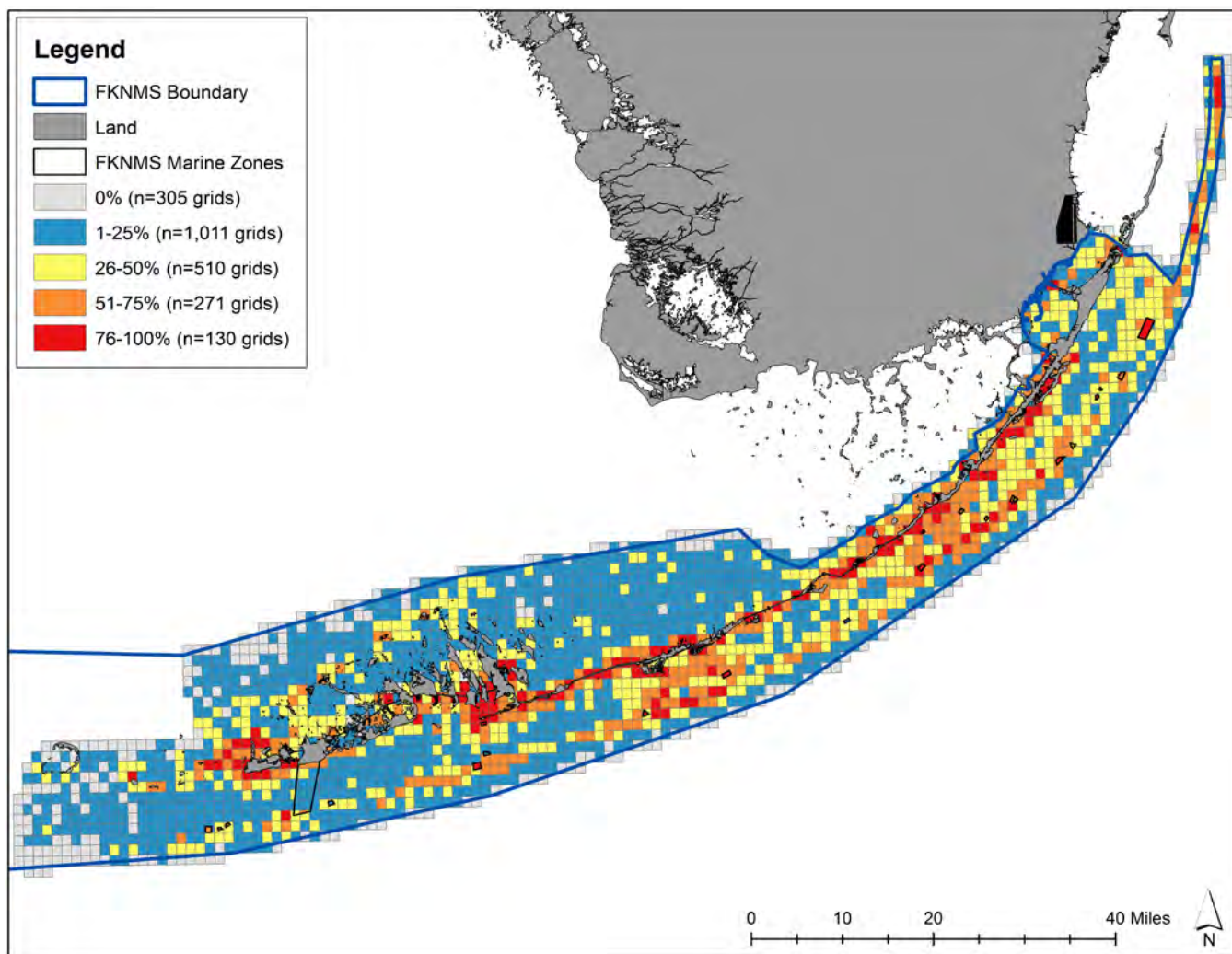


Figure 17 Map depicting the percent of time grids were occupied by boats when average daily wind speeds were less than 15 mph (n = 25 flights, total boat count = 47,909, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

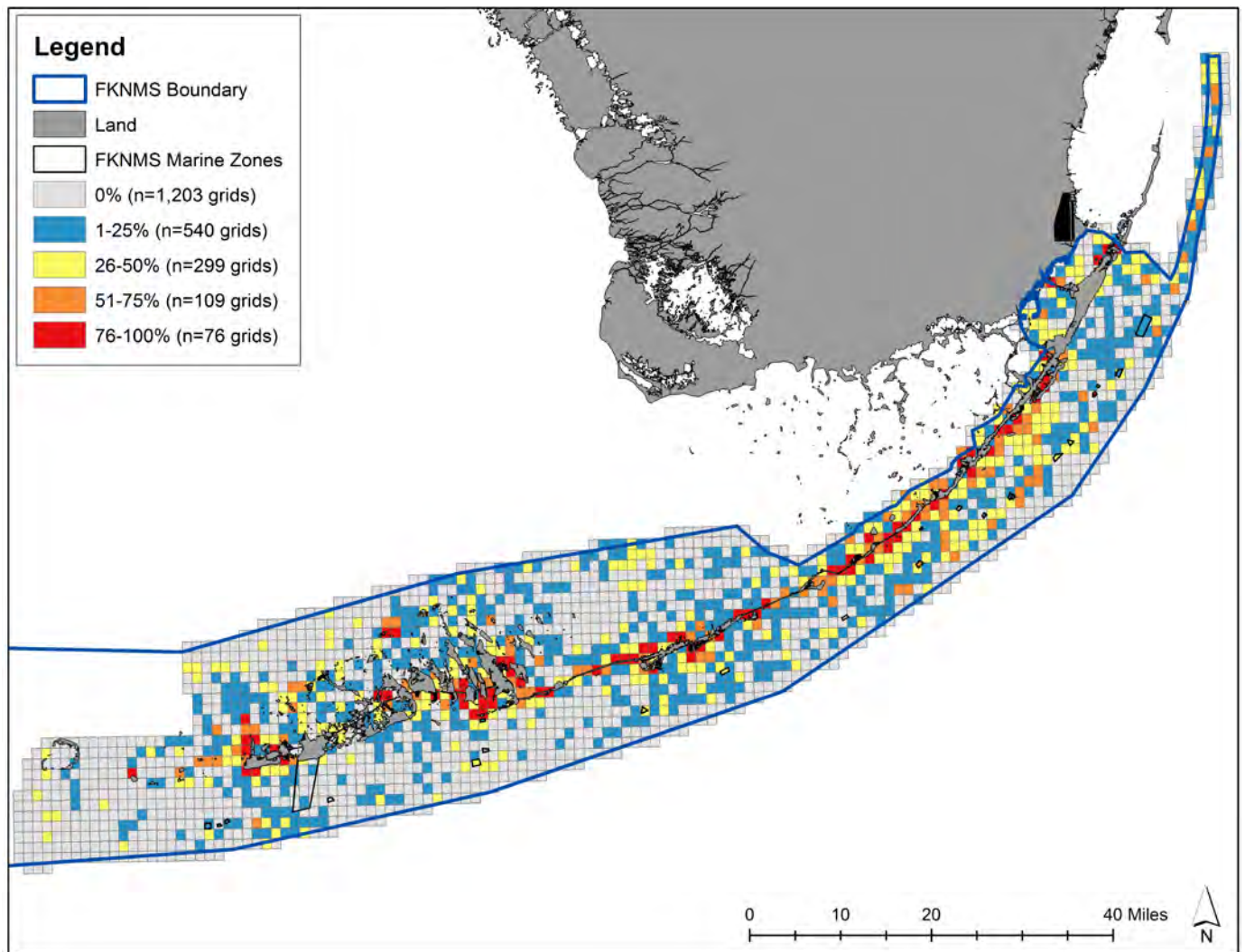


Figure 18 Map depicting the percent of time grids were occupied by boats when average daily wind speeds were greater than 15 mph (n = 4 flights, total boat count = 4,198; total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

References

IBM Corporation. (2012). SPSS (v 21). Armonk, NY, USA.

Dive Boat Activity During Lobster Season

Section at a glance

- ❖ *This chapter encompasses the 2-day sport dive season and the earliest days of the regular season (August 6-September 3).*
- ❖ *For the purposes of our surveys, a boat was considered diving if a dive flag was displayed and the boat was stationary, drifting, or moving at slow speeds.*
- ❖ *From the air, whether divers were fishing for lobster, spearfishing, or non-consumptively diving was unknown. However, the general increase in the number of dive boats and the shift in the location of most diving activity allows the inference that much of the activity during this time period was lobster diving.*
- ❖ *During both the Sport Season and the opening day of regular lobster season, the majority of boats observed were motorboats less than 30 ft. in length and were engaged in diving/snorkeling activity.*
- ❖ *Lobster diving effort tended to decrease as the month of August progressed, with peaks occurring on weekends.*
- ❖ *The majority of dive boats were observed on the Gulfside of the Florida Keys during both Sport Season and the first few weeks of the regular lobster season.*
- ❖ *Fewer dive boats were observed inside SPAs and the Ecological Reserve during Sport Lobster Season and the opening day of regular lobster season than other summer days.*

Introduction

The Caribbean spiny lobster (*Panulirus argus*) is a popular species for recreational and commercial harvest in the Florida Keys. Lobster can be recreationally harvested during the annual 2-day Sport Dive Season (Sport Season) and both recreationally and commercially harvested during the regular fishing season (Opening Day – August 6).

Sport season, also referred to as “Mini Season”, occurs annually during the last consecutive Wednesday and Thursday of July. During this time, fishers are permitted to recreationally harvest lobster by either diving (breath-holding, SCUBA, or hookah) or bullynetting (nets used from boats to ensnare lobster). Mail surveys of recreational lobster fishers conducted by FWC estimate that approximately 30-60,000 people participate in Sport Season annually, with the majority of these participants fishing in the Florida Keys (Sharp et al. 2005).

Commercial and recreational harvest occurs during the regular fishing season which opens August 6 and closes March 31 each year. Approximately 90% of the commercial catch comes from the Florida Keys, and during the 2016/17 fishing season it was valued at \$54 million. The commercial sector primarily harvests lobster using traps, however commercial fishers can also dive or use bullynets.

Lobster Season Specific Methods

Data from the main survey were queried to look at observations from Sport Season (July 27-28, 2016) and Opening Day (August 6, 2016). An additional seven flights were flown in 2017 to provide more detail on how lobster season changes boating activity throughout the first month of Lobster season (Table 1).

Table 6 Calendar of the seven addition lobster season flights conducted in 2017.

Date	Strata	Flight path
07/26/17	Lobster Holiday	Gulf AM, Ocean AM
08/06/17	Lobster Holiday	Gulf AM, Ocean AM
08/09/17	Lobster Season Summer Weekday	Gulf AM, Ocean PM
08/12/17	Lobster Season Summer Weekend	Gulf AM, Ocean PM
08/16/17	Lobster Season Summer Weekday	Gulf AM, Ocean PM
08/19/17	Lobster Season Summer Weekend	Gulf AM, Ocean PM
09/03/17	Holiday	Gulf AM, Ocean PM

Data on boating activity during Lobster Holidays was collected using the standard Gulfside and Oceanside flight paths. Due to the large number of boats present, the amount of time required to collect the data increased the duration of the flights which altered the time of day in which flights were usually completed. For example, on the first day of Sport Season 2016 (July 27), the Gulfside flight path which usually takes approximately 2 hours to complete took approximately 4 hours, thus delaying the start time of the Oceanside flight. The Oceanside flight was conducted again the second day of Sport Season, in the morning rather than afternoon. Flights on Opening Day 2016 were flown using the standard Gulfside in the morning, Oceanside in the afternoon flight plan. Anecdotal evidence suggests that Sport Season and Opening Day participants typically begin boating early in the morning, thus the delayed afternoon start time and completion of the flight after 5:00 of the Oceanside flight was deemed an inaccurate estimation of boating activity. In an effort to more accurately estimate boating activity, two planes were used on the first day of Sport Season and Opening Day 2017, allowing both Gulfside and Oceanside flight paths to be completed at the same time. The morning Gulfside and Oceanside flights from the first day of Sport Season 2016 and 2017 are directly comparable. Due to flight timing discrepancies on Opening Day 2016 and 2017, only the Gulfside flights are directly comparable. For all lobster season data, a boat was considered diving if a dive flag was displayed and the boat was stationary, drifting, or moving at slow speeds. From the air, whether divers were fishing for lobster, spearfishing, or non-consumptively diving was unknown. However, boat location appears to be a good indicator of participation in the lobster fishery. To understand the influence of lobster season on diving activity, the number of boats was compared using a combination of data collected from flights in August 2016 and 2017.

Sport Season

Characterization of Boat Types and Activities

The total number of boats, types of boats, and the activities they were engaged in were similar between years. The majority of boats observed during Sport Season included motorboats (96.2 %±1.45%), 91.90% ± 0.03% of which were less than 30 ft. in length. The remaining boat types were charter dive boats, construction vessels, personal watercrafts (PWCs), paddlecraft, military vessels, and sailboats each of which contributed to less than 1% of the boats observed.

The majority of boats (74.1% ± 0.9%) were engaged in diving/snorkeling activity or were running (21.8% ± 0.4%). Other activities observed included boats that were anchored, hook-and-line fishing, partying at a sandbar or engaged in water sports (Figure 1).

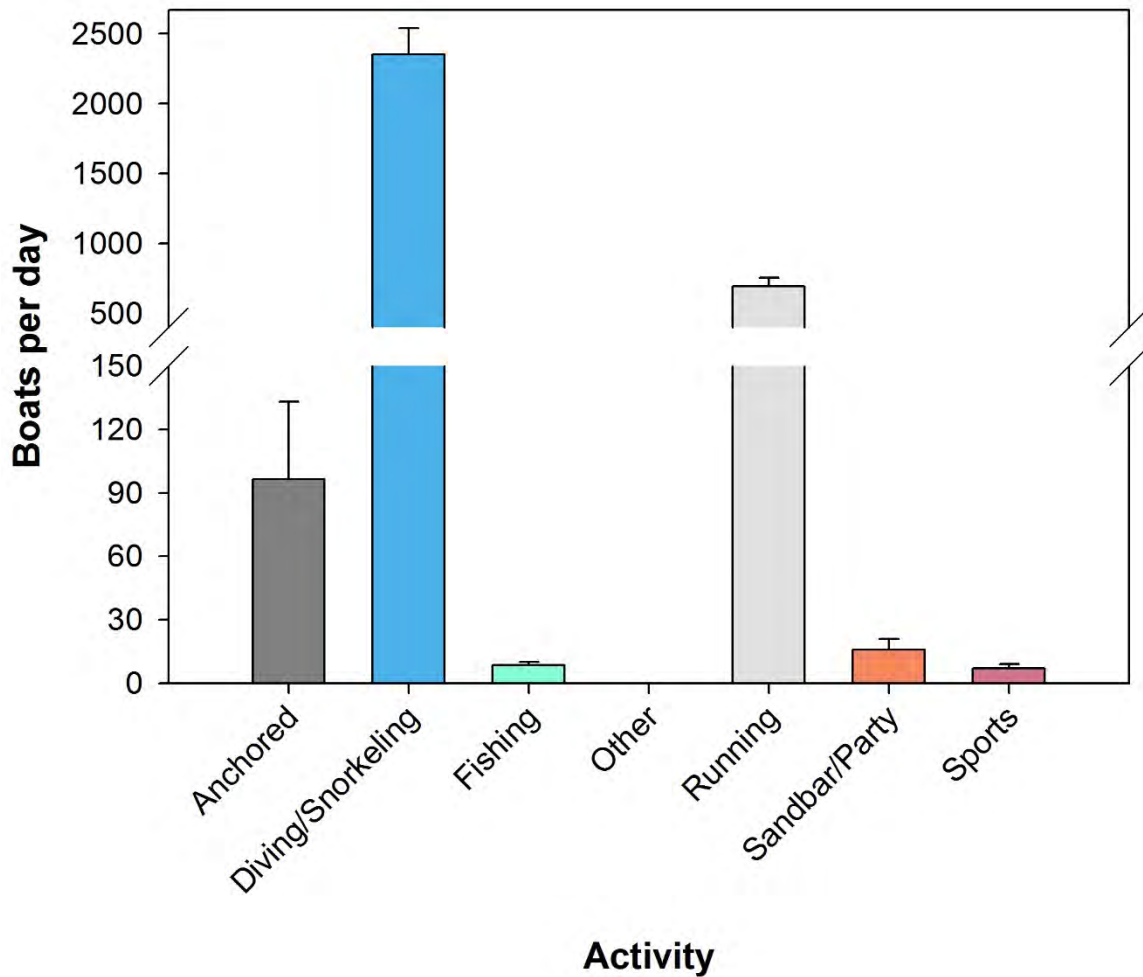


Figure 19 Average and standard deviation of the number of boats by activity type observed during the Gulfside flight on the first day of Sport Season 2016 and 2017.

Locations of Diving/Snorkeling Activity

During both the 2016 and 2017 seasons, over 50% of dive boats were observed on the Gulfside of the Lower Keys, with the next greatest number of boats observed on the Gulfside of the Middle Keys (Figure 2). The Oceanside boat counts may be an underestimate because the data was not collected on the first day of Sport Season for both

years. The number of dive boats observed during the morning on the second day of Sport Season 2016 was less than that observed during the first day of Sport Season 2017 but we do not have enough years of data to know if diving effort is typically similar across both days.

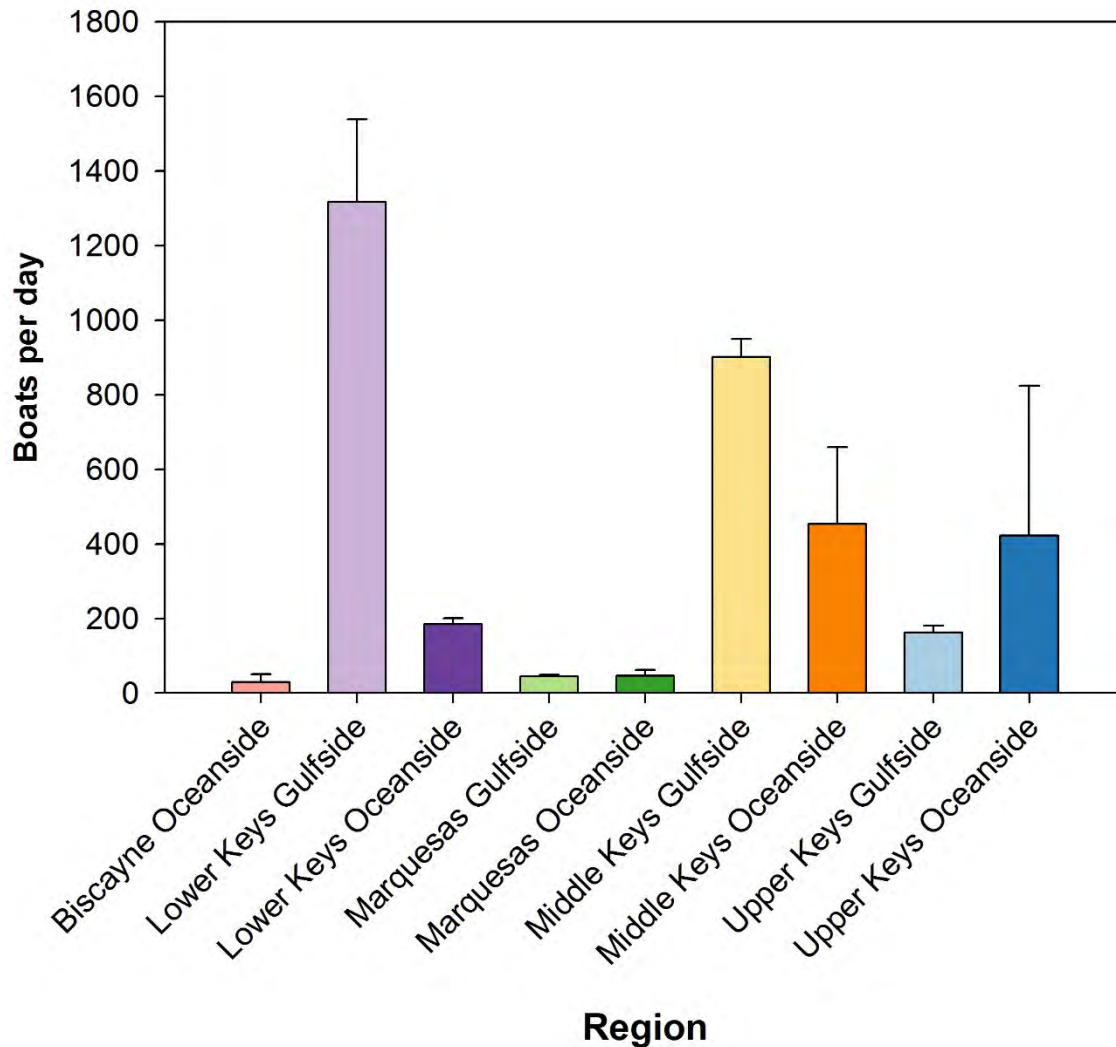


Figure 20 Average and standard deviation of the number of dive boats per general region of the FKNMS observed during the opening day of lobster Sport Season (July 26th or 27th) in 2016 and 2017 for Gulfside flights. Oceanside flights were conducted on the second day of Sport Season in 2016 and the first day of Sport Season in 2017.

Regular Season Opening Day

Characterization of Boat Types and Activities

The composition of boat types and the activities they were used for during the Lobster Season Opening Day were similar to those observed during Sport Season. The majority of boats observed during the opening day of lobster season were recreational motorboats (86.9% ± 0.4%), 90.5% ± 0.7% of which were less than 30 ft. in length. The

remaining boat types were comprised of charter dive boats (0.5% ± 0.3%), commercial fishing vessels (2.1% ± 0.2%), construction vessels (0.04% ± 0.01%), sightseeing vessels (11.0% ± 0.03%), personal watercrafts (PWCs) (3.1% ± 0.4%), paddlecraft (2.2% ± 1.0%), military vessels (0.04% ± 0.02%), and sailboats (5.0% ± 1.1%).

The majority of boats observed were motorboats engaged in diving/snorkeling activity (55.8% ± 4.3%) or were running (29.9% ± 1.6%). Other activities observed included boats that were anchored, hook-and-line fishing, partying at a sandbar or engaged in water sports or some other activity (Figure 3).

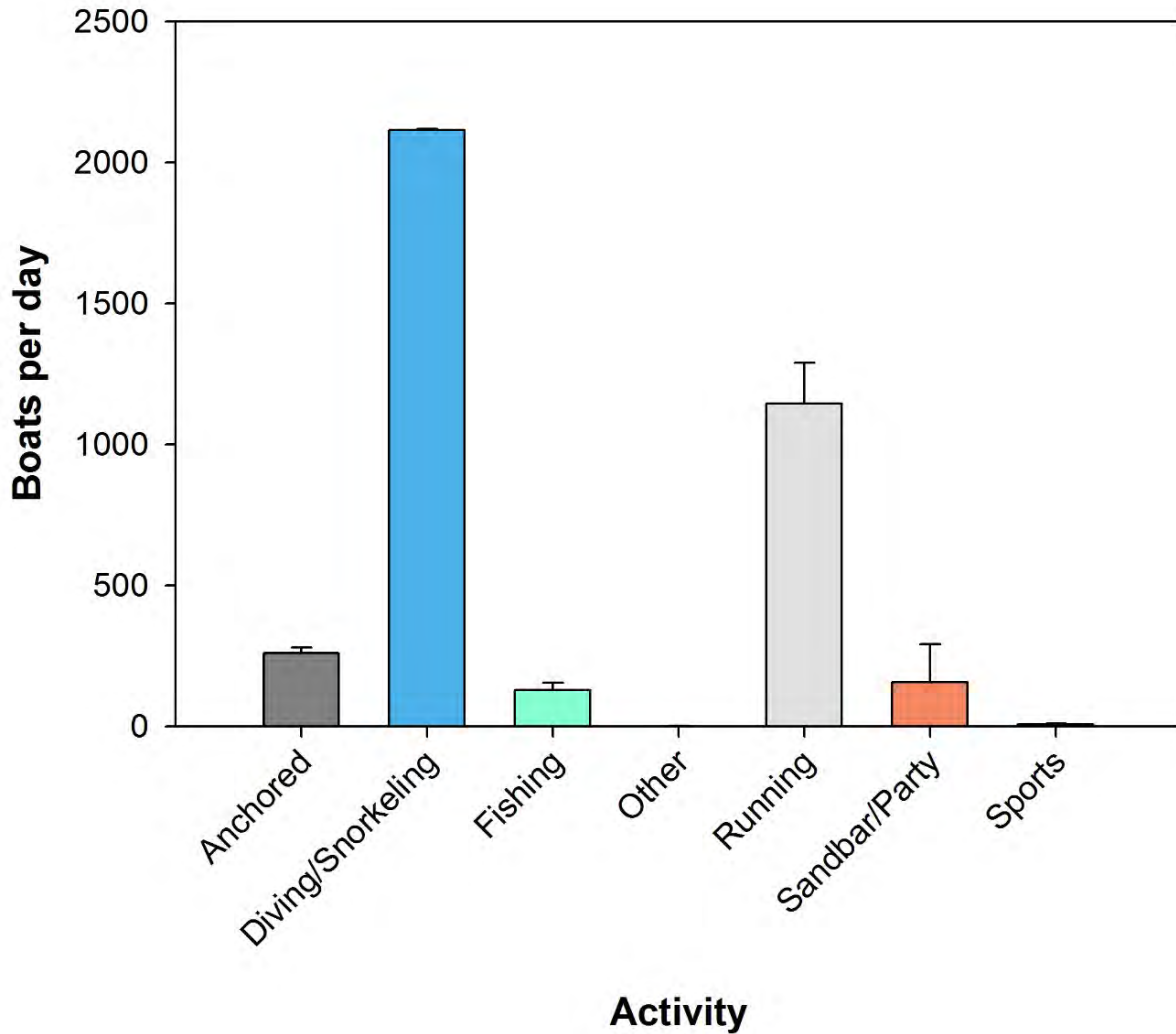


Figure 21 Average and standard deviation of the number of boats by activity type observed during the opening day of regular lobster season (August 6) in 2016 and 2017.

Locations of Diving/Snorkeling Activity

Boaters were observed diving/snorkeling in all regions surveyed during the opening day of spiny lobster season of 2016 and 2017. Overall a greater proportion of boats were observed diving/snorkeling on the Gulfside (69.5% ± 4.3%) than the Oceanside (30.5% ± 4.3%) of the Florida Keys. On average, the greatest number of dive boats were observed on the Gulfside of the Lower Keys, while the lowest numbers of boats were observed on the oceanside of the Biscayne and the Marquesas regions (Figure 4).

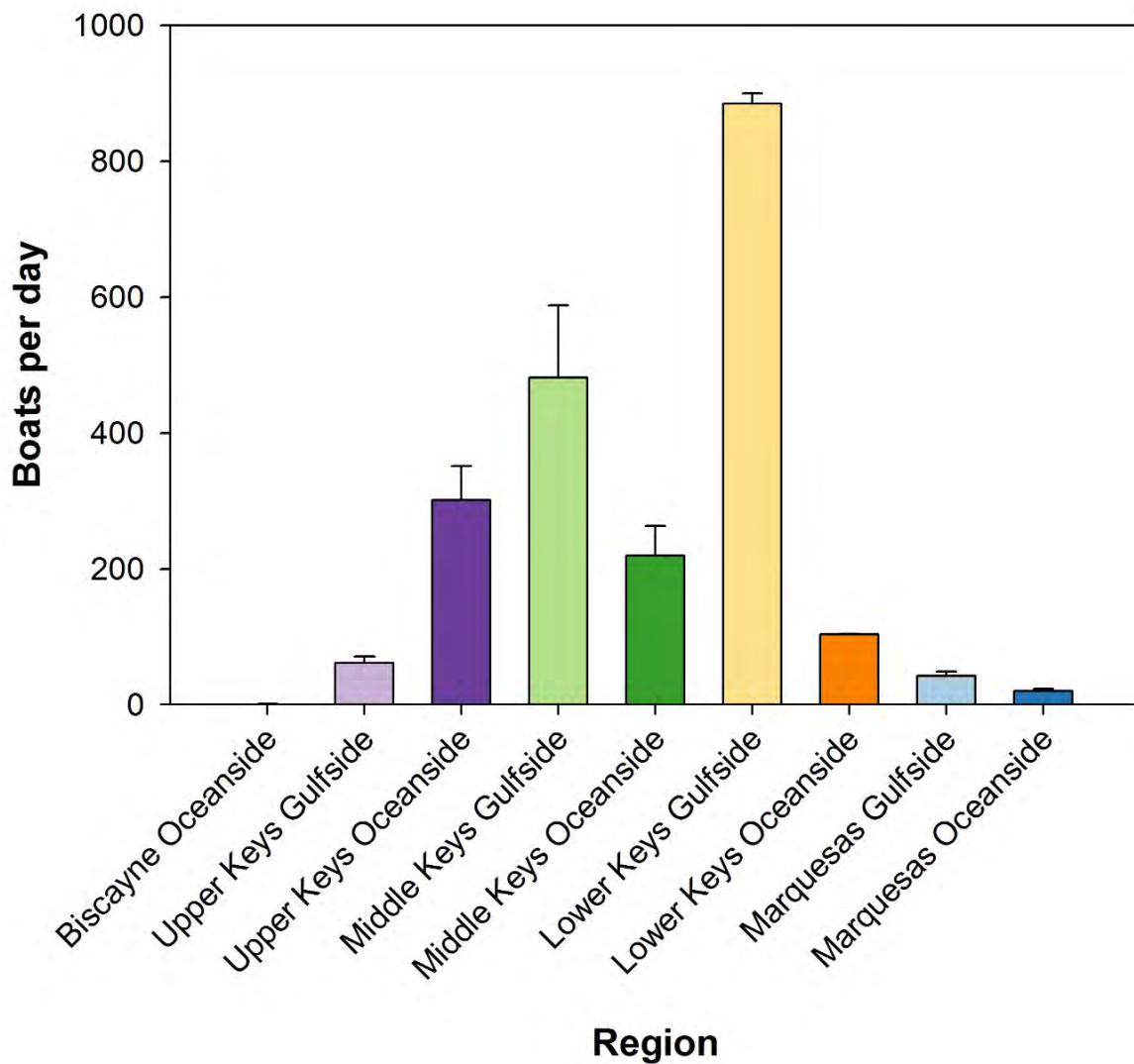


Figure 22 Average and standard deviation of the number of boats observed per region during the opening day of regular lobster season (August 6) in 2016 and 2017.

Influence of Lobster Season on Diving Effort

The total number of boats engaged in diving activity was influenced by lobster season both temporally and spatially. Spikes in diving effort were observed during Sport Season and the opening day of regular lobster season, but tended to decrease as the month of August progressed (Figure 5). Spatially, diving effort shifted from the Oceanside to the Gulfside of the Florida Keys during Sport Season and opening day of regular season (Figure 5). The density of dive boats was greatest on the Gulfside of the Middle and Lower Keys, and lowest in the Marquesas (Figure 6, Table 2).

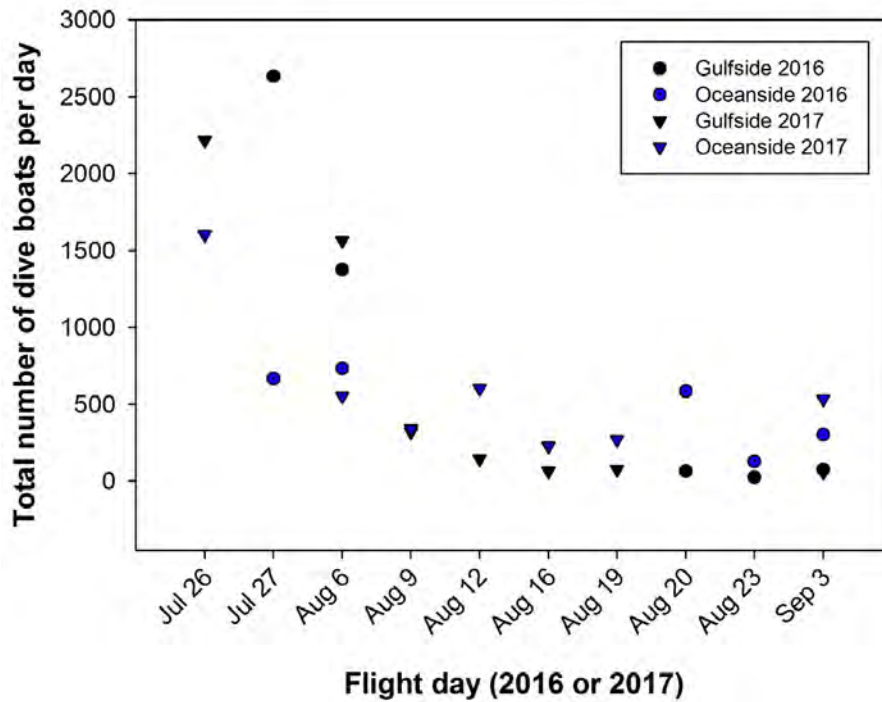


Figure 23 Total number of dive boats observed per day on the Gulfside and Oceanside of the Florida Keys during summer and lobster season flights conducted in 2016 and 2017.

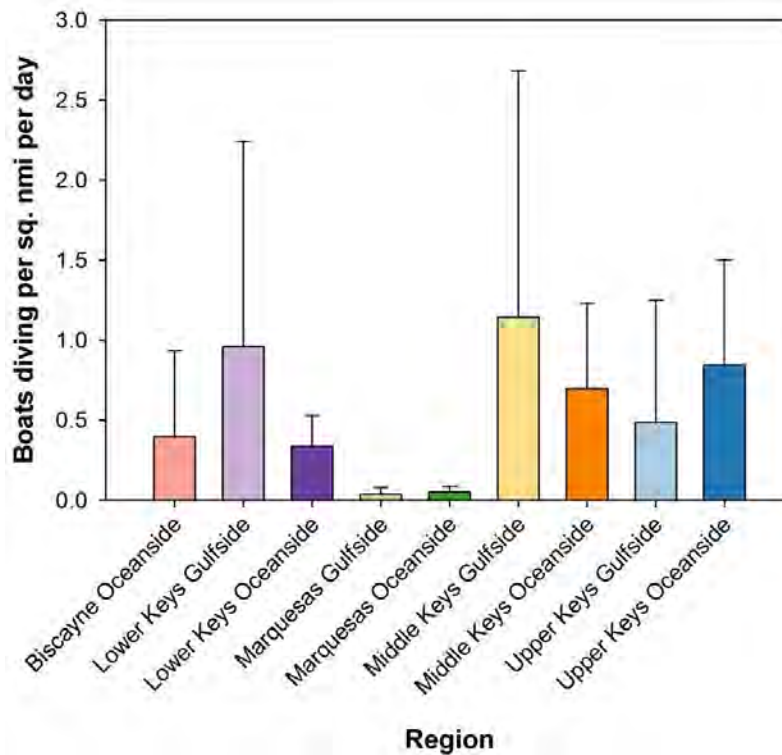


Figure 24 Average and standard deviation of the number of dive boats per square nautical mile during the first month of Lobster Season by region of the Sanctuary.

Table 7 Descriptive statistics [averages, standard deviations (st. dev.), and percentages] of counts and densities of recreational dive boats in the Sanctuary during the first month of Lobster Season 2016 and 2017 by region. Gulfside (GS), Oceanside (OS).

	Area (nmi ²)	Total Diving Boats			Density of Diving Boats	
		Average Boats per day	St. Dev. Boats per day	% Boats per day	Average Boats per nmi ²	St. Dev. Boats per nmi ²
Biscayne Reef	29	11.7	15.9	0.9	0.4	.05
Upper Keys GS	81	39.3	61.6	31.8	1.0	1.3
Upper Keys OS	273	229.9	179.4	7.09	0.3	0.2
Middle Keys GS	227	259.3	348.7	1.4	0.0	0.0
Middle Keys OS	279	194.3	147.7	1.6	0.1	0.0
Lower Keys GS	419	402.5	537.4	20.5	1.1	1.5
Lower Keys OS	267	89.8	51.6	15.4	0.7	0.5
Marquesas North	473	17.6	19.8	3.1	0.5	0.8
Marquesas South	399	20.5	13.8	18.2	0.8	0.7
Grand Total	2447					

Lobster season also influenced the number of dive boats observed in FKNMS Marine Zones. FKNMS Marine Zones refer to the Sanctuary Preservation Areas (SPAs), Ecological Reserves (ERs) and Research Only Areas (ROAs). During the summer, an average of $53.0 \pm 12.8\%$ of dive boats were in FKNMS Marine Zones per day, but during Sport Season 2016 and 2017 the number of dive boats in FKNMS Marine Zones declined to 28.5 ± 3.5 boats, which was only 0.8% of diving boats observed those days. The percent of dive boats in FKNMS Marine Zones remained low on Opening Day (4.5%) and August 9th (13.9%), but returned to average summer percentages by August 12th, which was the weekend after Opening Day of Lobster Season (Figure 7).

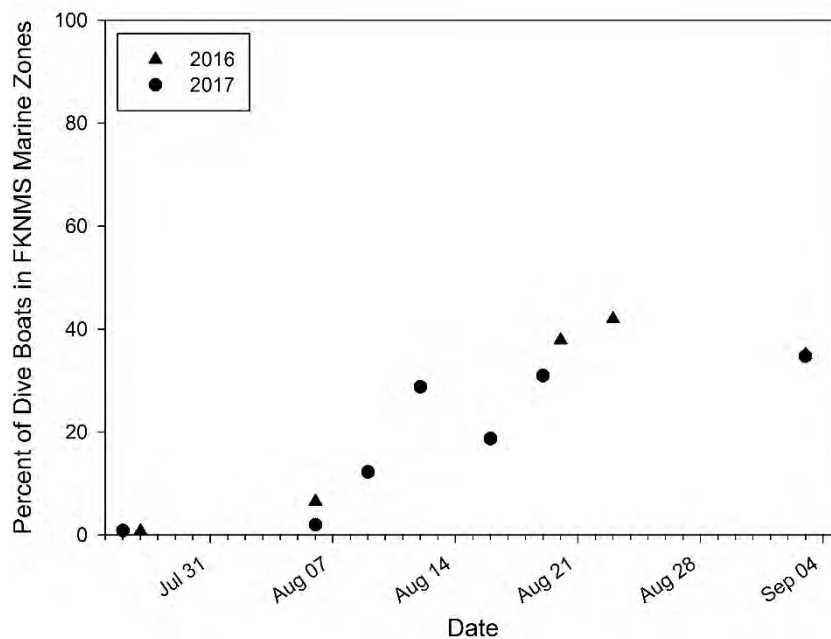


Figure 25 Percentage of dive boats observed inside FKNMS Marine Zones during lobster season flights in 2016 and 2017.

References

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Hook-and-Line Fishing

Section at a glance

- ❖ *A boat was considered to be hook-and-line fishing when actively using fishing poles or lines. Boats that had fishing gear but that were obviously in transit were not counted as fishing.*
- ❖ *At any given time, 15-28% of vessels in the Sanctuary were fishing.*
- ❖ *An average of 342 ± 190 vessels were observed fishing daily.*
- ❖ *Hook-and-line fishing boats were fairly spread throughout the sanctuary, but there were popular fishing areas – particularly along the reef tract and near bridges. During the summer, boats appeared to concentrate along the reef tract, nearshore, and near bridges, while boats were more spread out and less concentrated during the winter.*
- ❖ *Peak number of boats fishing on the Oceanside occurred at the beginning of grouper season in May and on a fair-weather day between Christmas and New Year’s Day, while the total number of boats fishing on the Gulfside was lower and relatively steady.*
- ❖ *Upper and Middle Keys reefs had the highest densities of boats fishing over coral habitat per area sampled, followed by Biscayne and Lower Keys reefs. Lowest fishing boat densities were observed over the Marquesas reefs.*
- ❖ *The majority of fishing boats were observed over hardbottom (28%) and over continuous reef (25%) habitats. Other reefs supported 13% of fishing boats, while bridges (12%) and deep areas offshore (12%) were also popular. Per area, bridges and continuous reef habitats saw the highest densities of fishing boats.*
- ❖ *Winds higher than 15 mph tended to reduce the number of fishing boats observed and increased the proportion of boats fishing nearshore, near bridges, and Gulfside.*

Introduction

Recreational fishing fuels the culture and economy of South Florida and the Florida Keys. Though the Florida Keys National Marine Sanctuary provides environments suitable for many different activities, recreational fishing has been a top endeavor of many of its visitors, worth \$500 million annually to the region (marineeconomics.noaa.gov, NOAA 2007). Fishing tournaments also attract both professional and amateur recreational fishing enthusiasts; during our survey period (February 2, 2016 – January 21, 2017) there were at least 21 fishing tournaments (8 focused on offshore fishing like billfish and dolphin, and 13 focused on nearshore and backcountry fishing for tarpon, redfish, bonefish, snook, etc.; see Appendix C). Recreational fishermen in the Keys operate from shore, bridges, private boats, and vessels for hire, which include charter boats and small guide boats (Bohnsack et al., 1994). Commercial hook-and-line fishing also occurs in the FKNMS. Florida’s commercial fisheries generate \$18 billion in sales each year, supporting approximately 90 thousand jobs (NMFS, 2016). Because we could not distinguish between commercial and recreational hook-and-line fishing activities, we use the term hook-and-line fishing or fishing for this chapter. However, we recognize that the vast majority of the vessels with active anglers are, in fact, recreational.

Fishing-specific Methods

For this survey, a boat was considered to be hook-and-line fishing when actively using fishing poles or lines. These observations included charter boats and commercial anglers (such as yellowtail fishers), since the difference between charter and privately owned recreational boats was not possible to differentiate during the aerial survey. Boats that had fishing gear but that were obviously in transit (*i.e.*, traveling at high speeds) were not counted as fishing at that time. Also, boats that had fishing gear and a dive flag displayed were counted as diving. Fishing boats that were counted in the survey could have been stationary, drifting, or moving at slow speeds (trolling). Since these surveys took place during the day between 8 AM and 6 PM, boats fishing at other times, at night for example, were not included in the study.

Statistical analyses were used to determine differences among fishing activity by season and weekday, by region, and by habitat. Negative binomial regressions with a log link function within generalized linear models (GLMs) were used to analyze count data, and gamma distributions with a log link function within GLMs were used to analyze the density (continuous) data. Homogeneous subsets for each category (*e.g.*, region, habitat, etc.) were identified via *a priori* pairwise contrasts. All statistical analyses were completed using SPSS (v 21, IBM Corp., Armonk, NY, USA).

Types of Boats Fishing

Hook-and-line fishing vessels included motorboats (99.9 %), 89.1% of which were under 30 ft. in length. Paddlecraft (kayaks, paddleboards and canoes) and sailboats made up less than 1% of all fishing vessels observed (total of 8 paddlecraft fishing, 7 sailboats fishing).

Seasonal Variation in Fishing

At any time during the aerial surveys, 15-28% of vessels were hook-and-line fishing throughout the Keys, and an average of 342 ± 190 (average \pm standard deviation) vessels were observed fishing each day. The most popular days for fishing were holidays (average of 416 ± 134 boats fishing) and weekends (Figure 1). Summer weekdays attracted somewhat fewer fishing vessels (average of 275 ± 160), but the least popular time to hook-and-line fish occurred on the opening days of lobster season, averaging only 103 ± 57 vessels, and representing only 5.4% of fishing boats (Figure 1). There was no difference between the number of boats fishing on weekdays or weekends and during summer or winter. Our observations of statistically similar number of fishing boats during the summer and winter or weekdays and weekends may not seem consistent with what many boaters have encountered, but this analysis does not consider weather. Winter includes many more days with high winds that were not surveyed and not conducive to fishing, but nice weather days in the winter were observed to have similar number of fishing boats as summer, including the peak day for fishing that we observed, a winter weekday, on Friday, December 29, 2016 (Figure 2).

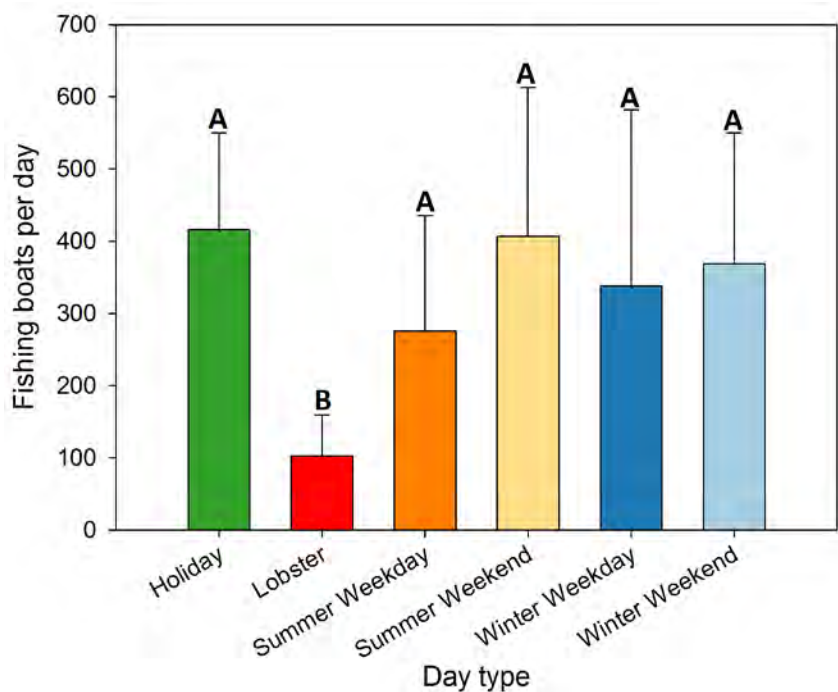


Figure 26 Average and standard deviation of the number of hook-and-line fishing boats by type of day flow (Wald $\chi^2 = 22.4$, $df = 6$, $p < 0.001$; $n = 2-8$ flights per day type; total fishing boats = 9,908). Letters indicate homogeneous subgroups ($p < 0.05$).

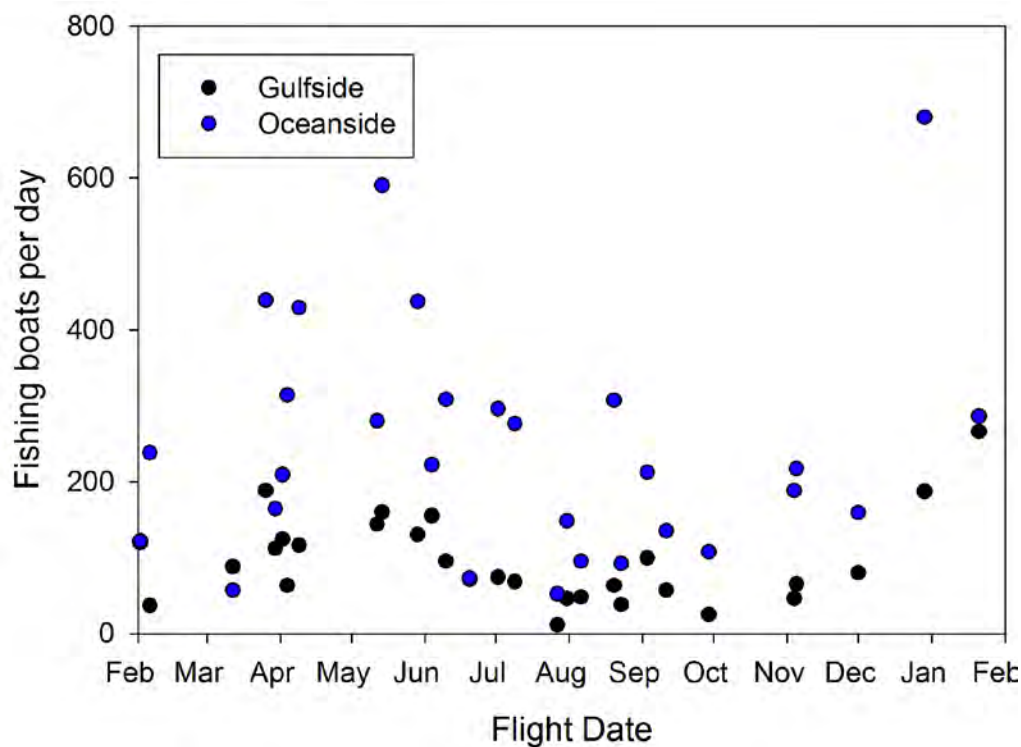


Figure 27 Total hook-and-line fishing boats observed by flight date on the Gulfside and Oceanside of the Sanctuary.

Though the Florida Keys are fished year-round, there are seasonal peaks during the winter tourist season and summer months (Bohnsack et al., 1994). Unlike diving boats which were more selective of their locations (see DivingDiving), fishing boats were more broadly spread throughout the Sanctuary from the Lower Keys through Biscayne (Figures 3, 4). However, there were several popular fishing areas – particularly along the reef tract (*i.e.*, the main coral barrier reef structure that extends North to South offshore of South Florida and the Florida Keys) and nearshore near bridges. Two fishing boats (less than 30 ft. in length) were observed in Sanctuary Preservation Areas, which are closed to fishing, during the 29 overflights of the Sanctuary.

The likelihood of a given area being occupied by fishing boats (*i.e.*, the percentage of time a boat was observed fishing within a grid) varied from summer to winter. During the summer, boats appeared to concentrate along the reef tract and near bridges, whereas boats were more spread out and less concentrated during the winter. For example, there were fewer unoccupied grids during the winter than during the summer. More grids with >50% occupancy were located along the reef tract and bridges during summer (n=88 grids) than winter (n=51 grids). The summer surveys also included several high-use areas (grids occupied during more than 50% of flights) on the Gulfside of the Lower Keys (Figure 3). These high-use areas on the Gulfside of the Lower Keys include natural cuts where currents bring in popular gamefish species, as well as flats frequented by fishermen. See Table 1 for a summary of fishing seasonal occupancy data in Figures 3 and 4.

Table 8 Summary of hook-and-line fishing grid occupancy data (from Figures 3 and 4).

	0% occupied	1-25% occupied	26-50% occupied	51-75% occupied	76-100% occupied
Summer					
# of grids = 2,426	56%	30%	10%	3%	<1%
Winter					
# of grids = 2,471	43%	43%	12%	2%	<1%

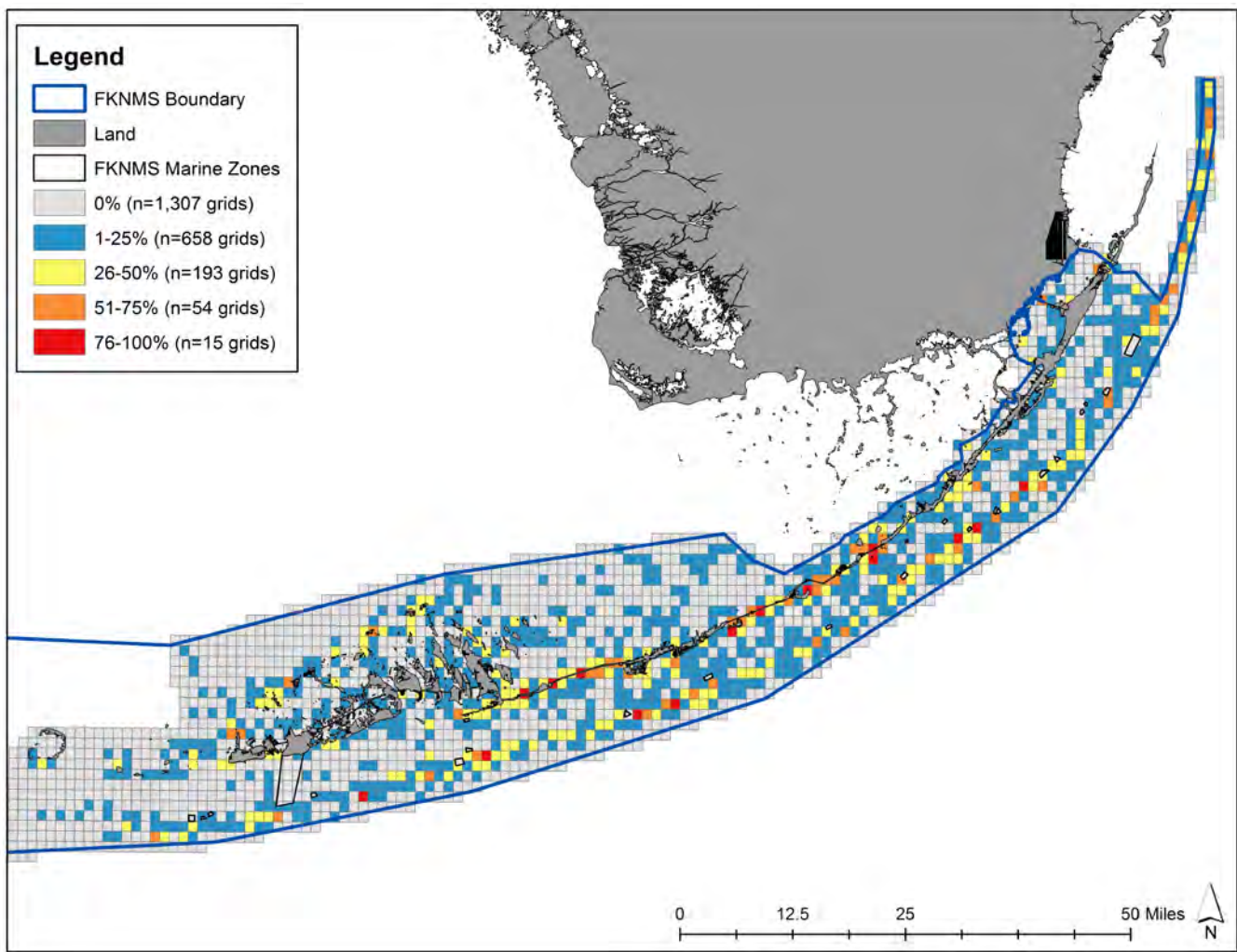


Figure 28 Map depicting the percent of time grids were occupied by hook-and-line fishing boats during our summer surveys (n = 9 flights, total boat count = 3,136, total grids = 2,426). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

Peaks in the number of boats fishing on the Oceanside occurred in May and December, while the total number of boats fishing on the Gulfside was relatively constant seasonally (Figure 4). A peak in fishing occurred on May 14, 2016 (590 boats Oceanside, 160 boats fishing Gulfside, Figure 4), which was a summer weekend in May and was our first summer flight since the opening of grouper season (grouper season May 1 – December 31). Another peak in fishing occurred on December 29, 2016, (680 boats Oceanside, 187 boats fishing Gulfside, Figure 4), which was a nice weather day with unseasonably warm temperature and low winds that occurred during the holiday break. Though lobster season brought high numbers of boaters, the number of fishing boats did not rise proportionately. The lowest numbers of boats fishing occurred during the lobster opening days, with fewer than 100 boats fishing Oceanside, and less than 50 boats fishing on the Gulfside (Figure 4).

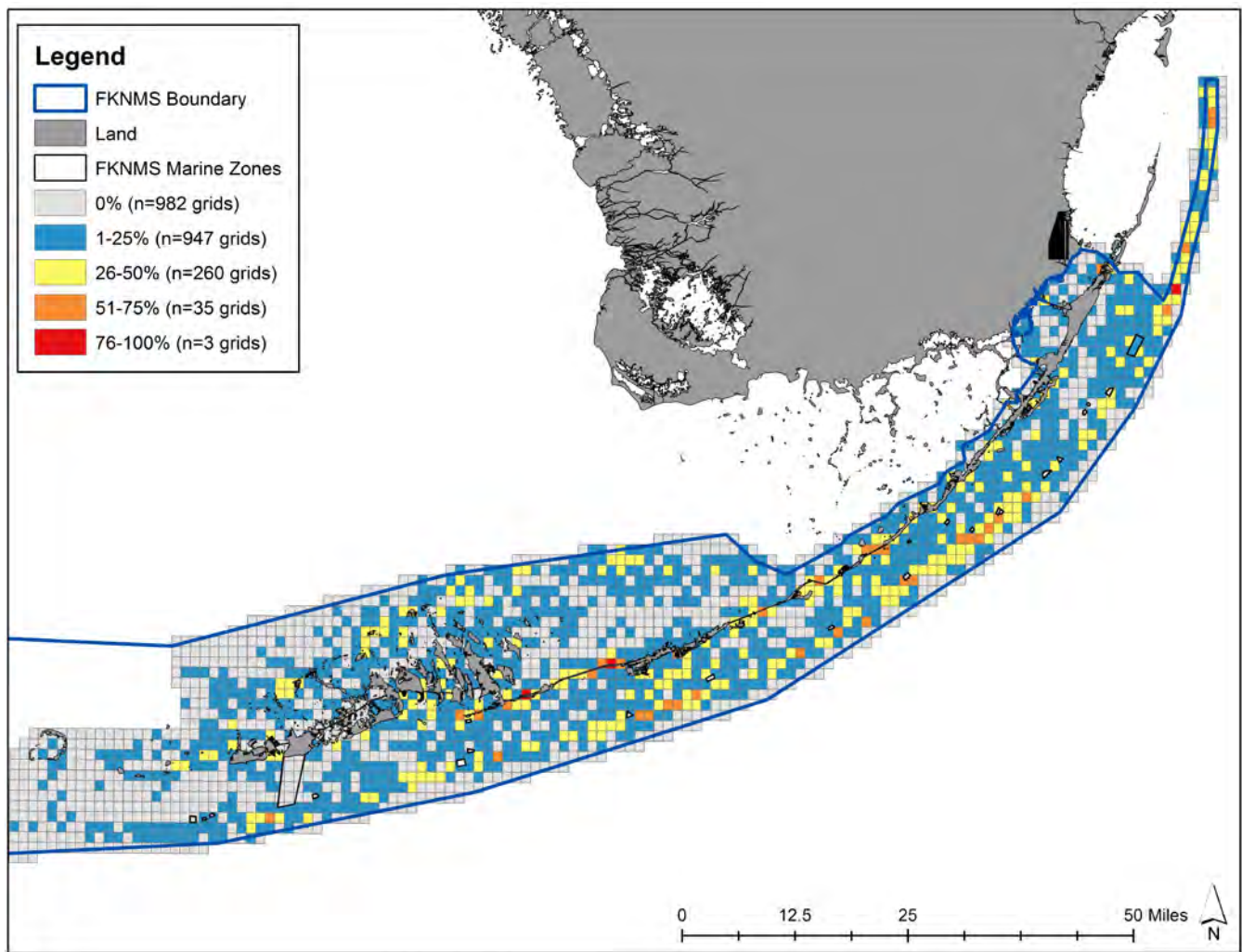


Figure 29 Map depicting the percent of time grids were occupied by hook-and-line fishing boats during our winter surveys (n = 15 flights, total boat count = 5,138, total grids = 2,471). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

Weather patterns as well as fish movement patterns play a role in determining where fishing occurs. With fairer but warmer conditions during the summer, many boats venture further from shore on the Oceanside. Thus, boaters may more frequently fish on the Oceanside, so long as good boating conditions permit. Relative peaks in the number of boats fishing on the Gulfside in the winter and spring were probably a result of both increased fish availability (especially during tarpon season) and reduced ability of small motorboats to venture offshore during windy winter days.

Fishermen target different species of fish depending on the time of year (Table 2). For example, those higher numbers of boats fishing on the Oceanside in the winter and spring were possibly targeting sailfish, blackfin tuna, and wahoo. Fishermen target tarpon near the bridges and on the Gulfside during the late spring and early summer months. As fish come and go from Keys waters, fishermen switch their focus to other species, depending on what's available and what's biting. Fishing for dolphin (mahi-mahi) becomes the target of many fishermen on the Oceanside during the summer and fall. Fishermen also target grouper around the Keys as soon as the season opens on May 1, which may explain the spike in fishing observed on our May 14 flight.

Table 9 Fish species targeted in South Florida and the Florida Keys during various times of the year, as outlined by Sportfishingmag.com and FloridaKeysFishingCharters.com.

	Flats	Backcountry/Bridges	Reefs/Wrecks	Deep Sea
Winter/Spring	Permit Redfish Snook Barracudas Sharks	Snapper Mackerel Bluefish Jacks Sharks Cobia Barracudas Seatrout Redfish Snook Grouper Tarpon	Yellowtail snapper Mutton snapper Mackerels: (King, Spanish, Cero)	Sailfish Dolphin Blackfin Tuna Wahoo
Summer/Fall	Tarpon Snook Bonefish Redfish Barracudas Sharks	Tarpon Snapper Mackerel Jacks Sharks Cobia Barracudas Seatrout Redfish Snook Grouper	Yellowtail snapper Mackerel Jacks Grouper Mangrove, Cubera, and Mutton snapper spawning aggregations	Dolphin Blackfin Tuna Wahoo Sailfish

Fishing by Region

The Florida Keys and surrounding waters are often divided into regions (*e.g.* Upper Keys, Middle Keys, Lower Keys) to help describe the locations and habitats of the Keys (see Methods section). Grids that included bridges or any portion of the Gulf were designated as Gulfside grids, since boater activity at bridges tends to be more aligned with that of other Gulfside boaters. We further designated areas surrounding the Marquesas Keys as Gulfside or Oceanside if a grid was north or south of those Keys. It is also important to note that the Biscayne region of the Florida Keys National Marine Sanctuary is adjacent to and offshore from, but not part of, Biscayne National Park.

Boaters were observed fishing in all regions surveyed, and fishing represented 7-23% of all boating activities for regions throughout the Florida Keys (see Overall section). Of all fishing boats, the highest number of boats fishing each day were observed Oceanside of the Middle Keys and Upper Keys (Table 3). The lowest numbers of boats fishing in the Sanctuary were observed in the Marquesas and the Gulfside of the Upper Keys (the portion of Florida Bay in the Sanctuary is relatively small). Overall, 72% of boats fished on the Oceanside (246 ± 190 boats daily), relative to the 96 ± 56 boats fishing each day on the Gulfside.

Of all regions surveyed, fishing was the most popular activity among boaters in the Biscayne region, with 63% of all observed boats in that region engaged in fishing. However, there were fewer fishing boats observed overall in the portion of Biscayne region relative to the rest of the Sanctuary (Table 3). Our findings for reefs in the Biscayne

region are similar to the composition of boaters in Miami-Dade (~59% of boaters were fishing), as noted by Behringer and Swett (2010). The portion of Biscayne that was evaluated during our current survey does not include Biscayne National Park (BNP) and the proportion of boats fishing in this region is a reflection of the small area observed and the high proportion of reef habitat included in this region (*i.e.*, along the offshore reef tract, see Figure 5).

Table 10 Descriptive statistics [averages, standard deviations (st. dev.), and percentages] of counts and densities of hook-and-line fishing boats in the Sanctuary by region. Gulfside (GS), Oceanside (OS).

	Total Fishing Boats				Density of Fishing Boats	
	Area (nmi ²)	Avg. Boats per day	St. Dev. Boats per day	% Boats per day	Avg. Boats per nmi ²	St. Dev. Boats per nmi ²
Biscayne Reef	29	25.0	26.1	7	0.90	0.88
Upper Keys GS	81	9.3	8.0	3	0.12	0.10
Upper Keys OS	273	73.3	52.2	21	0.27	0.19
Middle Keys GS	227	38.2	26.8	11	0.17	0.12
Middle Keys OS	279	89.4	53.8	26	0.32	0.19
Lower Keys GS	419	45.1	25.0	13	0.11	0.06
Lower Keys OS	267	48.8	29.8	14	0.18	0.11
Marquesas North	473	3.0	2.3	1	0.01	0.00
Marquesas South	399	9.7	6.3	3	0.03	0.02
Grand Total	2447					

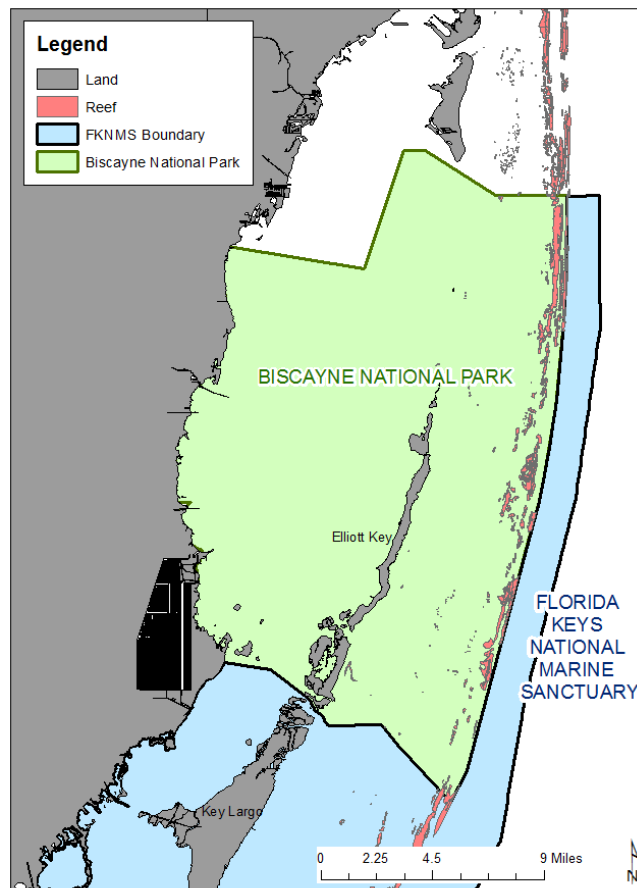


Figure 30 Map of Biscayne, with the region surveyed in the Sanctuary indicated in light blue.

Given the different habitats and size of each region it is difficult to compare the amount of fishing between regions and the relative amount of fishing on reef habitat. For example, the northern section of the Sanctuary, the Biscayne region, is a small area composed almost exclusively of continuous reef and deep unclassified habitats. We can, however, compare fishing activity in Biscayne and the rest of the regions in the Sanctuary if we include only these same two habitats. Fishing pressure over continuous reef habitat varied by region (Figure 6); Upper Keys and Middle Keys reefs had the highest density of boats fishing over continuous reef habitat, followed by Biscayne reefs and Lower Keys reefs, respectively. Sanctuary waters in the Upper Keys had almost twice the number of fishing boats per square nautical mile of reef as Biscayne and the Lower Keys. The lowest fishing boat densities were observed over Marquesas reefs.

South Florida fisheries are extremely complex due to the high number of targeted species, different types of gear used, and the availability of access points for the 80,000 residents of the Keys and millions of visitors (Moe, 1963; Bannerot, 1990; Bohnsack et al., 1994; NOAA 2007). The distribution of visitors in other marine parks is known to be influenced by infrastructure and access points, and activity tends to cluster around these access points (Coombes et al., 2009; Smallwood et al., 2012). Where people choose to fish is usually a result of what area is accessible to them. Many people are limited to the access provided at public boat ramps or where they live. Though boat ramps are located throughout the Sanctuary, some ramps are more accessible (*e.g.*, due to boat/trailer size, boat draft, parking, or launching fees) or may serve larger boating populations such as those near Miami, the Upper Keys, and the Middle Keys.

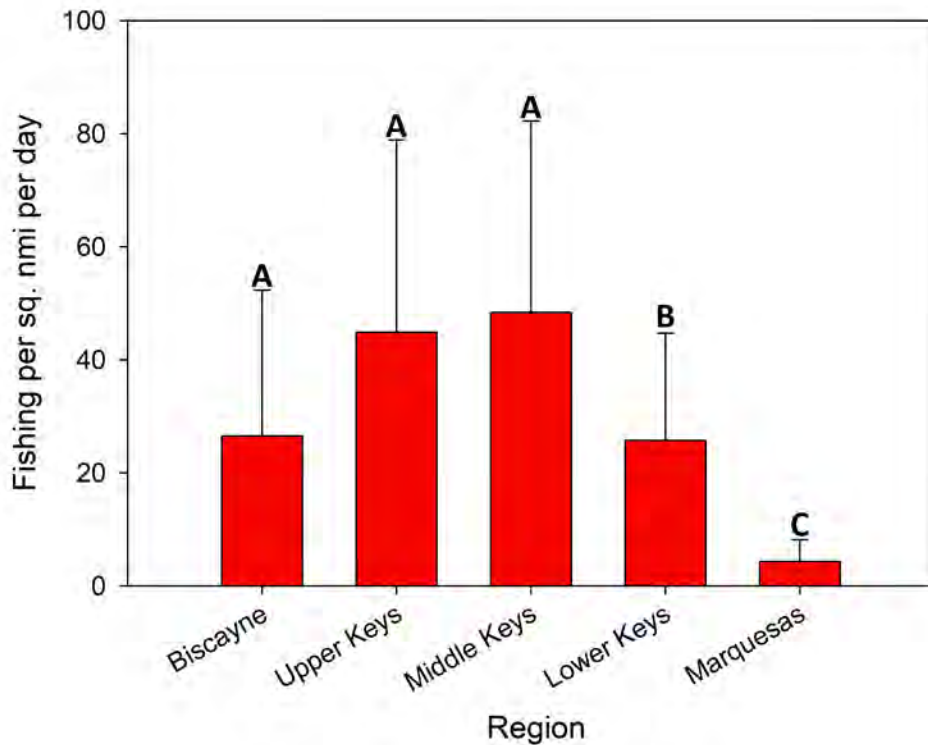


Figure 31 Average and standard deviation of the number of hook-and-line boats fishing over continuous reef habitat per square nautical mile (nmi²) by general region of the Sanctuary. Letters indicate regions with similar density of fishing boats. (Wald $X^2 = 277.0$, $df = 6$, $p < 0.001$; $n=27-29$ flights per region; total hook-and-line fishing boats =9,908). Letters indicate homogeneous subgroups ($p < 0.05$).

Habitats Fished

The type of habitat for each grid was designated by the most notable feature of each grid using a hierarchy of the habitats that are of the most interest to fishing and diving boats. Bridges held the highest rank in the hierarchy – any grid with a bridge within it was classified as a ‘bridge’, regardless of other habitats present in the grid. Grids with any amount of continuous reef were classified as such, followed by grids that contained other reef, pavement, or seagrass, and lastly, unconsolidated sediment (see Methods). Any grids within our study area that were beyond the 20-m contour line, where habitat data is not available, were labeled as “Deep unclassified”. The aerial survey of boats did not specifically evaluate what habitat was utilized by the observed boats. The assessment of the habitat likely used by boaters is subjective based on the likely feature or habitat available in the grid the boat was observed.

Fishermen target different habitats to seek a certain selection of fish that may reside in the habitat. Some habitats are common and account for the majority of fishing activity but some less common habitats like continuous reefs or bridges can concentrate fishing activity. Boats were observed fishing over all types of habitat, though the majority of fishing boats were observed over hardbottom (28%) and over continuous reef (25%). Other reefs supported 13% of fishing boats, while bridges (12%) and deep unclassified areas (12%) were also popular. The number of hook-and-line fishing boats observed varied significantly by habitat type. Significantly more fishing boats were observed over hardbottom and continuous reef habitats than all other habitat types, followed by other reef, bridges, and deep unclassified habitats. The lowest observations of fishing boats occurred over seagrass, followed by sand habitats (Figure 7).

Figure 32 The number and standard deviation (error bars) of hook-and-line fishing boats observed by habitat type (Wald $X^2 = 701.2$, $df = 6$, $p < 0.001$; $n=29$ flights; total hook-and-line fishing boats =9,908). Letters indicate homogeneous subgroups ($p < 0.05$).

The density of boats fishing varied significantly by habitat type. Significantly greater densities of fishing boats were observed near bridges and continuous reef habitats (Figure 8). The relatively high density of boats fishing in sand habitat is based on a very small area for this habitat (12 nmi²), and those sand patches are on the offshore edge of continuous reef habitat, so it's likely that boats counted in these grids were fishing off the edge of the reef. The lowest densities of fishing boats occurred over seagrass, hardbottom, other reef, and deep unclassified habitats, which together account for 84% of all habitat in the Sanctuary (Table 4). Because these habitats make up so much of the Sanctuary, they account for many hook-and-line fishing boats, but at relatively low densities compared to bridges and continuous reefs.

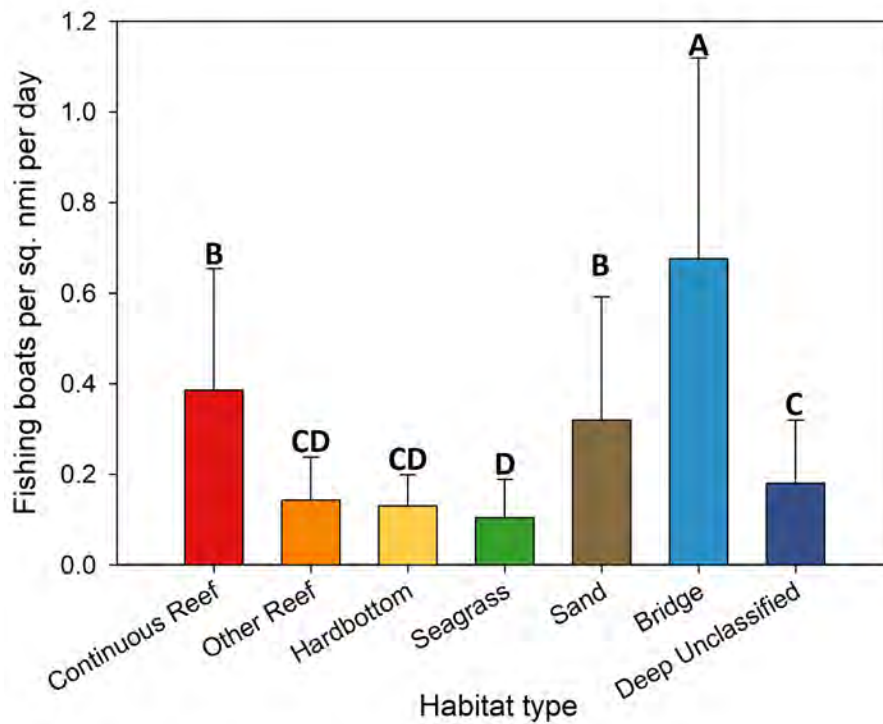


Figure 33 The average and standard deviation (error bars) of the density of hook-and-line boats observed per nmi² by habitat type (Wald $\chi^2 = 176.2$, $df = 6$, $p < 0.001$; $n=29$ flights; total hook-and-line fishing boats =9,908). Letters indicate homogeneous subgroups ($p < 0.05$).

The greatest densities of fishing boats were observed near bridges (0.7/nmi²) and over continuous reef habitat (0.4/nmi²) (Table 4, Figure 8). The density of fishing boats varies from the patterns seen in the total number of fishing boats by habitat in Figure 7 due to the amount of area covered by each habitat type (see Table 4 for area). For example, bridges and sand habitat make up only a small area (62 nmi² for bridges, 12 nmi² for sand), thus any boats fishing in these areas will produce a high density estimate. Though the density of boats at bridges makes up a small portion of the habitat of the Sanctuary, fishing near bridges is indeed a popular fishing tactic in the Keys. Bridges are accessible to boats of all sizes, even on days with high winds, and bridges support a diverse array of fish species due to the bridge structure and high current flow during tidal exchange.

Table 11 Descriptive statistics [averages, standard deviations (st. dev.), and percentages] of hook-and-line fishing boats in the Sanctuary by habitat type.

	Area (nmi ²)	Total Fishing Boats			Density of Fishing Boats	
		Avg. Boats per day	St. Dev. Boats per day	%Boats per day	Avg. Boats per nmi ²	St. Dev. Boats per nmi ²
Continuous Reef	223	85.8	59.8	25	0.4	0.3
Other Reef	312	44.7	29.6	13	0.1	0.1
Hardbottom	737	96.4	50.5	28	0.1	0.1
Seagrass	226	23.6	19.1	7	0.1	0.1
Sand	12	4.0	3.4	1	0.3	0.3
Bridge	62	42.2	27.7	12	0.7	0.4
Deep Unclassified	250	45.1	34.8	13	0.2	0.1

Wind

Weather has a great effect on boating, with more favorable weather allowing more vessels to participate in a plethora of activities. The highest counts of fishing boats were observed during days with an average wind speed of less than 10 mph (Figures 9a). Winds higher than 15 mph tended to reduce the number of fishing vessels observed and although we intentionally did not fly on days with winds over 20 mph, it was clear that winds over 20 mph greatly reduced the number of fishing boats (Figure 9a). Overall, the number of boats fishing on the Gulfside remained fairly constant regardless of wind speed ($r^2 = 0.001$, $p = 0.9$), which is a result of the greater protection from the wind for boats near land (Figure 9). The number of fishing boats on Oceanside declined as wind speed increased, ($r^2 = 0.187$, $p = 0.02$), indicating that boating drops off at greater wind speeds. Of those boats that did fish during high winds (15+ mph), the proportion of boats fishing Gulfside increased (Figures 9a,b).

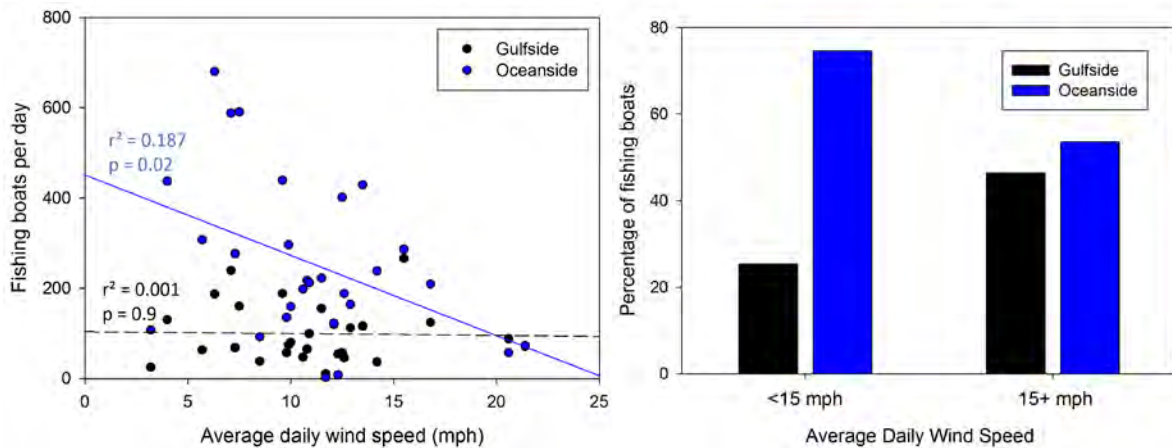


Figure 34 (a) Number of hook-and-line fishing boats per day observed on the Gulfside vs the Oceanside of the FKNMS by average daily wind speed; lines and r^2 values represent results of linear regressions. **(b)** Proportion of hook-and-line fishing boats observed on the Gulfside vs. the Oceanside on calm (<15 mph) days vs. on windy (15+ mph) days.

Wind not only affected the quantity of boats fishing, but it also influenced where boats fished. For example, on windier days, more boats were concentrated nearshore, around bridges, and on the Gulfside than on calm days, when boats were more concentrated Oceanside, particularly along the reef tract (Figures 10, 11). Though we only flew on four windy days (*i.e.*, Figure 11 is based on 4 flights), there was clearly reduced fishing along the Oceanside during our high wind flights, particularly in the Lower and Middle Keys. Only a small portion of all observed grids (27%) was occupied on windy days, whereas 65% of all observed grids were occupied on calm days (Figures 10, 11). On calm days 23 grids (56%) that were occupied >50% of the time were located offshore, along the reef tract; but on windy days, only 3 grids (6.8%) offshore were occupied (Figures 10, 11). Rather, 93.2% of the grids that were occupied more than 50% of the time on windy days were located nearshore. Grids along the Biscayne reef and parts of the Upper Keys were often occupied despite high wind speed. This is likely because wind direction is also a determining factor of boating conditions; for example, a West to North wind associated with cold fronts would not produce as high seas leeward of and in close proximity to land (*i.e.*, fetch) in these areas. Wind direction was not investigated as a factor of fishing location in this study due to the low number of days flown at each wind speed and direction combination.

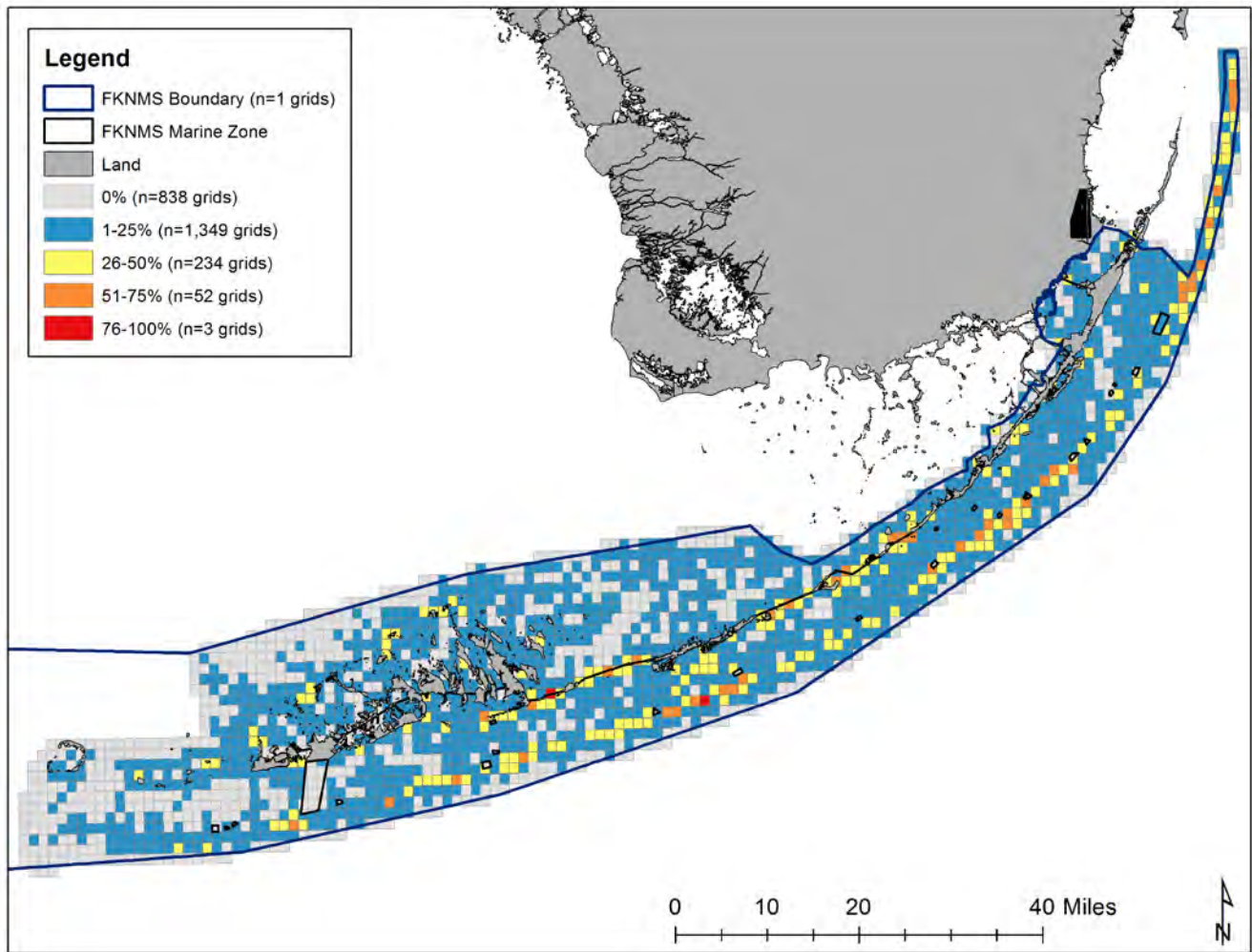


Figure 35 Map depicting the percent of time grids were occupied by hook-and-line fishing boats when average daily wind less than 15 mph (n = 23 flights, total hook-and-line boat count = 8,722, total grids = 2,476). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

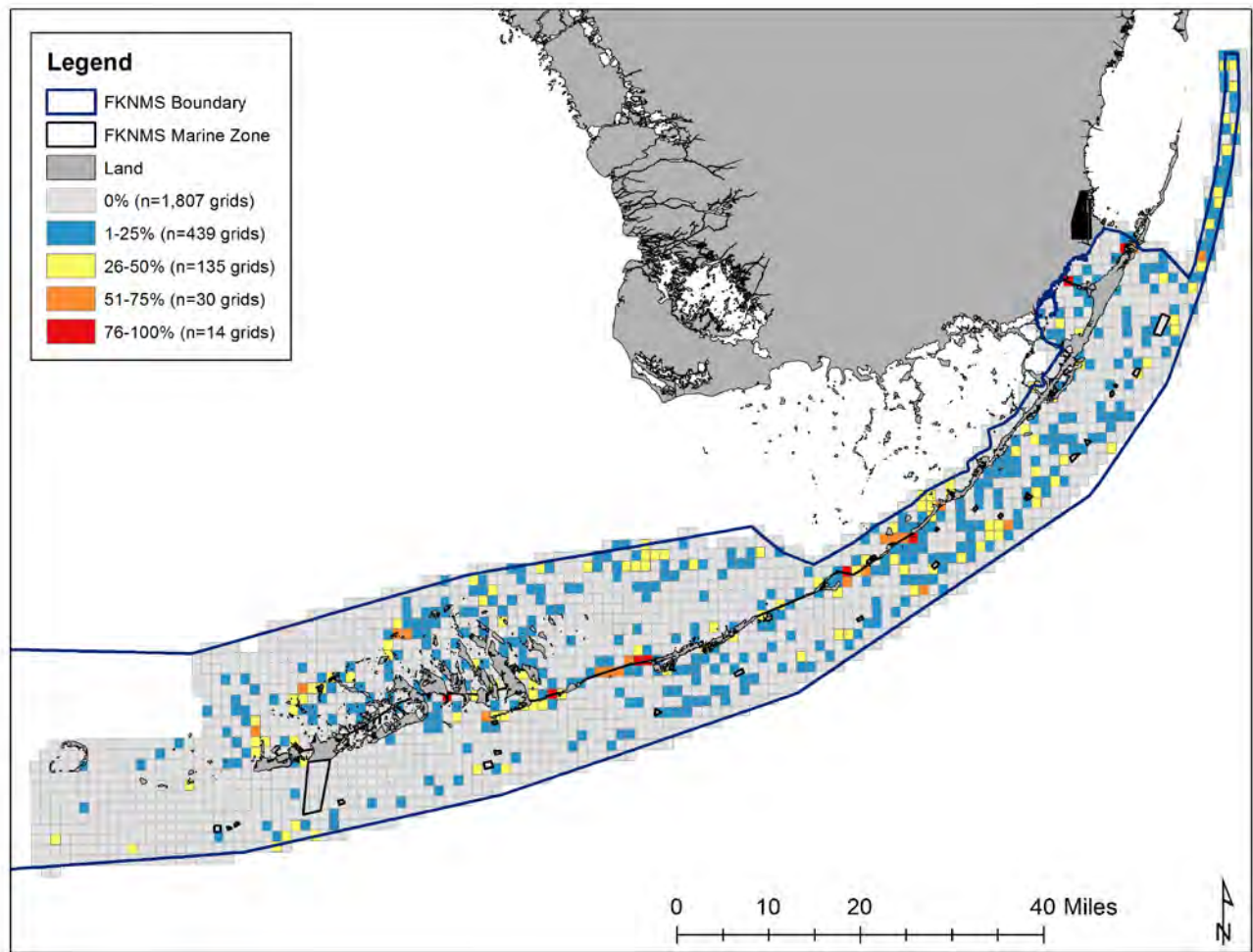


Figure 36 Map depicting the percent of time grids were occupied by hook-and-line fishing boats when average daily wind speeds were greater than 15 mph (n = 4 flights, total hook-and-line boat count = 1,186; total grids = 2,425). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

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Commercial Fishing

Section at a glance

- ❖ *For the purposes of our surveys, boats with commercial trap markings, head boats, and sponge fishers were termed “commercial fishing”.*
- ❖ *The peak number of commercial fishing boats were seen early in lobster and stone crab season and declined steadily from December to the close of the fishing seasons in the spring.*
- ❖ *A peak in the number of commercial fishing boats observed in December likely reflected a synchronizing of fishing trips after the Thanksgiving Holiday.*
- ❖ *The number and density of commercial fishing varied by region in the Sanctuary. Most commercial fishing (80%) occurred in the Middle and Lower Keys regions – predominantly on the Gulfside.*
- ❖ *The lowest density of commercial fishing boats occurred in the Marquesas, Biscayne, and Upper Keys regions, but these results should be considered in context relative to the great differences in area between these regions.*
- ❖ *Wind did not have as great of an effect on the number of commercial fishing boats as it did on the number of hook-and-line fishing boats, but more commercial fishing boats were Gulfside on windy days (15+ mph).*
- ❖ *Commercial fishing represented between 1-2% of boating activity in the Sanctuary, but comprised a greater portion of the boating activity (30%) in the less frequently visited Dry Tortugas region.*

Commercial Fishing

For purposes of these aerial surveys, boats with commercial trap markings (buoy colors and license numbers), head boats (charter boats for large numbers of recreational fishermen, also known as party boats), and sponge boats were termed “commercial fishing”. A notation error in the data collection process prevented differentiation of commercial fishing boats by type; however, there were 12 head boats registered in the study area (Florida Sport Fishing web site) and observations of only 24 small boats that were consistent with the size of sponge boats suggest that these two types of boats were rare during surveys, and results reported for commercial fishing represent boats used primarily in crustacean fisheries. This category does not include charter fishing boats like flats boats and other larger sport fishing charter boats. These charter boats were not consistently distinguishable from private boats during aerial surveys and any attempt to describe their activity would not be representative for the group (see Methods). Commercial fishing boats that were moving were not included in boat distribution estimates this section. Not including moving commercial fishing boats greatly reduced the number of boats reported in these maps, but preserved the assessment of fishing areas. We did not differentiate commercial fishing boats into categories other than boat length (less than or greater than 30 ft.). Thus, all commercial boats are discussed as a group, though there are various fisheries that operate at different times throughout the year. We recognize that commercial boats used for fishing traps may be used in other commercial fisheries, recreational fishing, recreational diving, other watersports, or leisure activities at sandbars. The presence of a commercial fishing boat in the closed fishing seasons or in areas closed to fishing does not indicate illegal activity.

Florida’s commercial fisheries generated \$231 million dollars in sales in 2016, supporting approximately 90,000 jobs (NMFS, 2016). In Florida’s 2016/2017 fiscal year, there were 9,382 active individual saltwater products licenses in Florida. During the calendar year 2016, when the majority of the survey flights occurred, commercial fishing in Miami-Dade and Monroe counties was valued at \$140 million dollars – which was 60% of the commercial fishing value for the State (Table 1). The top fisheries in the state include the spiny lobster and stone crab fisheries, both of which are fished extensively, but not exclusively in the Sanctuary.

Table 12 Commercial fishing landings summaries for all fisheries for the state of Florida for calendar year 2016. Landing summaries for the trap-based and sponge fisheries for Miami-Dade and Monroe counties (FWRI, 2018).

	Pounds	Trips	Average Price	Estimated Value
2016				
All Florida	85,356,440	374,764		\$231,382,055
South Florida	13,955,730	75,004		\$72,465,007
Miami-Dade				
All Species	1,372,288	7,766		\$4,807,926
Spiny Lobster	326,299	1,521	\$7.71	\$2,515,749
Stone Crab	27,949	381	\$12.77	\$437,349
Blue Crab	68,741	425	\$2.18	\$149,664
Monroe				
All Species	12,583,442	67,238		\$67,657,081
Spiny Lobster	5,002,889	18,183	\$8.24	\$41,201,807
Stone Crab	1,153,271	8,604	\$10.68	\$12,374,765
Sponge	188,847	286	\$1.43	\$269,198
Blue Crab	22,962	313	\$1.87	\$42,876

Results reported herein primarily reflect commercial lobster and stone crab trap fishing. The Caribbean spiny lobster (*Panulirus argus*) fishery was the most valuable commercial fishery in South Florida. The majority (90%) of the commercial spiny lobster catch in Florida comes from the waters surrounding the Florida Keys (Monroe, Table 1). Florida’s Marine Fisheries Information System (commonly referred to as trip tickets) had an average 112 lobster fishing trips each day in the waters surrounding Monroe County in August. This fishery is supported primarily through trap fishing, but there is also dive and a bully netting sectors. It’s unlikely that we captured any of the bully netting boats in our surveys, since they operate at night when the nocturnally active lobsters are moving in the shallows. Commercial lobster dive boats were classified as dive boats, but were not differentiated from recreational dive boats. The commercial lobster season opens August 6 each year, and closes March 31.

The commercial stone crab (*Menippe* spp.) was the second most commercial valuable fishery in Florida. This fishery is fished almost entirely with traps. The majority of stone crab fishing takes place on the Gulf coast of Florida, from Franklin to Monroe counties with Monroe County waters having an average of 61 stone crab trip ticket records each day in October. The commercial stone crab season opens October 15 and closes May 15.

The blue crab and sponge trip tickets in Monroe County included 599 fishing trips in 2016. No blue crab fishing boats were specifically noted during surveys, but it was difficult to differentiate a licensed blue crab boat from other trap pulling boats during aerial surveys and some trap pulling boats have all three, lobster, stone crab, and blue crab licenses. There were 16 commercial fishermen with blue crab landings in Monroe County in 2016 (FWRI 2018). Sponge fishermen work from small boats, sometimes associated with a larger “mother” ship, and scan the shallows for sponges. They use long poles equipped with hooks to harvest sponges from the seafloor (Stevely & Sweat, 2016).

Only small sponge fishing boats were observed in the Sanctuary during these aerial surveys. These smaller sponge vessels do not have individual licenses and the number of vessels cannot be estimated from landings records.

General trends in Commercial Fishing

There were 355 observations of commercial fishing vessels actively fishing in the Sanctuary during our 29 flight days; 347 of those observations were recorded during the lobster and stone crab fishing season (21 flights). Many more commercial boats were observed moving at full speed, presumably in transit to their fishing area or between lines of traps (512 boats). Most (93%) commercial fishing vessels observed were over 30 ft. in length. Many of the commercial vessels observed that were less than 30 ft. in length (24 boats) were small sponge fishers.

During the lobster and stone crab fishing seasons, commercial fishing boats were observed slightly more often on the Gulfside of the Keys. Commercial fishing varied by region of the Sanctuary; most (80%) commercial fishing occurred in the Middle and Lower Keys regions with the Middle Keys Gulfside having the highest density of commercial fishing boats (Table 2). In Table 2, only boats that were actively fishing were included; running vessels were not included making density and boat count data relative to each other and not representative of the total commercial boats in the regions. The few observations (<1%) of commercial fishing boats in the Biscayne region is relative to the small area of this region. Boat density was similar to the neighboring Oceanside and Gulfside regions of the Upper Keys.

Seasonal Variation in Commercial Fishing

The highest number of commercial fishing boats were seen early in lobster fishing season. The number of boats began to steadily decline at the onset of the stone crab season through to the end of the stone crab season in May. Stone crab fishing boats commonly fish outside of Sanctuary waters in the Gulf and the drop in the number of observations of commercial fishing boats likely reflected both the commercial fishing fleet operating more often outside of the Sanctuary in the stone crab fishery, and the gradual reduction in the number of trips associated with lower landings of both lobster and stone crab later in the fishing seasons. The peak number of commercial fishing boats correspond with the first day of the lobster and slightly before the beginning of the stone crab season. Although, surveys were not conducted every day, the observed peaks in boating activity were consistent with the intense fishing activity associated with opening day of the lobster fishing season and completion of a fishermen's "round" of fishing their lobster traps prior to focusing on deploying traps for stone crab season. A later peak in the number of commercial fishing boats observed on December 1, likely reflected a synchronizing of fishing trips at the beginning of the lobster and stone crab fishing seasons after the Thanksgiving Holiday when many boats resume fishing after celebrating the holiday (Figure 1, FWRI 2018). The phenomena of commercial fishing boats synchronizing trip dates likely occurs because of the preferred number of days traps are deployed (soak time) between the days the traps are pulled. When weather, holidays, or lunar phase suspend fishing, many boats may begin fishing on the same day. This peak in the number of commercial fishing boats likely reflected a synchronizing of fishing trips after the Thanksgiving Holiday and after a high-wind period that prevented boating. The highest numbers of commercial fishing boats observed during our surveys occurred on August 23, 2016 (34 boats; 7 Oceanside, 27 Gulfside), September 29, 2016 (36 boats; 15 Oceanside, 21 Gulfside), and on December 1, 2016 (40 boats; 31 Oceanside, 9 Gulfside).

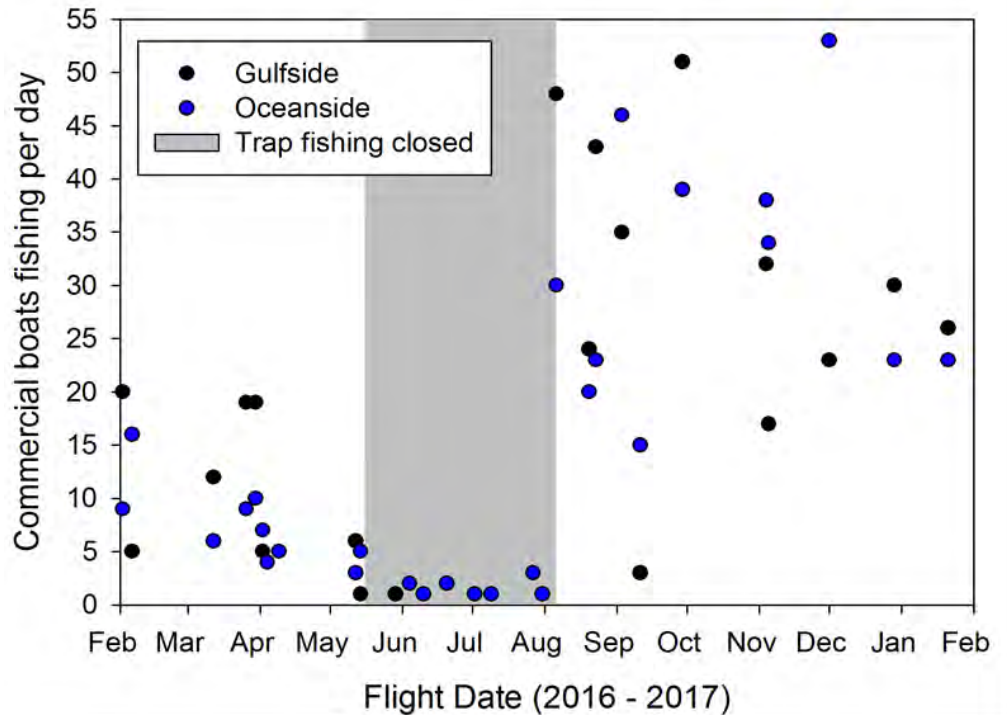


Figure 37 Total commercial fishing boats observed, both boats that were fishing and running by flight date on Gulfside and Oceanside of the Sanctuary. (n= 29 flights; total commercial fishing boats = 859).

Where Commercial Fishing Occurred

Commercial fishing represented less than 1% of all boating activities for all regions throughout the Florida Keys. Commercial fishing boats were observed throughout the Sanctuary and were highly dispersed (Figure 2). Surveys of boats in the Dry Tortugas (see Boat use near the Marquesas and Dry Tortugas) counted few boats in the region, but 30% of the boats were commercial fishing boats, making commercial fishing the most common activity in the region (excluding running boats). Spiny lobster traps are set in all regions and habitats of the Sanctuary from Florida Bay to the Gulf of Mexico (less than 30 ft. depths) and in the Atlantic both inshore and outside of the reef tract to depths of up to 150 feet. Lobster fishing also occurs outside of the Sanctuary. In the Sanctuary, stone crab traps are fished primarily nearshore and in Gulfside waters. Most of the stone crab fishery is on Florida’s west coast and is outside of Sanctuary waters (DiDomenico, 2001; Chiappone et al., 2005). Commercial sponge harvest in the Florida Keys occurs in shallow nearshore sponge flats (Stevely & Sweat, 2016). Head boats tend to fish near the continuous reef and patch reefs for snapper and grouper, or further from shore for dolphin (mahi-mahi).

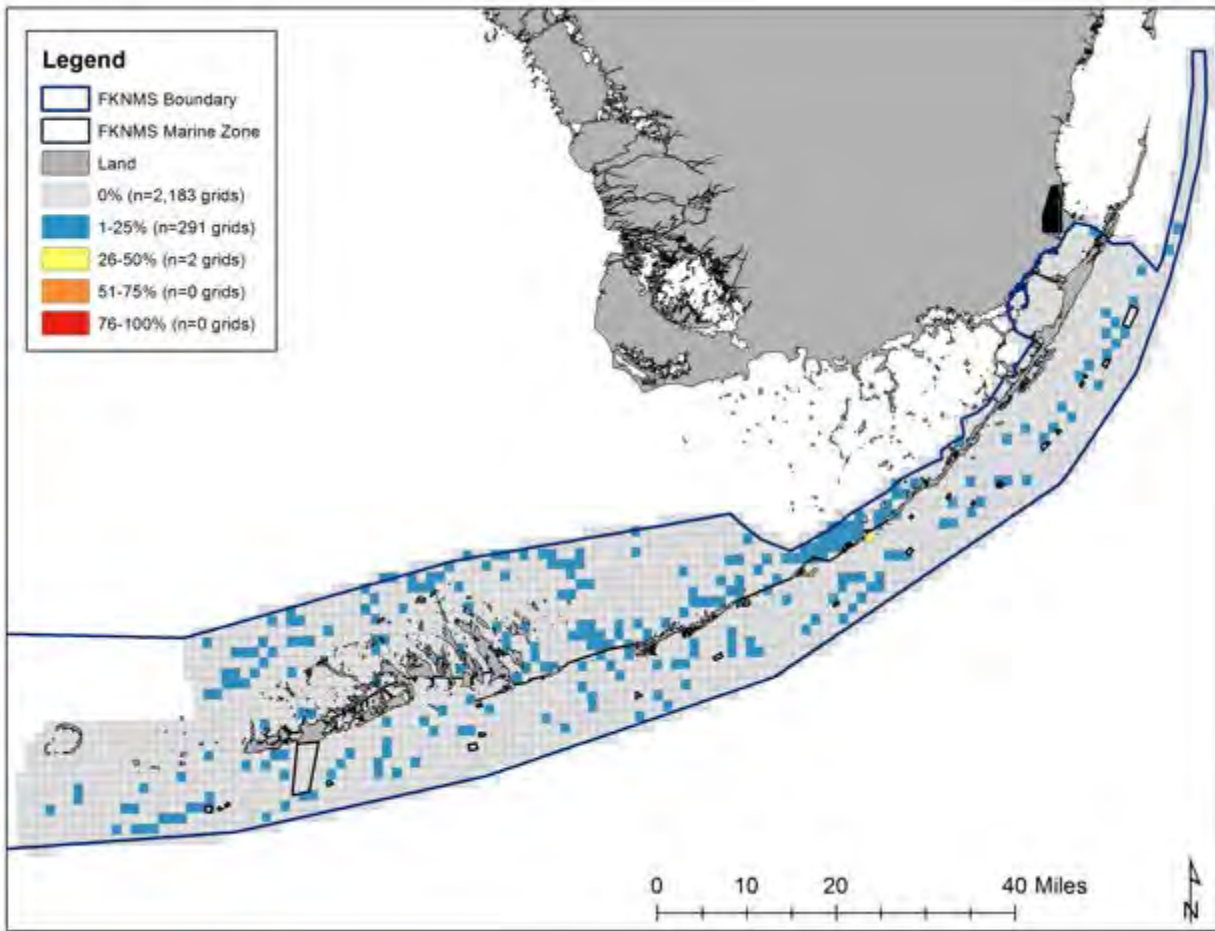


Figure 38 Map depicting the percent of time grids were occupied by commercial fishing boats during our surveys (n = 21 flights, total boat count = 347, total grids = 2,476). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

Commercial fishing varied by region of the Sanctuary; most (80%) commercial fishing occurred in the Middle and Lower Keys regions – predominantly on the Gulfside (Figure 3). The Biscayne, the Upper Keys regions, and the Marquesas Keys regions (only a part of the Marquesas region was surveyed) had the lowest density of commercial boats (Figure 4). The Dry Tortugas region was not included in this comparison (see Boat use near the Marquesas and Dry Tortugas). The great differences in the areas of these regions greatly affects interpretation of total counts of boats (Table 2).

Table 13 Descriptive statistics [averages, standard deviations (st. dev.), and percentages] of counts and densities of commercial fishing boats in the Sanctuary by region. Gulfside (GS), Oceanside (OS).

	Area (nmi ²)	Total Commercial Fishing Boats			Density of Commercial Fishing Boats	
		Avg. Boats per day	St. Dev. Boats per day	% Boats per day	Avg. Boats per nmi ²	St. Dev. Boats per nmi ²
Biscayne Reef	29	0.10	0.29	0.6	0.003	0.010
Upper Keys GS	81	0.14	0.35	0.9	0.002	0.004
Upper Keys OS	273	1.33	2.08	8.0	0.005	0.008
Middle Keys GS	227	4.19	3.02	25.2	0.018	0.013
Middle Keys OS	279	2.71	3.24	16.3	0.010	0.012
Lower Keys GS	419	4.24	3.95	25.5	0.010	0.009
Lower Keys OS	267	2.10	2.91	12.6	0.008	0.011
Marquesas North	473	0.57	0.79	3.4	0.001	0.002
Marquesas South	399	1.24	1.63	7.4	0.003	0.004
Grand Total	2447					

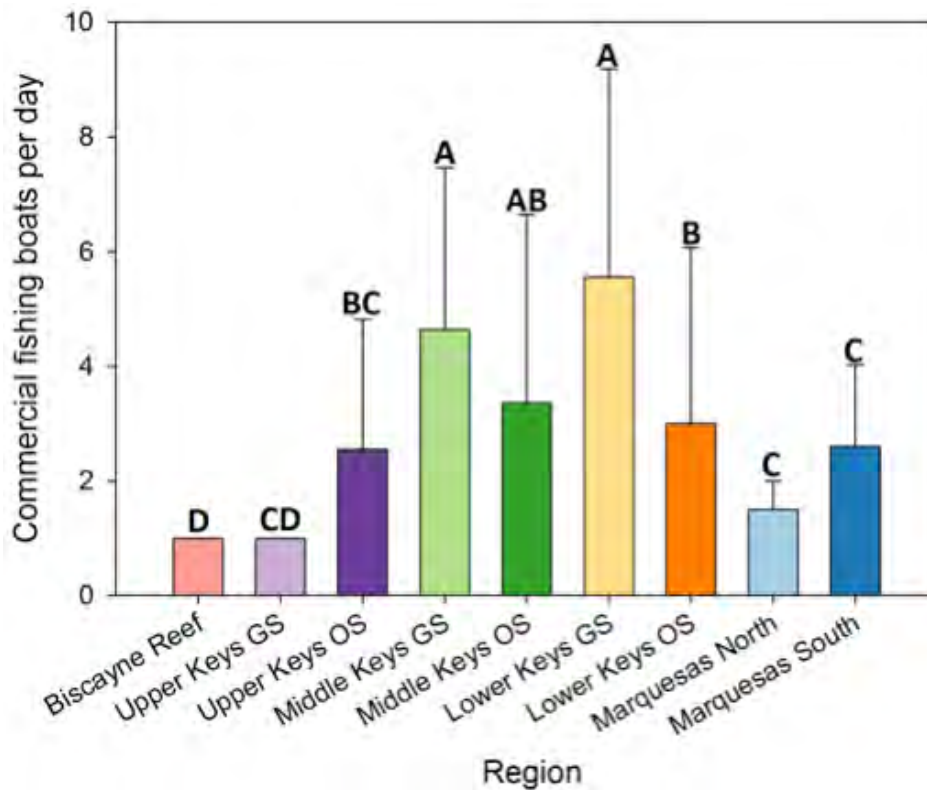


Figure 39 The number and standard deviation (error bars) of commercial fishing boats observed by region in the Sanctuary per day (Wald $\chi^2 = 102.7$, $df = 8$, $p < 0.001$; $n = 21$ flights per region; total commercial fishing boats in season = 347). Letters indicate homogeneous subgroups ($p < 0.05$).

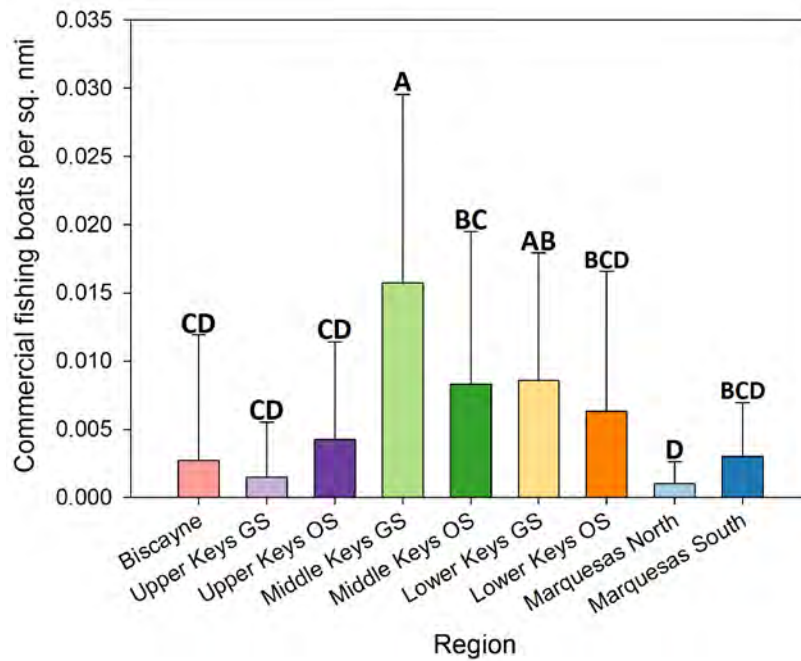


Figure 40 The number and standard deviation (error bars) of commercial fishing boats observed in the Sanctuary per square nautical mile (nmi²) by region (Wald $\chi^2 = 42.4$, $df = 8$, $p < 0.001$, $n = 21$ flights, total commercial fishing boats = 347). Letters indicate homogeneous subgroups ($p < 0.05$).

Wind

Winds higher than 15 mph tended to reduce the number of fishing vessels observed and although we intentionally did not fly on days with winds over 20 mph. High winds did not have as much of an effect on the number of commercial fishing boats as it did on the number of hook-and-line fishing boats (Figure 5a, see Hook-and-Line Fishing). Although there were fewer commercial fishing vessels observed on windy days (Figure 5b). The proportion of boats fishing Gulfside increased with wind speed (Figure 5b). No small commercial boats (less than 30 ft. in length) were observed fishing on days with winds over 15 mph. Fishermen check each trap every 1-2 weeks or occasionally longer, and though it may take several days to check all their traps, this allows some flexibility as to when trips occur.

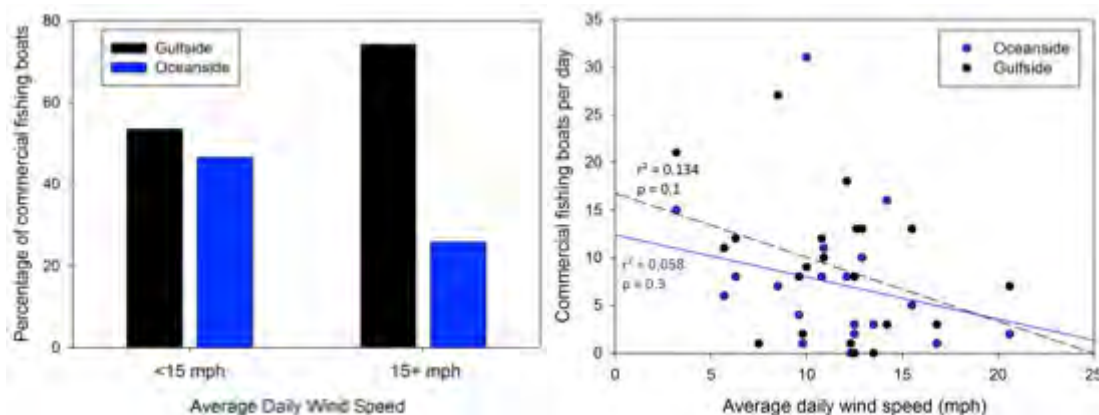


Figure 41 (a) Number of commercial fishing boats per day observed on the Gulfside or the Oceanside of the Sanctuary by average daily wind speed. Lines represent linear regressions with r^2 and p -value (data includes the 21 flights during lobster or stone crab fishing seasons; Oceanside $n = 153$ total boats; Gulfside $n = 171$ total boats). **(b)** Proportion of fishing boats observed on the Gulfside vs. the Oceanside on calm (<15 mph) days vs. on windy (15+ mph) days.

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Diving

Section at a glance

- ❖ *A boat was counted as diving when a dive flag was displayed or swimmers were in the water.*
- ❖ *Boats that had dive gear but that were obviously in transit were not counted as diving.*
- ❖ *There was an average of 172 ± 162 dive and 18 ± 10 charter dive boats observed each day.*
- ❖ *The greatest number of dive boats, 512 were seen on Memorial Day weekend.*
- ❖ *At any given time, 19% of vessels in the Sanctuary were diving. The number of dive boats varied by time of year, day of the week, and with wind speed.*
- ❖ *A greater number of dive boats were observed during the summer, particularly summer weekends.*
- ❖ *Dive boats were concentrated along continuous reef habitat on the Oceanside of the Florida Keys during both the summer (excluding lobster season opening days) and winter, with 55% of all dive boats observed in FKNMS Marine Zones.*
- ❖ *The highest densities of dive boats were observed at Upper and Middle Keys reefs.*
- ❖ *The majority of dive boats (67%) were at located at the continuous reef habitat. Other reefs and hardbottom supported 19% and 9% of dive boats respectively.*
- ❖ *Winds higher than 15 mph tended to reduce the number of dive boats observed.*

Introduction

Approximately 20-30% of the three million Keys visitors dive or snorkel during their visit (Leeworthy et al. 2010), making dive tourism an important contributor to the economy of the Florida Keys. These visitors spend approximately \$31 million on scuba diving and snorkeling activities annually (English et al., 1996). Scuba diving and snorkeling are a major attraction for visitors to the region; 88% of visitors in 2016 sought adventures that included scuba and snorkeling excursions while 26% of visitors went scuba diving and 55% snorkeled (Insights, Inc., 2016). Many of the residents of the Keys also participate in these same activities (Leeworthy and Wiley, 1997). Popular forms of diving in the Sanctuary often include snorkeling, scuba diving, or the use of snuba equipment. Types of divers in the Sanctuary include recreational divers, that either have their own boats or that go out with dive charters, commercial spearfishers, marine life collectors, construction divers, and scientists. Recreational divers and snorkelers that visit the Sanctuary primarily dive for wildlife viewing and to harvest fish by spearfishing and diving to collect lobster. Lobster sport season and the opening day of regular lobster season attract more than 30,000 visitors each year (Hunt, 1994). Charter dive and snorkel operators are widely used by visitors to the Keys. The number of participants per boat varies greatly with the boat size (from 6 to 140 dive/snorkelers per boat). Shivlani and Suman (2000) report that there were 75 dive operators in the Keys in 1995 that took approximately 550,000 divers out to Sanctuary reefs. Dive charter vessels commonly take their clients to the Sanctuary Preservation Areas (SPAs). Some of the most popular reefs were Looe Key SPA, Sombrero Reef SPA, Molasses Reef SPA, and Sand Key SPA (McClellan, 1996).

Dive-specific Methods

A boat was defined as diving when a dive flag was displayed or swimmers were in the water. For this study, we recorded the type of boat used, such as personal boats (*i.e.*, motorboat, sailboat, personal watercraft, or paddlecraft), “Charter Dive Boats” (*i.e.*, boats were marked with dive shop logos) or “sightseeing” boats (recognizable education groups, such as Seacamp or Boy Scouts, glass bottom boats, etc.) that were engaged in diving activities (see Diving). Other types of divers that operate in Sanctuary waters include commercial divers, such as commercial fishermen, marine life collectors, construction divers, and scientists; we did not distinguish these categories from the others for the purposes of this study. Any identification markings on these other types of dive vessels were not consistently visible from the air. Because we could not distinguish between charter, commercial, and recreational diving activities, we use the term diving for this chapter. However, we recognize that the vast majority of the vessels with dive flags are, in fact, recreational. All data was collected between the hours of 8 AM and 6 PM. Most dive activity occurs within the survey time frame; however, some diving does occur after sunset and could not be accounted for in these surveys.

Due to the unique number of boats diving and their spatial distribution during lobster season, boats observed during the 2-day Sport Season, opening day of regular lobster season have been excluded from most of the statistics in this chapter. A few analyses, mostly related to general trends and seasonal activity include lobster season data. Because numbers of dive boats and their use of resources shifts so markedly during the early lobster season, the exclusion of that activity from most analyses in this chapter permits an evaluation of how divers utilize the Sanctuary during the rest of the year.

General Trends

The majority of boats engaged in diving/snorkeling activity (hereafter referred to as dive boats) were comprised of motorboats (92.1%), and charter dive boats (5.1%). Charter sports, educational, personal watercraft (PWC), paddlecraft, and sailboats made up the remaining 2.8% of boats observed with divers.

Seasonal Variation in Diving

At any given time during the aerial surveys, 19% of all vessels observed were diving. An average of 172 ± 162 dive boats were observed diving each day. An average of 18 ± 11 charter dive boats were observed each day.

During lobster season an average of $1,803 \pm 834$ boats were diving (see Dive Boat Activity During Lobster Season). The most popular non-lobster dive days were holidays (average of 422 ± 64 all dive boats) and summer weekends (291 ± 218 boats) (Figure 1). The most popular season to dive was during the summer. However, the number of dive boats was similar on summer weekdays (100 ± 48 boats) and during the winter. Overall, fewer diving boats were observed during the winter season with the majority observed during winter weekdays (92 ± 90 boats). The winter season tends to have more days with higher winds, which, in addition to reducing the ability of boats to venture offshore, may also reduce water visibility, making winter less conducive for diving. In contrast, the number of charter dive vessels observed was more constant throughout the surveys regardless of the type of day or season.

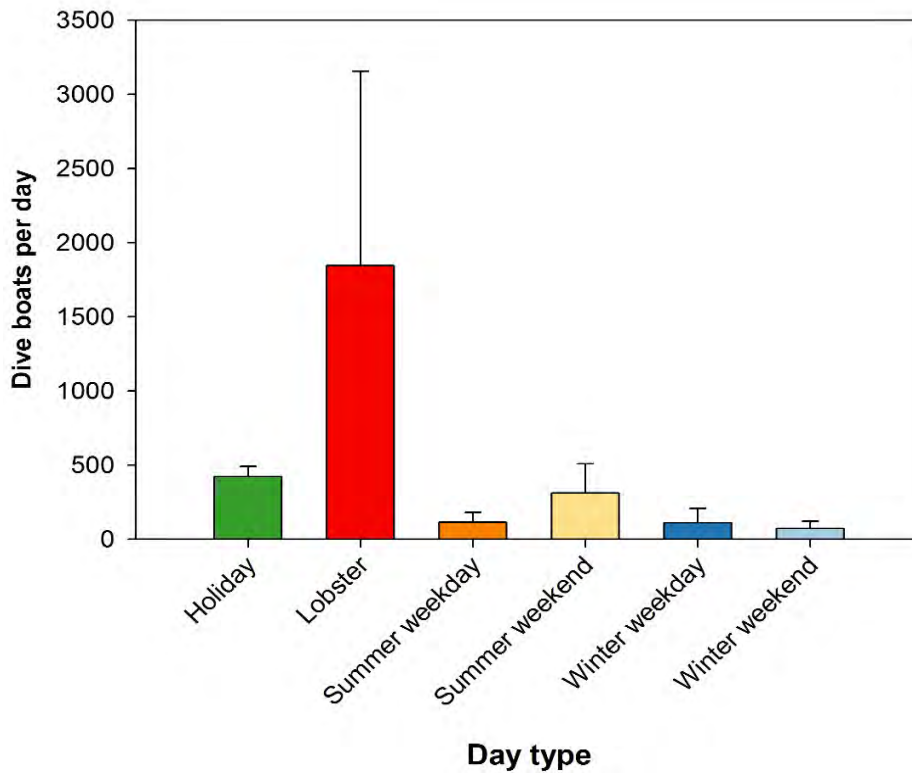


Figure 42 Average and standard deviation of the number of all dive boats by type of day flown.

Peaks in the number of boats diving on the Oceanside during the summer coincided with May 29 (Memorial Day weekend, 512 boats), July 27-28 (Lobster sport season, 667 boats), August 6 (Regular lobster season opening day, 734 boats), and August 20 (Summer weekend, 585 boats) (Figure 2). Another peak in diving occurred on Dec. 29, 2016 (Winter weekday, 328 boats). The number of boats diving on the Gulfside was relatively constant throughout the year with peaks occurring during lobster sport season, opening day of regular lobster season. The number of dive boats on the Gulfside slowly declined as lobster season progressed and returned to the level of effort observed during the rest of the year after the first week of lobster season. The lowest number of boats diving occurred March 12 (Winter weekend, 7 boats) on the Oceanside, and multiple winter days on the Gulfside (Feb 2, 6, and April 2, 9; 0 boats were observed).

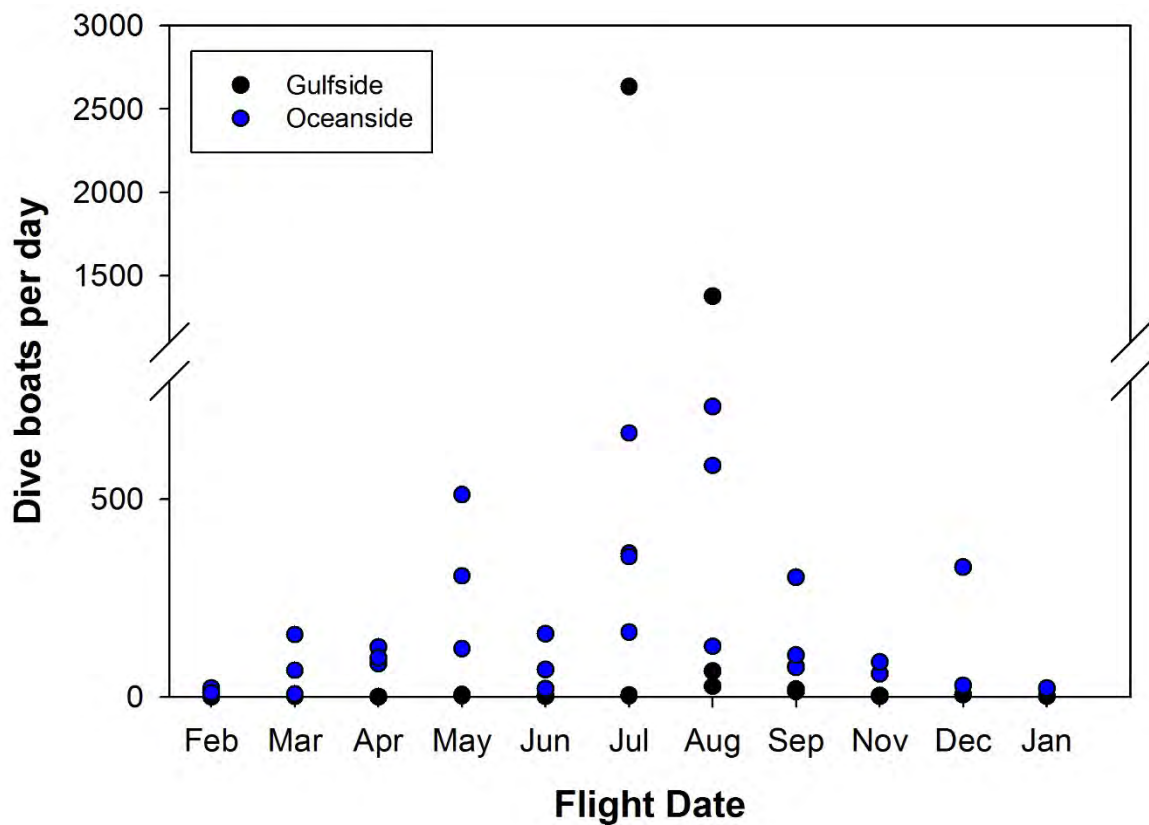


Figure 43 Total dive boats observed by flight date on the Gulfside and Oceanside of the Sanctuary.

Diving by Region

Boaters were observed diving in all regions surveyed, and diving represented 7-26% of all boating activities for regions throughout the Florida Keys. Of all diving boats, the greatest number of boats diving each day were observed in the Upper and Middle Keys, particularly on the Oceanside (Table 1). The lowest number of boats diving each day were observed in the Marquesas and the Biscayne reef area. Overall, when the opening days of lobster season are excluded, 94% (162 ± 153 boats daily) of boats were diving on the Oceanside of the Sanctuary, relative to the 6% (10 ± 18 boats daily) diving on the Gulfside.

Table 14 Descriptive statistics [averages, standard deviations (st. dev.), and percentages] of counts and densities of dive boats in the Sanctuary by region. Gulfside (GS), Oceanside (OS). Excludes all dive boats observed during lobster season openers and the first month of lobster season through August 20.

	Total Dive Boats				Density of Dive Boats	
	Area (nmi ²)	Avg. Boats per day	St. Dev. Boats per day	% Boats per day	Avg. Boats per nmi ²	St. Dev. per nmi ²
Biscayne Reef	29	5.04	9.35	3	0.17	0.32
Upper Keys GS	419	0.69	1.29	1	0.01	0.02
Upper Keys OS	267	54.88	52.30	36	0.20	0.19
Middle Keys GS	473	2.19	4.85	2	0.01	0.02
Middle Keys OS	399	54.62	59.23	34	0.20	0.21
Lower Keys GS	227	4.81	10.02	3	0.01	0.02
Lower Keys OS	279	26.69	25.93	17	0.10	0.10
Marquesas North	81	0.38	0.74	0	0.001	0.002
Marquesas South	273	6.42	4.72	4	0.02	0.01
Grand Total	2447					

Diving by Habitat

The type of habitat for each grid was designated by the most notable feature of each grid using a hierarchy of the habitats that are of the most interest to fishing and diving boats. Bridges held the highest rank in the hierarchy – any grid with a bridge within it was classified as a bridge, regardless of other habitats present in the grid. Grids with any amount of continuous reef were classified as such, followed by grids that contained other reef, pavement, or seagrass, and lastly, unconsolidated sediment. There were no grids labeled as artificial habitat or dredged/excavated area. Any grids within our study area that are beyond the 20-m contour line, where habitat data is not available, were labeled as “Not Classified” (See Methods). The aerial survey of boats did not specifically evaluate what habitat was utilized by the observed boats. The assessment of the habitat likely used by boaters is subjective based on the likely feature or habitat available in the grid the boat was observed.

Divers target different habitat depending on their diving activity. Some habitats are used for sightseeing, while others are used to target species for harvest such as lobster or fish species that can be speared. Boats were observed diving over all types of habitat, though the majority of diving boats were observed over continuous reef (67%) and other reefs (19%), while fewer boats were diving near hardbottom (9%), bridges (2%) and seagrass (1%) (Figure 3, Table 2). Greater numbers of boats were observed diving over continuous reef habitat in the Upper and Middle Keys (Figure 4), but these regions also contain the greatest area of this habitat (See Methods).

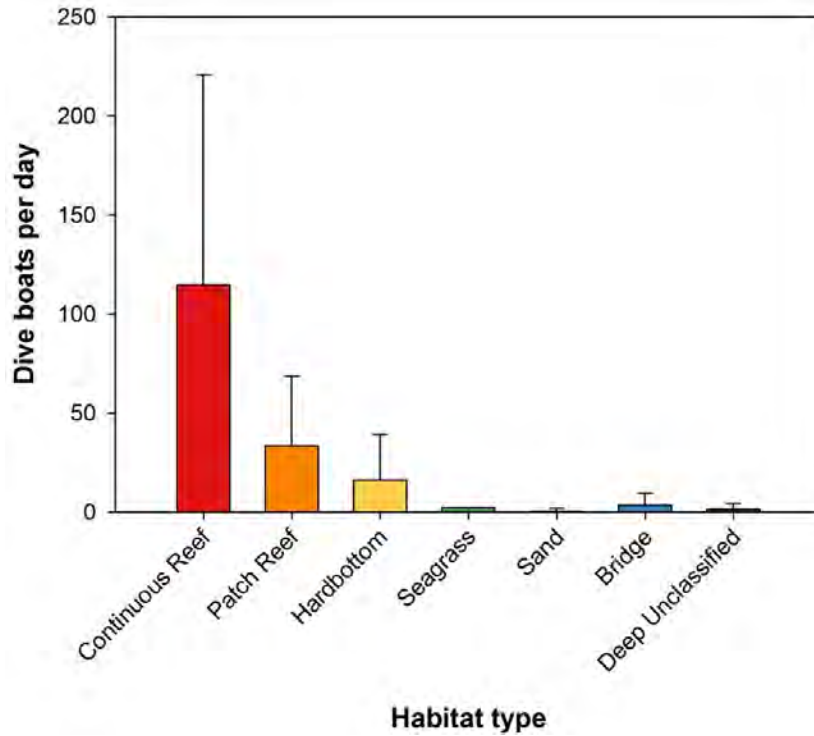


Figure 44 The average and standard deviation of the number of dive boats observed by habitat type. Excludes all dive boats observed during lobster season openers and the first month of lobster season through August 20.

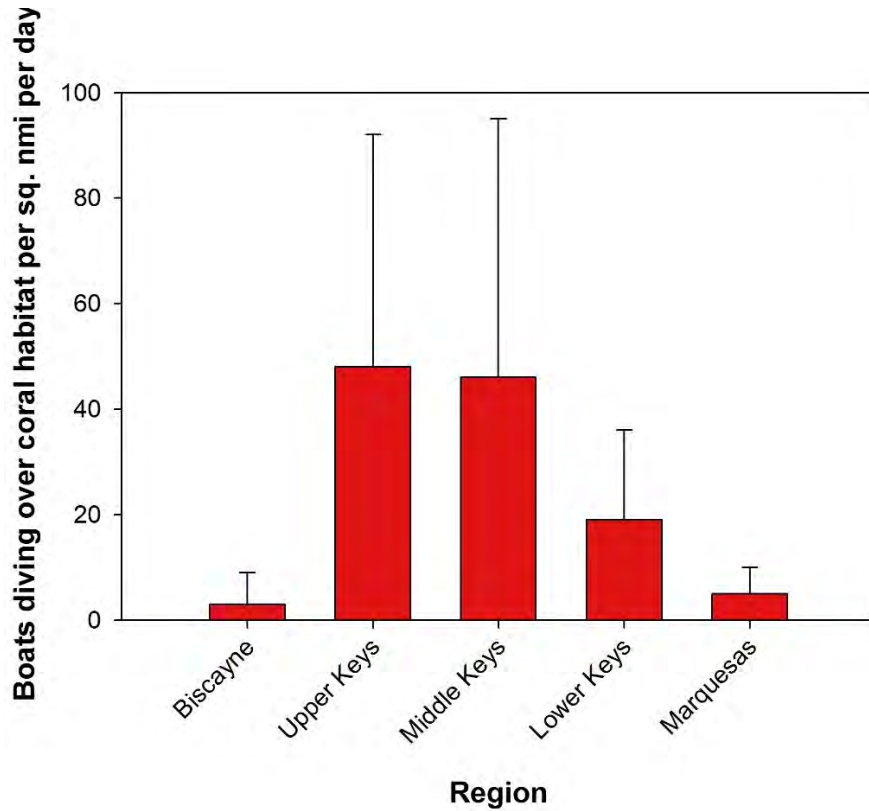


Figure 45 The average and standard deviation of the number of dive boats observed per nmi² in continuous reef habitat by region. Excludes all dive boats observed during lobster season openers and the first month of lobster season through August 20.

Table 15 Descriptive statistics [averages, standard deviations (st. dev.), and percentages] of counts and densities of dive boats in the Sanctuary by habitat. Excludes all dive boats observed during lobster season openers.

	Area (nmi ²)	Total Dive Boats			Density of Dive Boats	
		Avg. Boats per day	St. Dev. Boats per day	% Boats per day	Avg. Boats per nmi ²	St. Dev. Boats per nmi ²
Continuous Reef	223	105.42	96.50	69	0.47	0.43
Patch Reef	312	29.08	27.56	19	0.09	0.09
Hardbottom	737	12.85	16.80	8	0.02	0.02
Seagrass	226	1.96	3.42	1	0.01	0.02
Sand	12	0.38	1.39	<1	0.03	0.11
Bridge	62	3.08	5.52	2	0.05	0.09
Deep Unclassified	250	0.58	0.93	<1	0.002	0.003

Diving/Snorkeling Activity in FKNMS Marine Zones

Approximately 54.9% of all diving boats (excluding lobster season opening days) were observed within the boundaries of FKNMS Marine Zones. FKNMS Marine Zones refer to the Sanctuary Preservation Areas (SPAs), Ecological Reserves (ERs) and Research Only Areas (ROAs). Boats in Marine Zones were predominantly motorboats (~80%) and charter dive boats (~13%). Most motorboats were less than 30 ft in length (~85%), whereas charter dive boats were mostly greater than 30 ft in length (~96%). The total number of diving boats in SPAs was greatest during holidays (244 ± 97 boats) and summer weekends (147 ± 67 boats) (Figure 5). Fewer diving boats were observed in Marine Zones during the winter, with winter weekends (38 ± 32 boats) frequently having the lowest counts. The number of dive boats in Marine Zones decreased during lobster sport season and the opening day of regular lobster season (See Dive Boat Activity During Lobster Season), but the number of charter dive boats remained constant. The total number of dive boats observed per day at Looe Key SPA provides an example of the patterns described above (Figure 6). The greatest number of both motorboats and charter dive boats were observed in Upper and Middle Keys SPAs. This may be influenced by the time in which each region was surveyed. Upper and Middle Keys SPAs were typically surveyed between 1 and 2 PM, whereas Lower Keys SPAs and ERs were typically surveyed between 3 and 4 PM. A survey of dive operator activity in the Florida Keys did however find that operators in the Upper Keys had the greatest number of trips, with 75% of the trips going to FKNMS SPAs (Shivlani and Suman 2000).

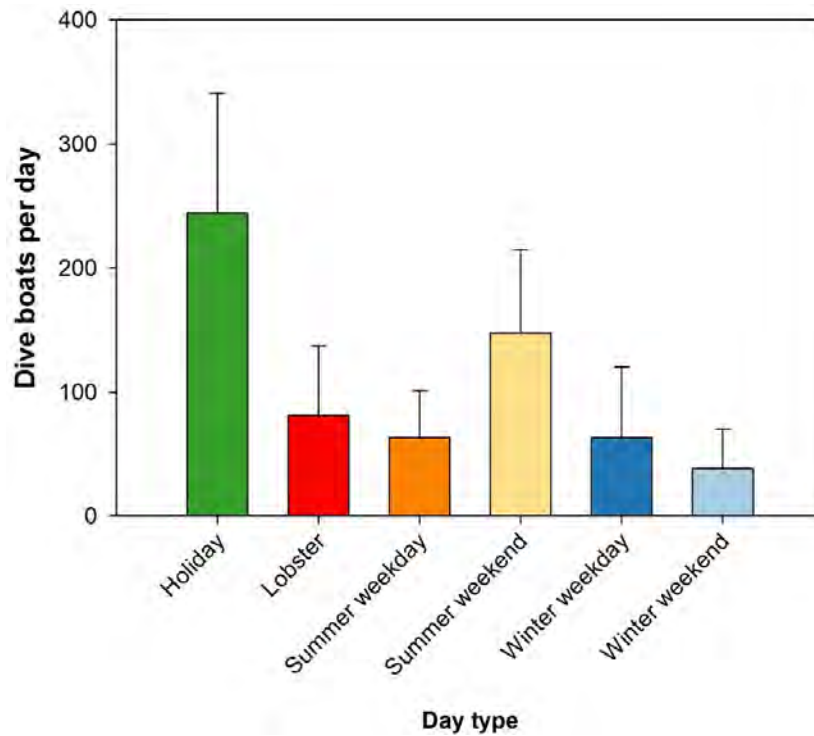


Figure 46 Average and standard deviation of the number of dive boats observed inside the boundaries of FKNMS SPAs by type of day flown.

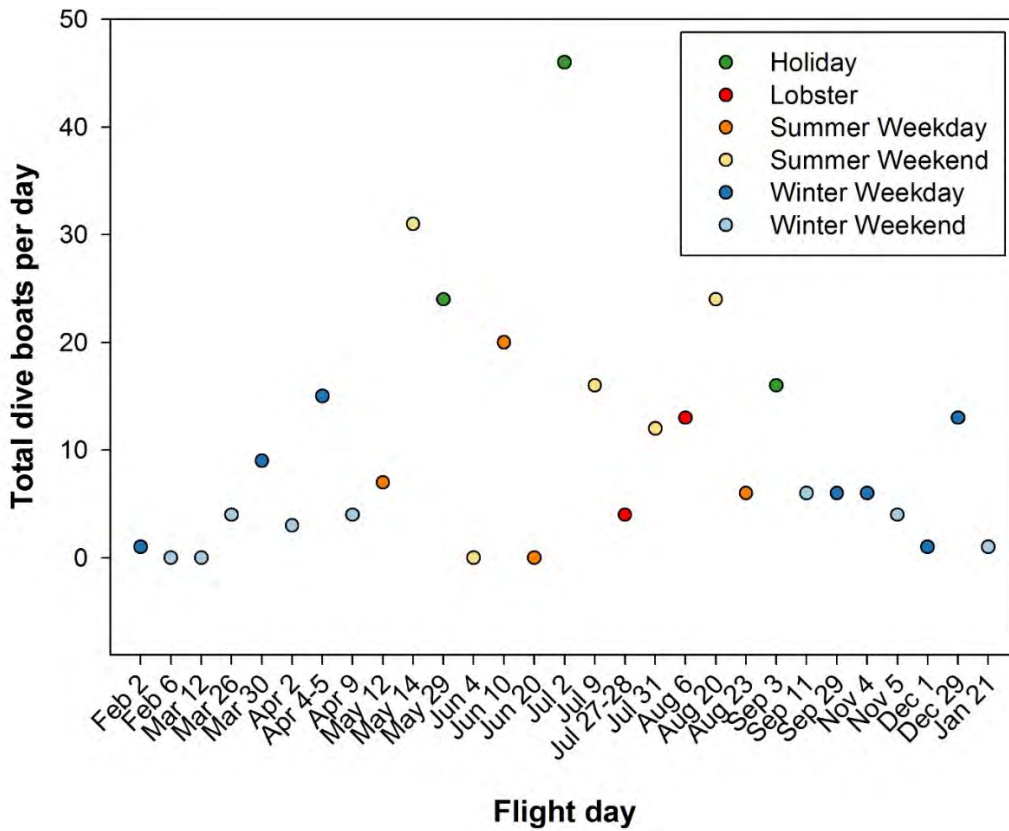


Figure 47 Total number of dive boats observed per flight day inside the boundaries of Looe Key SPA.

Occupancy

The likelihood of a given area being occupied by dive boats (*i.e.*, the percentage of time of time a boat was observed diving within a grid) was similar during the summer (Figure 7) and winter (Figure 8). Fewer dive boats were observed during the winter, and thus fewer grids were occupied, but diving effort was concentrated along the continuous reef on the Oceanside of the Florida Keys regardless of the season (Table 3). The exception to this trend was during the lobster sport season, where diving effort temporarily shifted from the Oceanside to the Gulfside of the Florida Keys (1-25% occupancy) (Figure 9) (See Dive Boat Activity During Lobster Season). Overall, grids that were the most frequently occupied by dive boats contained either all or some portion of an FKNMS SPA. All grids containing SPAs were occupied in over 50% of the flights. The most frequently occupied grids contained the Grecian Rocks, Looe Key, and Sombrero Reef SPAs (Table 4). Many SPAs also shared a grid with other features such as Sanctuary mooring balls that could also have attracted dive boats. Other grids that were frequently occupied contained popular dive spots such as Pickles Reef (63% occupancy) and Western Dry Rocks (78% occupancy) during the summer, and the Lakes region between Archer Key and Mule Key (50% occupancy), Western Sambo Ecological Reserve (WSER) (47% occupancy), and the reef east of Davis Reef SPA (47% occupancy) during the winter. The boundaries of twelve of the 18 SPAs, as well as WSER intersected multiple grids, therefore the number of boats observed in a grid is not necessarily representative of the total number of boats observed in a SPA overall.

Occupancy was also calculated for each individual FKNMS Marine Zone. Approximately 78% of the SPAs were occupied in over 50% of the surveys and were popular dive spots that concentrated dive boats. The most frequently occupied SPAs were Alligator Reef and Looe Key (Table 5). Boats were only observed in ROAs during three flights. The ROAs are special use areas that are set aside for scientific research and educational purposes, and require a permit for entry therefore very few boats were observed in these areas. The WSER encompasses a much larger area than the SPAs which includes multiple grids. In general, the most frequently occupied areas of WSER were nearshore and offshore with no dive boats observed in the Hawk Channel (middle) of the WSER (Figures 7, 8, 9). Marine Zones were more frequently occupied during summer than winter when the average wind speed tends to be lower and there is an overall greater number of dive boats on the water.

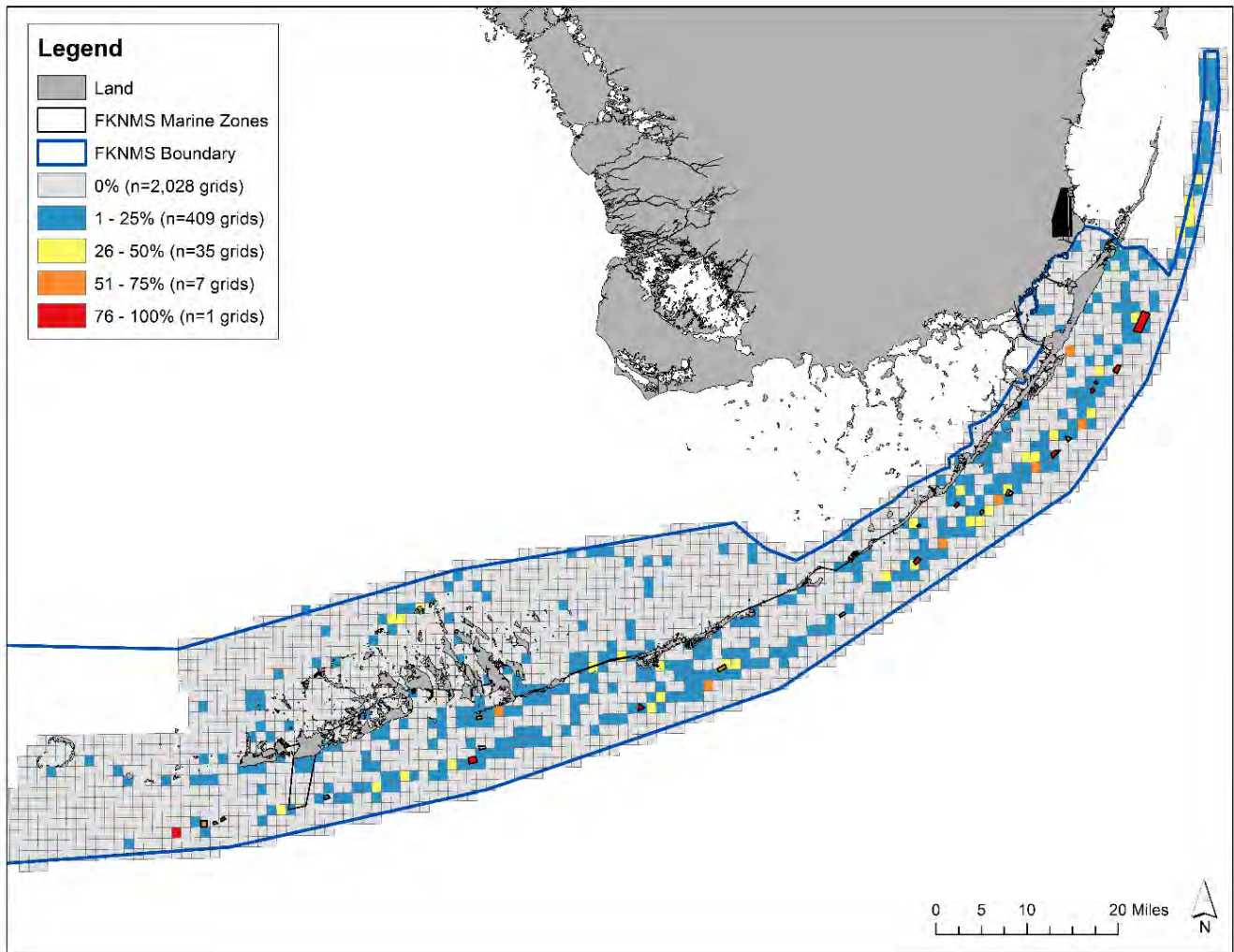


Figure 48 Map depicting the percent of time grids were occupied by dive boats during our summer surveys (n = 9 flights, total boat count = 2,027, total grids = 2,429). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

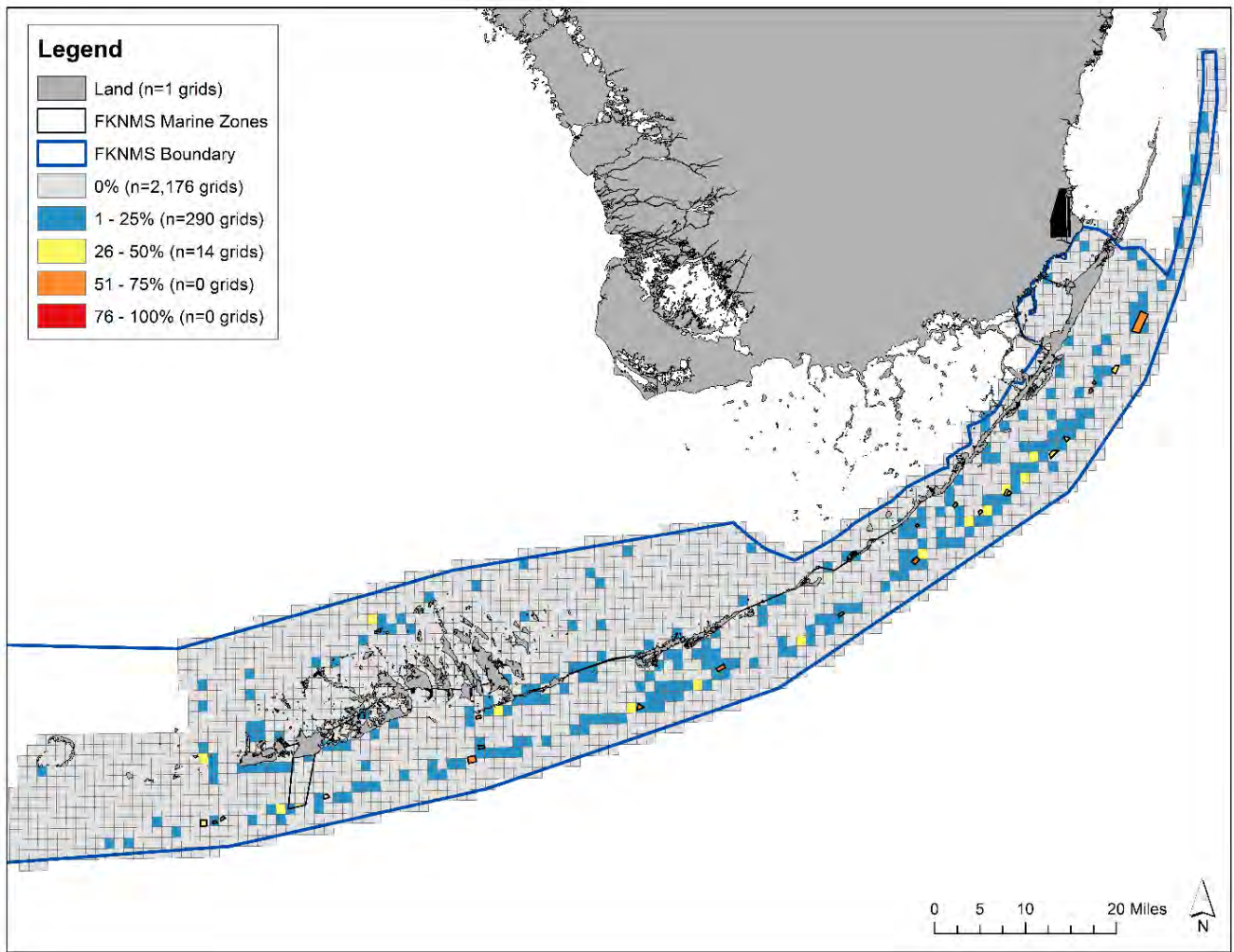


Figure 49 Map depicting the percent of time grids were occupied by dive boats during our winter surveys (n = 15 flights, total boat count = 1,344, total grids = 2,472). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

Table 16 Summary of dive boat grid occupancy data (from Figures 7, 8).

	0% occupied	1-25% occupied	26-50% occupied	51-75% occupied	76-100% occupied
Summer					
# of grids =					
2,429	81%	17%	2%	1%	1%
Winter					
# of grids =					
2,472	87%	12%	1%	<0%	<0%

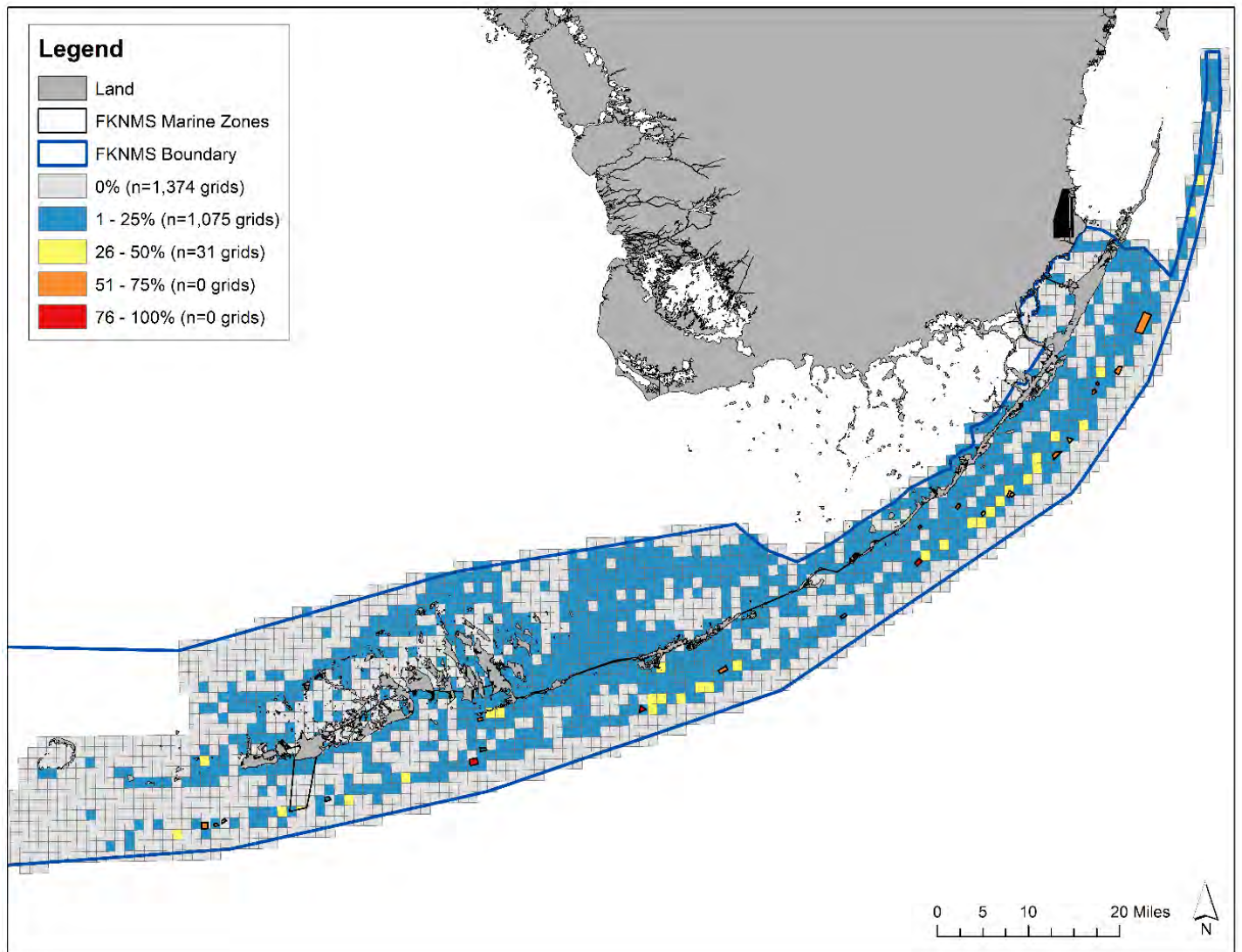


Figure 50 Map depicting the percent of time grids were occupied by dive boats during all surveys (summer, winter, and lobster season) (n = 29 flights, total boat count = 10,046, total grids = 2,480). FKNMS marine zones are depicted using the same color scheme but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

Table 17 Features identified in grids that were the most frequently occupied by dive boats (n = 29 flights, total boat count = 10,046, total grids = 2,480).

Grid	% of flights grid was occupied	Predominant Feature in Grid	Other Features in Grid	Boats inside SPA	Boats outside SPA
12543	100	Grecian Rocks SPA		144	2
5473	86	Looe Key SPA		289	4
6521	86	Sombrero Reef SPA		320	2
9228	83	Alligator Reef SPA	3 mooring buoys outside SPA	460	29
7354	76	Coffins Patch SPA		102	24
11303	76	Molasses Reef SPA	4 mooring buoys outside SPA	218	4
12750	75	Key Largo Dry Rocks SPA	3 mooring buoys outside SPA	168	11
6298	69	Newfound Harbor SPA		56	6
10053	69	Cheeca Rocks SPA	2 mooring buoys outside SPA	96	18
10680	69	Conch Reef SPA		38	15
4417	66	Eastern Dry Rocks SPA		41	0
4415	59	Sand Key SPA	2 mooring buoys outside SPA	49	0
4416	59	Rock Key SPA	1 mooring buoy outside SPA	31	2
11717	59	French Reef SPA	2 mooring buoys outside SPA	86	6
12958	57	The Elbow SPA	4 mooring buoys outside SPA	45	0
10265	55	Davis Reef SPA		45	7
10469	55	Hen and Chickens SPA		163	9
13991	52	Carysfort SPA	1 mooring buoy outside SPA, fish spawning aggregation	99	2

Table 18 Descriptive statistics [averages, standard deviations (std. dev.), and percentages] of dive boat occupancy in FKNMS marine zones (SPAs, ROAs, and ER). (n = 29 flights, total boat count = 10,046, total grids = 2,480).

FKNMS Marine Zone	% of surveys grid was occupied	Avg. Boats per day	Std. Dev. Boats per day
Alligator Reef	79%	21	31
Looe Key	79%	12	11
Sombrero Reef	76%	13	11
Grecian Rocks	72%	5	4
Carysfort	69%	5	7
Molasses Reef	69%	11	11
Western Sambo ER	69%	3	3
Cheeca Rocks	66%	5	3
Key Largo Dry Rocks	66%	9	6
Newfound Harbor	62%	3	3
Coffins Patch	59%	6	4
Hen and Chickens	59%	10	10
The Elbow	55%	2	2
Conch Reef	52%	2	1
Sand Key	52%	3	2
Eastern Dry Rocks	48%	2	1
French Reef	48%	5	5
Davis Reef	45%	4	3
Rock Key	28%	2	1
Tennessee Reef ROA	10%	<1	<1
Eastern Sambos ROA	3%	<1	1
Conch Reef ROA	0%	0	0
Looe Key ROA	0%	0	0

Wind

Wind has a great effect on boating, with more favorable weather allowing more vessels to participate in diving. These more favorable wind days tend to occur more often in the summer than winter. The greatest counts of dive boats were observed during days with an average wind speed of less than 10 mph (Figure 10a). Winds greater than 15 mph tended to reduce the number of dive boats observed and although we intentionally did not fly on days with winds over 20 mph, it was clear that winds over 20 mph greatly reduced the number of dive boats (Figure 10a). Overall wind speed did not influence the location of diving as the proportion of boats diving on the Gulfside and Oceanside remained fairly constant regardless of wind speed (Figure 10b). This is more likely a reflection of diver preferences than the influence of wind (Figures 7, 8).

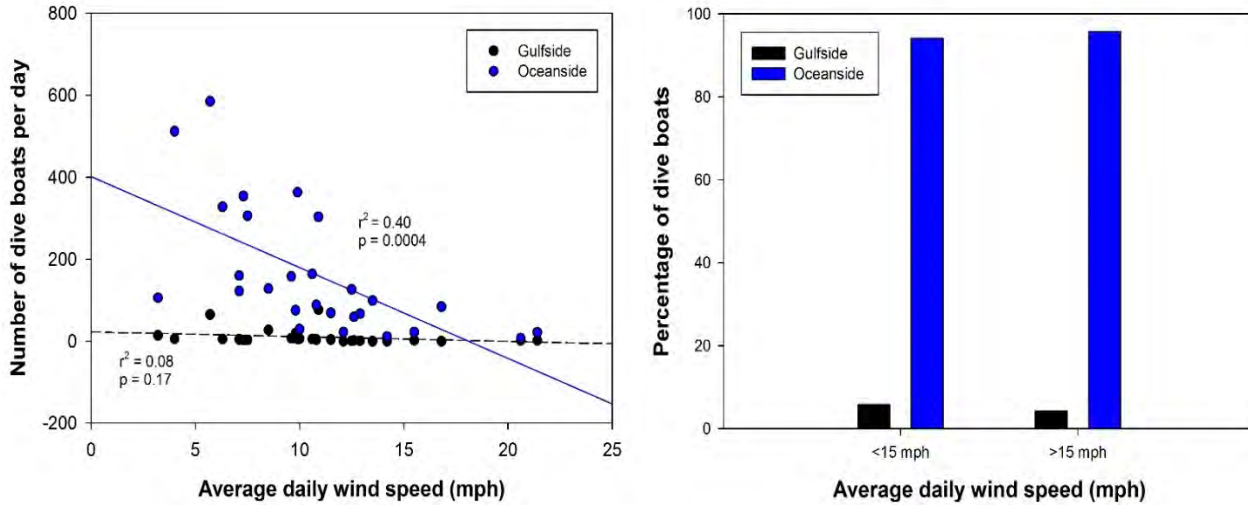


Figure 51 (a) Number of dive boats per day observed on the Gulfside vs the Oceanside of the FKNMS by average daily wind speed; lines and r^2 values represent results of linear regressions. **(b)** Proportion of dive boats observed on the Gulfside vs. the Oceanside on calm (<15 mph) days vs. on windy (15+ mph) days.

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Sandbars

Section at a glance

- ❖ *A popular activity location in the shallow waters of the Sanctuary are “sandbars”, also known as sandbar parties, or party zones. The locations and habitat have become synonymous with the activity.*
- ❖ *The majority (86.8%) of boats at the sandbars were small motorboats less than 30 feet in length.*
- ❖ *Partying at sandbars was a substantial activity for boaters in the Sanctuary; 9.4% of all boats observed were at sandbars.*
- ❖ *The greatest numbers of boats at sandbars were observed on holiday weekends, peaking at 1200 boats during Memorial Day weekend but averaging 697±444 boats on holiday weekends, and 304±77 boats on other summer weekends.*
- ❖ *Nineteen sandbar areas were identified throughout the Sanctuary; the largest and most popular area by far was Whale Harbor Sandbar near Islamorada with an average of 132±91 boats during holiday and summer weekends, and a peak of 331 boats observed during Memorial Day Weekend.*

Introduction

The shallow nearshore waters skirting the Florida Keys are home to multiple party zones, often colloquially referred to as sandbar parties or simply sandbars. These sandbars attract groups of boats that anchor or raft to each other. Boaters spend their time partying, relaxing, and generally enjoying the shallow water (Figure 1). Boaters at the sandbars generally don't participate in activities such as fishing, diving, or snorkeling – instead, boats classified as participating in sandbar activities were characterized by boats anchored in shallow water, generally with people standing in the water near the boat. Typically, sandbar boats tend to aggregate in relatively high densities at a few popular sandbar locations, but for the purposes of this study, any single boat in any location could have been characterized as partying. Overall, 9.4% of the boats observed in the survey were at a sandbar; hence, sandbar parties were a substantial activity for boaters within the Florida Keys National Marine Sanctuary.



Figure 52 Whale Harbor Sandbar is the most popular sandbar where boaters aggregate. This photo was taken on Memorial Day Weekend 2016 by Emily Hutchinson.

Sandbar-specific methods

Statistical analyses were used to determine differences in the number and type of boats at sandbars among day types (*i.e.* weekdays, weekends, season, and holidays). Negative binomial regressions with a log link function within generalized linear models (GLMs) were used to analyze boat count data. Homogeneous subsets for each category (*i.e.*, day type, sandbar location) were identified via a priori pairwise contrasts. The percent of boats seen during different day types were calculated with a weighted average number of boats that considers the differences in sample sizes amongst day types. All statistical analyses were completed using SPSS (v 21, IBM Corp., Armonk, NY, USA).

Types of Boats at Sandbars

The majority of boats observed at sandbars were small motorboats (86.8%). Large motorboats (7.3%), personal watercrafts (PWC, 4.1%) and paddlecraft (1.4%) were also found at sandbars, though in some cases the paddlecraft were brought to the sandbar by other, larger vessels, as opposed to being the primary means of transportation at the sandbar. The majority of boats at the sandbar appeared to be private, recreational boaters; however, observations of the sandbars from the aerial survey could not consistently identify charter boats. Boats-for-hire do advertise charter trips to the sandbar.

Temporal Variation in Sandbar Activity

Although there were boats at sandbars throughout the year, there were certain times when sandbars were a more popular. Holiday weekends were the most popular times for boaters at sandbars; 52% of boats at sandbars throughout the survey were observed on holiday weekends, with an average of 697 ± 444 boats (average \pm standard deviation, Figure 2). Memorial Day Weekend had the greatest number (1200) of sandbar boats by a large margin – there were over twice as many boats as the next biggest sandbar day, which was the July 4th three-day weekend in 2016. Memorial Day Weekend’s popularity in our study may have been due to being sampled on Sunday, whereas the other holidays (July 4th Weekend and Labor Day Weekend) were both sampled on Saturdays. Anecdotally, Sundays seem to be the more popular weekend day for sandbars, based on the popularity of phrases like “Sandbar Sunday” and “Sunday Funday” on social media. This study did not have enough aerial surveys to test the hypothesis that Sundays are the more popular day of the week for sandbar parties; instead, Saturdays and Sundays were combined to compare weekends to weekdays, within seasons. Summer weekends were popular days to go to the sandbar, with an average of 304 ± 77 boats participating in sandbar activities any given Saturday or Sunday on a summer weekend, making up 22.7% of sandbar boats from the survey. There was no significant difference between the number of boats observed at sandbars during holiday weekends and summer weekends, for further analyses the two day types were combined and referred to as “high-use” periods ($p < 0.05$, Figure 2).

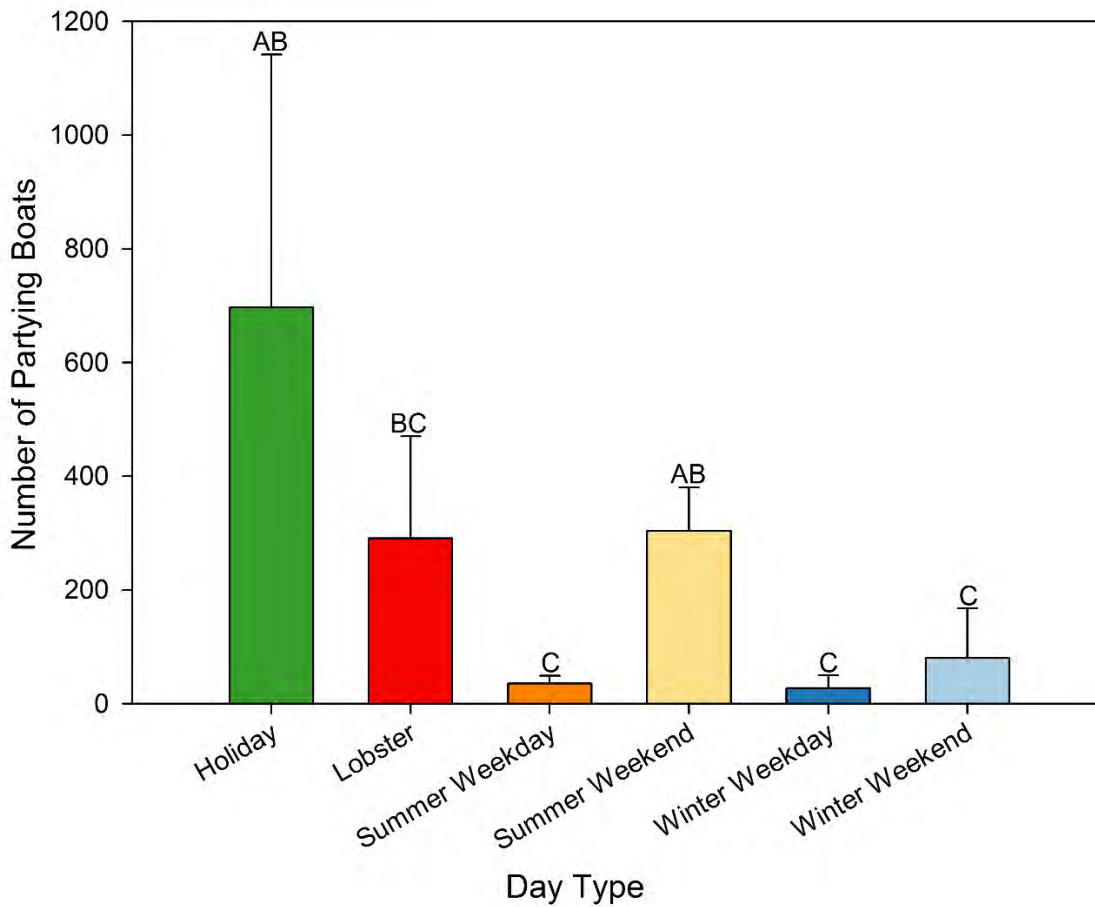


Figure 53 Average and standard deviation of the number of sandbar boats by type of day (Wald $\chi^2 = 91.025$, $df = 5$, $p < 0.001$; $n = 2-8$ flights per day type; total sandbar boats = 5,143). Letters indicate homogeneous subgroups ($p < 0.05$).

Winter weekends did not seem to attract as many revelers – an average of 80 ± 87 boats were observed at sandbars on winter weekends (8% of boats that were at sandbars). Going to the sandbars was also less common on weekdays both during the summer (35 ± 13 boats, 2.6% of sandbar boats) and winter (27 ± 23 boats, 2.4% of sandbar boats). There were no significant differences between the number of boats observed at sandbars during winter weekends, winter weekdays, and summer weekdays, and for further analyses the three day types were combined and referred to as “low-use periods” ($p < 0.05$, Figure 2).

Lobster Sport Season and Lobster Season Opening day were not significantly different from high-use periods or low-use periods (Figure 2). It is important to note that flights during Lobster Sport Season were conducted in the morning in an attempt to observe peak lobster fishing activity, possibly at the expense of missing peak boating activity at the sandbars. The number of boats observed at sandbars during Lobster Season Opening day, which fell on a Saturday in 2016, was typical of other summer weekends (Figure 3).

Similar patterns of seasonal variation were observed within Biscayne National Park by Ault et al. (2008). In general, there were greater proportions of boats engaged in sandbar activities during spring, summer, and fall weekends (30-40% of boats), when compared to weekdays (5-10% of boats). Indeed, it appears as if the popularity of

sandbars extends beyond this survey’s definition of summer; in 2016 weekends between late March and Labor Day weekend were observed with an average of 350 boats at sandbars, whereas other winter days had averages of only 33 boats (Figure 3).

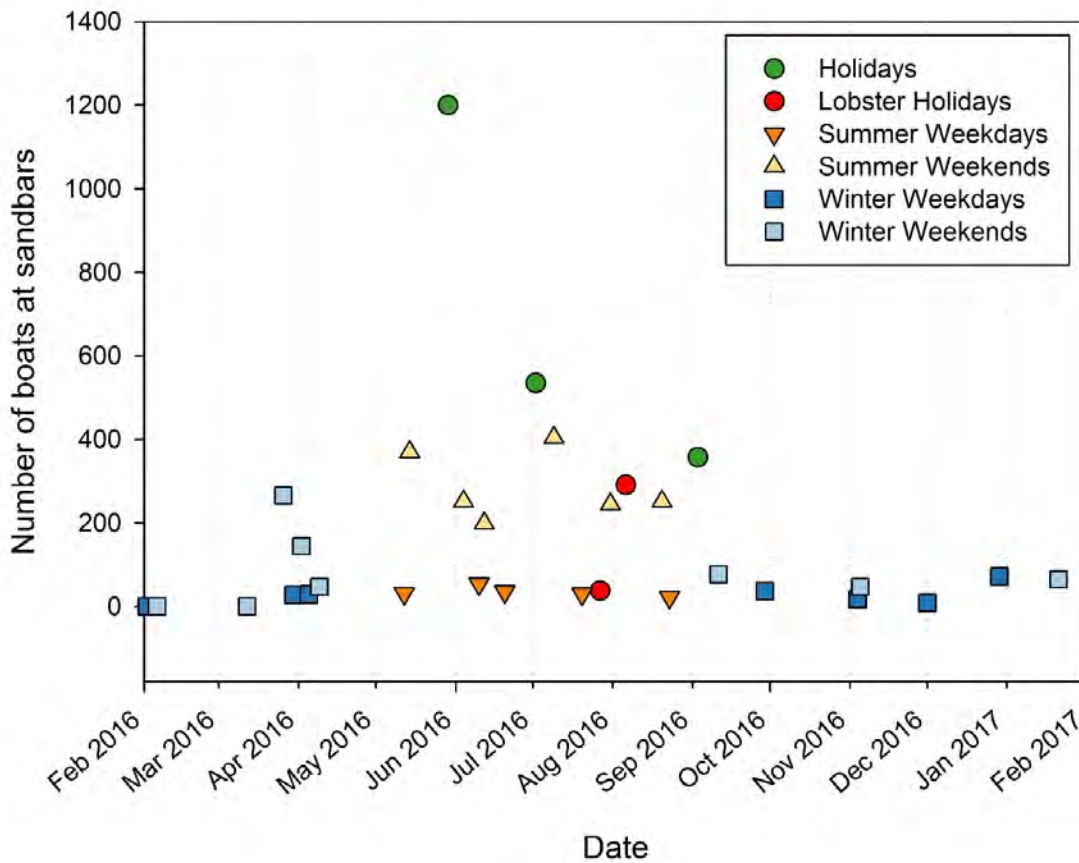


Figure 54 Number of boats observed at sandbars during each day type. Holidays refer to Memorial Day weekend, July 4th weekend, and Labor Day weekend. Lobster holidays refers to Lobster Sport Season and Lobster Season Opening Day.

The timing of the flights may have affected the count of boats at some sandbar locations, particularly on the Gulfside, which was always surveyed in the morning. A one-day study of the effects of survey time on boating patterns in the Lower Keys was conducted on June 17, 2017, which was a summer weekend. This one-time survey suggests that the number of boats at sandbars tended to increase throughout the morning and early afternoon to reach a peak in the mid-afternoon, and the number of boats appeared to decrease late in the day (19:00) as sunset approached (Figure 3). Sunset occurred at 20:18 in Key West on June 17, 2017.

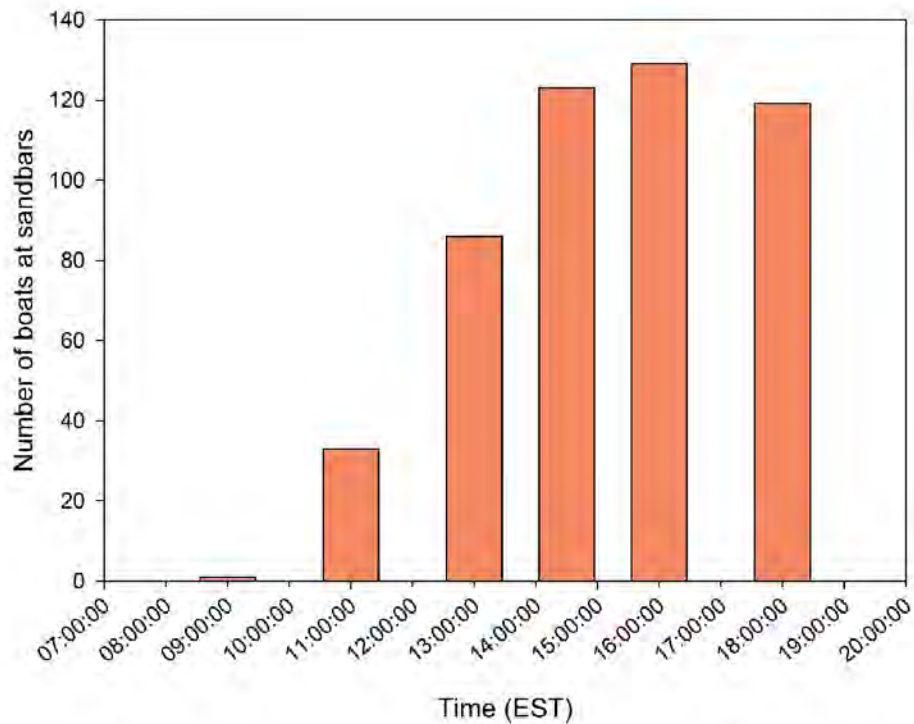


Figure 55 A one-day study of the effects of time-of-day on number of boats at sandbars during a summer weekend. Sunset on this day (June 17, 2017) occurred at 20:18 in Key West. The time on the x axis refers to the start time of the flight.

Sandbars in Different Regions

Although any number of boats could have been considered to be partying at any location, there were some locations throughout the Keys where boats tended to aggregate at sandbars, and locals have given names to these spots. By far, the largest sandbar parties tended to occur at Whale Harbor (Figure 5), which is often referred to simply as “the sandbar” by locals in the Upper Keys. Boats at Whale Harbor accounted for 31% of the boats observed at sandbars during the survey. Whale Harbor is unique in that it consistently has more boats than other sandbars. During high use times (summer weekends and holidays), an average of 132 ± 91 boats were observed at Whale Harbor - nearly 3 times more than the average of the next most popular sandbar, Mosquito Bank, which had an average of 49 ± 56 boats (Figure 6). Mosquito Bank is uniquely situated at a shallow sand patch near the reef tract, making it the only offshore sandbar observed. The Upper Keys were also home to other popular sandbars near Rodriguez Key, Tavernier Key, and Main Key (in Barnes Sound). Overall, the Upper Keys were home to not only the largest and most popular sandbar at Whale Harbor, but also the most moderately-sized sandbars (with between 14-50 boats) when compared to other regions of the Keys (Figure 5).

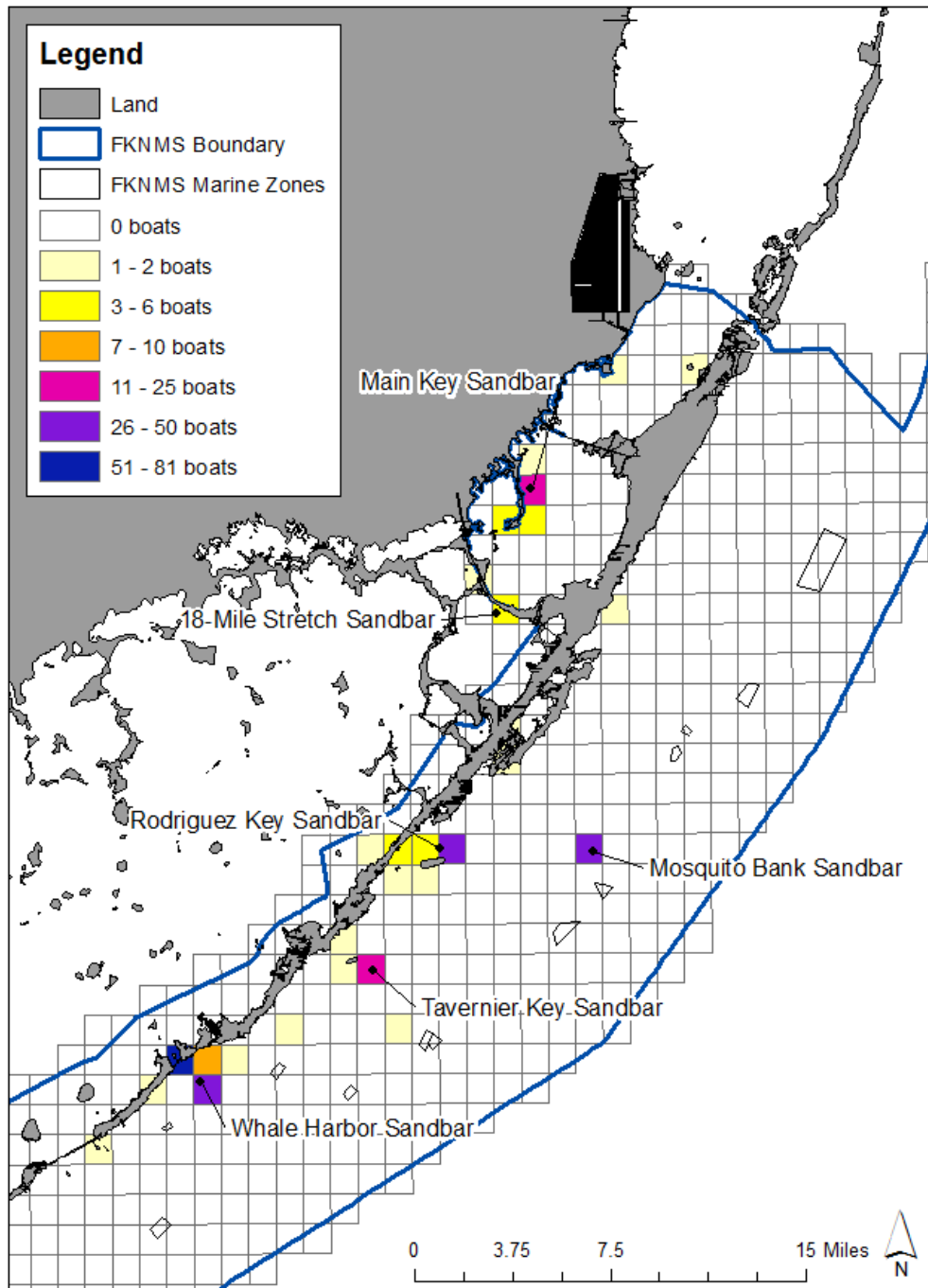


Figure 56 The average number of boats observed at popular sandbar areas during high-use times in the Upper Keys. Each grid represents 1 square latitude-longitude minute, which is approximately 1 square nautical mile.

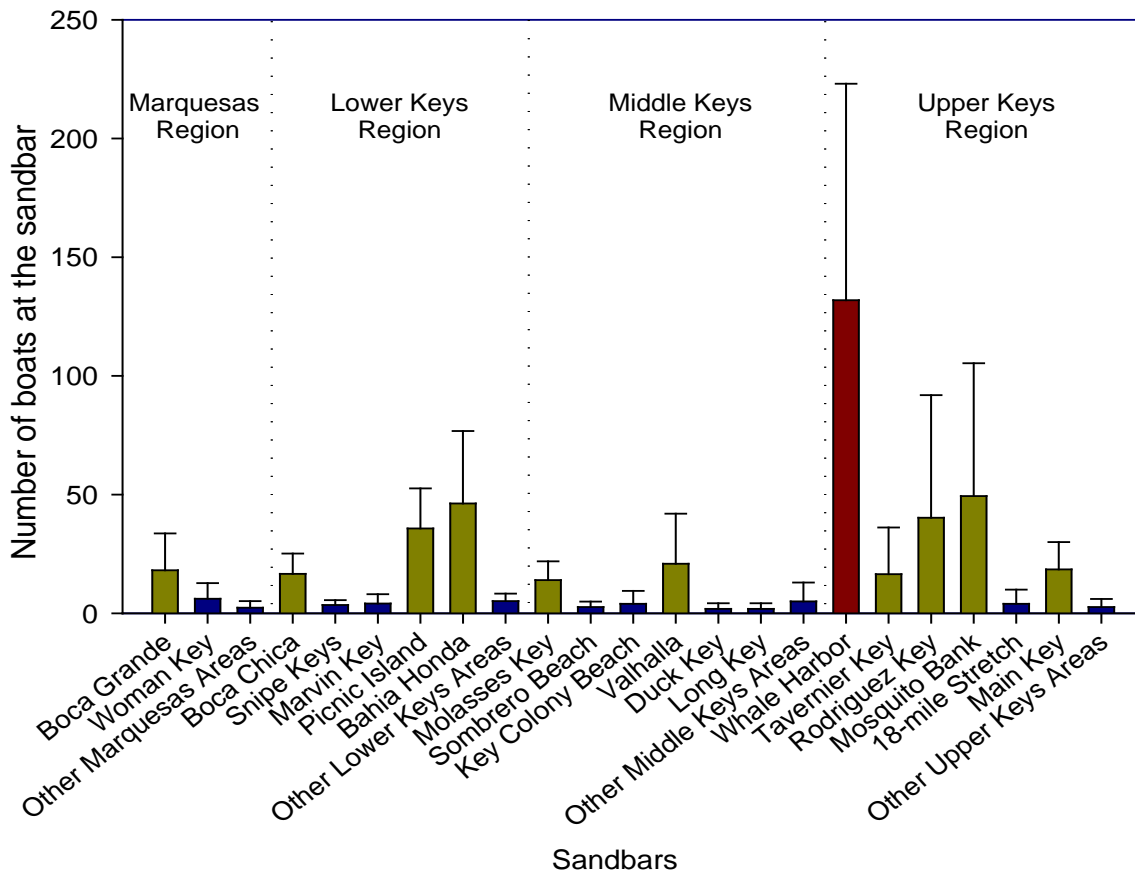


Figure 57 The average (\pm standard deviation) number of boats that were observed at various sandbars throughout the Keys during high-use times (holiday weekends and summer weekends). Whale Harbor is the most popular sandbar in the Florida Keys, and has uniquely high counts of boats. Sandbars that are in dark yellow are moderately-sized sandbars that host an average of 14-50 boats during high-use times. Sandbars in dark blue have the lowest average boat count (<6 boats) during high-use times.

Boats in the Middle Keys tended to aggregate at a sandbar nicknamed “Valhalla” due to its proximity to the privately-owned Valhalla Island, or at Molasses Key near the Seven Mile Bridge (Figure 3). Valhalla was observed with 21 ± 21 boats during high use times. Both Valhalla and Molasses Key are considered moderately-sized sandbars. There are a number of sandbars in the Middle Keys that have smaller crowds (Figures 7); Key Colony Beach, Duck Key, and Long Key each had an average of less than 4 boats during high-use times.

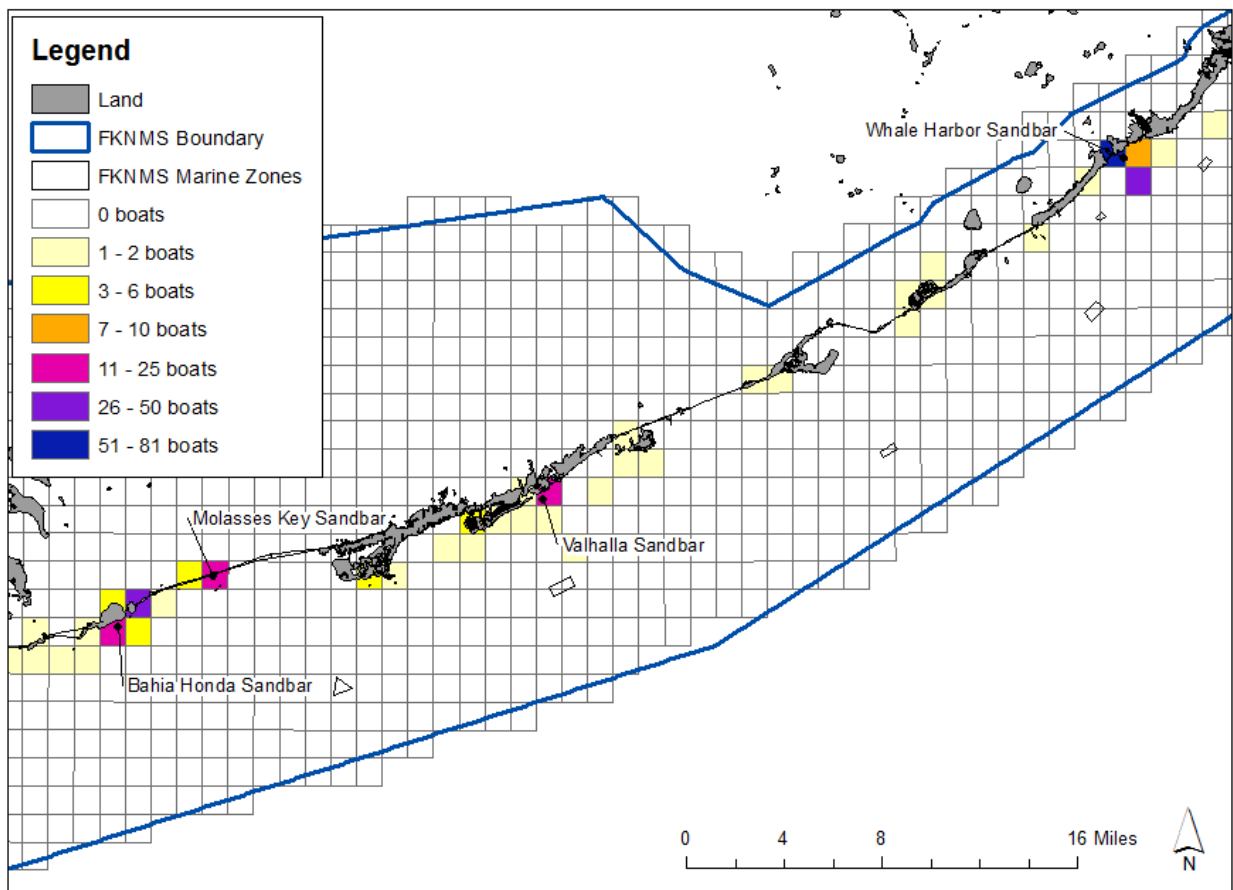


Figure 58 The average number of boaters observed at popular sandbar areas during high-use time in the Middle Keys. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

Many sandbars were also observed in the Lower Keys (Figure 8); Bahia Honda was the most popular sandbar location, with an average of 46 ± 30 boats during high use times, although it should be noted that there were generally several groups of boats that congregated at various locations surrounding the State Park (Figure 8). Picnic Island in Newfound Harbor was another popular sandbar; overall 10% of all boats at sandbars were observed at Picnic Island, although during high use times, fewer boats were observed (36 ± 17 boats) than at Bahia Honda. Typically, boats at Picnic Island are found in a denser aggregation than those surrounding Bahia Honda (Figure 8, 9). Boca Chica Beach was also a popular destination, with an average of 16 ± 9 boats at the sandbar during high use times. Snipe Key and Marvin Key were Gulfside destinations that were visited frequently by low numbers of boats ($4 \pm 2-4$ boats during high use times, Figure 8); thus, these may be sandbar locations suited to boaters who preferred a smaller crowd (Figure 9, 10). Boats from Key West also headed further west to the Marquesas Region to sandbars near Boca Grande and other outlying islands.

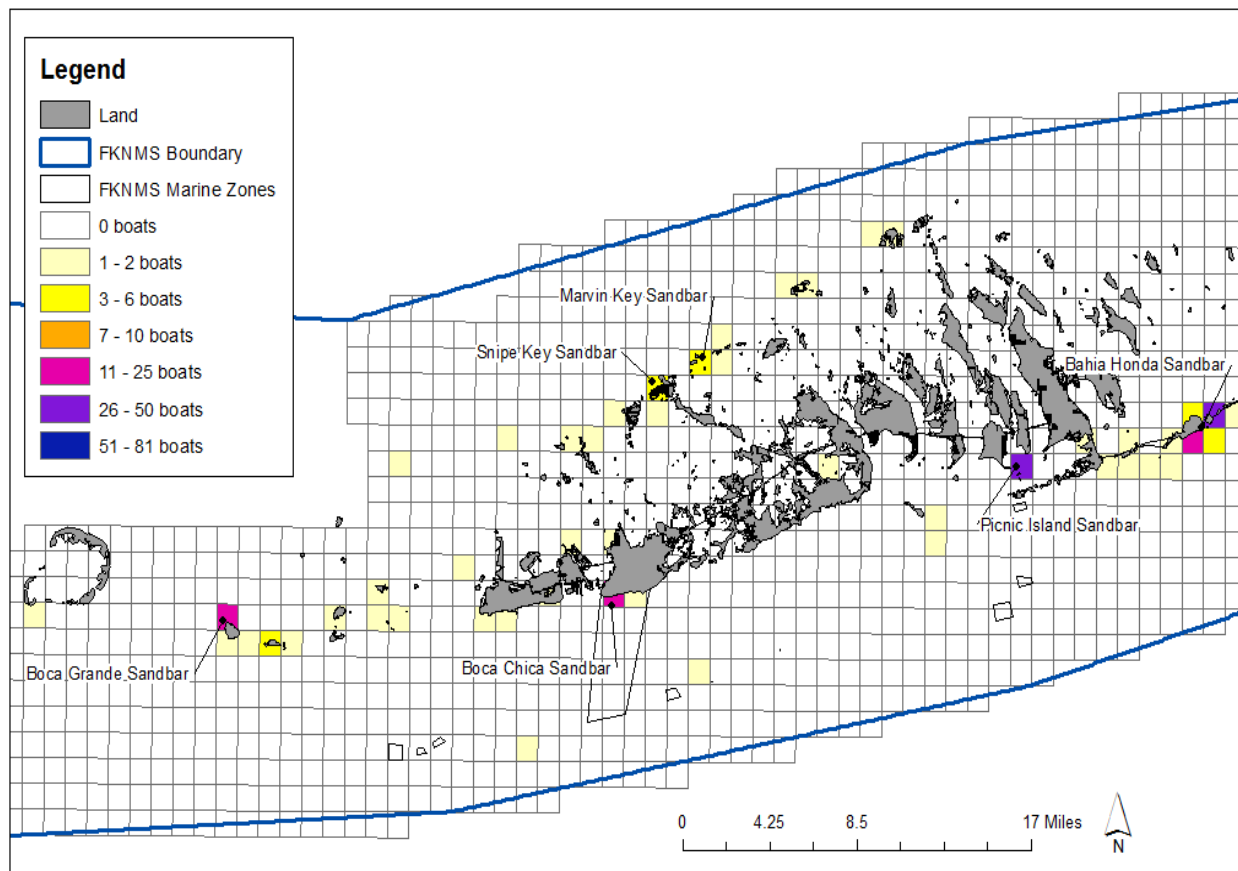


Figure 59 The average number of boats observed at popular sandbar areas during high-use times in the Lower Keys. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.



Figure 60 Boats at Picnic Island on September 4, 2016. Picnic Island is an example of a moderately-sized sandbar that hosts an average of 14-50 boats during high-use times. Photo taken by Maria Cooksey.



Figure 61 Boats at a sandbar near Marvin Key. This photo was taken on July 30, 2016 by Maria Cooksey.

Occupancy

Although some sandbars had consistently larger crowds than others, the frequency in which a sandbar was occupied was not affected by the size of the aggregation of boats; 67.8% of our named sandbars were occupied during more than half of our high-use time surveys. Each of the large (Whale Harbor) and moderately-sized sandbars (Bahia Honda, Boca Chica, Boca Grande, Main Key, Molasses Key, Mosquito Bank, Picnic Island, Rodriguez Key, Tavernier Key, and Valhalla) were occupied during every holiday and summer weekend survey (Figure 11). Of the smaller sandbars (an average of less than 6 boats per day), Marvin Key was also occupied during 100% of the holiday and summer weekend surveys and Snipe Keys and Woman Key were occupied more than 75% of the time.

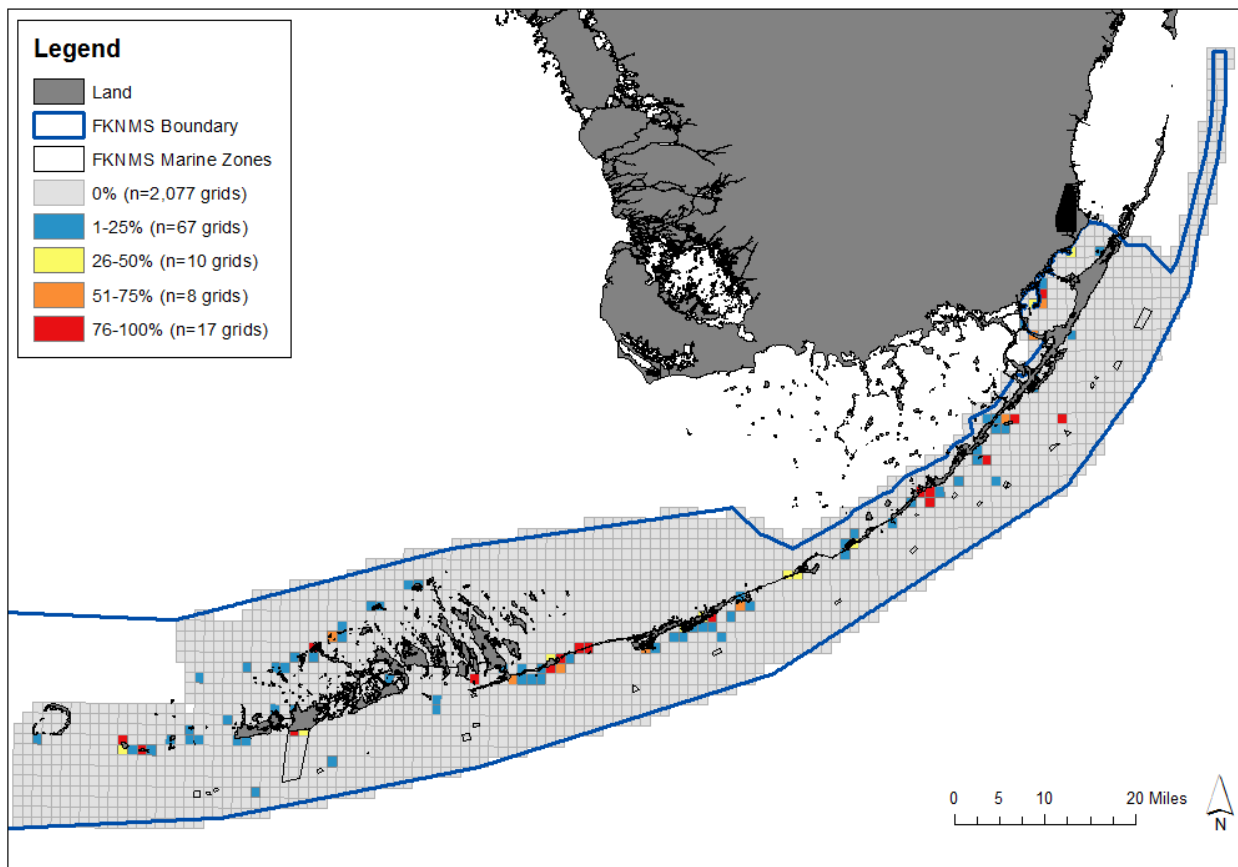


Figure 62 Map depicting the percent of time grids were occupied by boats at sandbars during surveys conducted at high-use times. (n = 8 flights, total boat count = 3,611, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

Potential Impacts to Habitat of Sandbar Parties

Although it is not clear when going to the sandbars became a popular activity in the Keys, Resolution 07-02-09 from the Village of Islamorada mentions that the Whale Harbor sandbar was reported in local and national news in 2002 (Resolution 07-02-09, 2007) and anecdotes from locals trace the aggregations of boats at the famed sandbar to the early 1990s. Boat aggregations at sandbars are often associated with marine debris and noise pollution. Human disturbances and noise pollution at sandbars that are in close vicinity to bird nesting sites may cause qualitative and quantitative impacts to colonial waterbirds and their nestlings (Rodgers and Smith 1995). There are also known impacts that are associated with the repeated and concentrated anchoring of boats in a small area, namely the destruction of seagrass meadows (Milazzo et al 2002). Seagrass and sessile invertebrates are also found in lower densities and cover in areas with more foot traffic, particularly in areas with softer substrates (Milazzo et al 2002, Liddle, M.J., 1991, Eckrich and Holmquist 2000). Although it is outside the scope of work of this report to address the impacts of sandbar parties on the benthic community, satellite or other aerial imagery could be used to monitor any potential changes to benthic habitat at sandbars in the future (Figure 11).

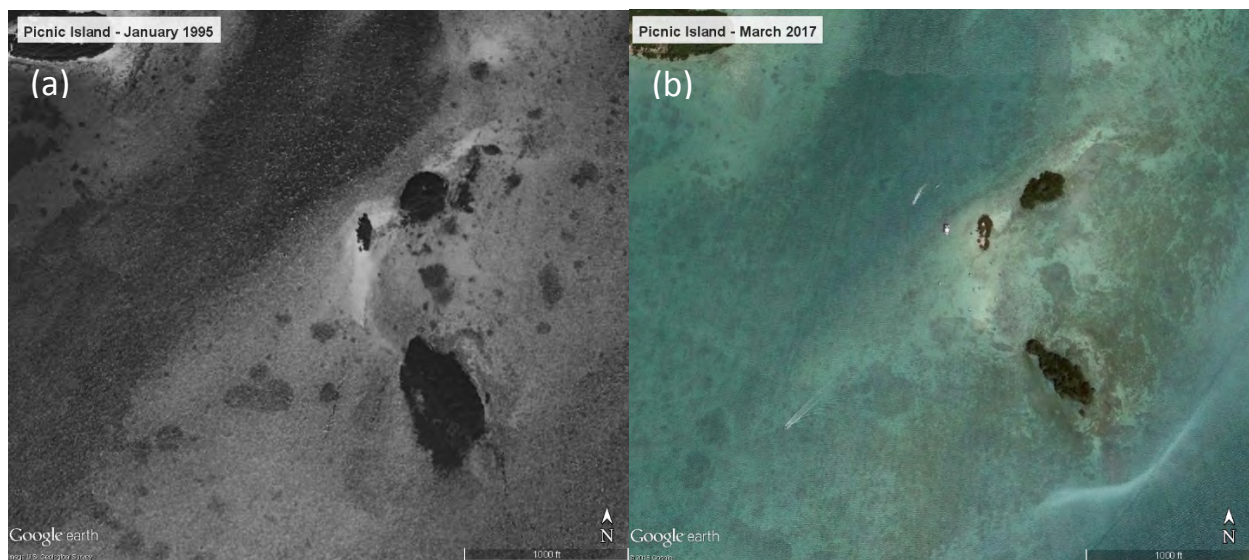


Figure 63 Satellite imagery of Picnic Island in **(a)** January 1995 and **(b)** March 2017. Source: **(a)** Google Earth Pro 7.1.5.1557. (January 25, 1995). Picnic Island, Florida Keys. 24° 38"06.13" N, 81°23'38.99" W, Eye altitude 4543 feet. U.S. Geological Survey. [March 9, 2018]. **(b)** Google Earth Pro 7.1.5.1557. (March 18, 2017). Picnic Island, Florida Keys. 24° 38"06.13" N, 81°23'38.99" W, Eye altitude 4543 feet. U.S. Geological Survey. [March 9, 2018].

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Watersports

Section at a Glance

- ❖ *Watersports include paddling (in paddlecraft such as kayaks, paddleboards, and/or canoes), riding personal watercraft (PWCs), and boats participating in adventure sports (tubing, parasailing, and many other similar activities).*
- ❖ *Paddling was the most popular watersport (4.5% of all boats).*
- ❖ *An average of 80.3 ± 65.6 moving paddlecraft (mean \pm SD) were observed per day.*
- ❖ *Most paddlecraft were observed in nearshore waters adjacent to Florida State Parks.*
- ❖ *PWCs made up 3.8% of all boats.*
- ❖ *An average of 67.8 ± 39.0 running PWCs (mean \pm SD) were observed per day.*
- ❖ *Most PWCs (64.9%) were observed near Key West, or at the congregations of boats at sandbars (12.2%).*
- ❖ *Adventure sports made up 0.5% of the boats seen in the Sanctuary.*
- ❖ *An average of 8.3 ± 5.4 adventure sport boats were observed per day.*
- ❖ *Most adventure sports were observed near Key West.*
- ❖ *The greatest numbers of boats, including paddlecraft and PWC, participating in watersports were observed on holiday weekends (320.0 ± 132.8 boats) and summer weekends (92.0 ± 25.4 boats).*

Introduction

In the Florida Keys, there are several popular water sports that are enjoyed by both locals and tourists alike. Of all visitors in 2016, 88.3% sought “adventure/kayaking” experiences during their time in the Keys. (Insights Inc., 2016). Keys residents also participate in various watersports and account for an unknown portion the boat counts in this study. For the purpose of this study, three types of watersport activities were considered: paddling (in kayaks, paddleboards, canoes), riding personal watercraft (PWC), and participating in adventure sports (tubing, parasailing, water skiing, riding banana boats, and many other similar activities). Throughout our survey, 8.7% of boats within the Sanctuary (156.45 ± 103.9 boats per day, mean \pm SD) were paddling, riding PWCs, or participating in adventure sports).

Paddling was the most popular watersport (4.5% of all boats). An average of 80.3 ± 65.6 moving paddlecraft were observed per day. Paddling refers to moving relatively slowly in a kayak, canoe, paddleboard, or other paddlecraft (although kayaks, etc. with trolling motors would be classified as paddling as well). Paddlecraft can be rented from many waterfront hotels and motels, and watersport companies throughout the Keys, either with guided ecotours or for general exploration. Visitors and locals who have their own paddlecraft launch from nearly any location with water access, and they are not limited by availability of boat ramps.

Personal watercraft are jet-driven vessels typically under 13 feet in length. PWCs made up 3.8% of all boats and an average of 67.8 ± 39.0 running PWCs (mean \pm SD) were observed per day. As with paddlecraft, some PWC are privately owned, but PWCs can also be rented at various waterfront hotels and watersport companies, generally for

use within a designated area or on a guided tour. There are also several “Jet Ski Clubs” in the Keys, Miami, and surrounding areas that organize group ride events, where aggregations of PWC riders follow a route designated by the event organizers.

Adventure sports were defined as boats with participants who were parasailing, riding banana boats, tubing, water skiing, wakeboarding, and other variations of towing people or objects behind a boat that is moving at a relatively high speed. Adventure sports made up 0.5% of the boats seen in the Sanctuary. On average, 8.3 ± 5.4 adventure sport boats were observed per day. Parasailing and other adventure sport operations are generally run from waterfront hotels and watersport companies. Resident boaters also participate in adventure sports. Adventure sport rides are typically ephemeral; parasailing only lasts 20-30 minutes per ride (www.keyscaribbean.com/adventure).

Watersports-Specific Methods

Statistical analyses were used to determine differences in the number and type of boats participating in watersports among day types (*i.e.* weekdays, weekends, season, and holidays). Negative binomial regressions with a log link function within generalized linear models (GLMs) were used to analyze boat count data. Homogeneous subsets for each category (*i.e.*, day type) were identified via a priori pairwise contrasts. The percent of boats seen during different day types were calculated with a weighted average number of boats that considers the differences in sample sizes amongst day types. All statistical analyses were completed using SPSS (v 21, IBM Corp., Armonk, NY, USA).



Figure 64 Parasailing is an adventure sport that was observed in the Florida Keys National Marine Sanctuary. Photo taken by Nick Parr on August 12, 2017.

Seasonal variation in Watersports

Paddling, riding PWCs, and participating in adventure sports followed similar trends throughout seasons (Table 1). The greatest number of watersport activities occurred during holiday weekends (320.0±132.8 boats) and summer weekends (231.0±31.2 boats). Memorial Day weekend had the greatest number of boats participating in watersports; there were 191 PWC, 289 paddlecrafts, and 27 adventure sports boats during the survey May 29, 2016. There was no significant difference between the number of boats participating in watersports during holiday weekends and summer weekends; for further analyses the two day-types (holiday weekends and summer weekends) were combined and renamed as “high-use” periods ($p < 0.05$, Figure 2).

There were no significant differences between the number of boats observed participating in watersports during winter weekends (121.3±61.8 boats), winter weekdays (107.1±92.2 boats), and summer weekdays (92.0±25.4 boats), and for further analyses these three day-types were combined and referred to as “low-use periods” ($p < 0.05$, Figure 2). The number of watersports craft counted on Lobster Sport Season and Lobster Season Opening day were not significantly different from high-use or low-use periods (Figure 2).

In 2008, Leeworthy et al 2010 estimated that 8.83% of visitors to the Keys in the summer used PWC, whereas 2.96% of winter visitors rode PWC.

Table 19 The number of personal watercraft (PWC), paddlecraft (kayaks, paddleboards, and/or canoes), and adventure sport boats (average and standard deviations) for different day types. N = number of days surveyed.

	N	PWC	Paddlecraft	Adventure Sports	Grand Total
Holiday	3	132.3±42.4	171.3±83.3	16.3±7.6	320.0±132.8
Lobster	2	78.0±42.0	80.5±30.5	8.5±1.5	167.0±74.0
Summer Weekdays	4	50.8±8.1	37.3±16.9	4.0±2.1	92.0±25.4
Summer Weekends	5	91.0±23.3	128.6±26.7	11.4±1.9	231.0±31.2
Winter Weekdays	7	44.9±13.4	56.4±74.3	5.9±2.6	107.1±92.2
Winter Weekends	8	55.1±31.6	58.5±30.0	7.6±5.3	121.3±61.8
Grand Total	29	67.8±39.0	80.3±65.6	8.3±5.4	156.5±105.8

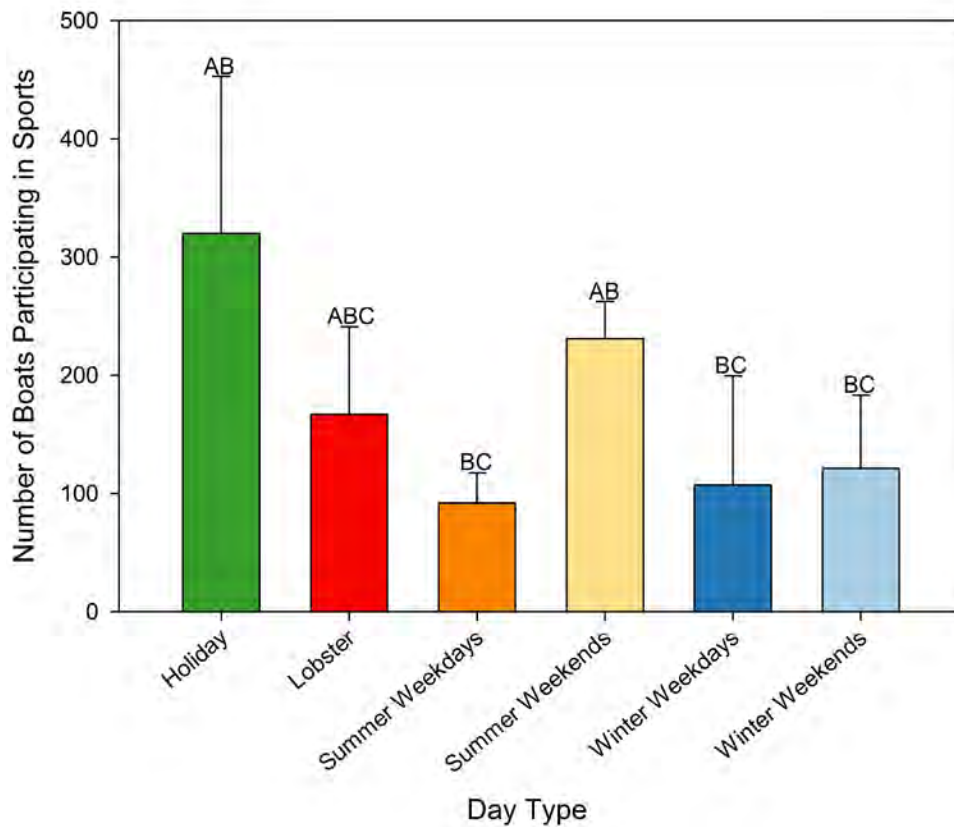


Figure 65 Average and standard deviation of the number of watersport craft by type of day flown (Wald $X^2 = 62.891$, $df = 5$, $p < 0.001$; $n = 2-8$ flights per day type; total watersport boats = 4,537). Letters indicate relative high (A) and low-use times (C) (homogeneous subgroups ($p < 0.05$)).

Spatial variations in Watersports

Boats that are participating in watersports are highly transient and the exact location of any boats participating in watersports is highly dependent on the time of observation. Paddling, riding PWC, and adventure sports exhibited different spatial trends during high-use times.

Paddlecraft were typically observed in nearshore habitats, although at a few times (7 occasions) they were observed along the reef tract (Figure 3). Paddlecraft were most commonly observed (during 50-100% of surveys) in nearshore waters along local Florida State Parks, namely: John Pennekamp Coral Reef State Park, Lignumvitae Key Botanical State Park, Indian Key Historical State Park, Long Key State Park, Curry Hammock State Park and Bahia Honda State Park. Paddlecraft were observed in more than 75% surveys along the southern coast of Key West.

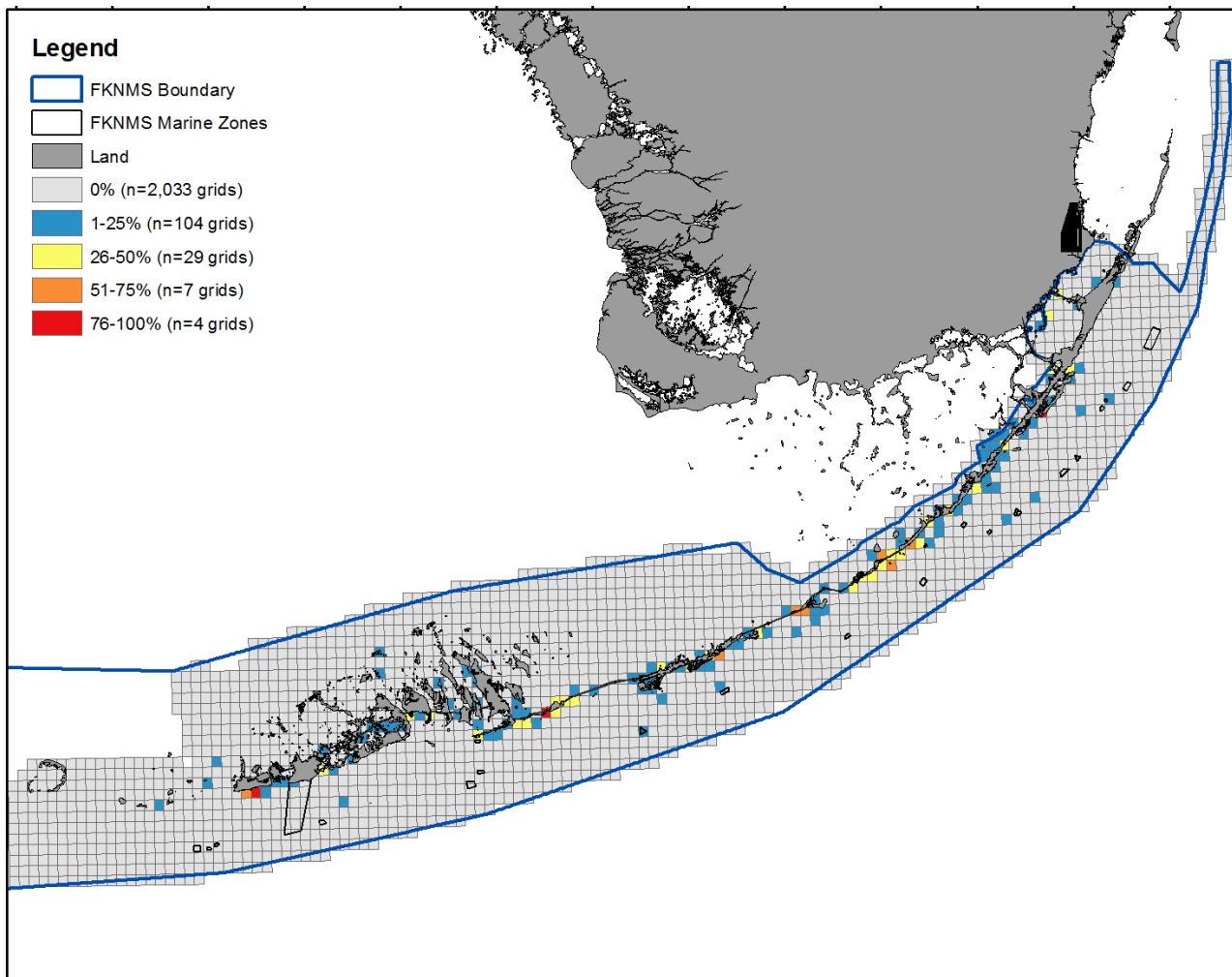


Figure 66 Map depicting the percent of time grids were occupied by paddlecraft (kayaks, paddleboards, and/or canoes) during surveys conducted at high-use times. (n = 8 flights, total boat count = 1,157, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

PWC are highly visible craft used mostly nearshore. PWCs were observed once or twice in 104 of our survey grids nearshore throughout the Keys during high-use times on holiday weekends and summer weekends. Most PWCs (64.9%) were observed in waters surrounding Key West (Figure 4). There are several charter companies in Key West that offer 1.5 hour long PWC tours with a route that encircles the island. These tours have various starting points and staggered starting times so that there effectively could be a group of PWCs on a tour at any area in nearshore waters near Key West; grids around Key West were occupied by PWCs during 26-75% of the surveys during high-use times. PWCs were also commonly observed near Ohio Key, Whale Harbor Channel, and Rodriguez Key. It is possible that use of PWCs in these areas was linked to sandbar activity (see Sandbars). Of the PWCs observed in this survey, 12.2% were in known sandbar locations.

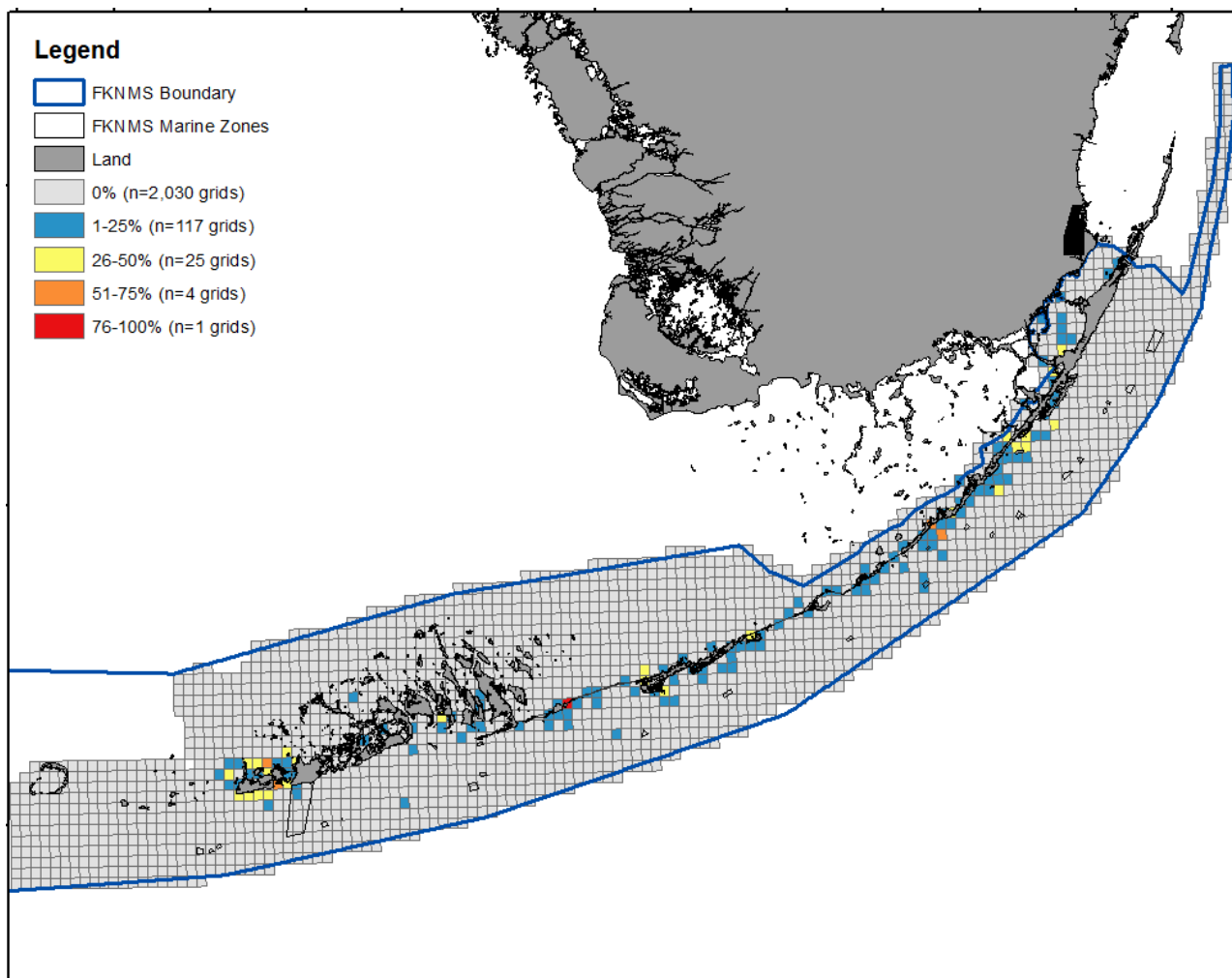


Figure 67 Map depicting the percent of time grids were occupied by personal watercraft (PWC) during surveys conducted at high-use (holiday and summer weekends) times. (n = 8 flights, total boat count = 852, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

Adventure sports were the least commonly observed watersport activity in the survey. The majority of adventure sports were observed in the coastal waters surrounding Key West (Figure 5).

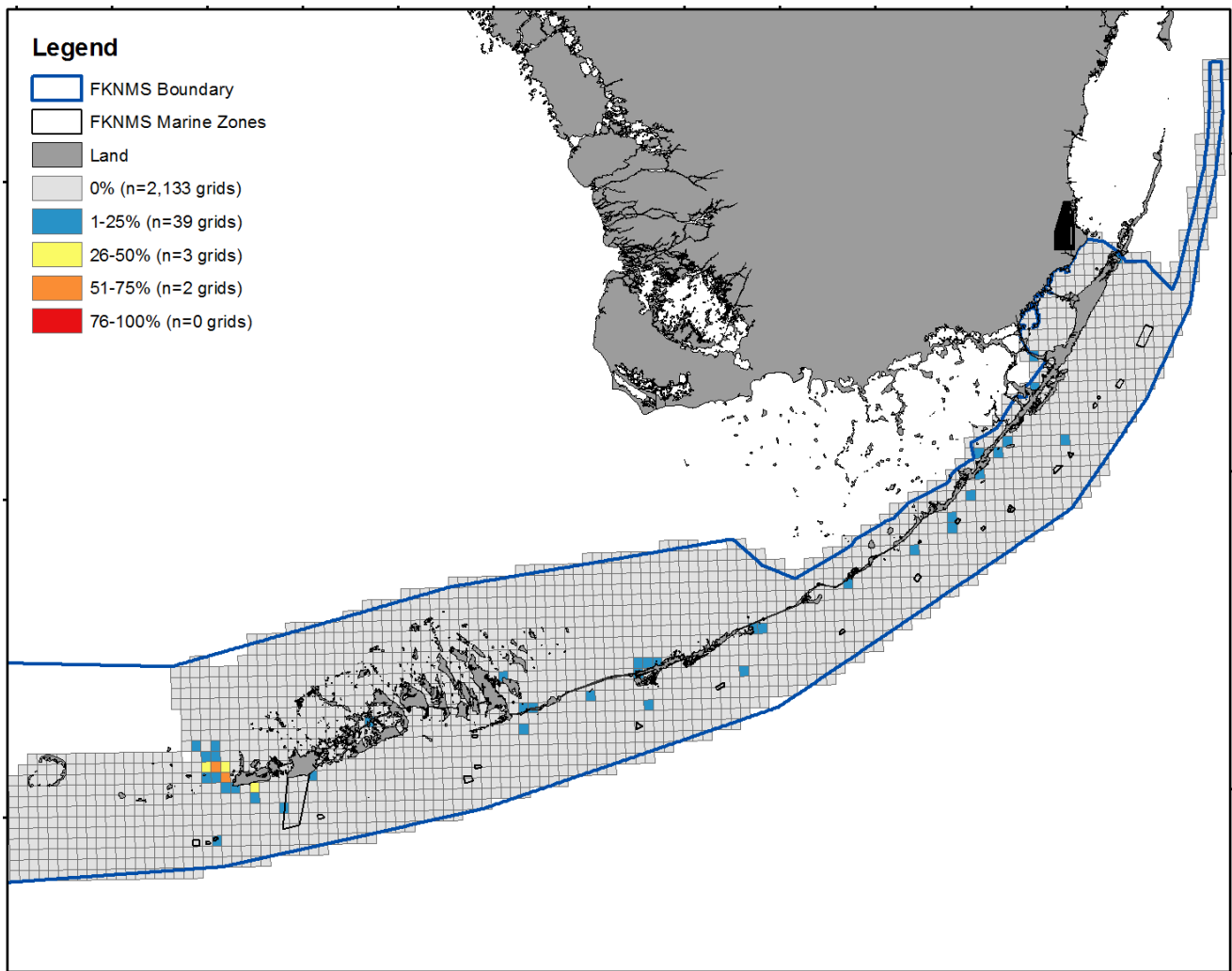


Figure 68 Map depicting the percent of time grids were occupied by boats participating in adventure sports during surveys conducted at high-use (holiday and summer weekends) times. (n = 8 flights, total boat count = 106, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

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Running and Anchored Boats

Section at a glance

- ❖ *A “running” boat was one that was underway, making way, and not obviously engaged in some other activity.*
- ❖ *The number of running boats averaged 529 ± 242 boats per day, and represented $31\% \pm 5\%$ of all boats observed. These boats were potentially participating in other activities during the day, but not at the time and location when counted.*
- ❖ *Running boats were common nearshore, in both Gulfside and Oceanside areas in the Upper, Middle, and Lower Keys regions.*
- ❖ *Running boats were also seen 25-50% of the time in most grids further offshore Oceanside near Marathon and the Upper Keys.*
- ❖ *A boat was defined as “anchored” if it was anchored or moored, but was not participating in another activity such as diving, fishing, or at a sandbar.*
- ❖ *The number of anchored boats remained relatively constant for all flights, averaging 240 ± 42 boats per day, representing $17\% \pm 8\%$ of all boats per flight.*
- ❖ *The largest anchorages in the Sanctuary: Boot Key Harbor, Key West Bight, and Garrison Bight Key West were not surveyed due to proximity to airports.*
- ❖ *Anchored boats were in isolated locations nearshore, especially on the lee side of islands throughout the Sanctuary.*

Introduction

This section focuses on the observations of boat activities that were defined as running and as anchored. Intuitively, all boats spend part of their day as running boats. A boat’s observed activity may be running, but presumably many running boats were in transit to or from other activities, such as fishing, diving, or spending time at sandbars. Running boats were likely not at the preferred location for their primary activity, creating a challenge to fully describe the number of boats utilizing various locations for diving, fishing, or other activities. However, there is considerable value in understanding the location of high boat traffic areas regardless of the primary activities of those boats.

Boats classified as anchored also created a challenge for this aerial survey methodology. Anchored boats might also participate in other activities during the day, similar to running boats. However, because of the relatively high counts of anchored vessels, their locations and identification of frequent anchorage sites is likely relevant to use of Sanctuary resources. Taken together, running and anchored boats accounted for 48% of the boating activity in the Sanctuary.

Methods

For the purposes of this study, a “running” boat was one that was underway, making way, and not obviously engaged in some other activity (such as watersports or fishing). A boat was defined as “anchored” if it was: 1) anchored or moored to a mooring ball, and 2) was not visibly participating in another activity (such as diving, fishing, sandbar, etc.). We did not differentiate between anchored and moored vessels for this study. Many of the “anchored” vessels observed nearshore in this section were likely live-aboard vessels that were moored or anchored in mooring fields. However, there were some mooring areas that were always occupied with vessels, but that were not captured during this study due to logistical issues. The largest anchorages in the Sanctuary, Boot Key Harbor near Marathon and Key West Bight and Garrison Bight near Key West were not surveyed. These anchorages were near the airport take-off and landing zones preventing our planes to systematically circle these high boat abundance sites and make accurate counts of boats. Personal watercraft (PWC) and paddlecraft were not included in this section (see Watersports).

Statistical analyses were used to determine differences in the number and type of anchored and running boats among day types (*i.e.* weekdays, weekends, season, and holidays). Negative binomial regressions with a log link function within generalized linear models (GLMs) were used to analyze boat count data. Homogeneous subsets for each category (*i.e.*, day type) were identified via a priori pairwise contrasts. The percent of boats seen during different day types were calculated with a weighted average number of boats that considers the differences in sample sizes among day types. All statistical analyses were completed using SPSS (v 21, IBM Corp., Armonk, NY, USA).

Types of Boats

Running boats consisted mostly of motorboats (87%); 72% of running boats were less than 30 ft. in length. Sailboats made up 8% of all running boats, followed by commercial fishing boats (3%), and charter dive boats (1%). All other boat types made up less than 1% of daily running boat observations.

Anchored boats consisted mostly of motorboats (56%) and sailboats (43%). Most anchored boats were greater than 30 ft. in length (71%). Other boat types such as construction, educational, military/law enforcement, and cargo boats were seldom observed anchored (less than 2 boats per day on average).

Running and Anchored boats by Season

The number of running boats varied by season (Figure 1). The number of running boats was proportional to the total number of boats observed in the Sanctuary (See Overall Results). The number of running boats averaged 529 ± 242 boats per day, and represented $31\% \pm 5\%$ of all boats per flight. The number of anchored boats remained relatively the same throughout all flights, at an average of 240 ± 42 boats per day, representing $17\% \pm 8\%$ of all boats per flight (Figure 1).

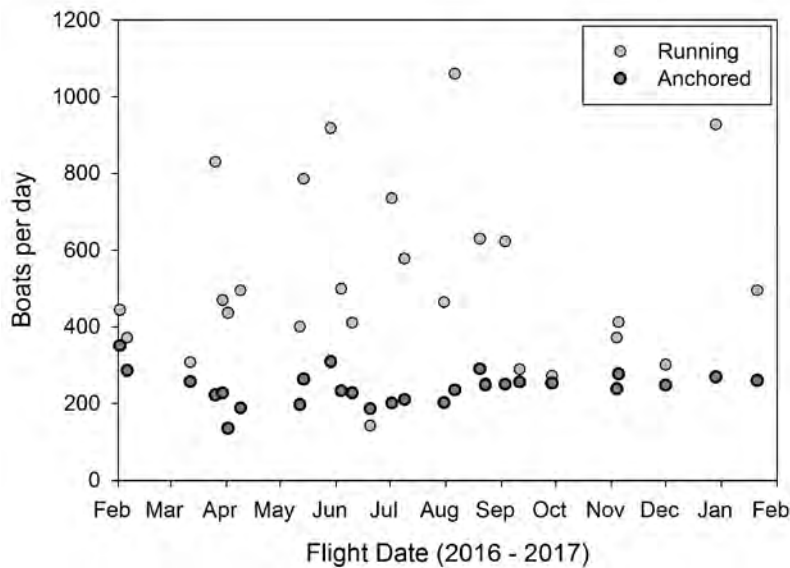


Figure 69 Total number of running boats and anchored boats observed in the Sanctuary by flight date (29 flights, total of 15,348 running boats and 6,961 anchored boats observed).

Just as the number of running boats reflected the total number of boats each day, the pattern of running boats by day type also matched that of all the boats observed in the Sanctuary (see Overall Results). Thus, the most popular boating days were lobster season opening days (1065 ± 6 running boats per day), followed by holidays (758 ± 122 running boats per day) and summer weekends (591 ± 205 running boats per day). Winter weekends, and winter and summer weekdays saw fewer boats per day (Figure 2). The number of anchored boats was similar among all day types (Figure 2).

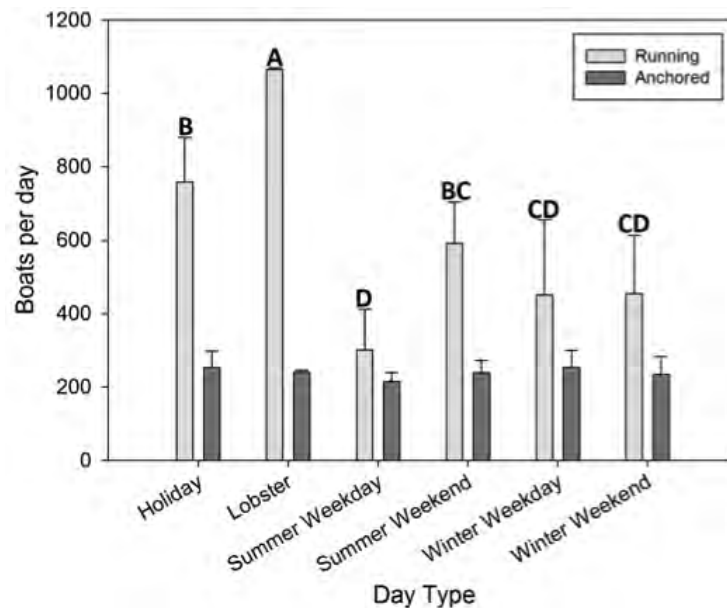


Figure 70 Average and standard deviation of the number of boats running and anchored in the Sanctuary by type of day flown (Wald $X^2 = 179.1$, $df = 5$, $p < 0.001$; $n = 2-8$ flights per day type; a total of 15,348 running boats and 6,961 anchored boats observed). Letters indicate homogeneous subgroups among running boats per day type ($p < 0.05$); there were no significant differences among the number of anchored boats by day type.

Running and Anchored Boats by Region

The Florida Keys and surrounding waters are often divided into regions (*e.g.* Upper Keys, Middle Keys, Lower Keys) to help describe the locations and habitats of the Keys (see Methods). Grids that included bridges or any portion of the Gulf were designated as Gulfside grids, since boater activity at bridges tends to be more aligned with that of other Gulfside boaters. We further designated areas surrounding the Marquesas Keys as Gulfside or Oceanside if a grid was north or south of those Keys. It is also important to note that the Biscayne region of the Florida Keys National Marine Sanctuary is adjacent to, but not part of Biscayne National Park.

Running Boats

Running boats were concentrated nearshore, especially around bridges and channels throughout the Lower, Middle, and Upper Keys regions of the Sanctuary (Figure 3, Table 1). Figure 3 identifies the likelihood of a given area being occupied by running boats (*i.e.*, the percentage of time a running boat was observed within a grid). Regions of highest traffic for running boats in the Sanctuary (grids with greater than 75% occupancy, which represented less than 1% of all grids) were located near bridges and main waterways (Figure 3, Table 1). For the Upper Keys, these included the Marvin D. Adams Waterway Bridge at mile marker 103, which is the only boat access from the Oceanside to Florida Bay through Key Largo. Other Upper Keys high-traffic areas included those channels that lead from John Pennekamp Coral Reef State Park and Port Largo, as well as Tavernier Creek, Windley Key, which are all main channels that allow passage between the Oceanside and Gulfside (Table 1). Vaca Cut was a high-traffic zone in the Middle Keys as well as the channel under Seven Mile Bridge adjacent to the western edge of Marathon. The Lower Keys had high-traffic in the main channels like Boca Chica and in the oceanside Key West Southwest Channel (Table 1). Medium-traffic areas (where running boats were seen in 25-75% of flights, 17% of all grids) were found at Snake Creek and Whale Harbor Channel in the Upper Keys, in Hawk Channel near Marathon, and in Newfound Harbor Channel and Northwest Channel in the Lower Keys. Low-traffic areas (grids with 0-25% occupancy; 82% of all grids surveyed) appeared to be relatively random and situated further from land and reef structure, and not in the main channels or transit areas.

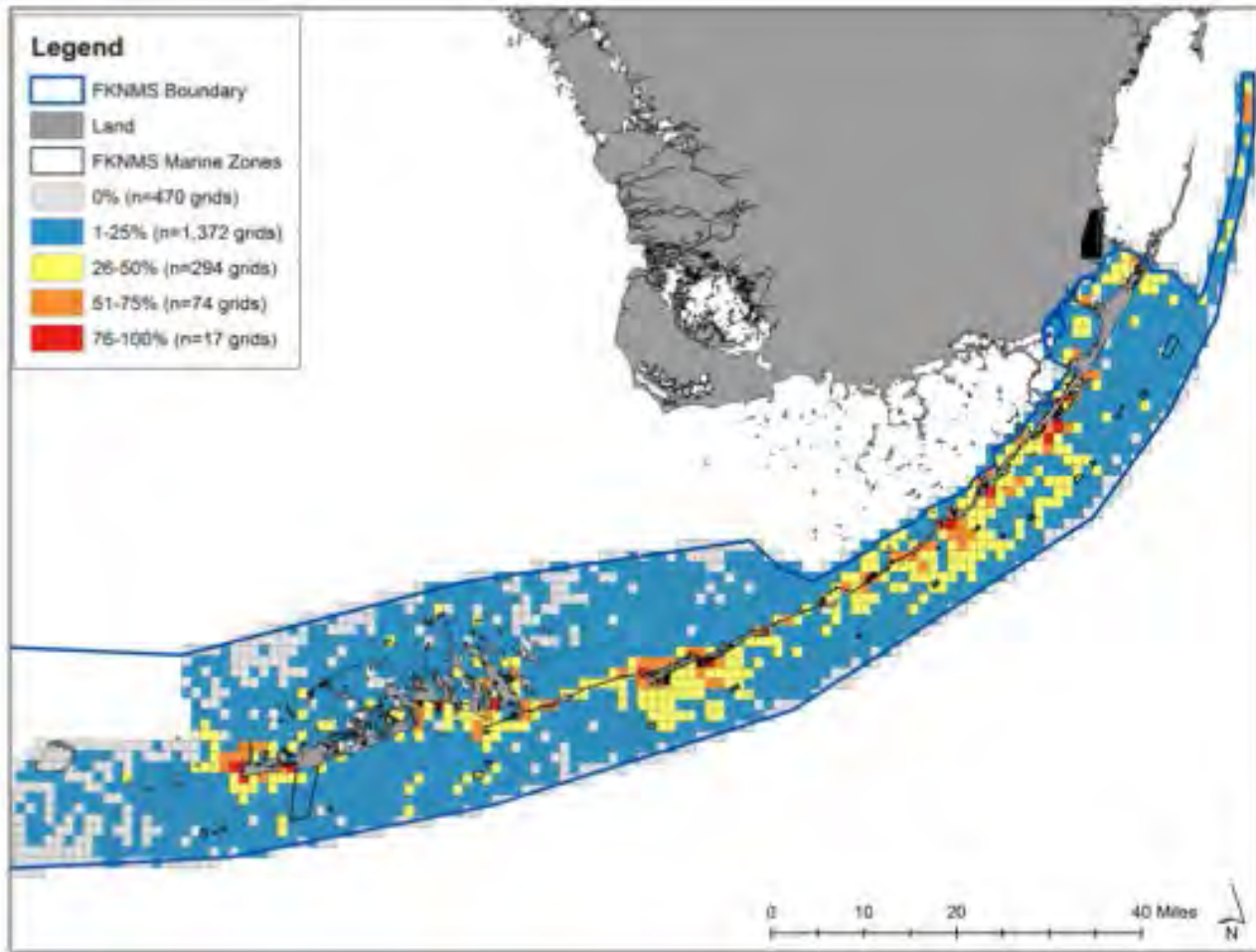


Figure 71 Map depicting the percent of time grids were occupied by running boats (n = 29 flights, total boat count = 15,348, total grids = 2,227) Each grid represents 1 square minute, which is approximately 1 square nautical mile.

Table 20 Highest areas of boat traffic (number of running boats) identified by the average and maximum number of vessels per observation (n=29 flights, total boats observed running = 15,348). Percent occupancy (% Occ.) reflects the percentage of time a running boat was observed within a grid. Regions of highest traffic for running boats in the Sanctuary (grids with >75% occupancy, <1% of all grids) were located near bridges and main waterways (Figure 3).

Location	Nearest Island(s)	Description	Running Boats		
			Avg. #	Max #	% Occ.
Upper Keys					
Marvin D. Adams Cut	Key Largo	Only cut through Key Largo	2	9	79
South Sound Creek	Key Largo	Main Channel out of Pennekamp	5	16	83
Port Largo Channel	Key Largo	Main Channel out of Port Largo	3	13	86
Tavernier Creek Channel	Plantation Key + Tavernier	Main Channel/Bridge	4	14	100
Snake Creek	Windley Key + Plantation Key	Main Channel/Bridge	2	22	55
Windley Key Channel	Windley Key + Plantation Key	Main Channel/Bridge	6	78	83
Whale Harbor Channel	Upper Matecumbe + Windley Key	Main Channel/Bridge	4	27	59
Middle Keys					
Vaca Cut	Marathon	Main Channel/Bridge	7	19	100
7 Mile Bridge/	Marathon (Vaca Key)	Main Channel on South side of Marathon	3	8	86
Sister Creek Channel	Marathon (Vaca Key)	Channel out of Marathon Oceanside	2	7	69
Lower Keys					
Kemp Channel	Cudjoe + Summerland	Main Channel/Bridge	2	12	83
Boca Chica Channel	Stock Island + Boca Chica	Main Channel	2	6	76
Key West SW Channel	Key West	Main Channel out of Key West	4	15	83

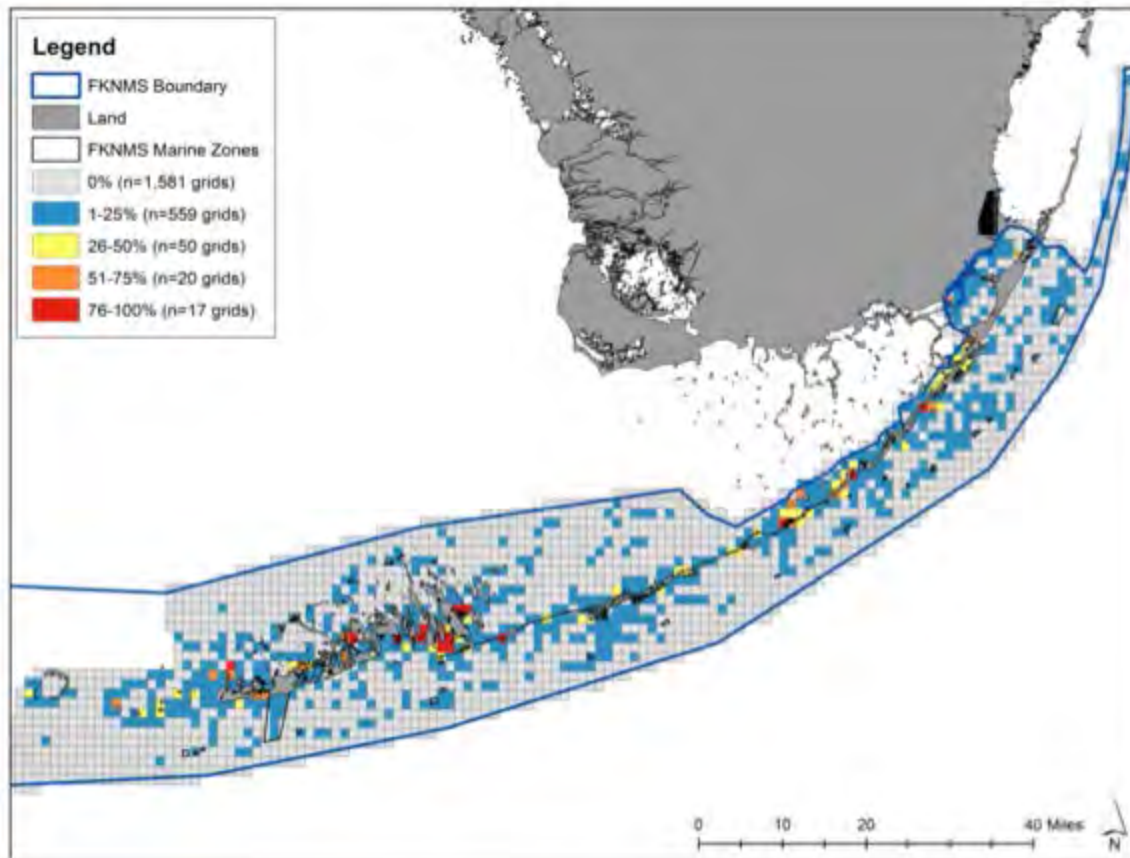


Figure 72 Map depicting the percent of time grids were occupied by anchored boats (n = 29 flights, total boat count = 6,961, total grids = 2,227). Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile. Boot Key Harbor and Key West Anchorages were not measured in this study due to proximity to airports.

Anchored Boats

Anchored boats were most consistently seen in nearshore areas, especially in alcoves on the lee side of islands and near bridges throughout the Sanctuary, which are generally popular mooring areas (Figure 4, Table 2). Anchored boats were also seen during 1-25% of the flights in areas throughout the Sanctuary, which may be indicative of boats that were not yet clearly participating in an activity.

Table 21. Most popular anchorage areas in the Sanctuary identified by the average and maximum number of anchored boats per observation (n=29 flights, total boats observed anchored = 6,961). Percent occupancy (% Occ.) reflects the percentage of time an anchored boat was observed within a grid. The most commonly used anchorages in the Sanctuary (grids with >75% occupancy, <1% of all grids) were in alcoves on the lee side of islands and near bridges (Figure 4). Boot Key Harbor and Key West Anchorages were not measured in this study due to proximity to airports, thus the quantities of boats in these anchorages were unknown.

Anchorage Location	Side	Anchored Boats		
		Avg. #	Max #	% Occ.
Upper Keys				
Gilbert's	Gulfside	7	11	75
Tarpon Basin	Gulfside	9	23	47
Buttonwood Sound	Gulfside	8	28	43
Mariner's Club/Rock Harbor	Oceanside	3	22	21
Key Largo/Rodriguez	Oceanside	7	19	93
Mangrove Marina	Gulfside	9	21	48
Windley Harbor	Gulfside	6	13	93
Upper Matecumbe	Gulfside	8	38	48
Little Basin	Gulfside	16	25	69
Middle Keys				
Boot Key Harbor	Oceanside	unknown	unknown	unknown
Lower Keys				
Doctor's Point	Gulfside	4	7	93
Niles Channel	Gulfside	3	4	100
Bahia Honda	Gulfside	3	4	76
Pine Channel	Oceanside	8	14	93
Niles Channel	Oceanside	5	6	86
Horseshoe Island/Coupon Bight	Oceanside	5	11	79
Key West Anchorage	Oceanside	unknown	unknown	unknown

References

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Boat use near the Marquesas and Dry Tortugas

Section at a Glance

- ❖ *NOAA Office of Marine and Aviation Operation aircraft completed six flights west of Key West in the Marquesas and Tortugas regions, providing the first systematic counts of boats in these regions.*
- ❖ *An average of 95.8 ± 40.0 (mean \pm standard deviation) boats per day were observed in the Marquesas region.*
- ❖ *The Lakes area contained 55% of the boats observed in the Marquesas region.*
- ❖ *An average of 18.0 ± 2.9 boats per day were observed in the Dry Tortugas region, with 37.0% of those boats observed within the boundaries of the Dry Tortugas National Park (DRTO).*
- ❖ *Most of the boats in the Marquesas and Dry Tortugas regions were running (34.3%) or anchored (19.6%).*
- ❖ *Hook-and-line fishing (18.6%) and commercial fishing (10.1%) were also popular activities.*

Introduction

The National Oceanic and Atmospheric Administration (NOAA)'s Office of Marine and Aviation Operation provided an aircraft to complete a small number of flights west of Key West. These flights and surveys over the Dry Tortugas and Marquesas regions were outside the main scope of work for this project. The number and timing of these flights was heavily influenced by the availability of the NOAA aircraft, which then has limited our ability to quantitatively summarize the results. Nevertheless, these surveys represent the first attempt to survey the western portion of the Sanctuary.

The Marquesas region is named for the uninhabited chain of mangrove islands about 25 miles west of Key West. The Dry Tortugas are located at the westernmost region of the Florida Keys National Marine Sanctuary, approximately 70 miles to the west of Key West. The waters surrounding the islands of the Marquesas and the Dry Tortugas are home to seagrass beds, coral reef habitats, and hardbottom areas, and this diverse benthic habitat supports a range of megafauna, including several important commercial fish species (Feeley et al., 2018, Ault et al., 2013). The Marquesas and Tortugas areas are isolated from the populated areas of the Florida Keys and the Florida mainland, but their unique ecological and cultural resources warrant special protection. The Sanctuary surrounds the Dry Tortugas National Park (DRTO) and includes two ecological reserves: the Tortugas North Ecological Reserve (TNER) and Tortugas South Ecological Reserve (TSER). Fishing and anchoring are prohibited in the TNER, the TSER, and in the 46-square mile Research Natural Area within DRTO.

Methods

In order to supplement the aerial survey with information about the usage of the Tortugas and Marquesas Regions, 6 flight surveys were conducted from February 4, 2016 to September 30, 2016 (Table 1) in a special flight path over this area of the Sanctuary (Figure 1). The northern flight circuit focused on the DRTO and TNER areas. The southern flight circuit observed the southern border of DRTO, the TSER and the Lakes area of the Marquesas, which is the shallow waters surrounding the small islands west of the southwest channel in Key West to Boca Grande Key.

The boundaries of the Marquesas and Dry Tortugas regions reflect designations that are commonly used by the Sanctuary. A map was created to divide the one-minute grids into these regions; if a grid was bisected by the boundary of two regions, the entire grid was designated as being part of the region in which the grid centroid was located.

Table 22 Dates and day types of flights over the Marquesas and Dry Tortugas regions of the Sanctuary.

Date	Day Type
2/4/2016	Winter Weekday
4/3/2016	Winter Weekend
4/7/2016	Winter Weekday
7/30/2016	Summer Weekend
9/25/2016	Winter Weekend
9/30/2016	Winter Weekday

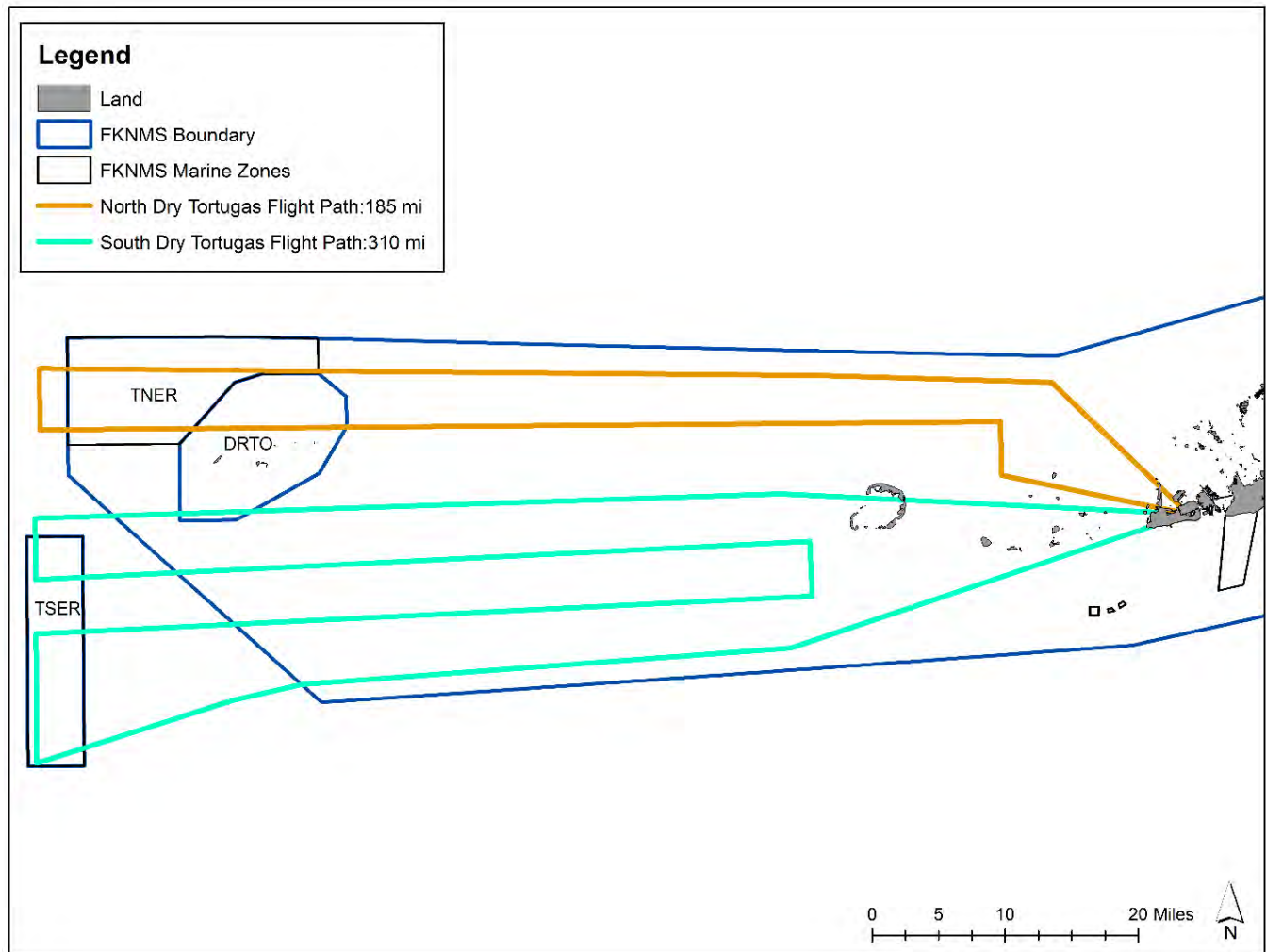


Figure 73 Flight paths over the Marquesas and Dry Tortugas regions of the Sanctuary. TNER = Tortugas North Ecological Reserve; DRTO = Dry Tortugas National Park; TSER = Tortugas South Ecological Reserve

Weather

Five of the six flights were conducted with average daily wind speeds below 15 knots; the survey on April 3, 2017 had wind speeds of 17.9 mph. It is highly likely the boating patterns in the Marquesas and Dry Tortugas are highly affected by wind; however, the small number of surveys and opportunistic timing of the flights prevented any inference of the effect of wind on boating in these regions. All wind data was collected from the National Weather Service National Data Buoy Center's quality-controlled archive of marine observations at two weather stations representing the Lower Keys (Key West) and the Dry Tortugas (Pulaski Shoals Light). Key West Weather Station is located at 24°33'21" N 81°48'28". Pulaski Shoals Light Weather Station is located at 24°41'36" N 82°46'23" W and is within the boundaries of the Dry Tortugas National Park. The daily average wind speed was calculated at the two weather stations by taking the average of all wind speed measurements observed between 9 AM and 5 PM Eastern Standard Time. The wind speed assigned to each flight sample was calculated as the average of the daily average wind speeds between the two weather stations.

Types of boats in the Marquesas and Dry Tortugas regions of the Sanctuary:

A total of 575 boats were observed within the Marquesas Region during the 6 flights, with an average of 95.8 ± 40.0 (mean \pm standard deviation) boats per day. Of those 575 boats, more than half of them were in the Lakes region (55.5%, 319 boats). The majority of boats (65.6%) were motorboats (62.8 ± 34.6 motorboats per day). Sailboats represented 16.0% of the boats (15.3 ± 9.6 sailboats per day) observed, whereas commercial fishing vessels represented 11.0% of the boats observed (10.5 ± 8.3 vessels). Personal watercraft (PWC) were seen exclusively in the Lakes region, and comprised of 6.1% of the vessels observed (5.8 ± 7.0 PWCs). Other boat types such as military/law enforcement, paddlecraft (e.g. kayaks, paddleboards, canoes), cargo ships, and cruise ships were observed in frequencies of 0-4 vessels. The majority of boats were less than 30 feet in length (55.8% of boats).

A total of 108 boats were observed within the Dry Tortugas region during those flights, with an average of 18.0 ± 2.9 boats per day. The majority of those boats (38.9%) were motorboats ($n=7.0 \pm 4.3$ boats), although commercial fishing vessels (34.5%) and sailboats (25.3%) made up large proportions of the boats in the region; an average of 6.3 ± 3.6 commercial fishing vessels and 4.5 ± 4.1 sailboats were observed in the Tortugas region during the flights. A single kayak was observed in the Dry Tortugas National Park during our September 30, 2016 flight. The majority of boats in the Tortugas region were over 30 feet in length (85.0%), which is a shift from the trend in the Lower, Middle, and Upper Keys, and Biscayne regions, where the majority of boats (72.5-80.7%) are less than 30 feet in length. One commercial fishing vessel was observed inside the TSER, but this is not necessarily an indication of illegal activity.

Boater Activity by Region

Boater activity patterns also varied in the two regions (Figure 2). Boats that were running (38.6%) or anchored (18.4%) were the most commonly observed in the Marquesas. Hook-and-line fishing represented 21.9% of boating activity in the Marquesas, which was an average of 21.0 ± 15.9 fishing boats per day. Of the boats that were hook-and-line fishing, 43.6% were observed within the Lakes area. An average of 6.3 ± 5.7 commercial fishing boats were observed (6.6%) and only 7.9% of commercial fishing boats were within the Lakes area. Other activities like diving/snorkeling (1.9%), sandbar/party (1.4%), adventure sports (4.3%), commercial fishing (6.6%), riding PWCs (6.1%), and paddling (0.7%) were observed in frequencies below an average of 6 boats per day. Every PWC,

paddlecraft, adventure sports boat, and boat at a sandbar that were observed during the 6 surveys were within the Lakes area.

Anchored (35.2%) and running boats (27.8%) were again the most commonly observed boats in the Tortugas region (Figure 2). Commercial fishing represented 24.1% of the boating activity noted in the Tortugas region. It is important to note that because so few boats were observed in the Tortugas region that this represents 4.5 ± 3.3 commercial fishing vessels. Hook-and-line fishing vessels made up 9.3% of the boats (1.7 ± 2.1 boats).

Of the boats that were observed in the Tortugas region, 36.1% of boats were inside DRTO, which was a daily average of 6.5 ± 4.2 boats. The majority of boats seen inside of the DRTO (89.7%) were anchored. The remaining boats that were observed were running (3 boats), diving (1 boat), or paddling (1 kayak). Every vessel (including kayaks and dinghies) that visits the DTRO must obtain a permit that identifies park users and their intended activities throughout their visit to the National Park. In the latter half of 2016 (May-December 2016), DRTO issued an average of 2.8 ± 2.0 permits per day, with as many as 9 permits being issued in a day (person communication DRTO staff).

Only 4 boats were observed inside the TNER during the 6 flights, and 1 boat was observed inside the TSER.

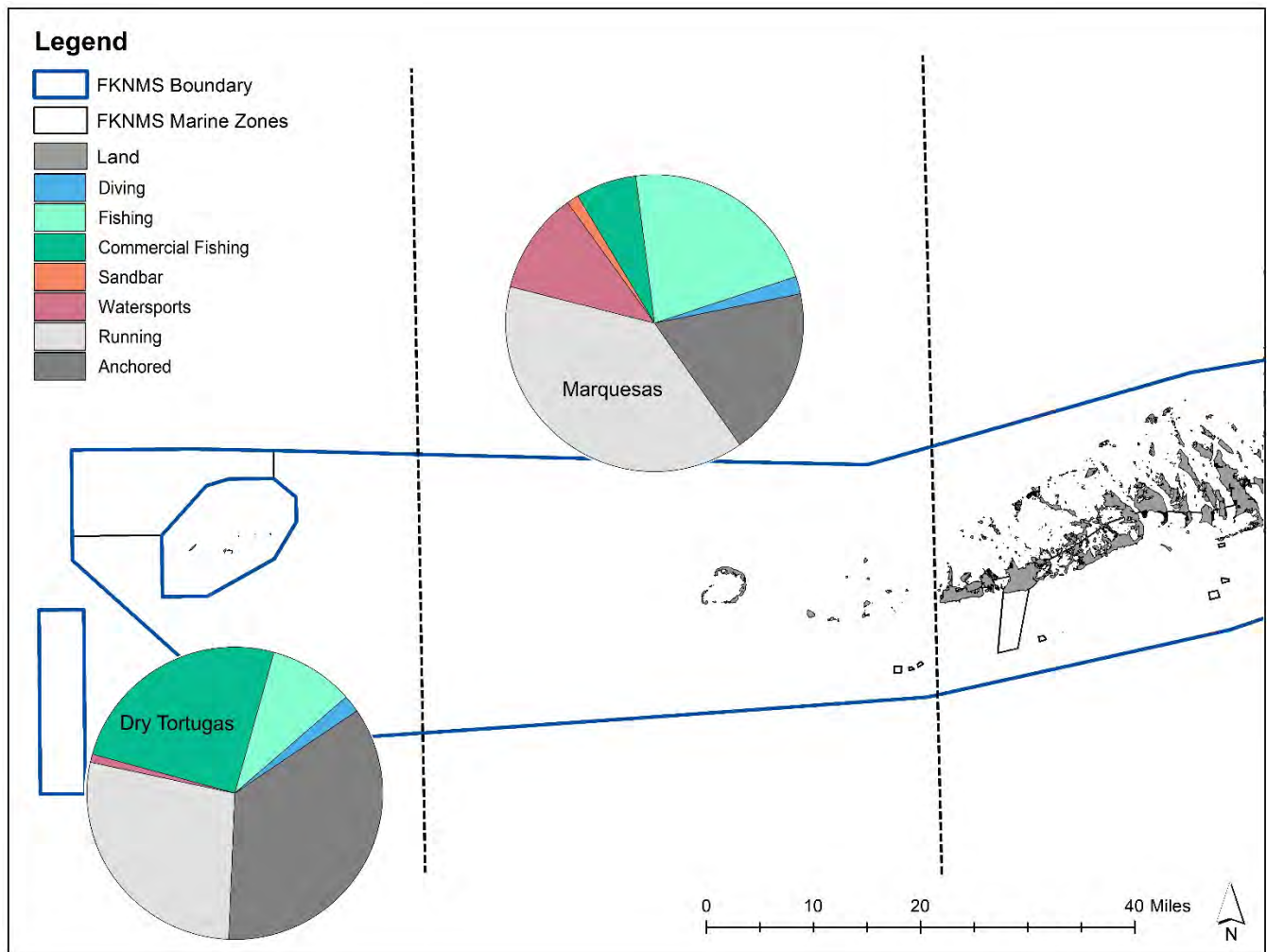


Figure 74 Activity (percentages of boats observed in Marquesas and Dry Tortugas regions of the Sanctuary (n=6 flights, total = 683 boats)

Region Use by Boaters:

During the 6 flights over the Marquesas and Dry Tortugas regions, only 0.5% of the grids contained boats in over 50% of the surveys, and the more frequently occupied grids are all within a 10-square nautical mile radius of Key West or the Garden Key anchorage in DRTO (Figure 3). There are no other areas in the Marquesas and Dry Tortugas regions of the Sanctuary where a boat was observed within a grid during more than half of the surveys.

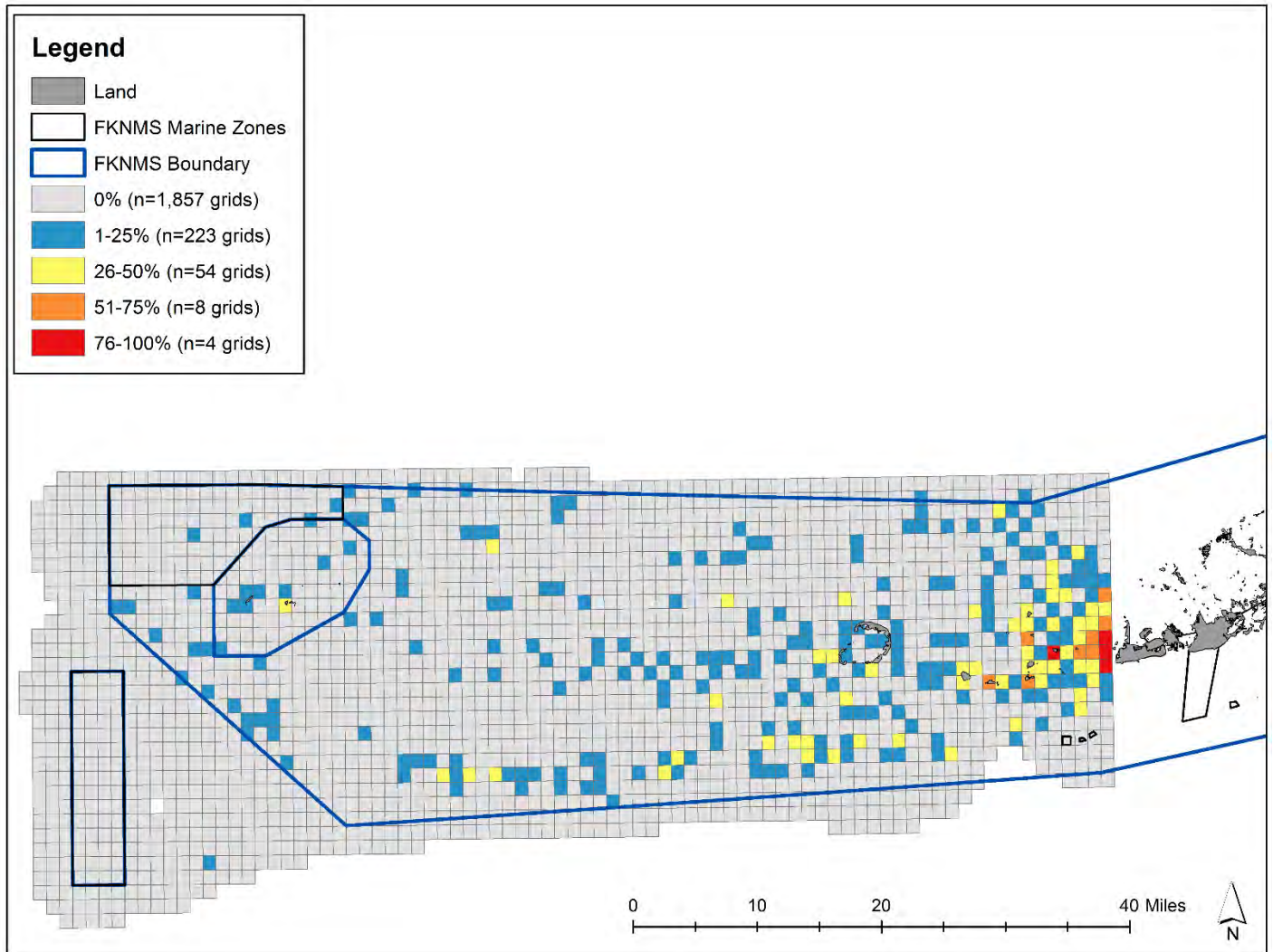


Figure 75 Map depicting the percent of time grids were occupied by boats in the Marquesas and Dry Tortugas regions. (n= 6 flights, total boat count = 682, total grids = 2,119) Each grid represents 1 square minute, which is approximately 1 square nautical mile.

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All boats

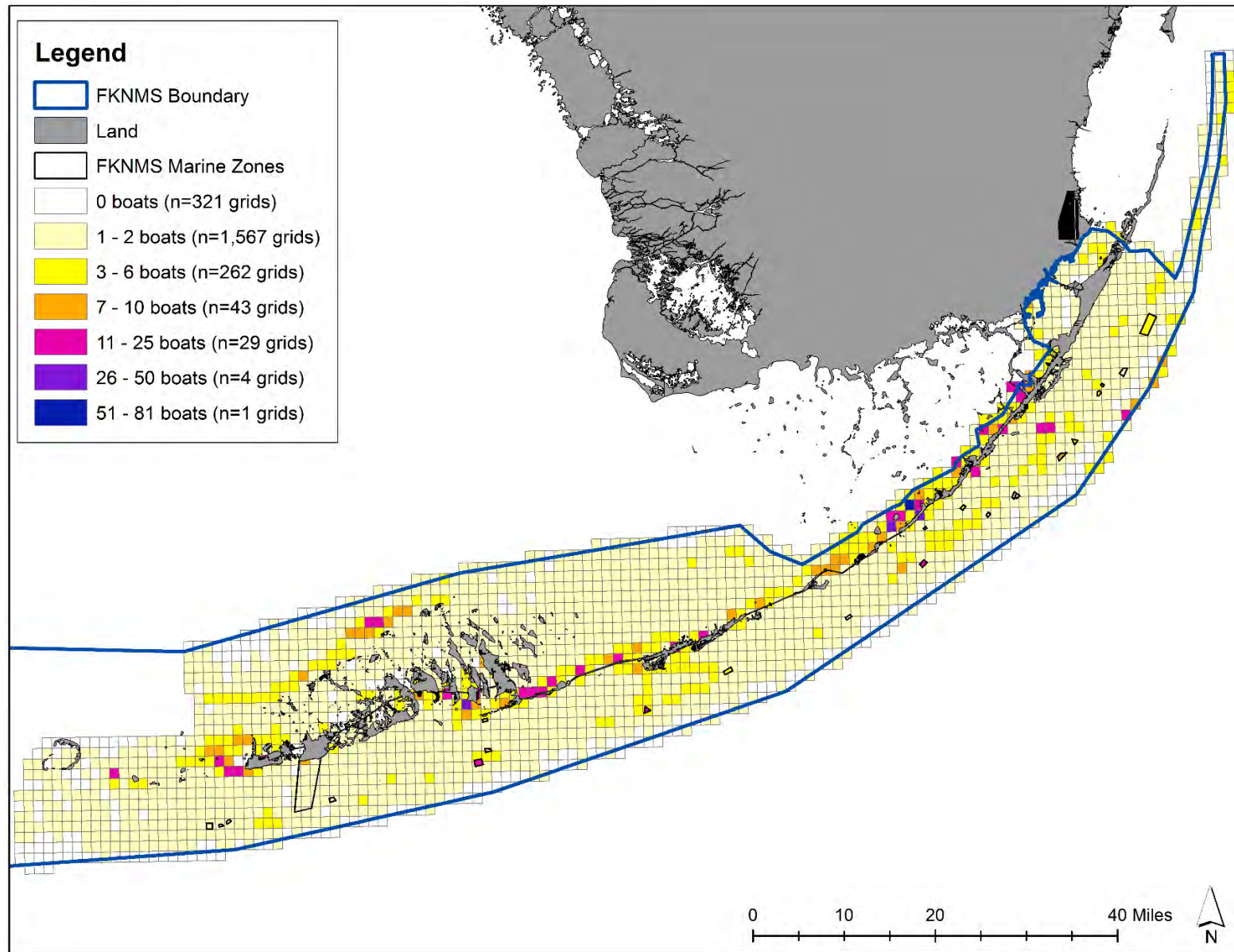


Figure 1 The average number of boats per grid during all 2016-2017 surveys. (n = 29 flights, total boat count = 52,107, total grids = 2,227). FKNMS are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

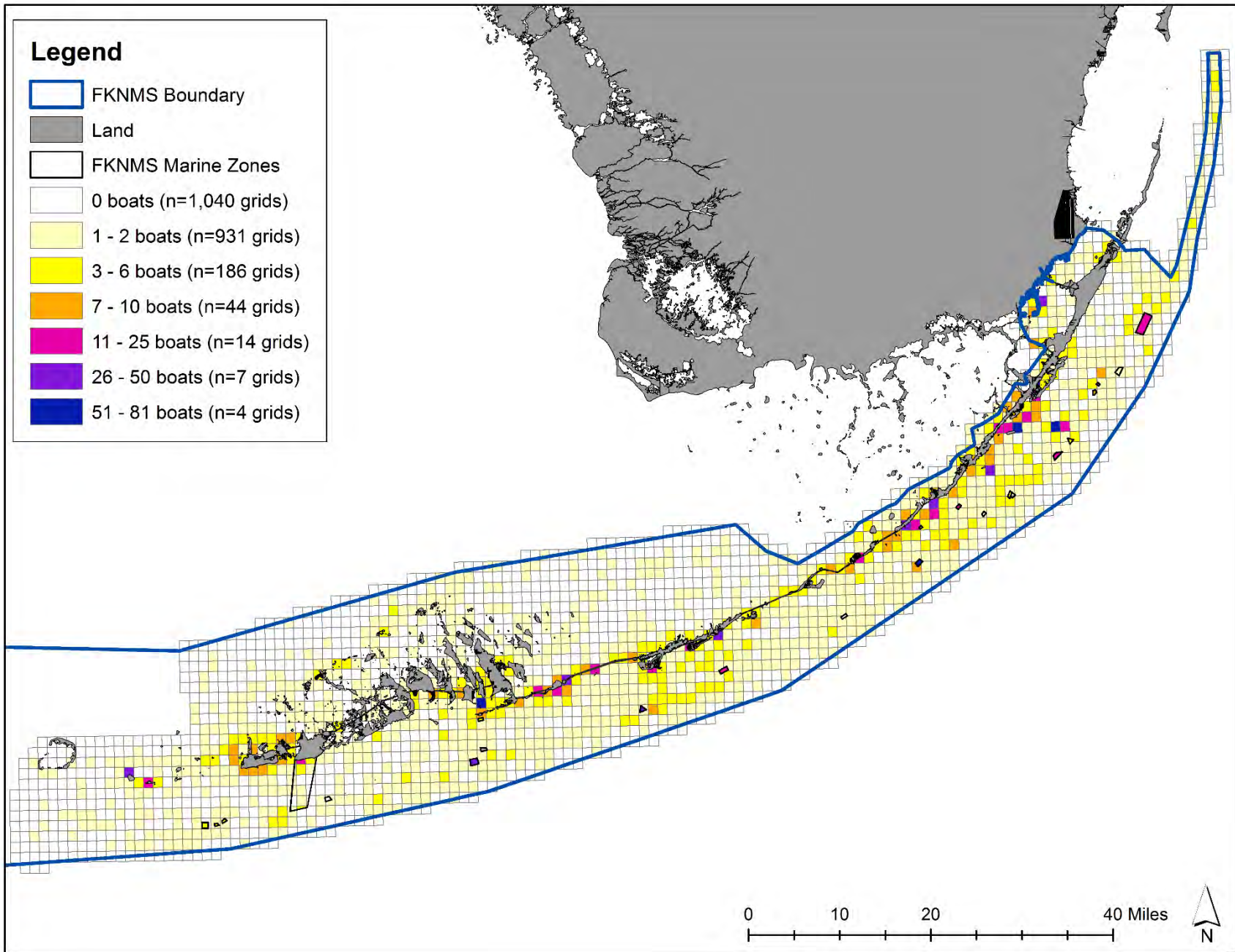


Figure 2 The average number of boats per grid during Holidays (Memorial Day Weekend [May 29, 2016], Independence Day Weekend [July 2, 2016], and Labor Day Weekend [September 3, 2016]). (n = 3 flights, total boat count = 7,759, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

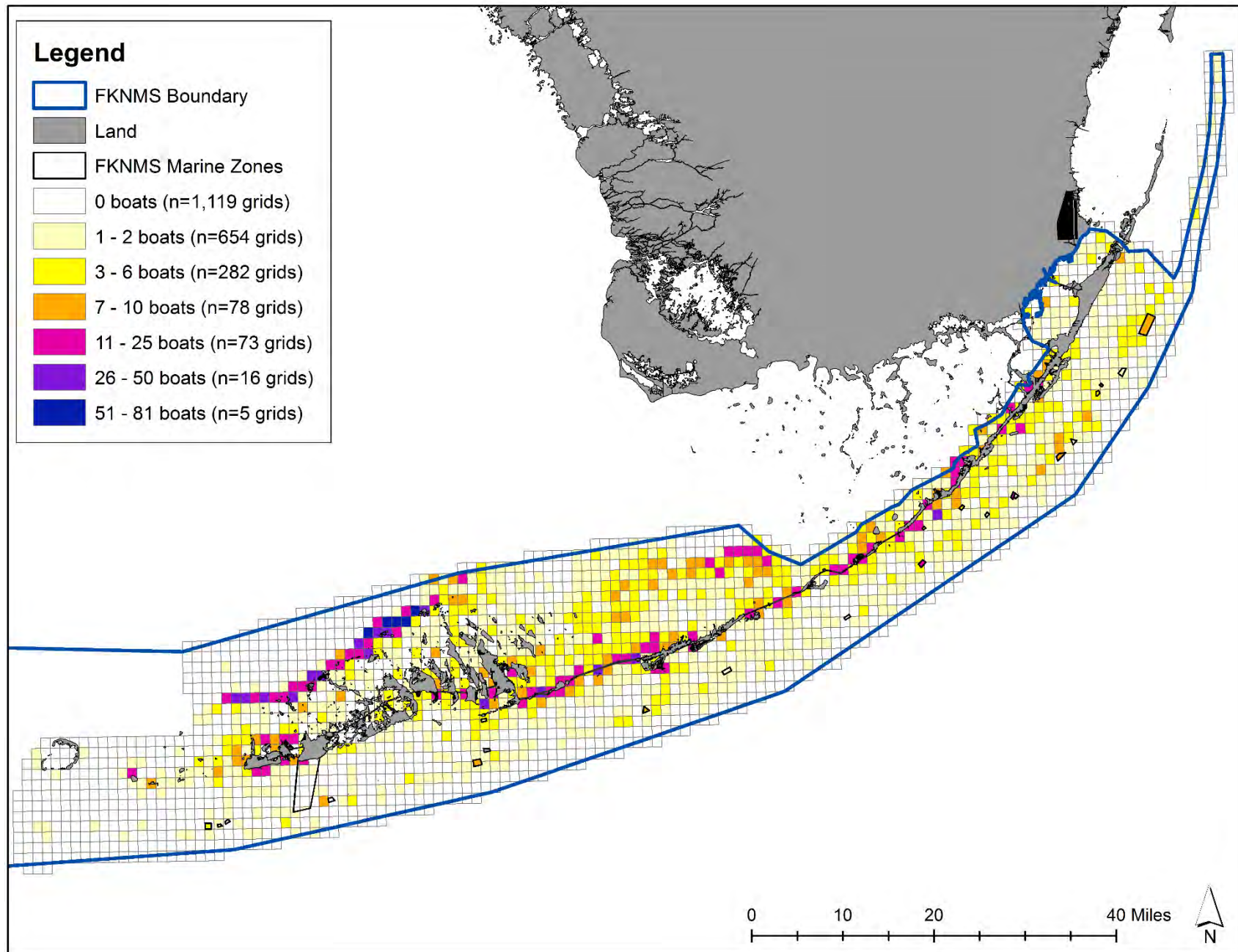


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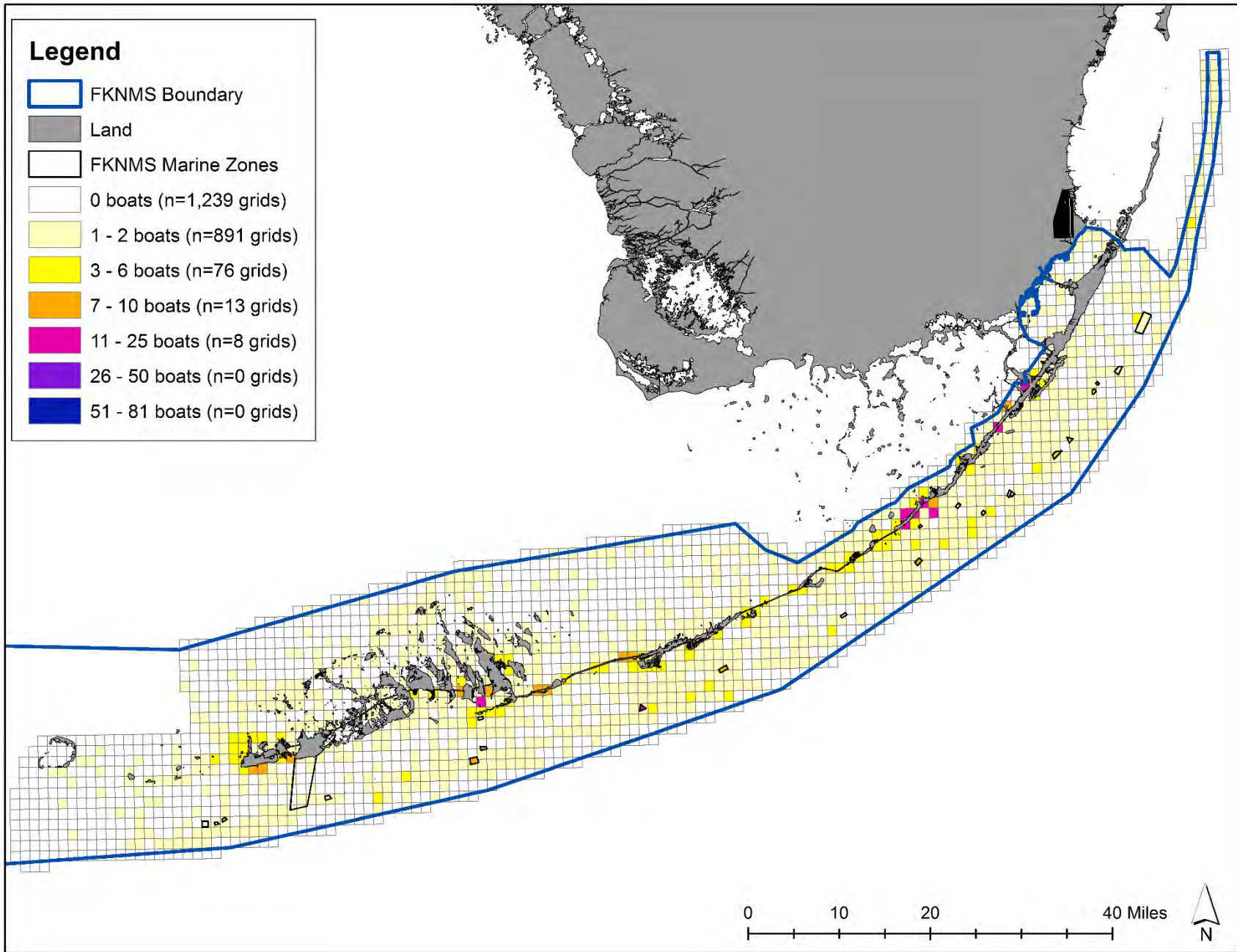


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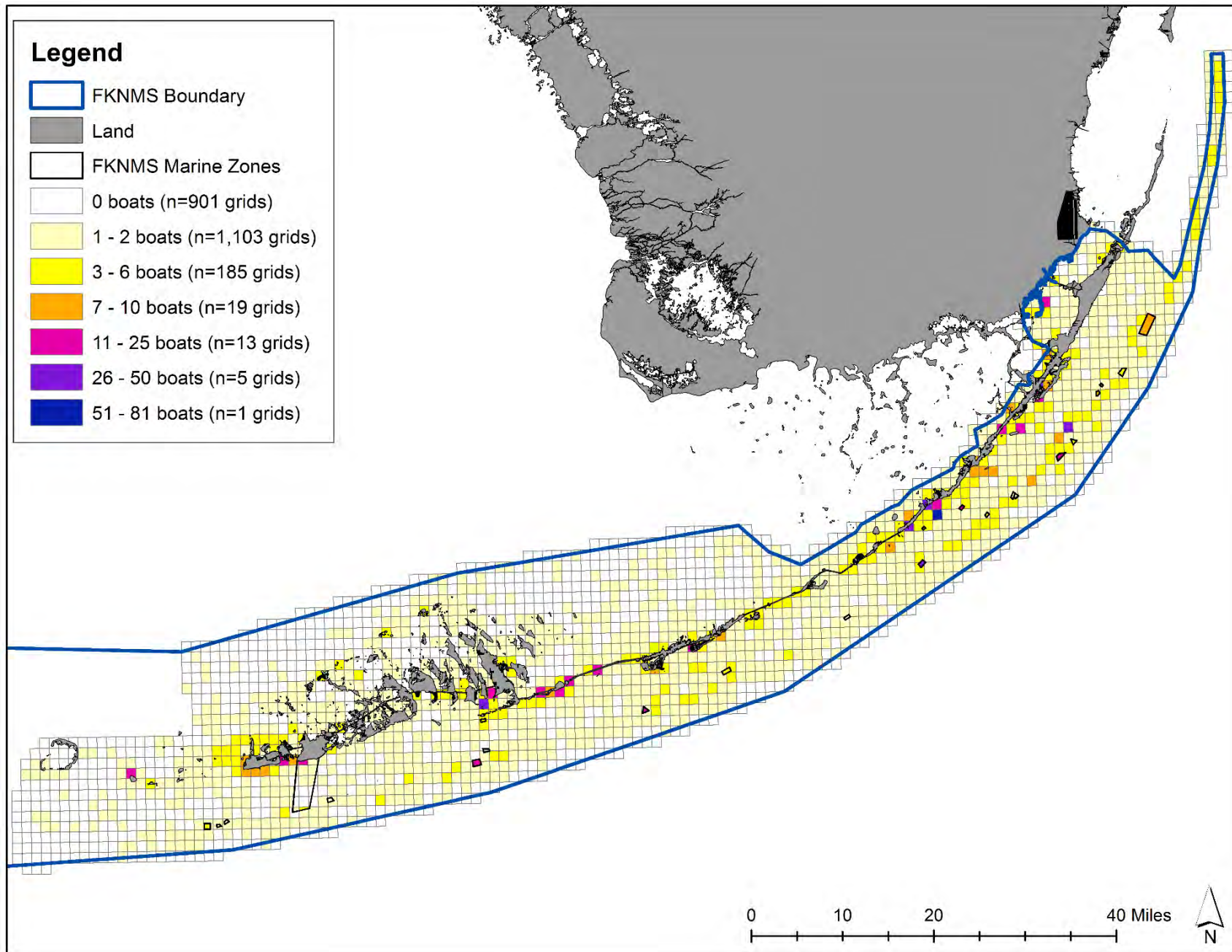


Figure 5 The average number of boats per grid during summer weekends. (n = 5 flights, total boat count = 9,561, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

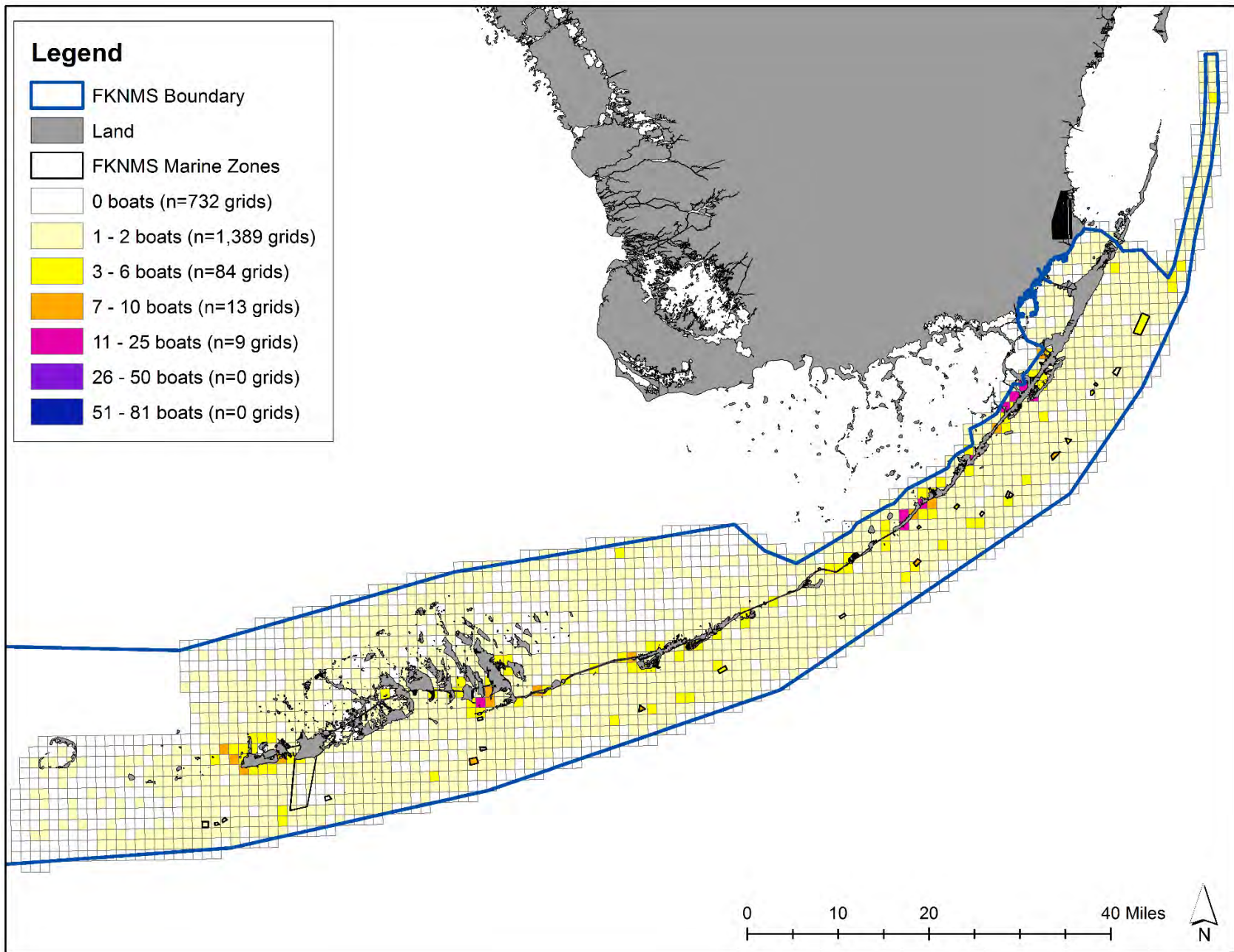


Figure 6 The average number of boats per grid during winter weekdays. (n = 7 flights, total boat count 8,684, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

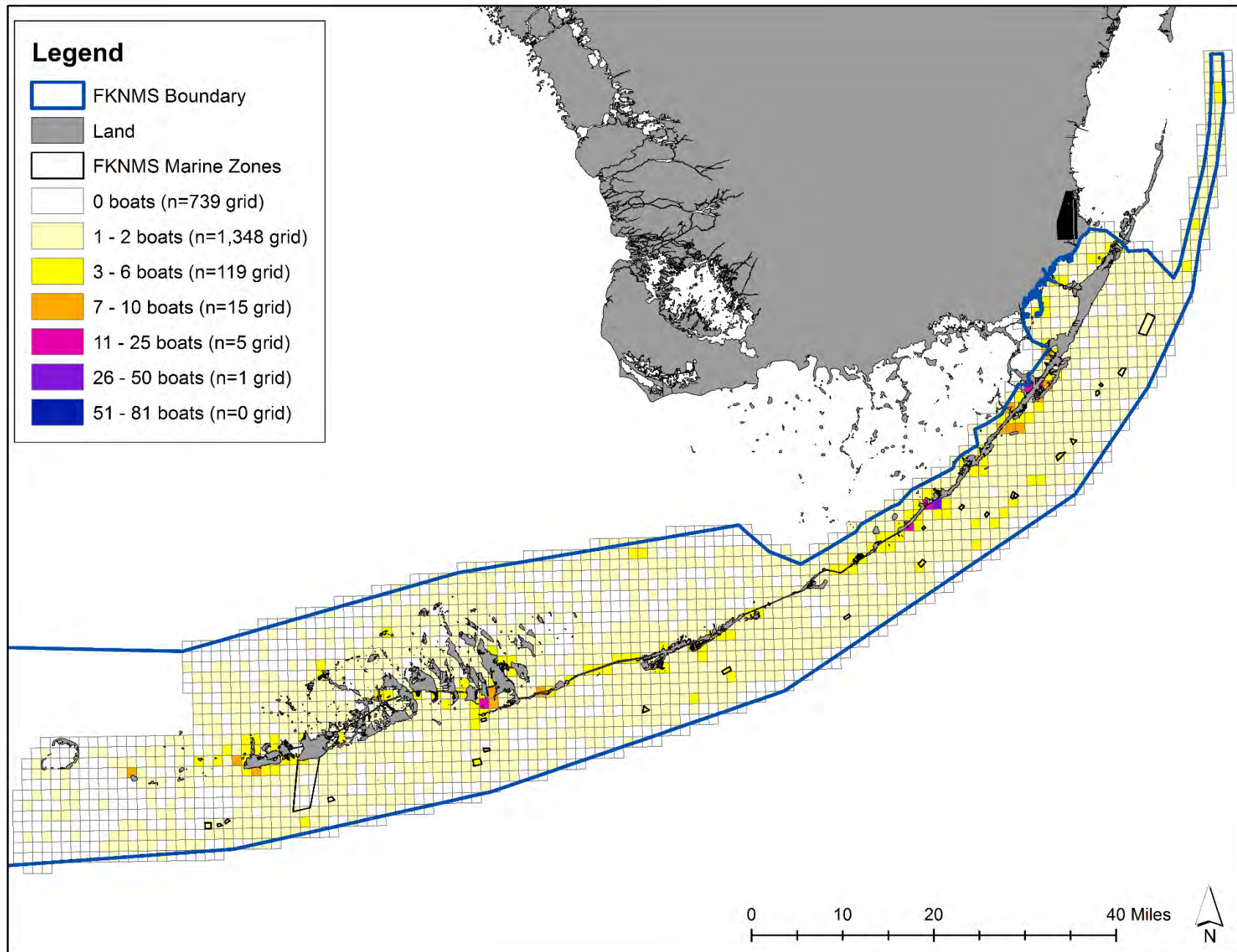


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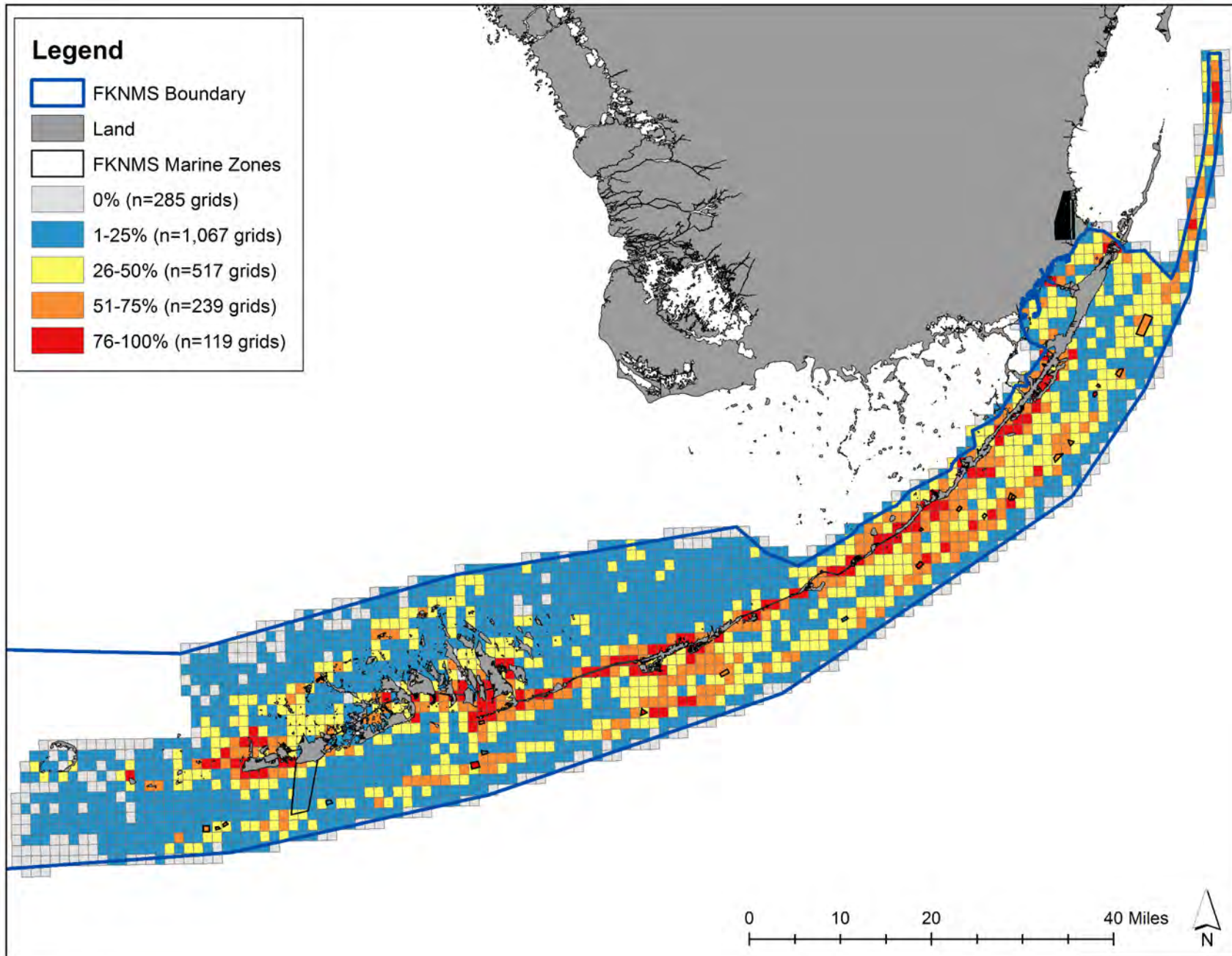


Figure 8 Map depicting the percent of time grids were occupied by boats during all 2016-2017 surveys. (n = 29 flights, total boat count = 52,107, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

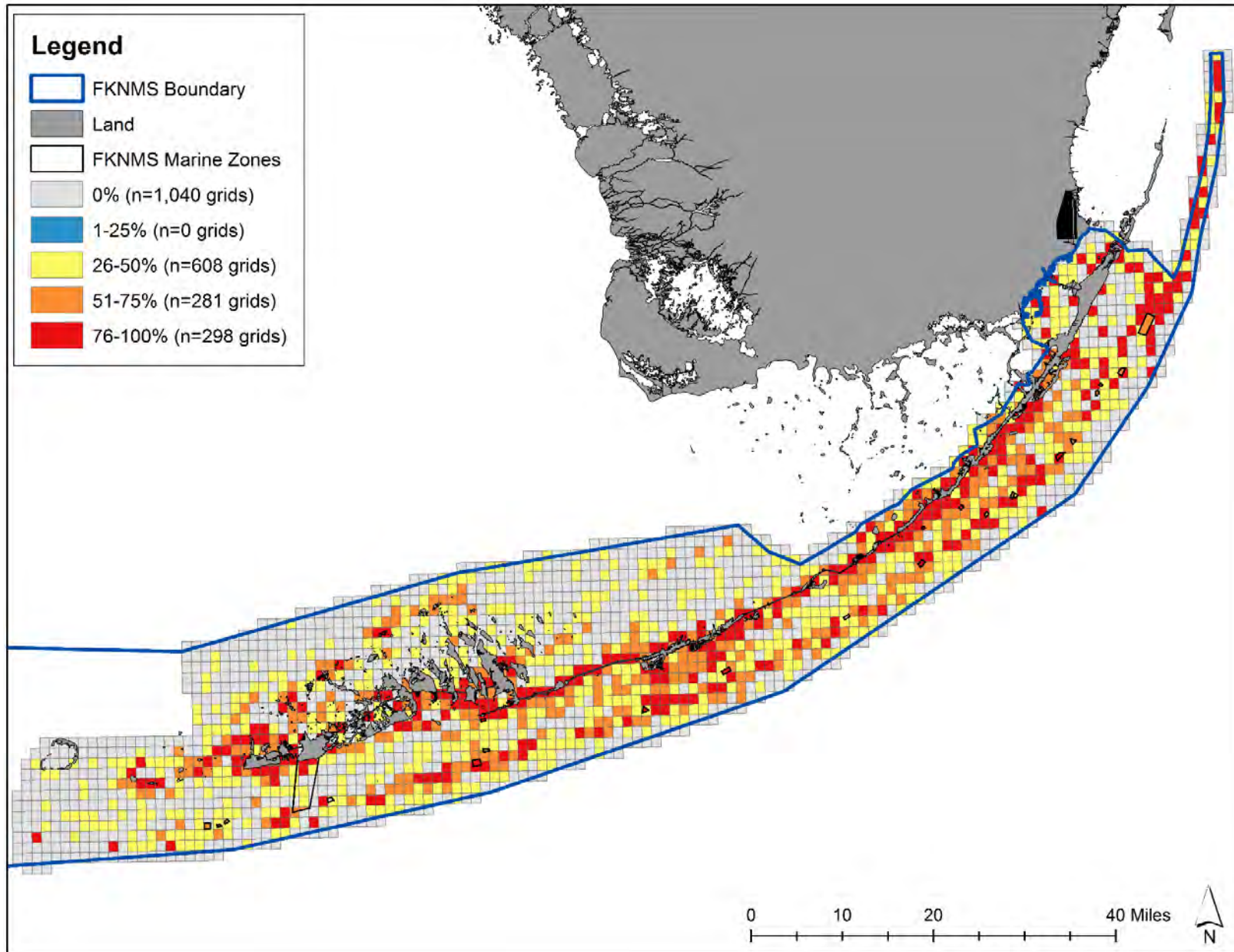


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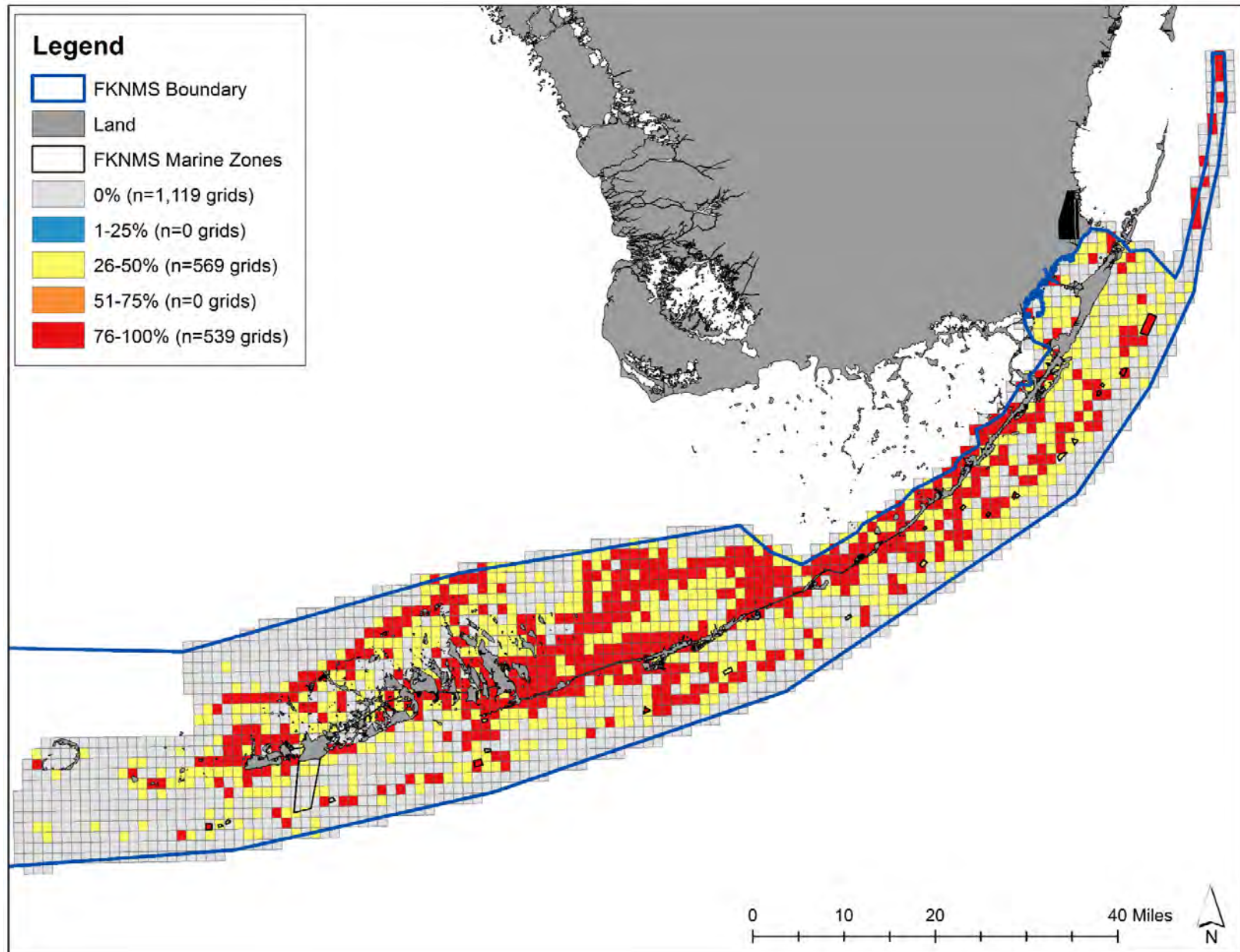


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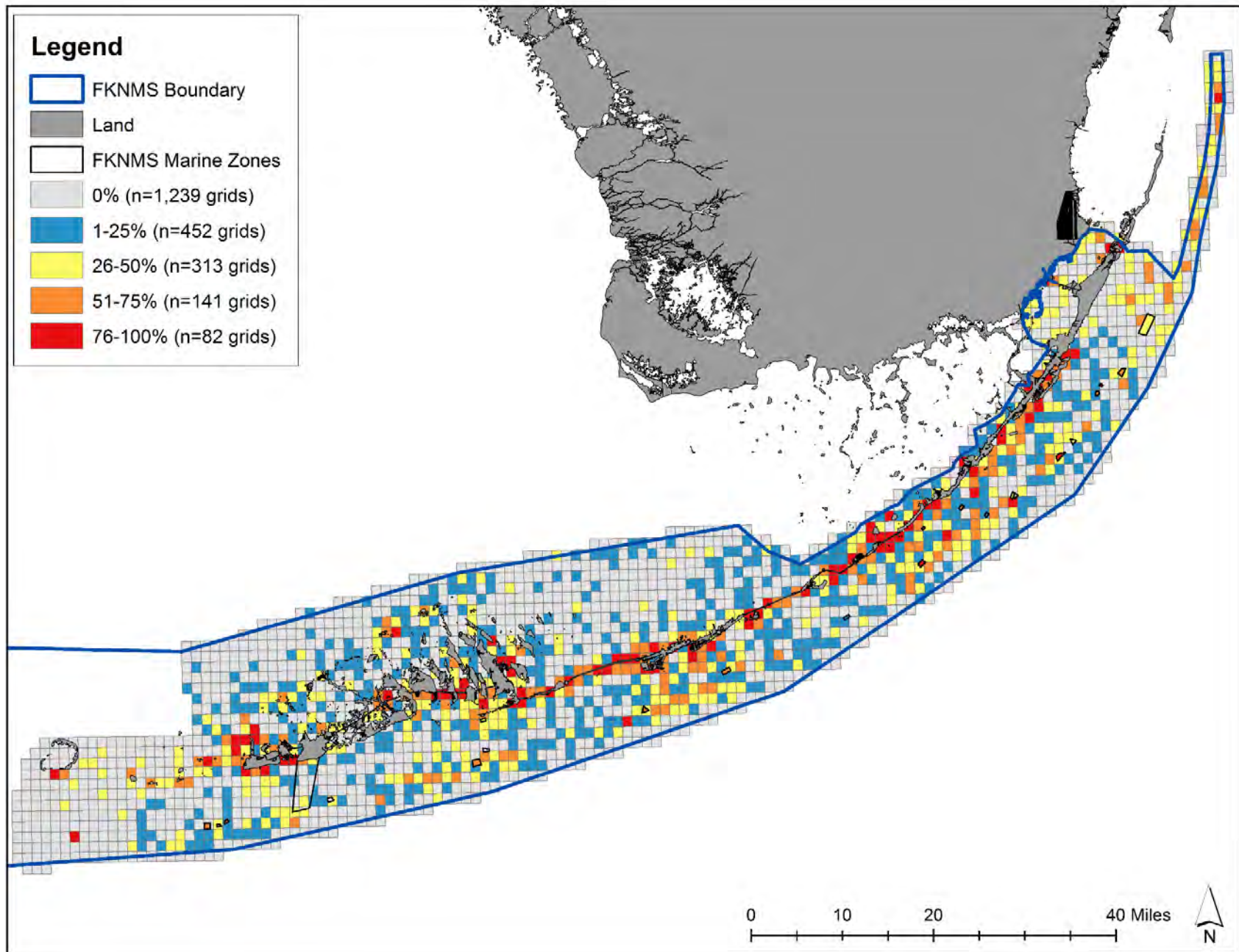


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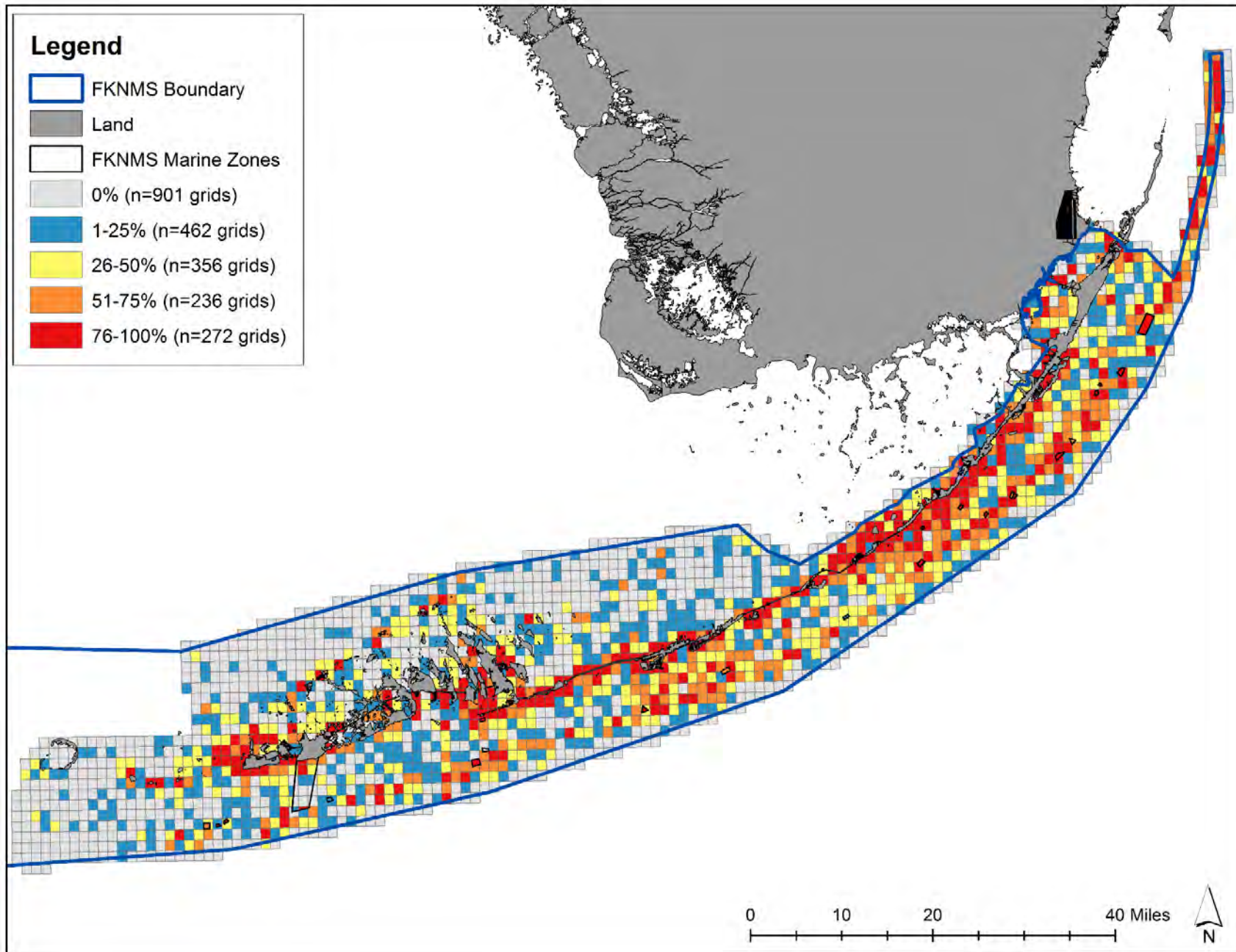


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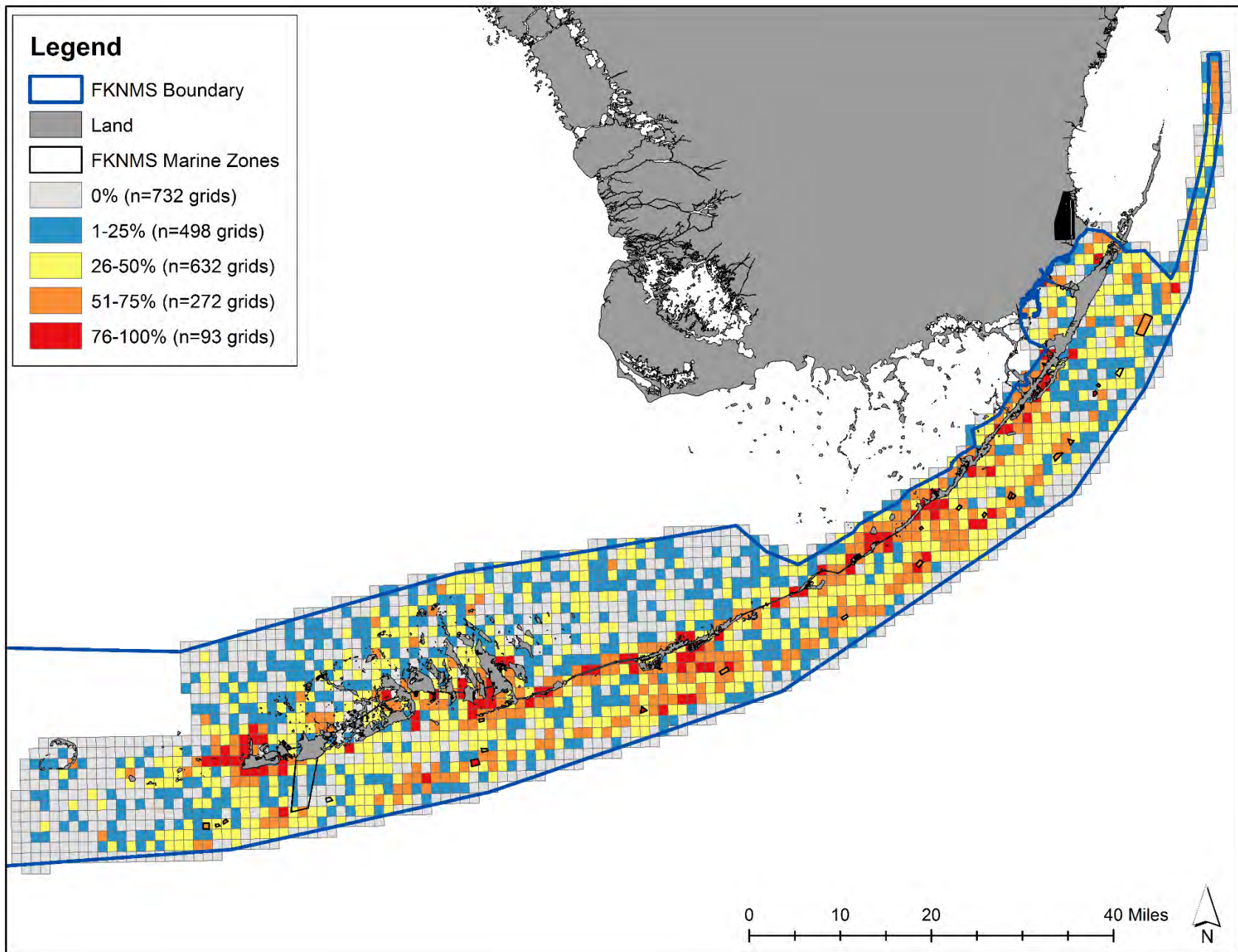


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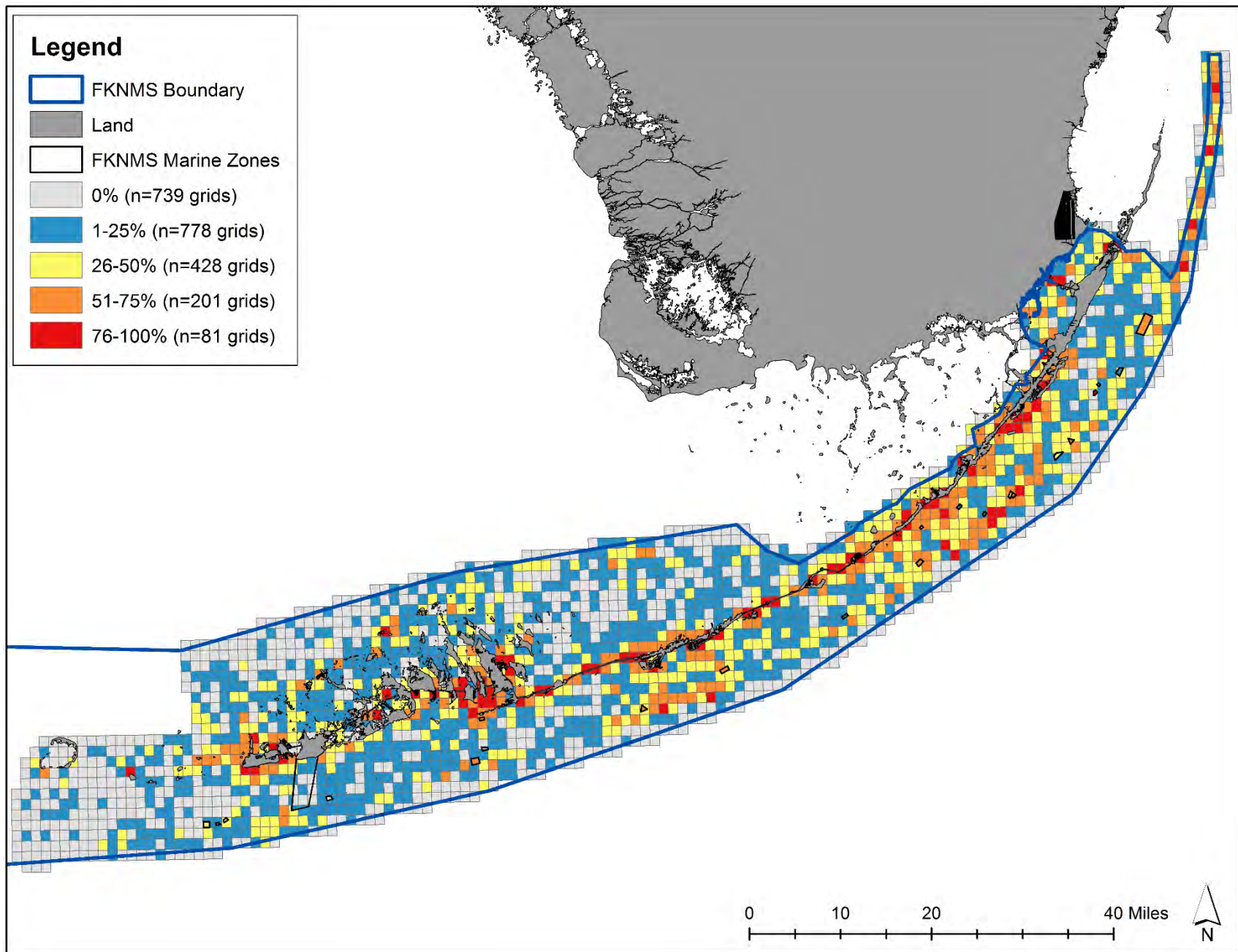


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Anchored Boats

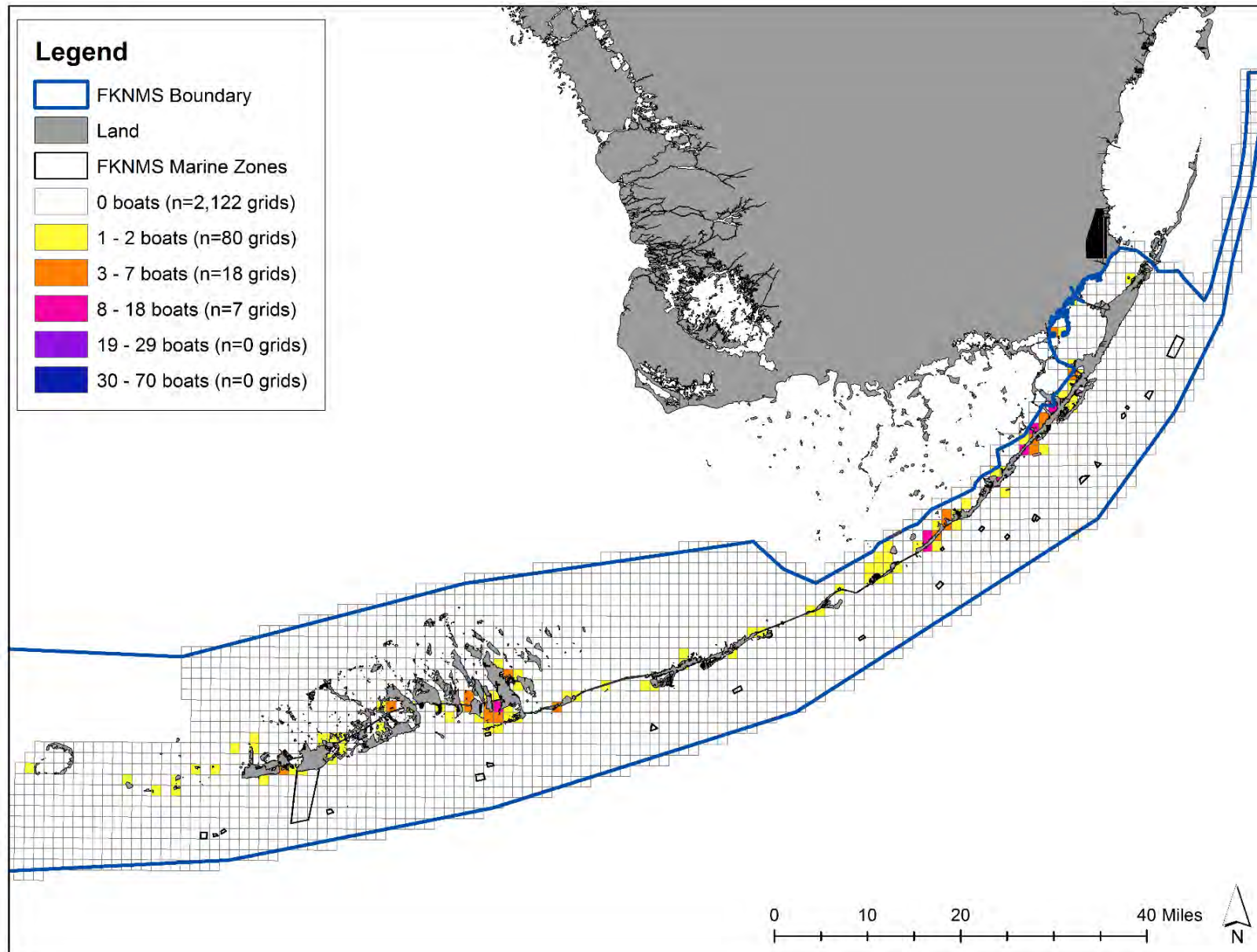


Figure 15 The average number of anchored boats observed during all 2016-2017 surveys. (n = 29 flights, total boat count = 15,348, total grids = 2,227) FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square minute, which is approximately 1 square nautical mile.

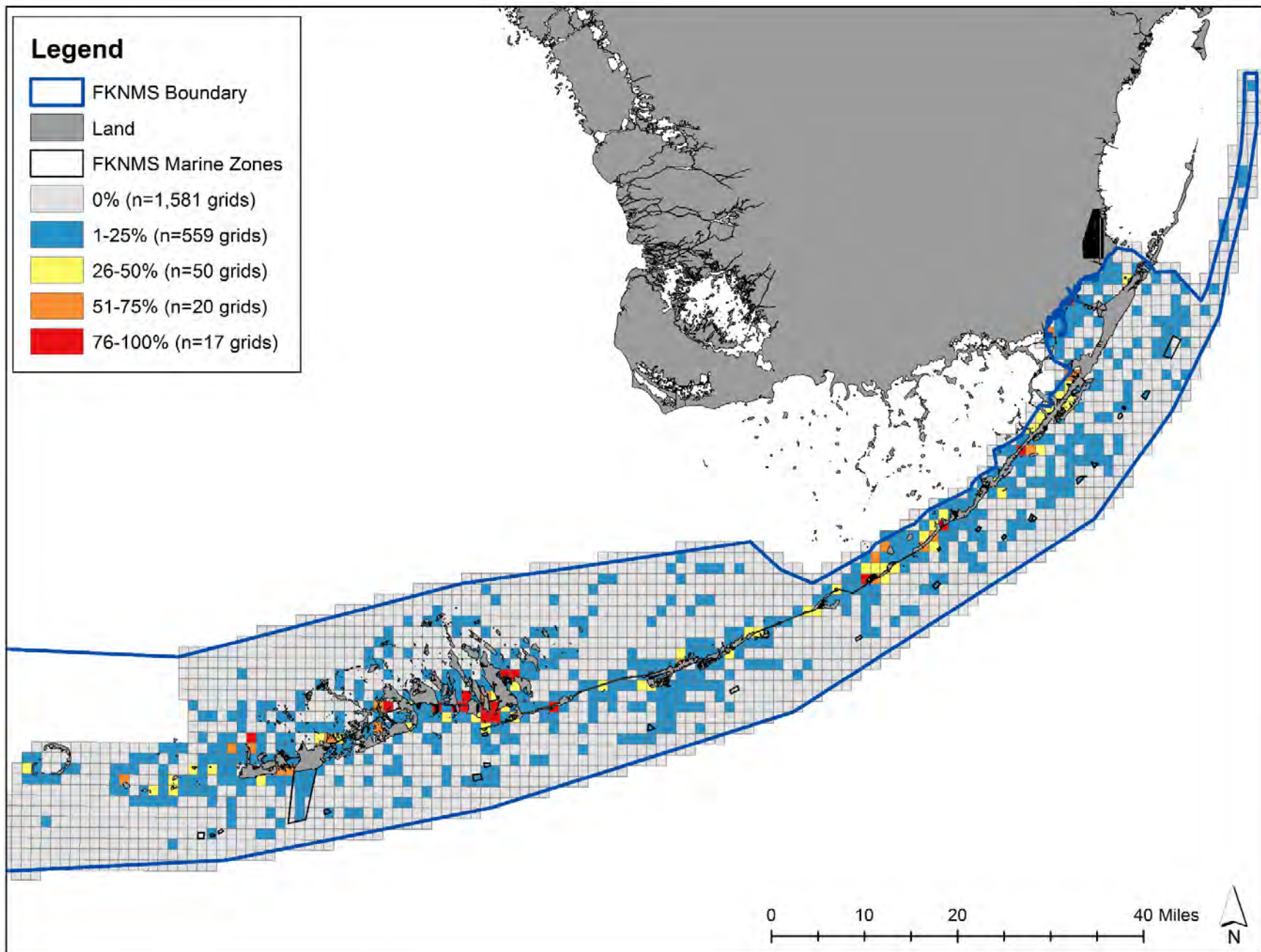


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Commercial Fishing

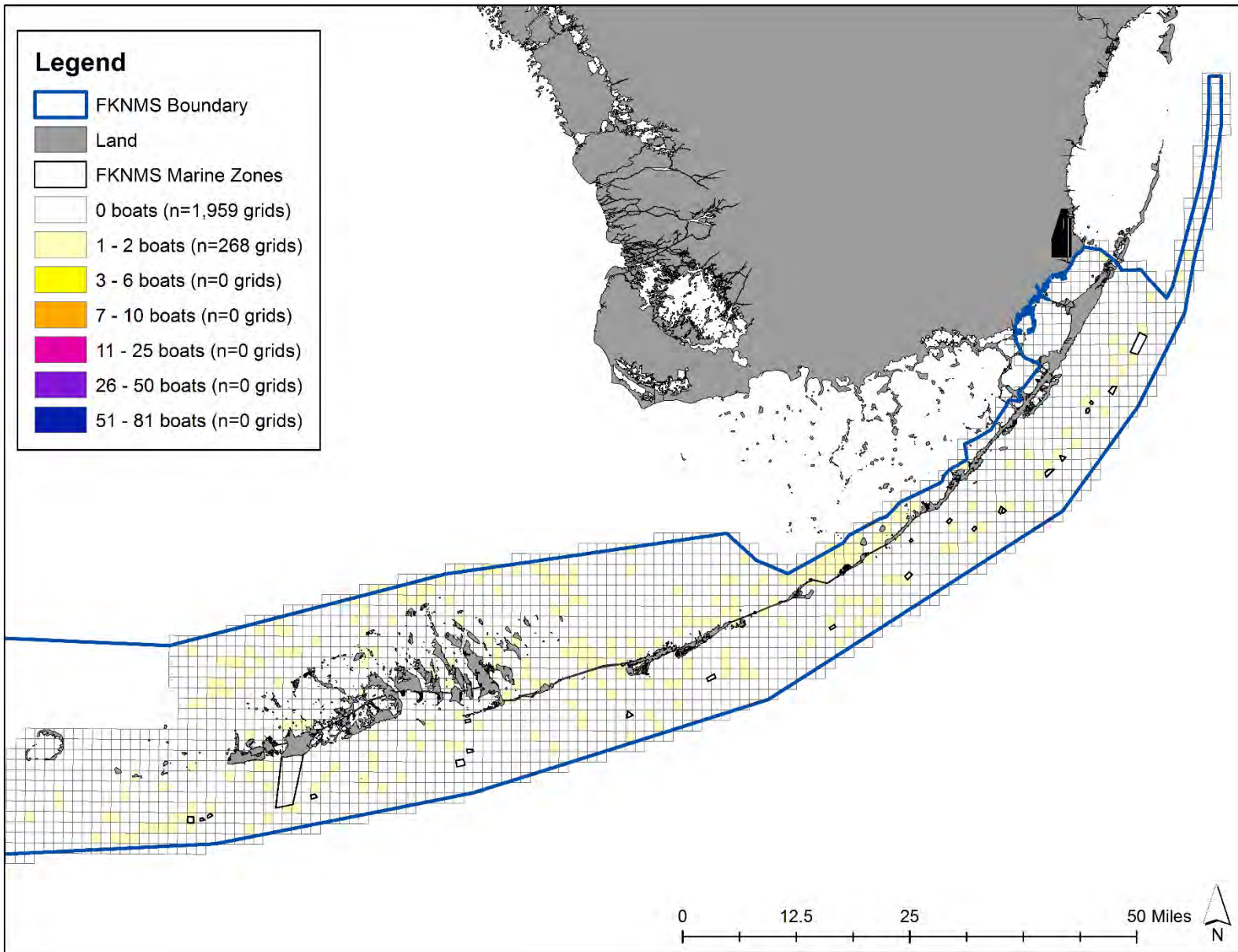


Figure 17 The average number of commercial fishing boats observed during all 2016-2017 surveys. (n = 29 flights, total boat count = 347, total grids = 2,476). FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square minute, which is approximately 1 square nautical mile.

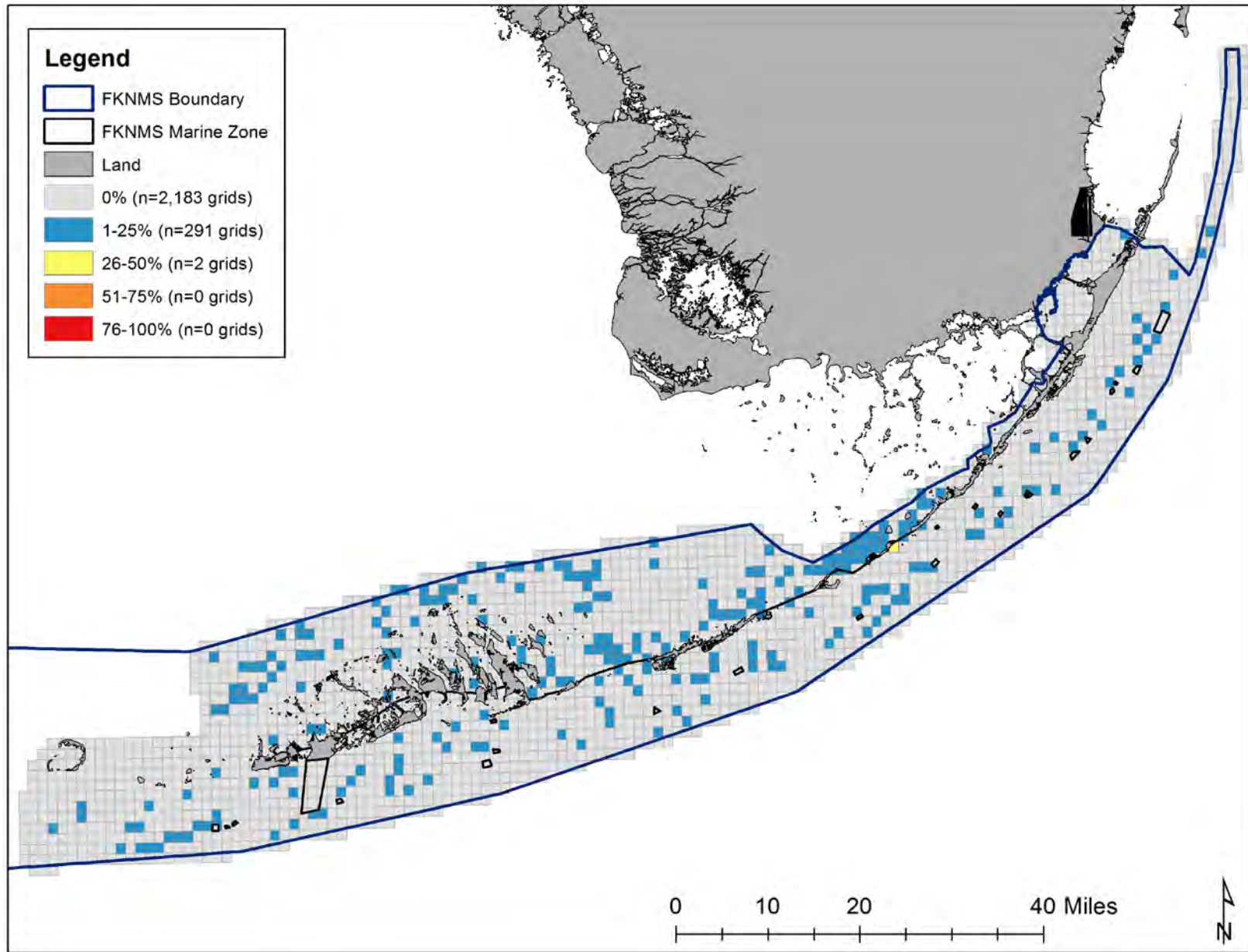


Figure 18 Map depicting the percent of time grids were occupied by commercial fishing boats during our surveys (n = 21 flights, total boat count = 347, total grids = 2,476).). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

Diving

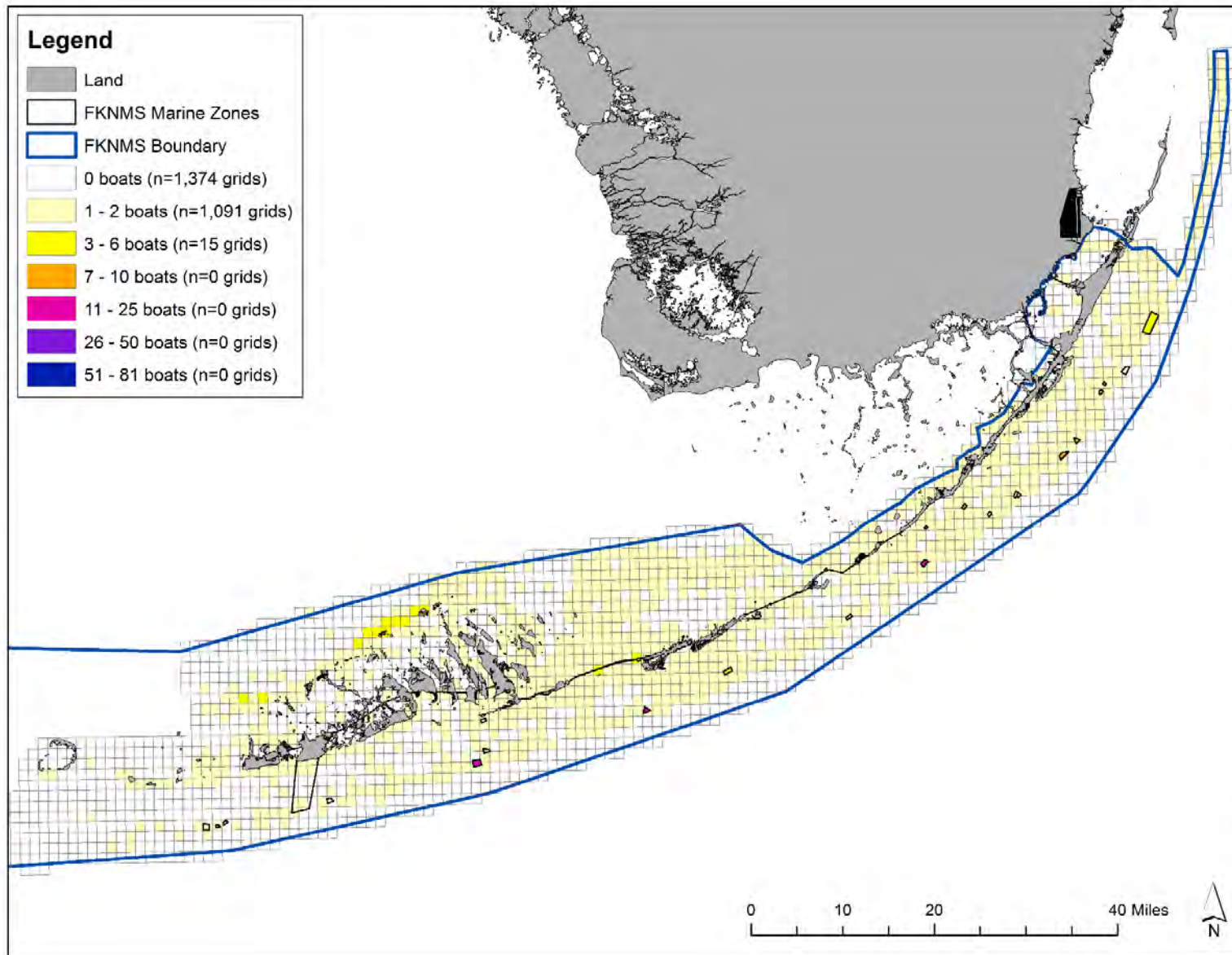


Figure 19 The average number of diving boats observed during all 2016-2017 surveys. (n = 29 flights, total boat count = 9884, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

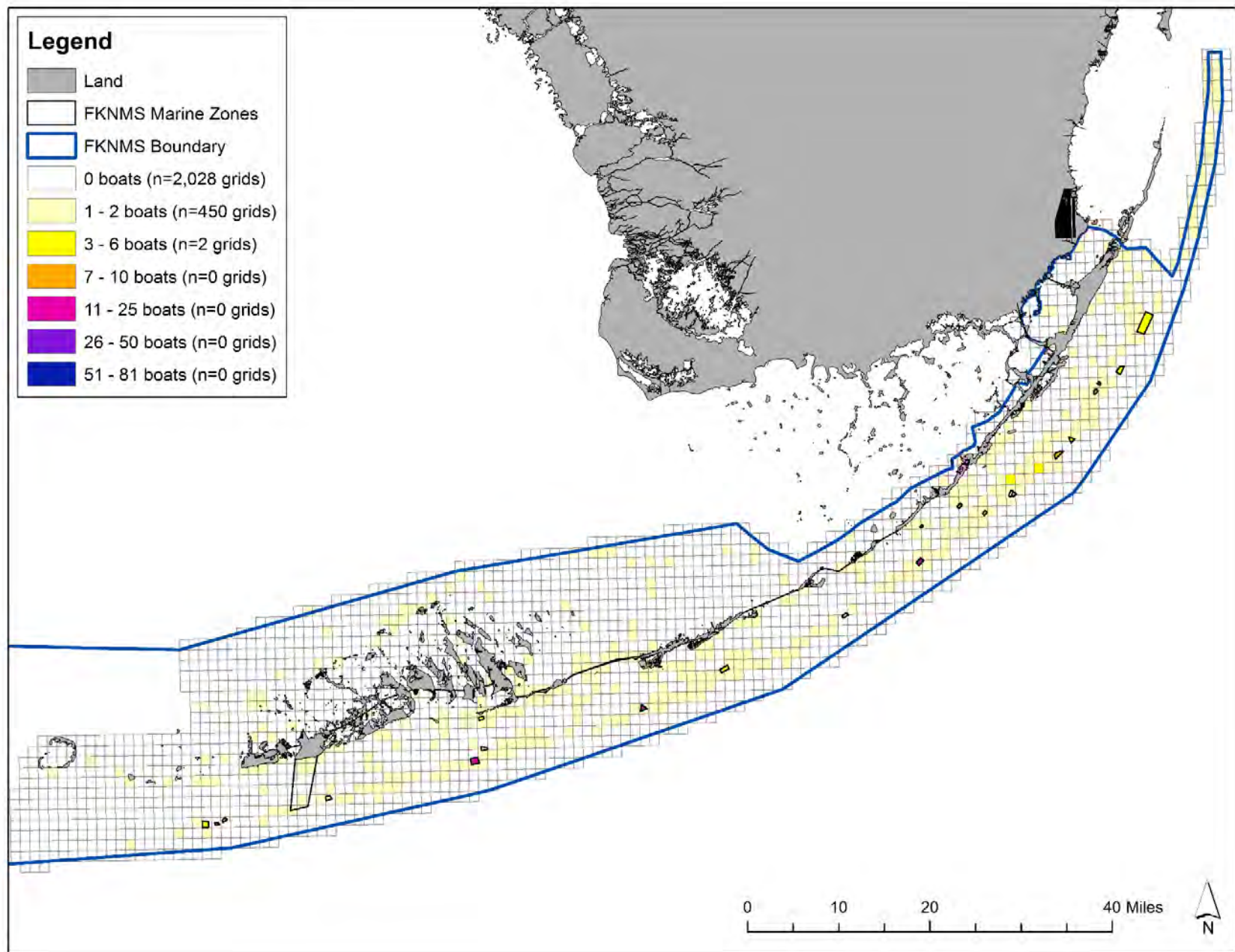


Figure 20 The average number of diving boats observed during our summer surveys. (n = 9 flights, total boat count = 2,027, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square minute, which is approximately 1 square nautical mile.

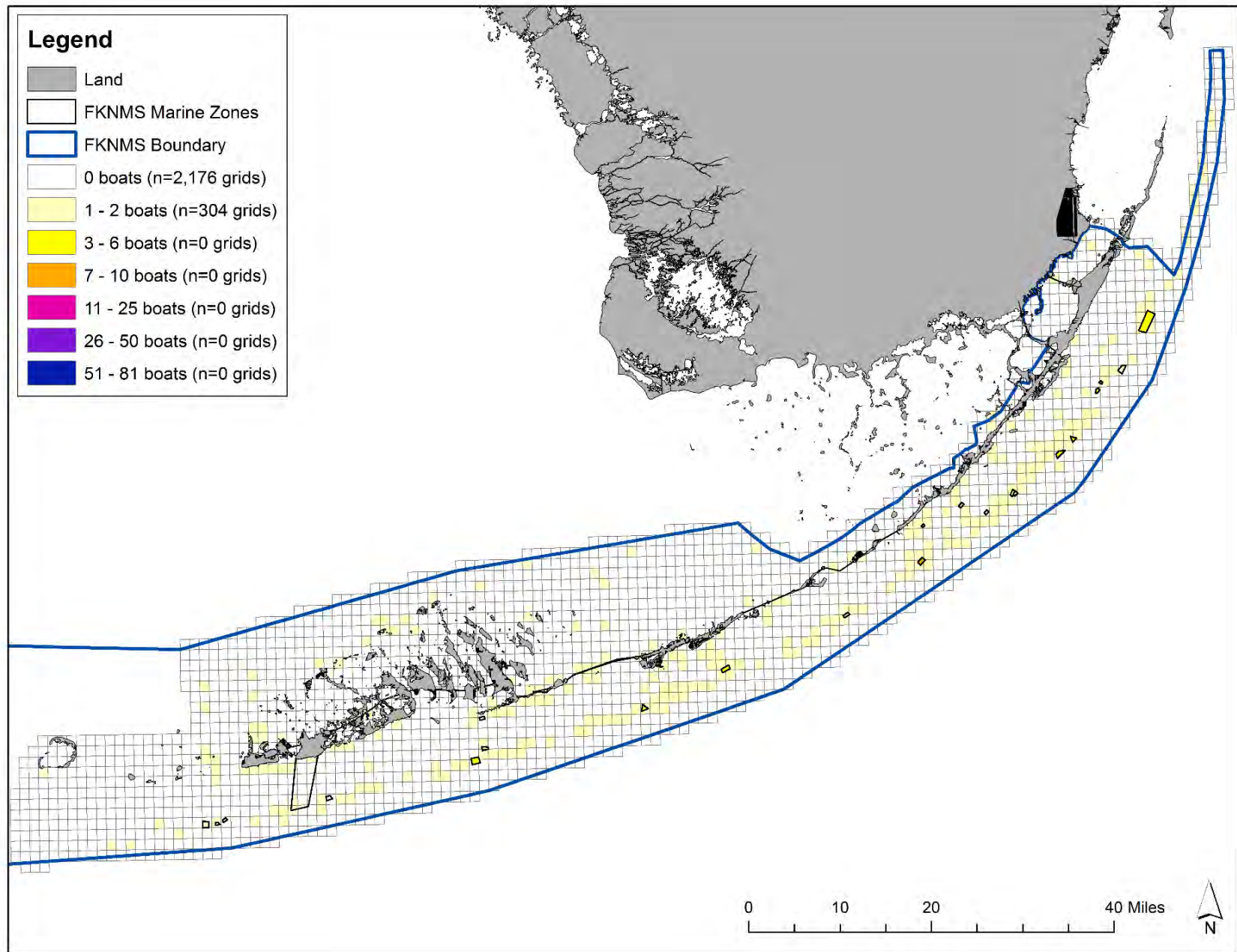


Figure 21 The average number of diving boats observed during our winter surveys. (n = 15 flights, total boat count = 1,344, total grids = 2,472). FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square minute, which is approximately 1 square nautical mile.

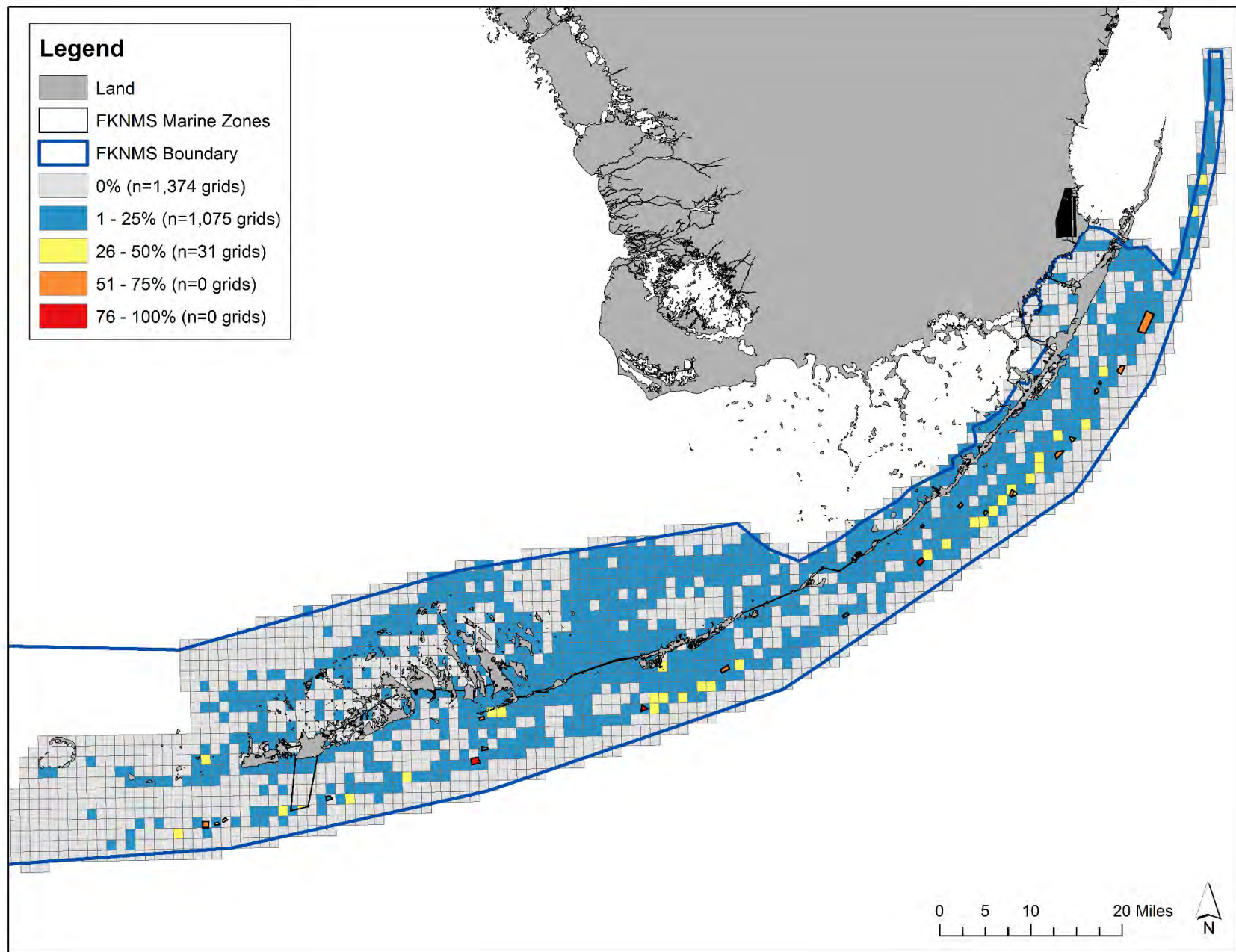


Figure 22 Map depicting the percent of time grids were occupied by dive boats. (n = 29 flights, total boat count = 9884, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

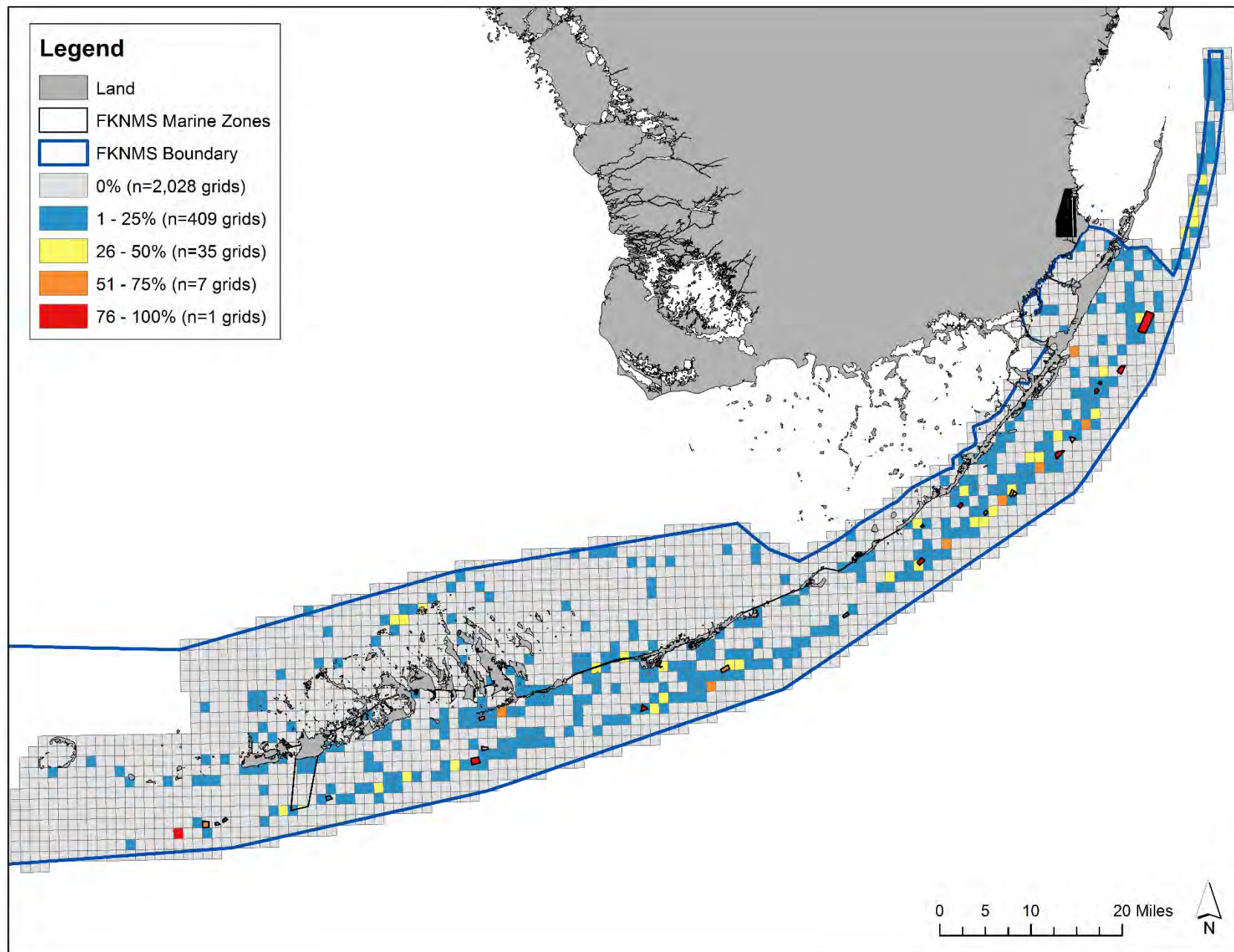


Figure 23 Map depicting the percent of time grids were occupied by dive boats during our summer surveys (n = 9 flights, total boat count = 2,027, total grids = 2,429). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

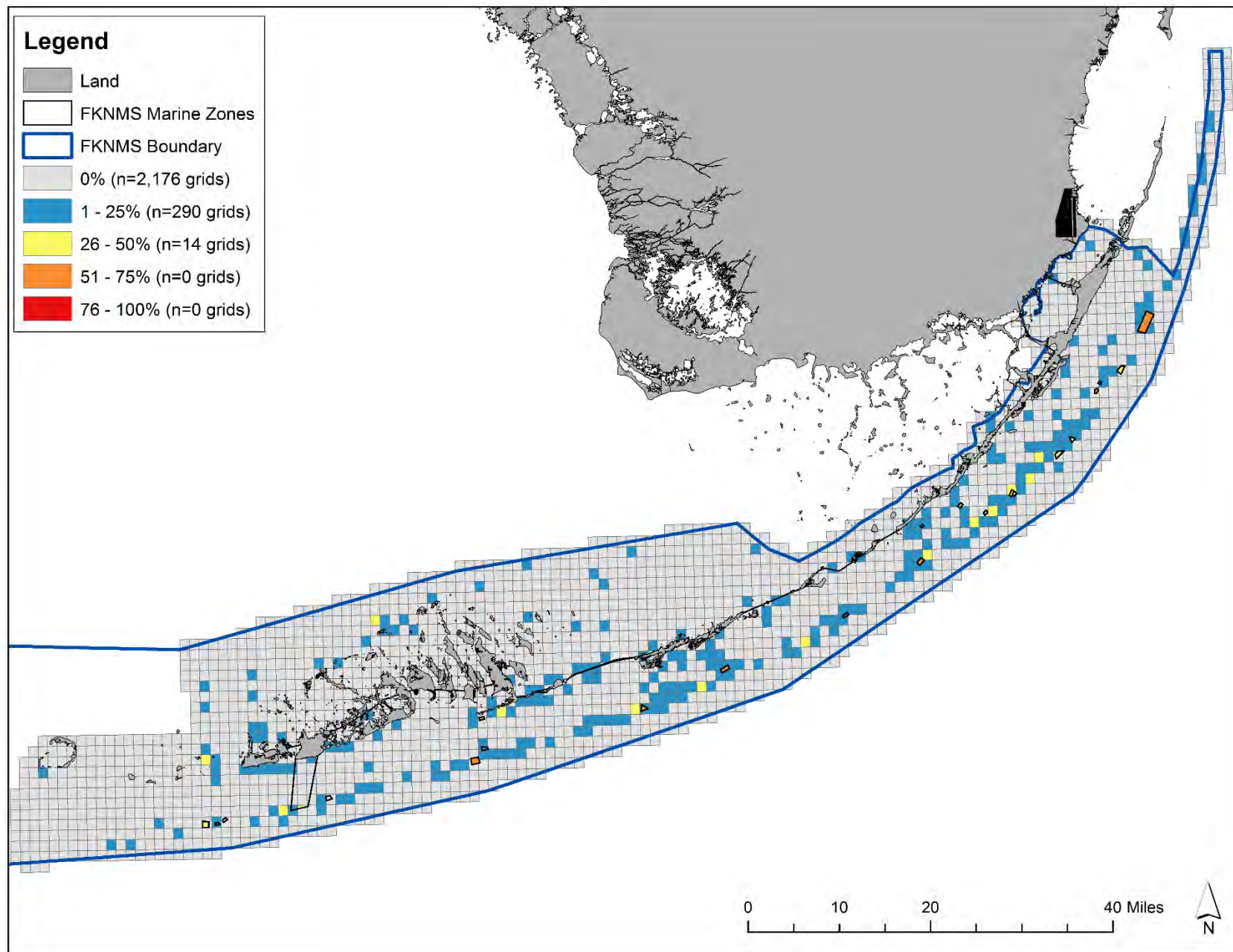


Figure 24 Map depicting the percent of time grids were occupied by dive boats during our winter surveys (n = 15 flights, total boat count = 1,344, total grids = 2,472). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

Hook-and-Line Fishing

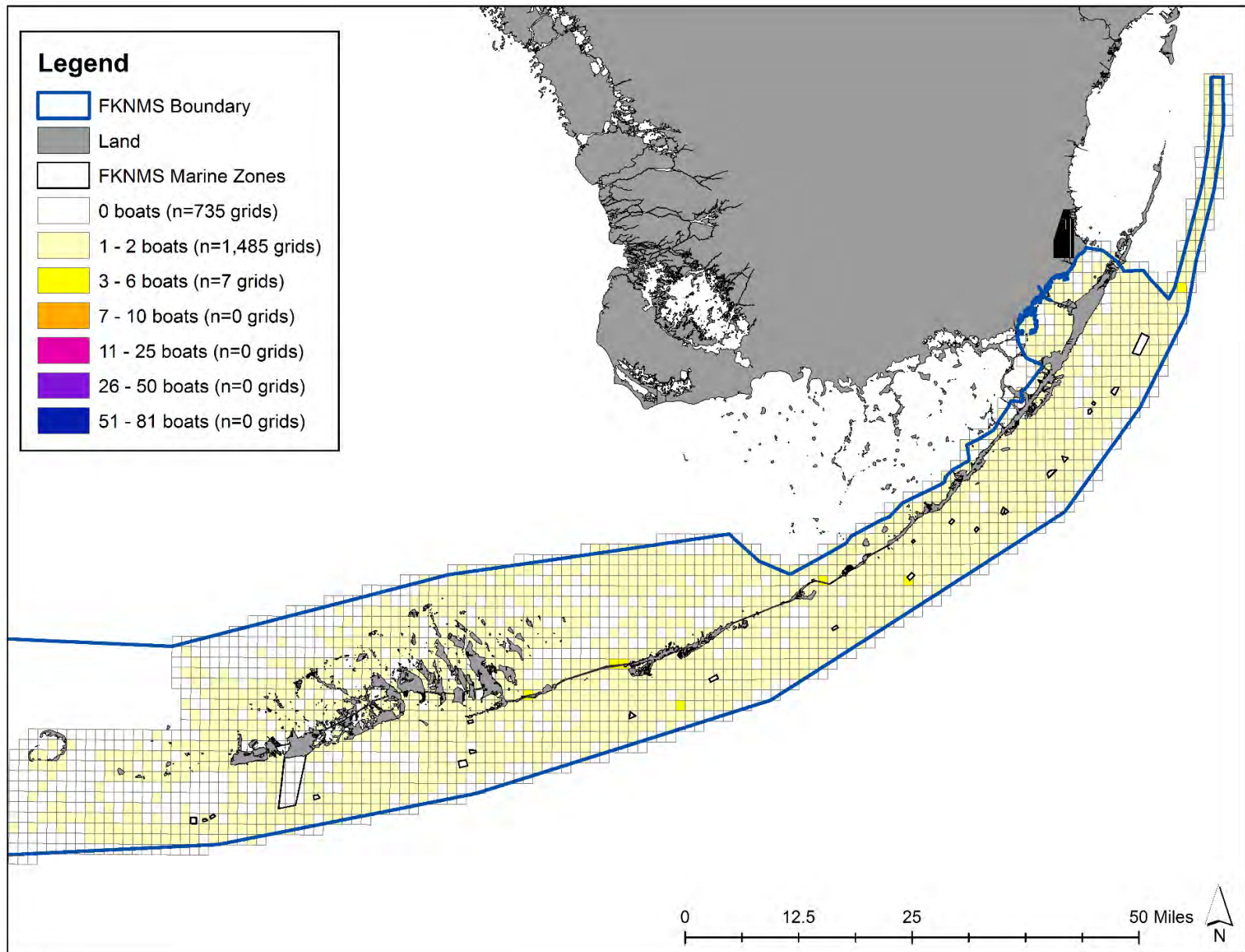


Figure 25 The average number of hook-and-line fishing boats observed during all 2016-2017 surveys. (n = 29 flights, total boat count = 9,908, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

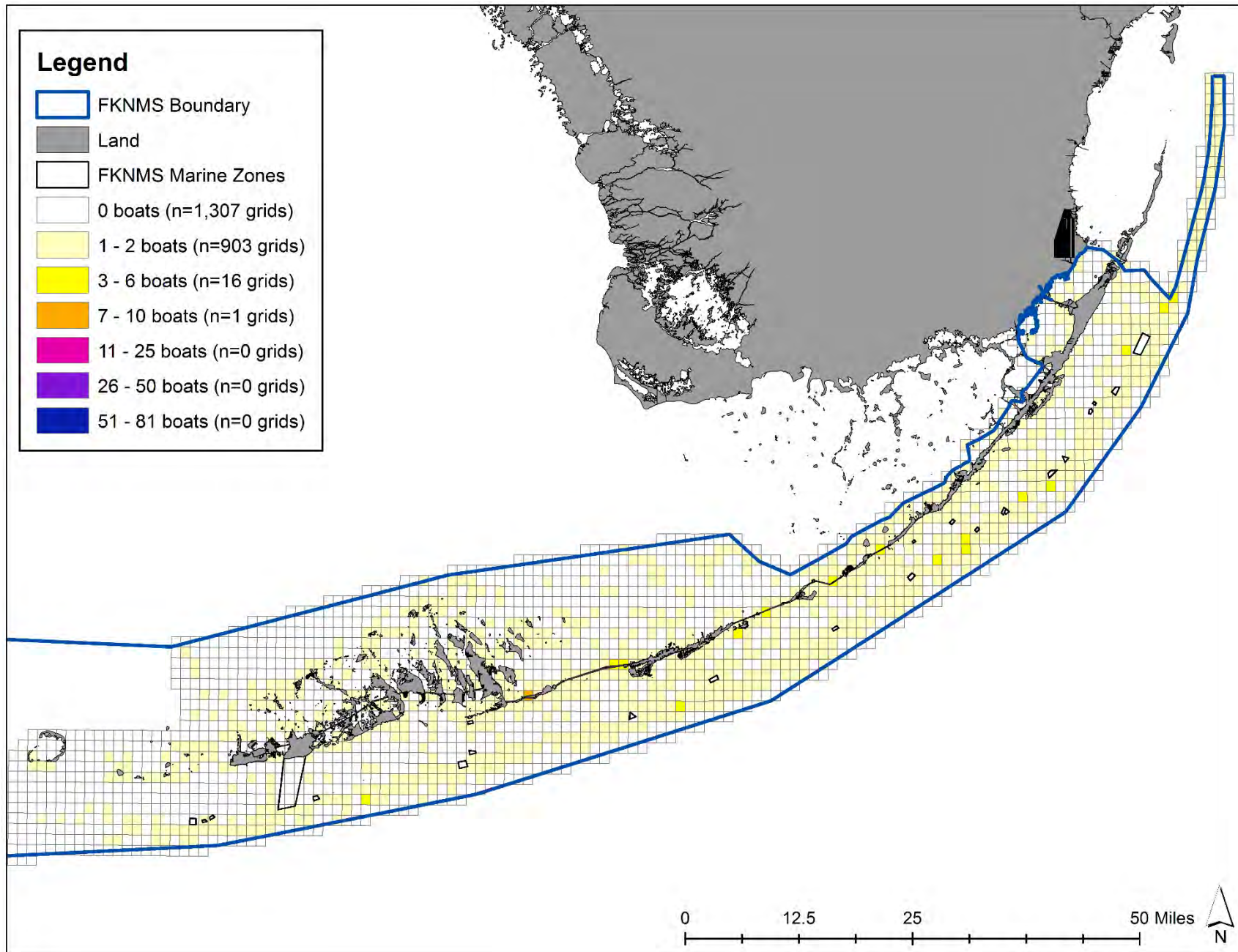


Figure 26 The average number of hook-and-line fishing boats observed during our summer surveys. (n = 9 flights, total boat count = 4,396, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square minute, which is approximately 1 square nautical mile.

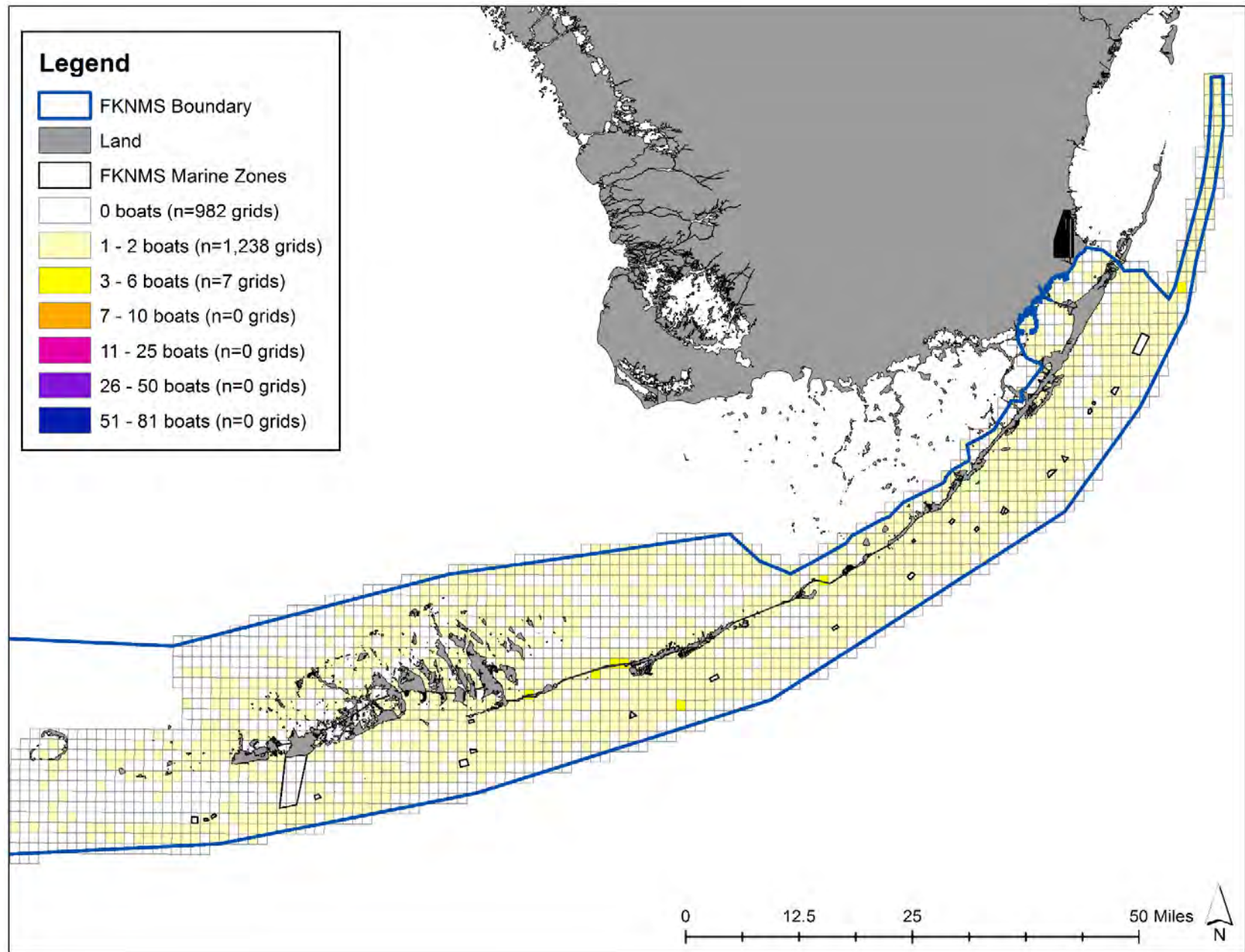


Figure 27 The average number of hook-and-line fishing boats observed during our winter surveys. (n = 15 flights, total boat count = 5,312, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square minute, which is approximately 1 square nautical mile.

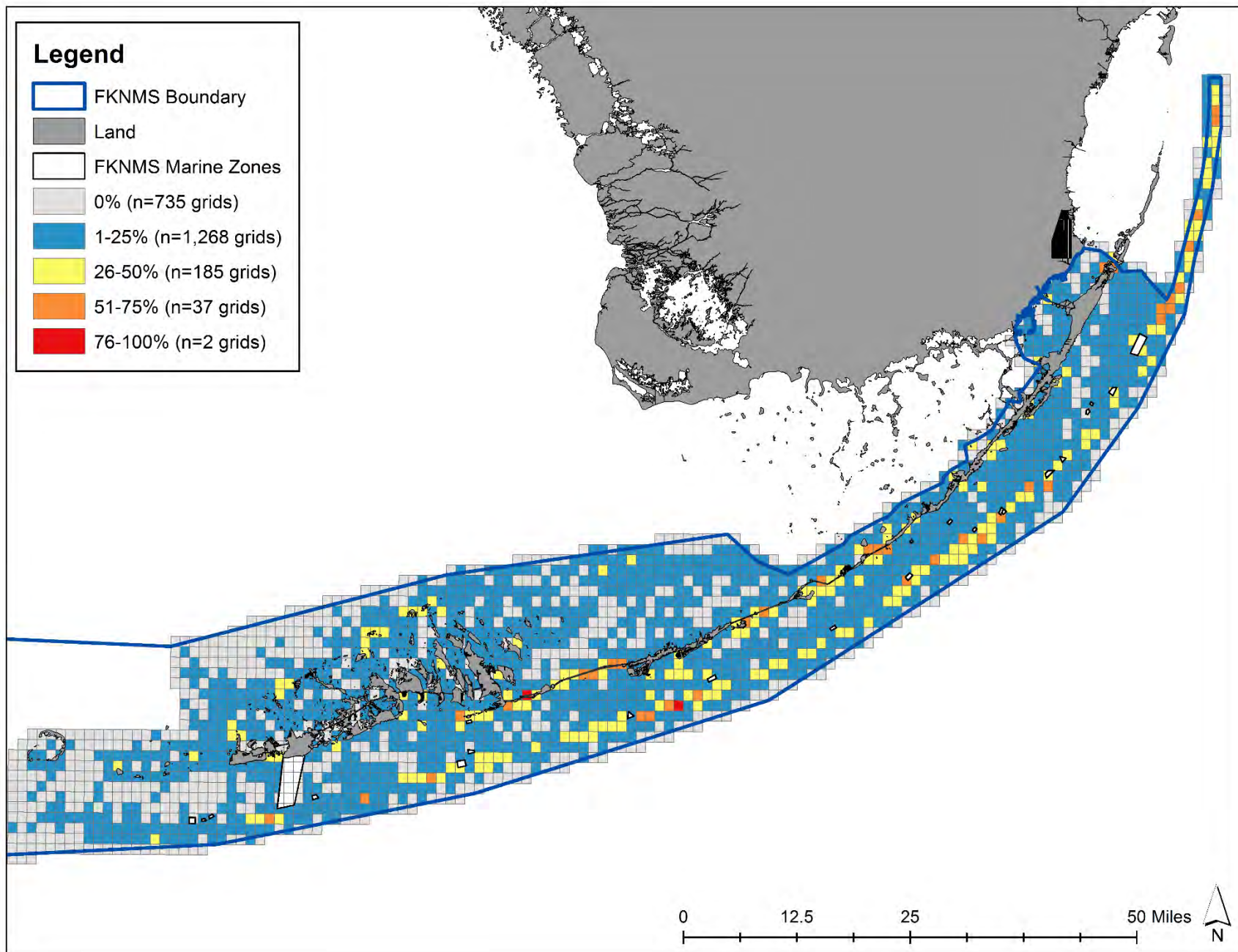


Figure 28 Map depicting the percent of time grids were occupied by hook-and-line fishing boats during all 2016-2017 surveys. (n = 29 flights, total boat count = 9,908, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

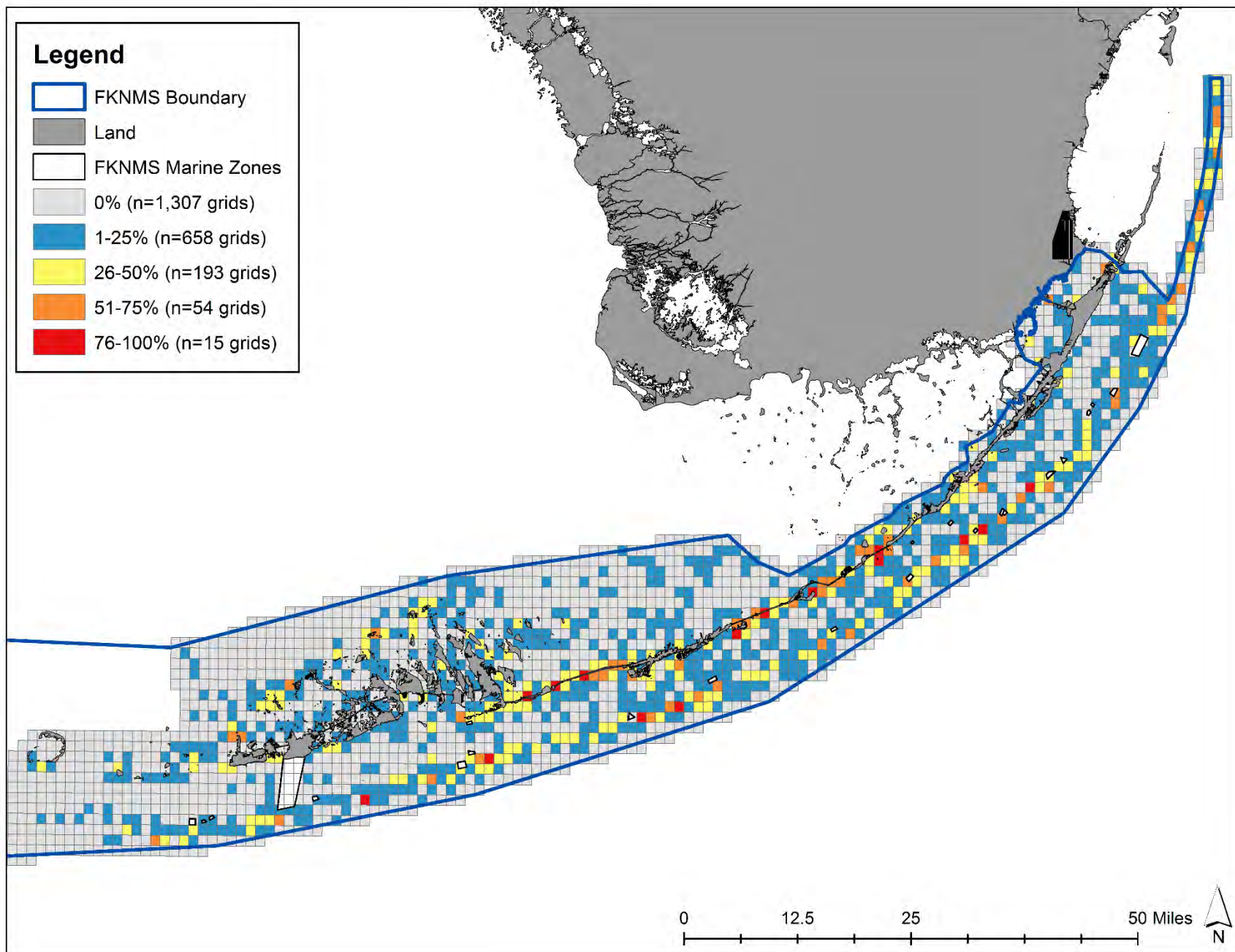


Figure 29 Map depicting the percent of time grids were occupied by hook-and-line fishing boats during summer surveys. (n = 9 flights, total boat count = 4,396, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

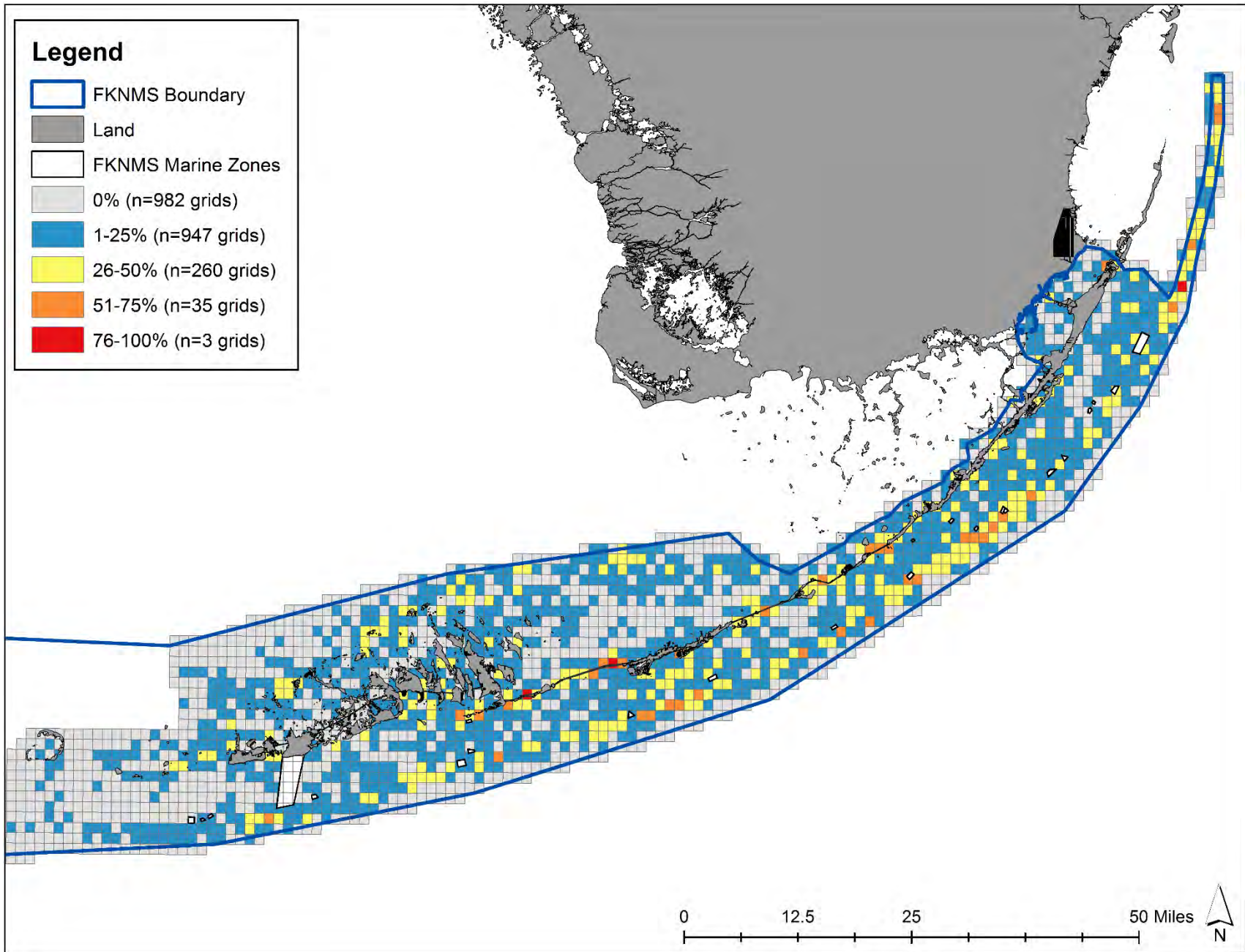


Figure 30 Map depicting the percent of time grids were occupied by hook-and-line fishing boats during winter surveys. (n = 15 flights, total boat count = 5,312, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

Running

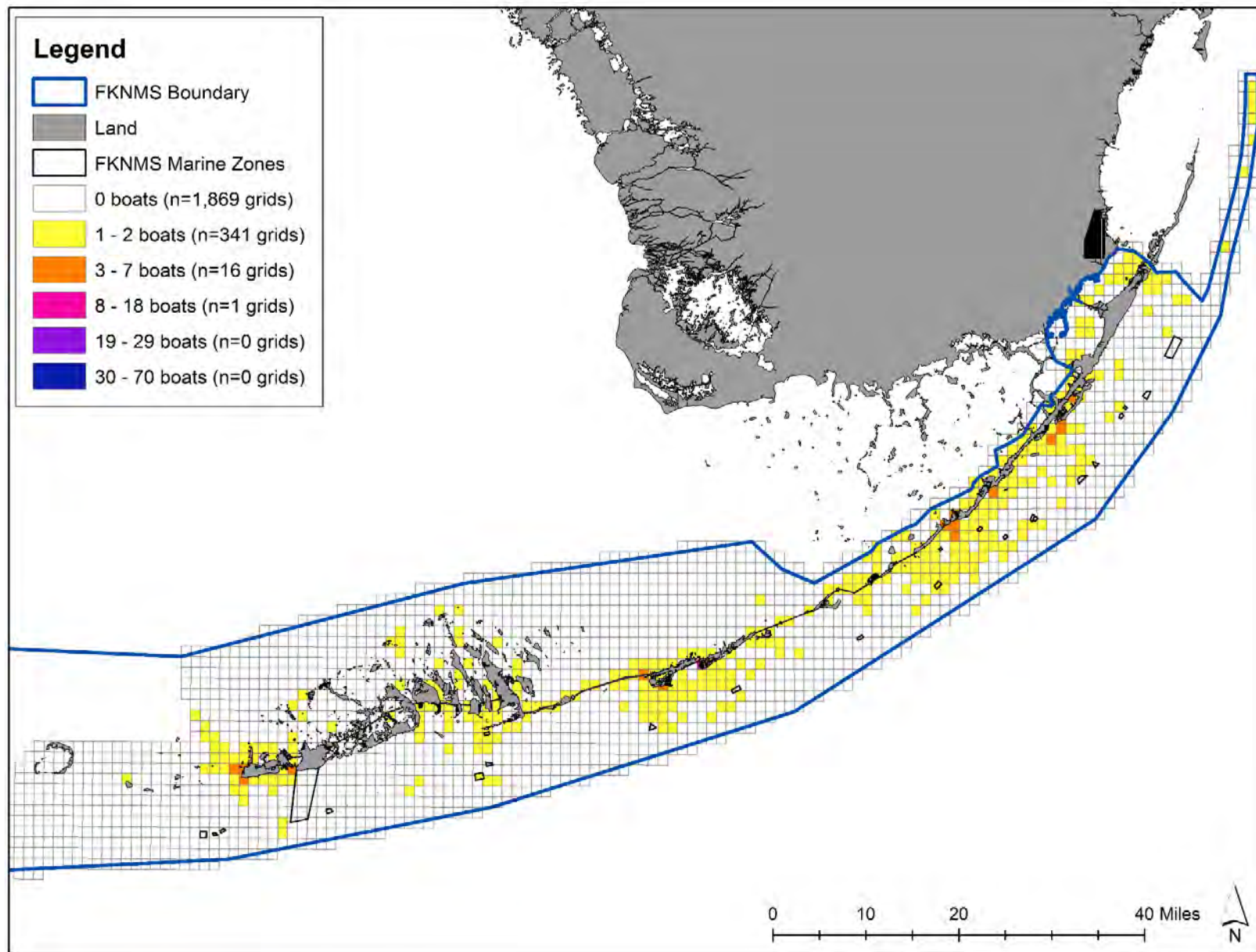


Figure 31 The average number of running boats per grid during all 2016-2017 surveys. (n = 29 flights, total boat count = 15,348). FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

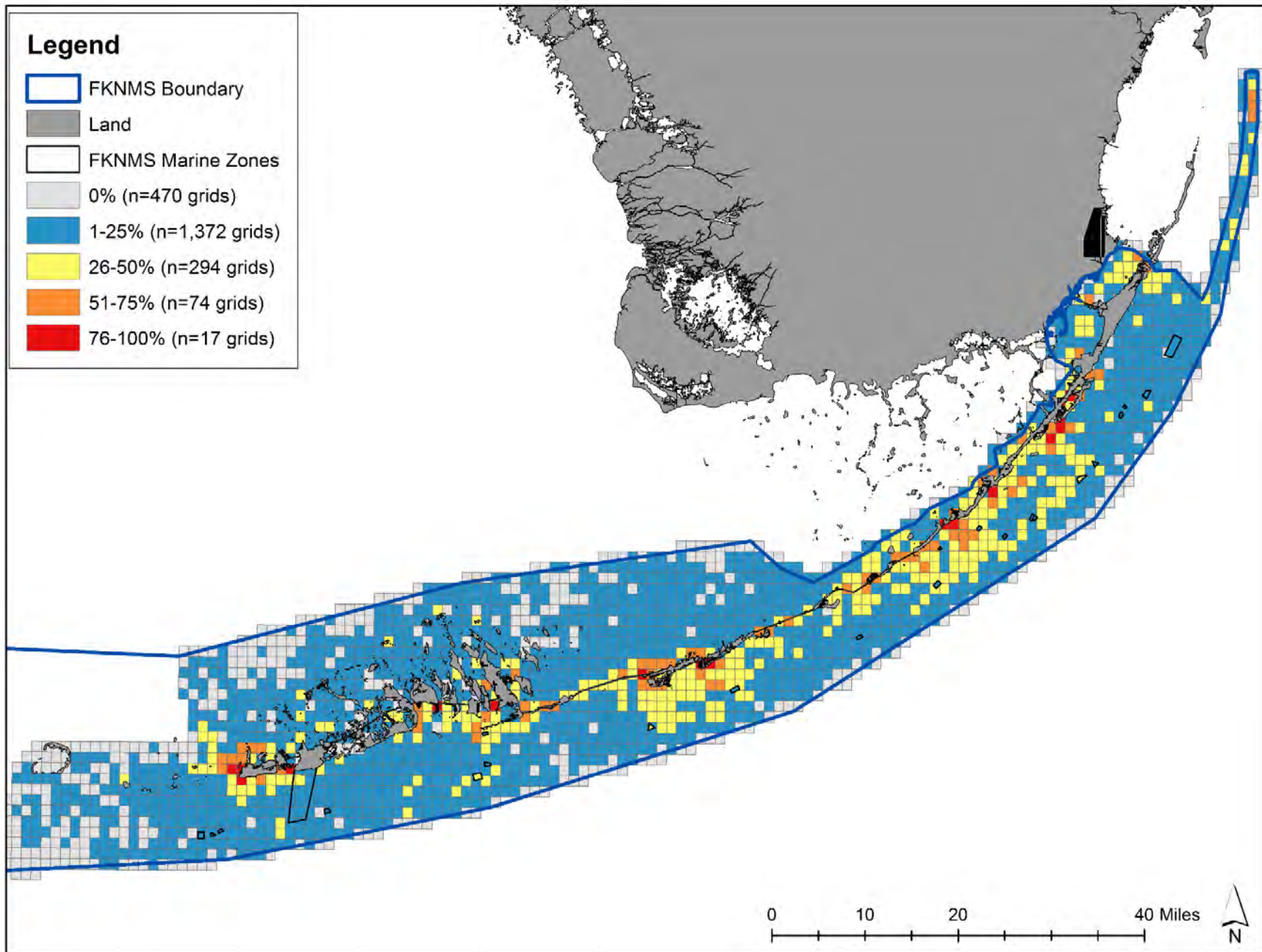


Figure 32 Map depicting the percent of time grids were occupied by running boats during all 2016–2017 surveys (n = 29 flights, total boat count = 15,348, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

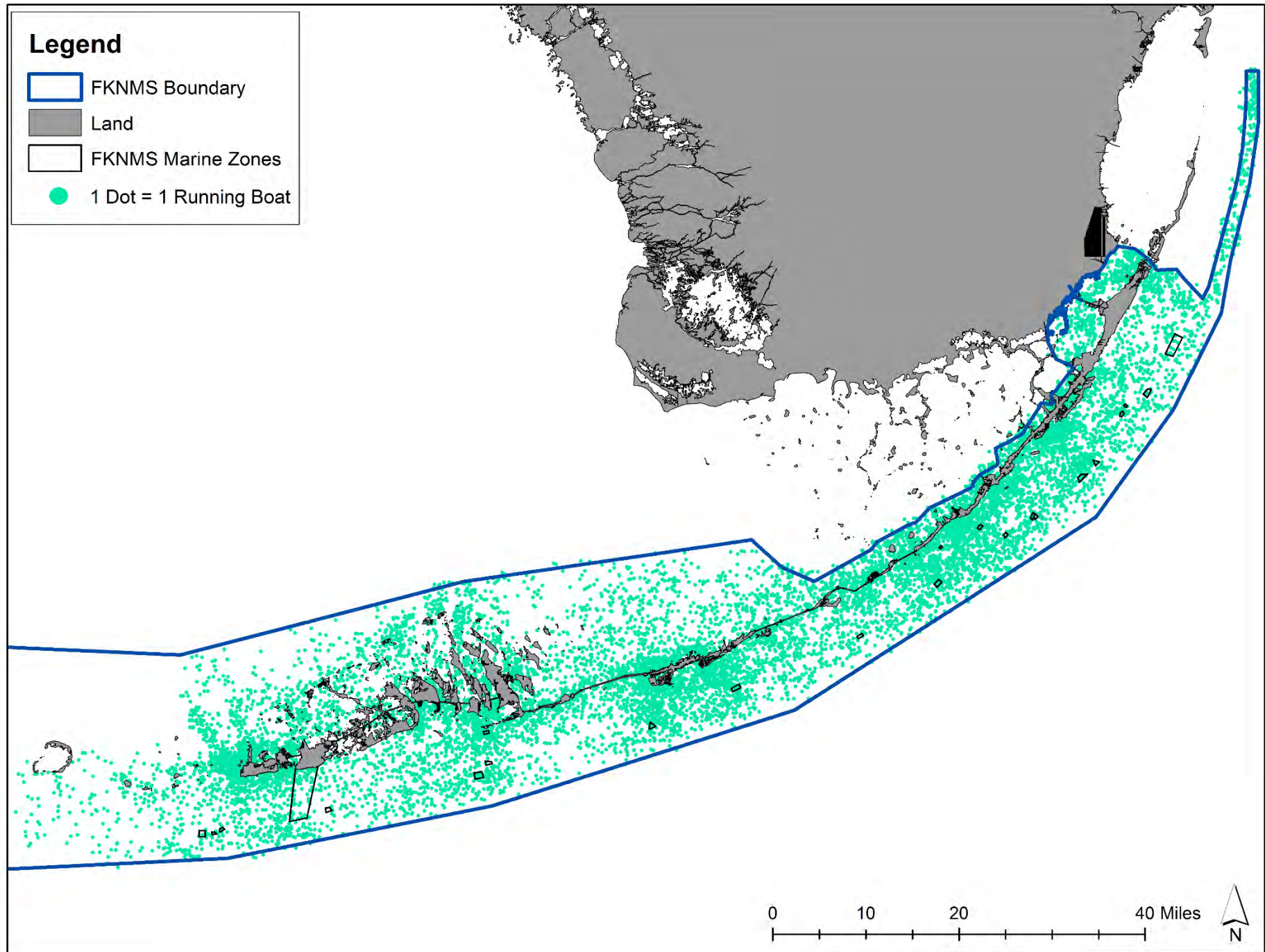


Figure 33 Dot density (1 dot = 1 running boat) of all boats observed running during aerial surveys of the Sanctuary (n = 29 flights, total boat count = 15,348).

Sandbars

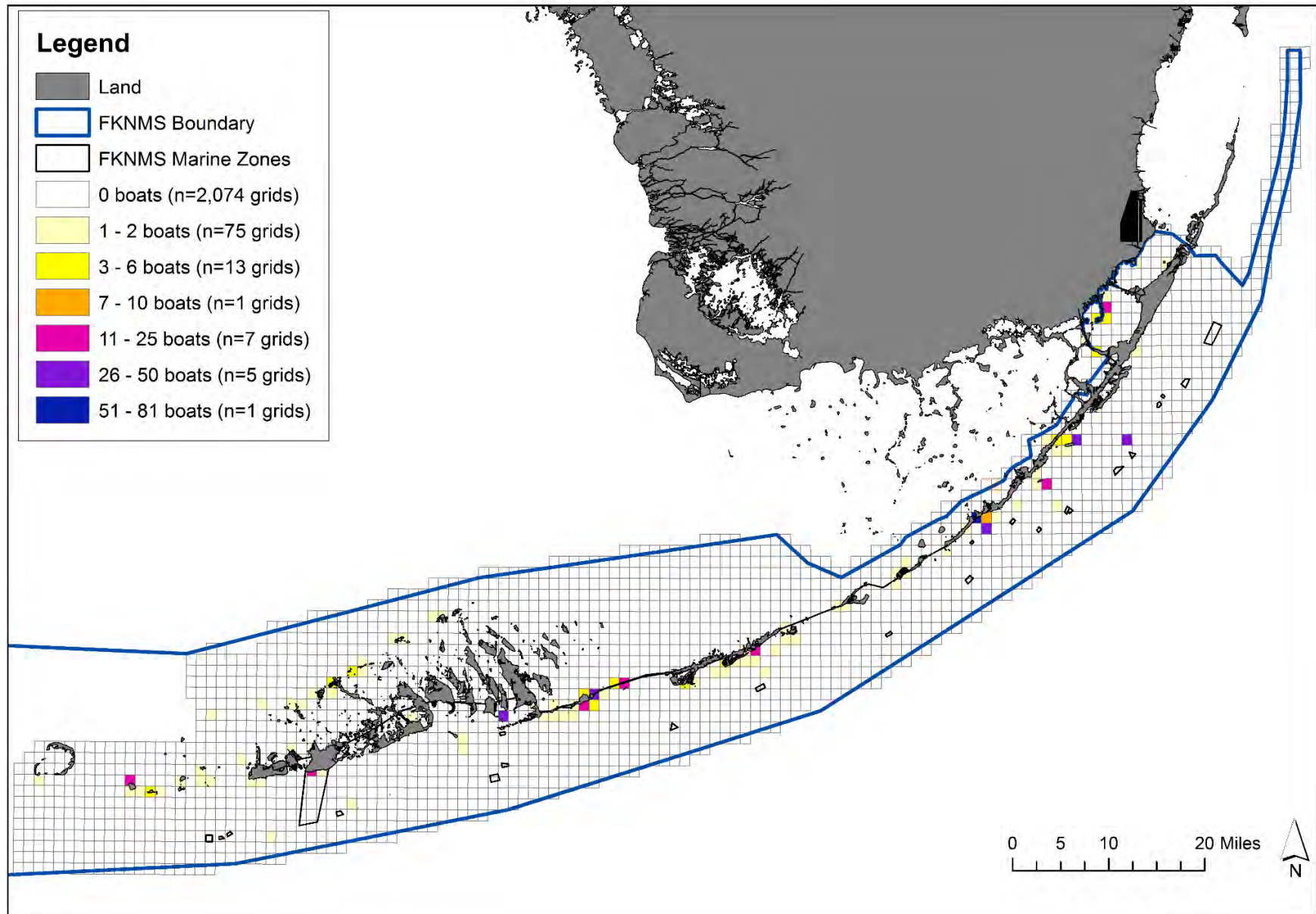


Figure 34 The average number of boats at sandbars per grid during all 2016-2017 surveys. (n = 29 flights, total boat count = 4,915, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

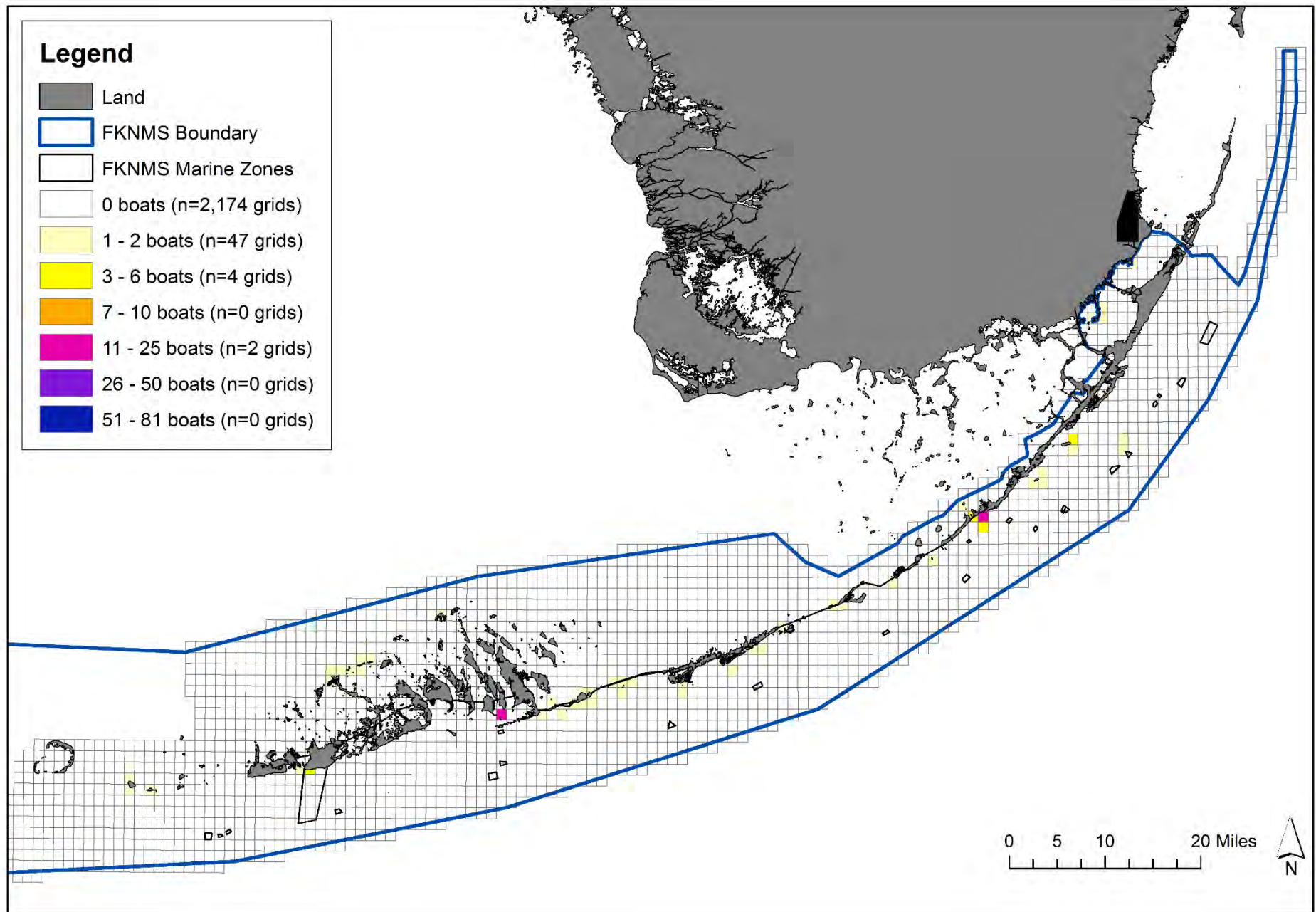


Figure 35 The average number of boats at sandbars per grid during surveys conducted at high-use times (Holiday and summer weekends). (n = 8 flights, total boat count = 3,479, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

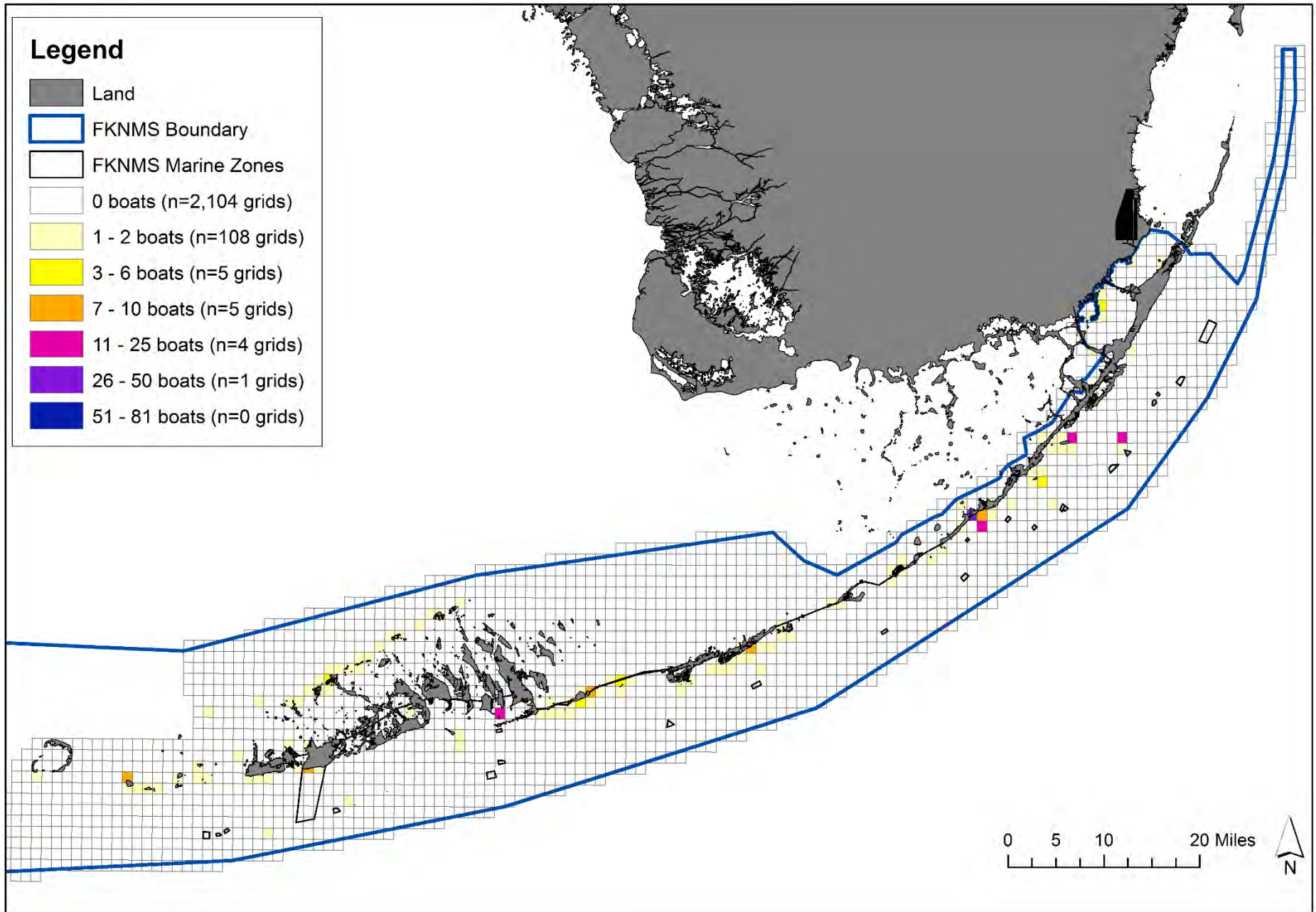


Figure 36 The average number of boats at sandbars per grid during surveys conducted at low-use times (winter weekdays and weekends and summer weekdays). (n = 19 flights, total boat count = 934, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

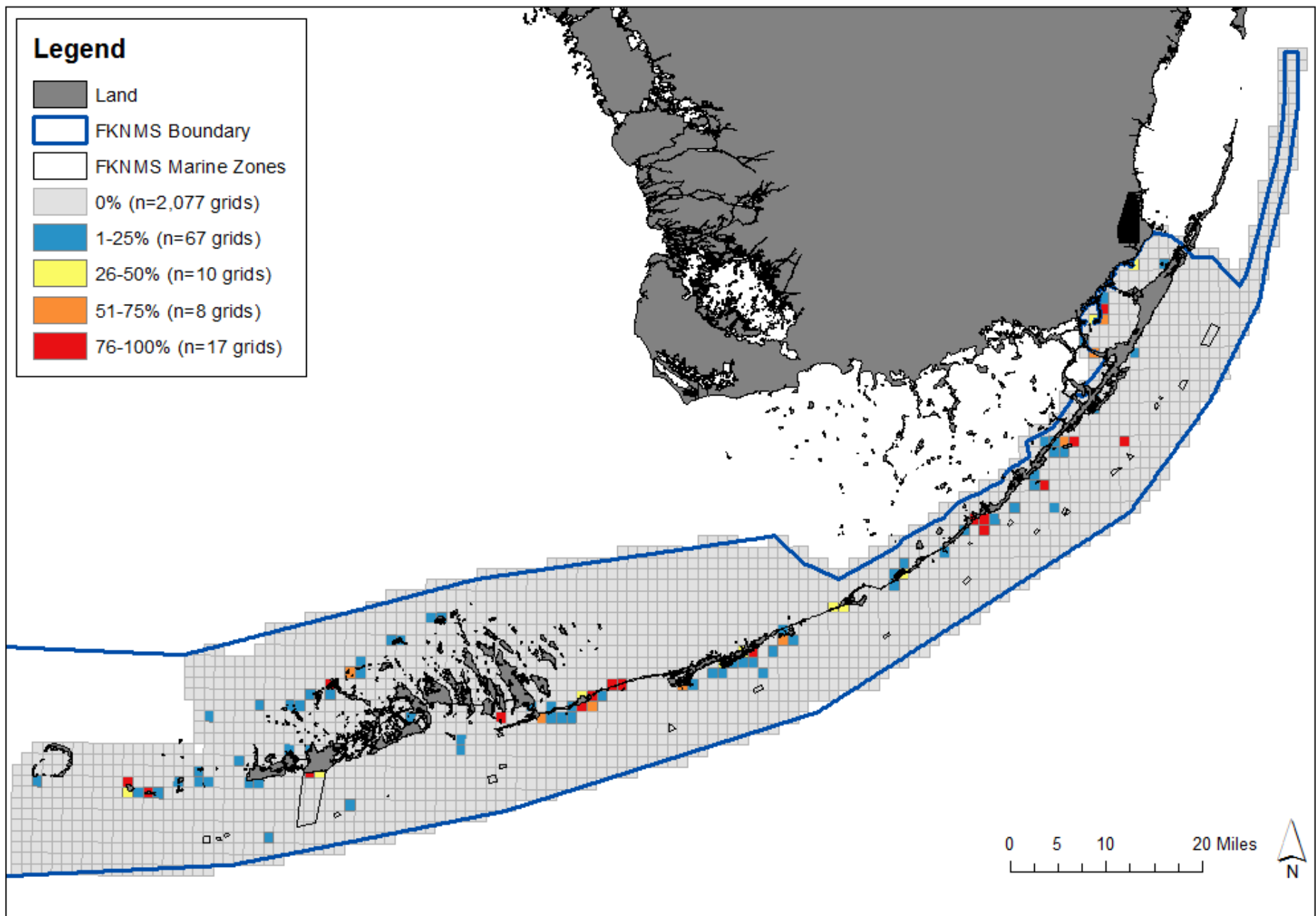


Figure 37 Map depicting the percent of time grids were occupied by boats at sandbars during all 2016-2017 surveys. (n = 29 flights, total boat count = 4,915, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

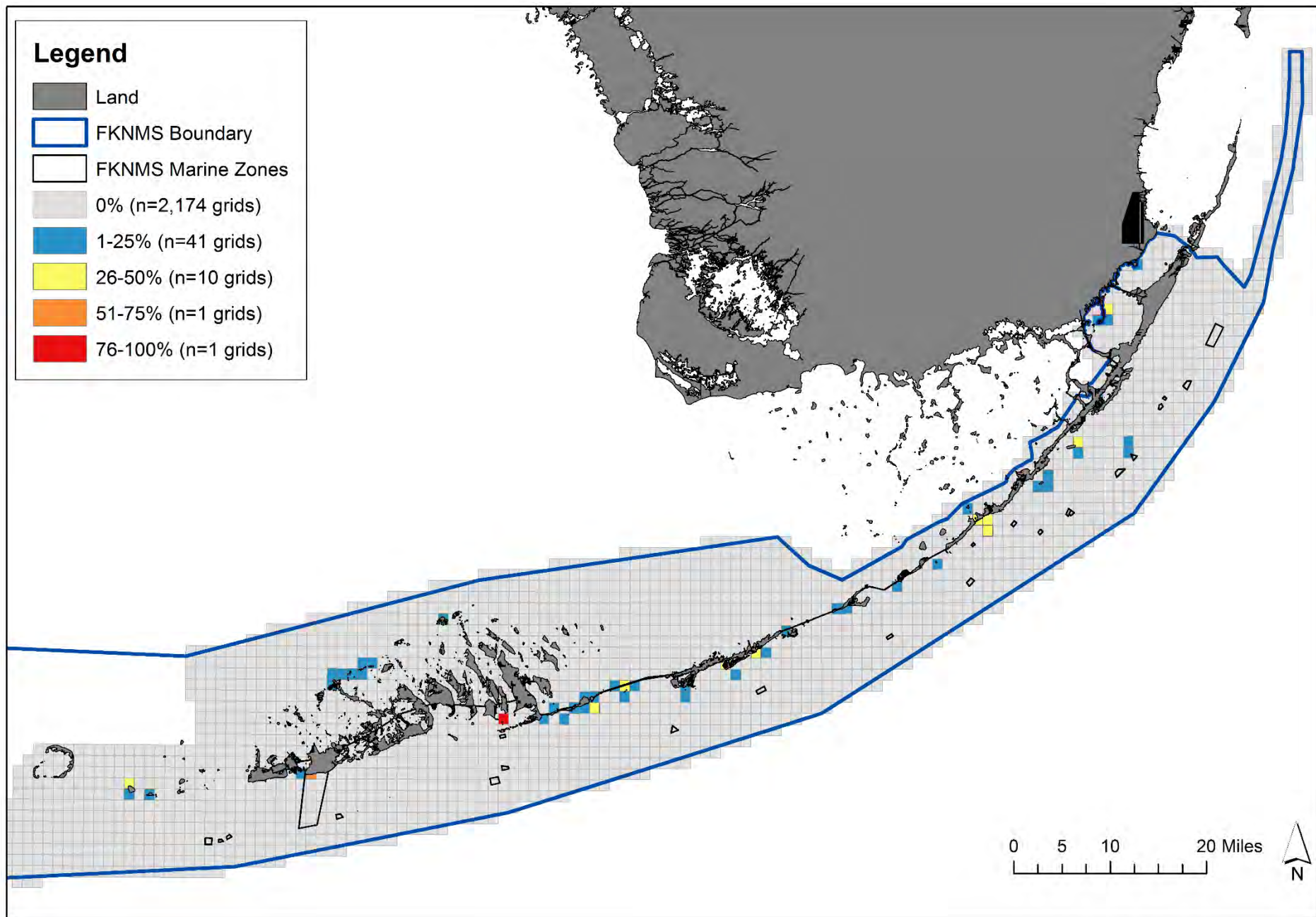


Figure 38 Map depicting the percent of time grids were occupied by boats at sandbars during surveys conducted at high-use times (Holiday and summer weekends). (n = 8 flights, total boat count = 3,479, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

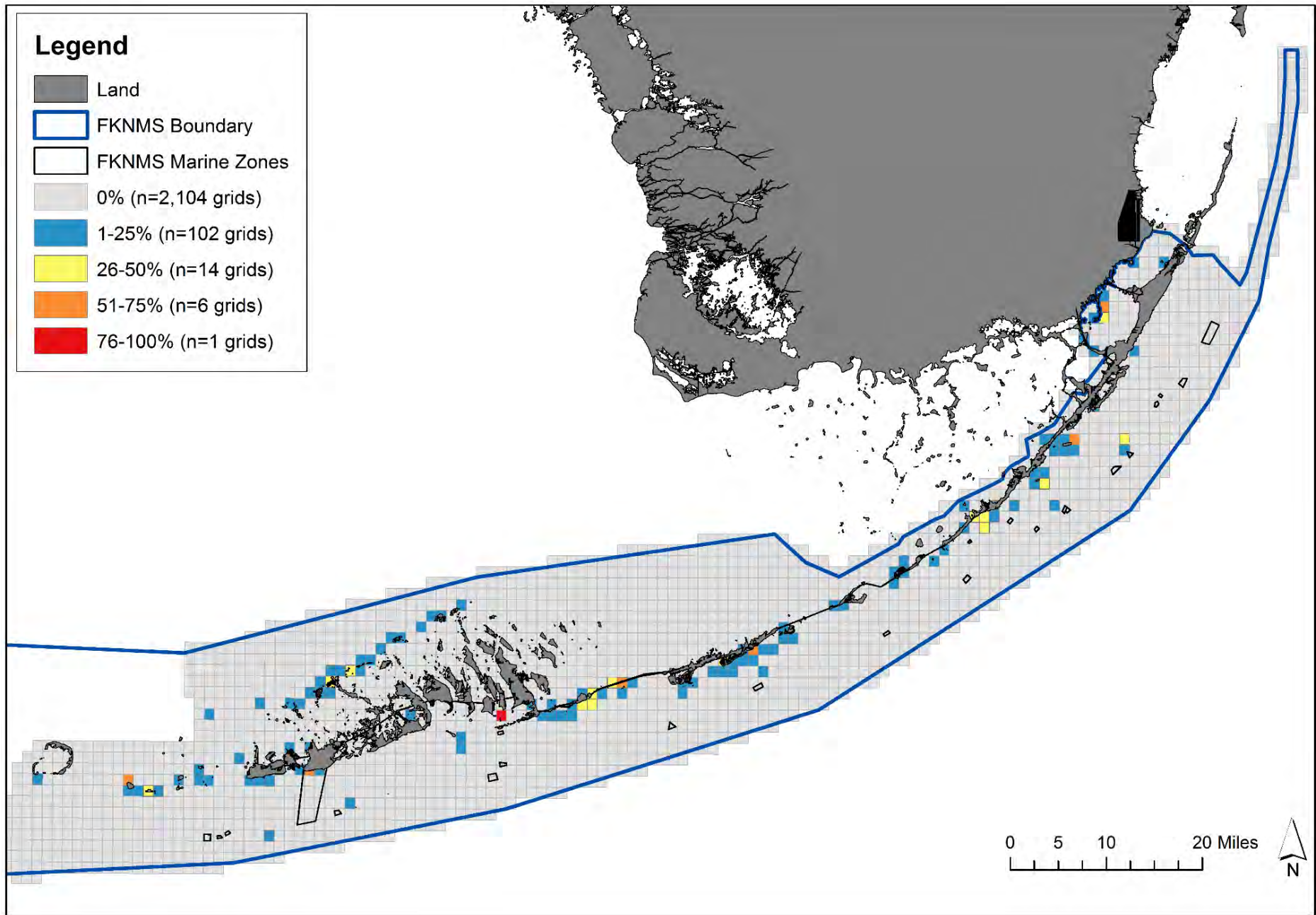


Figure 39 Map depicting the percent of time grids were occupied by boats at sandbars during surveys conducted at low-use times (winter weekdays and weekends and summer weekdays). (n = 19 flights, total boat count = 934, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

Watersports – Adventure Sports

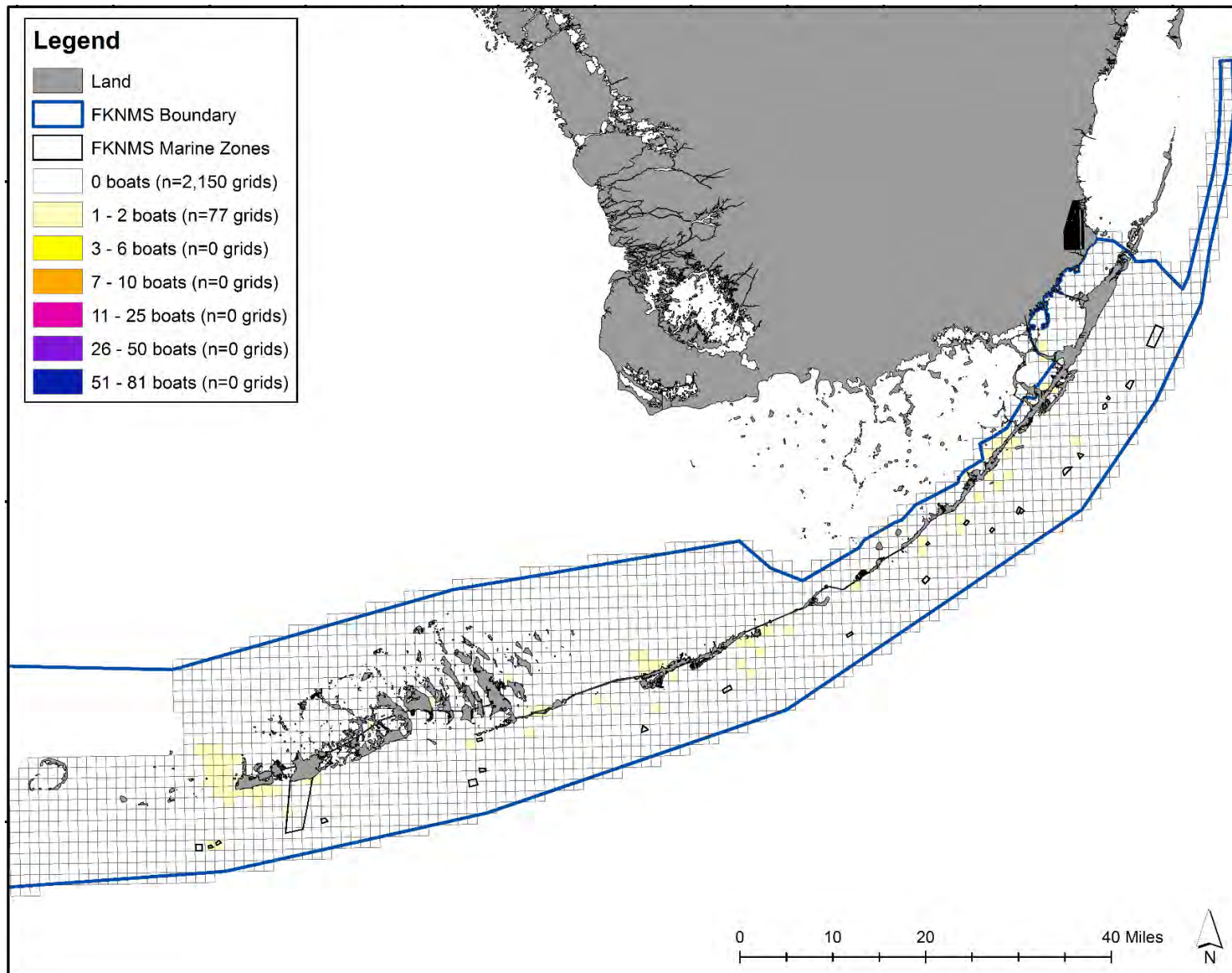


Figure 40 The average number of boats participating in adventure sports (e.g. parasailing, tubing, waterskiing, etc.) per grid during all 2016-2017 surveys. (n = 29 flights, total boat count = 240, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

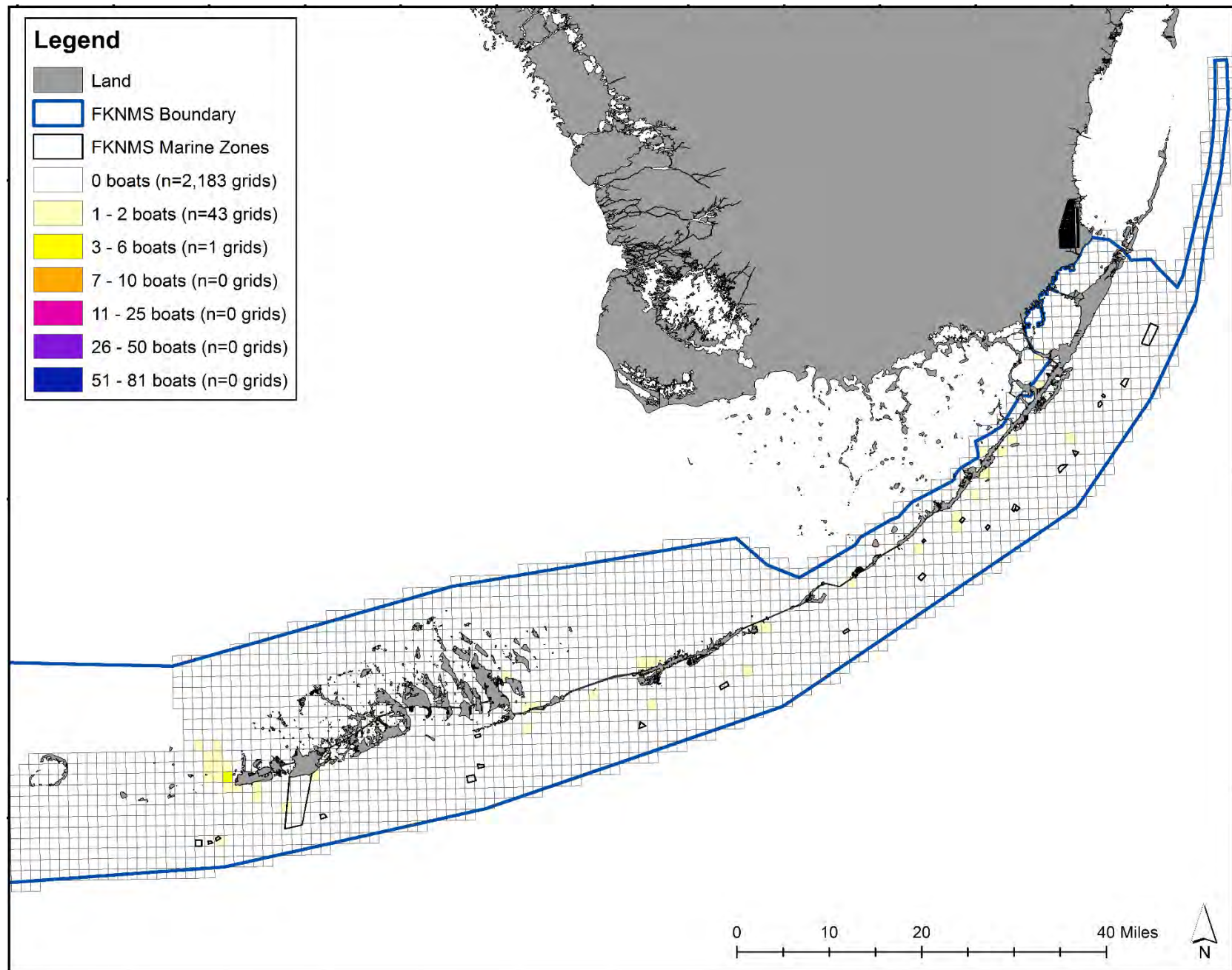


Figure 41 The average number of boats participating in adventuresports (e.g. parasailing, tubing, waterskiing, etc.) during surveys conducted at high-use (holiday and summer weekends) times. (n = 8 flights, total boat count = 106, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

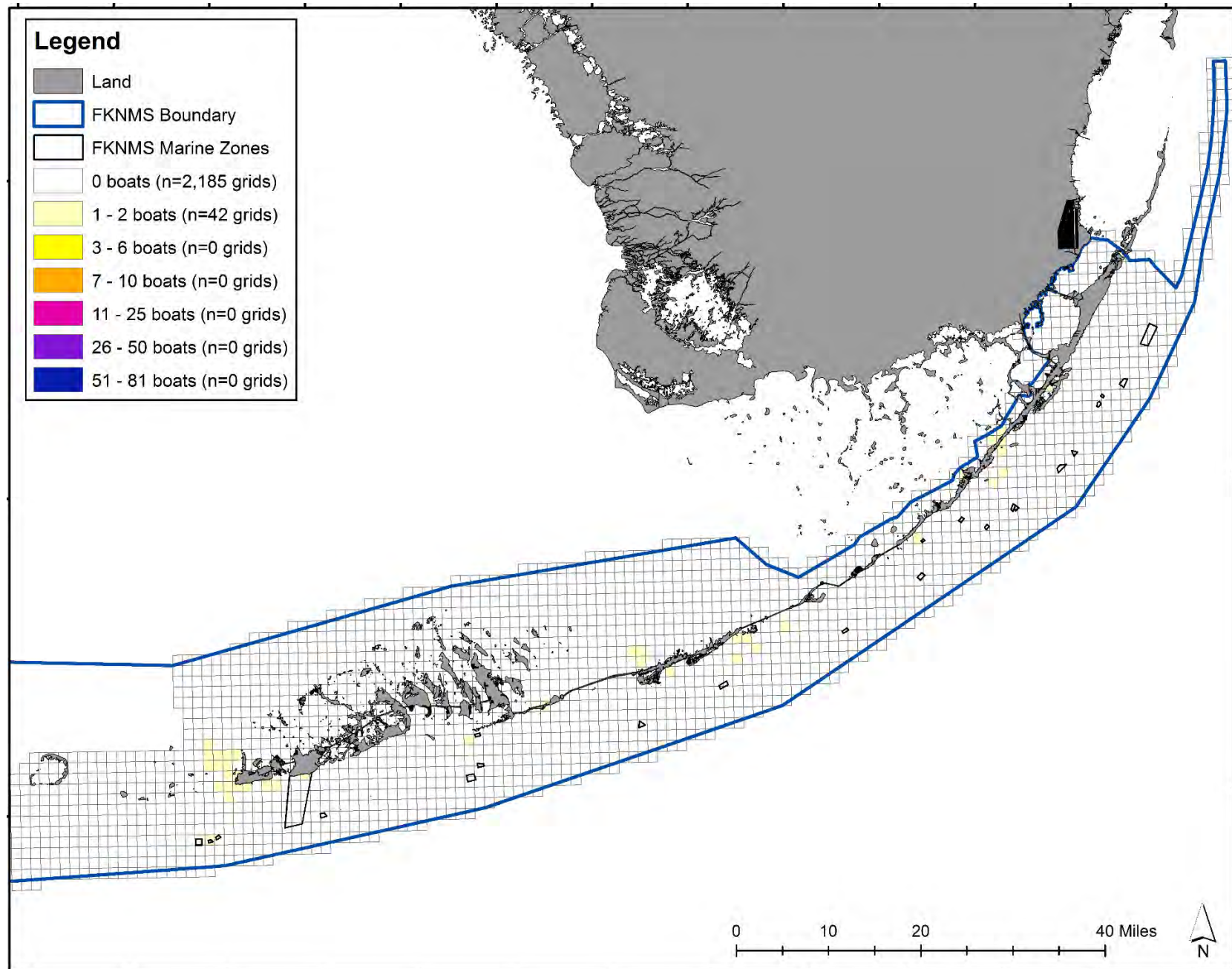


Figure 42 The average number of boats participating in adventure sports (e.g. parasailing, tubing, waterskiing, etc.) during surveys conducted at low-use times (winter weekdays and weekends and summer weekdays). (n = 19 flights, total boat count = 117, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

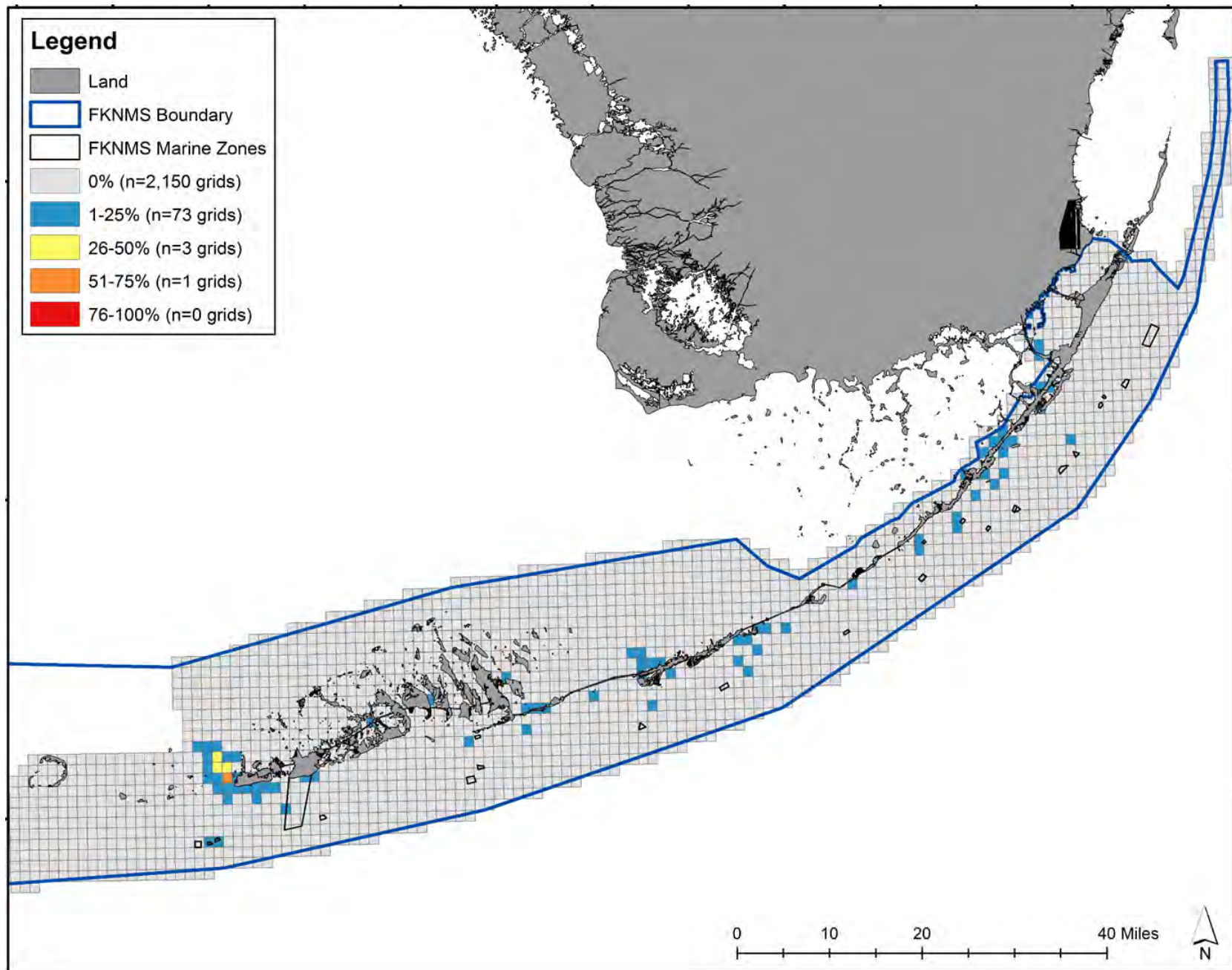


Figure 43 Map depicting the percent of time grids were occupied by boats participating in adventure sports (e.g. parasailing, tubing, waterskiing, etc.) during all 2016-2017 surveys. (n = 29 flights, total boat count = 240, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

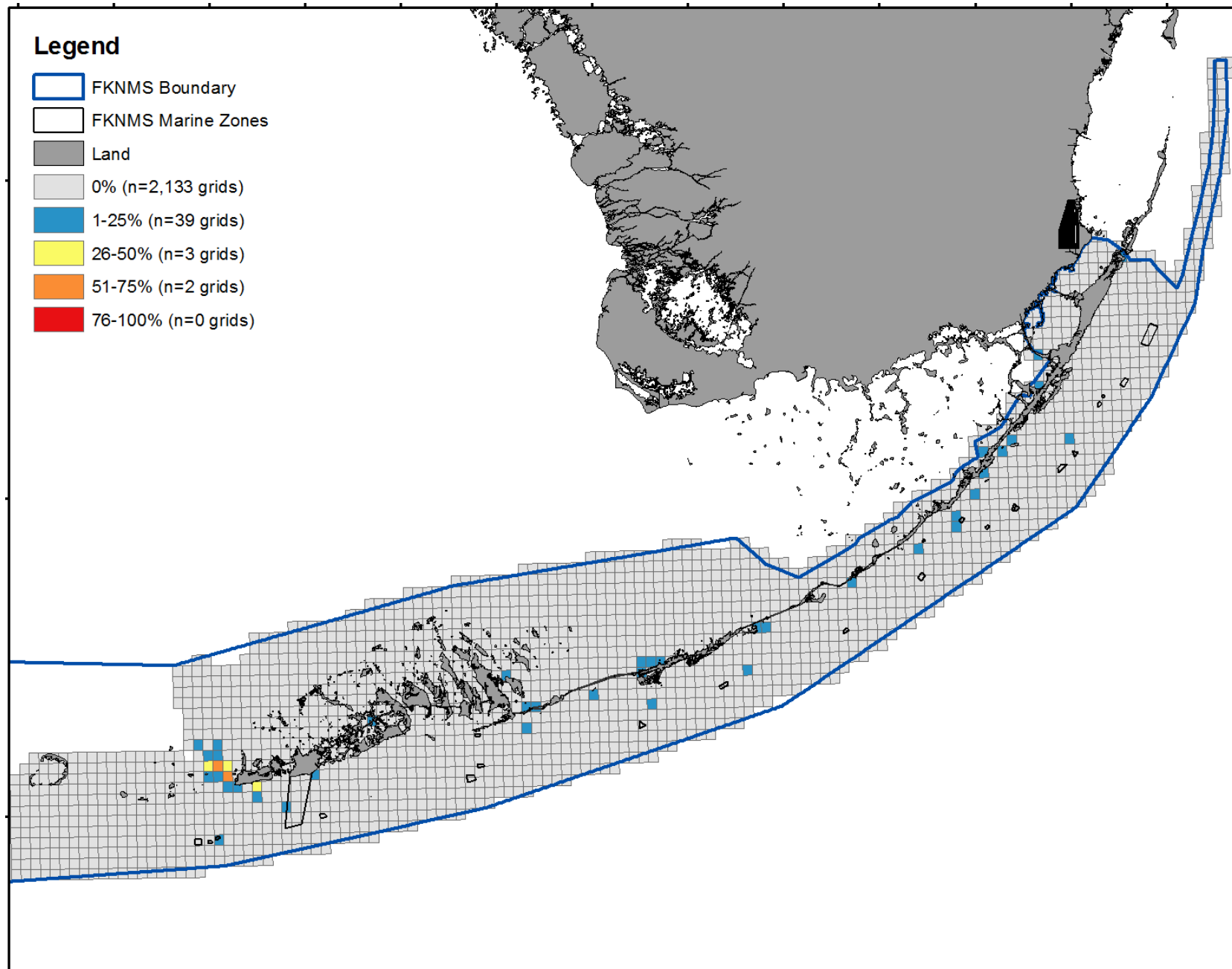


Figure 44 Map depicting the percent of time grids were occupied by boats participating in adventure sports (e.g. parasailing, tubing, waterskiing, etc.) during surveys conducted at high-use (holiday and summer weekends) times. (n = 8 flights, total boat count = 106, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

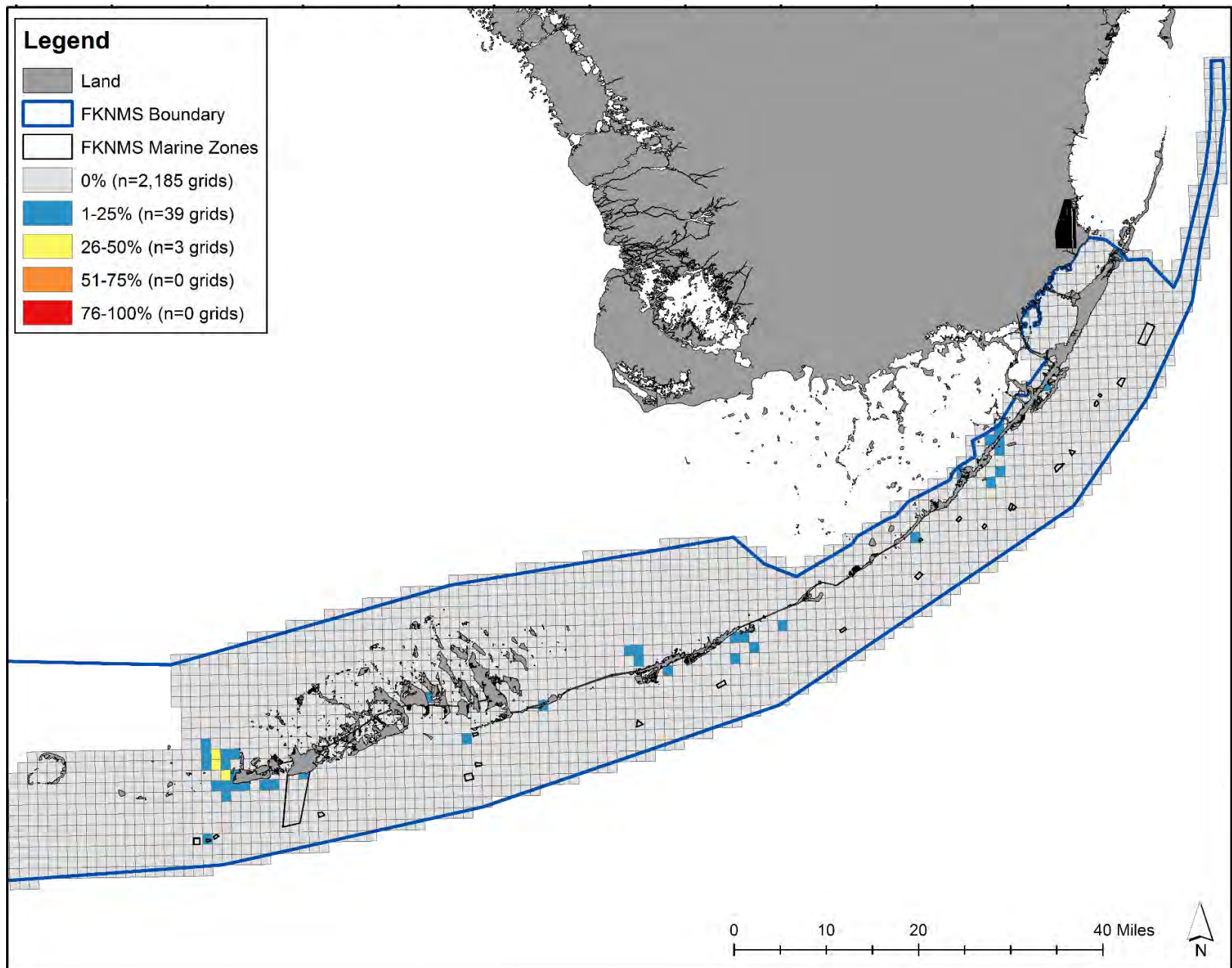


Figure 45 Map depicting the percent of time grids were occupied by boats participating in adventure sports (e.g. parasailing, tubing, waterskiing, etc.) during surveys conducted at low-use times (winter weekdays and weekends and summer weekdays). (n = 19 flights, total boat count = 117, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

Watersports – Paddlecraft

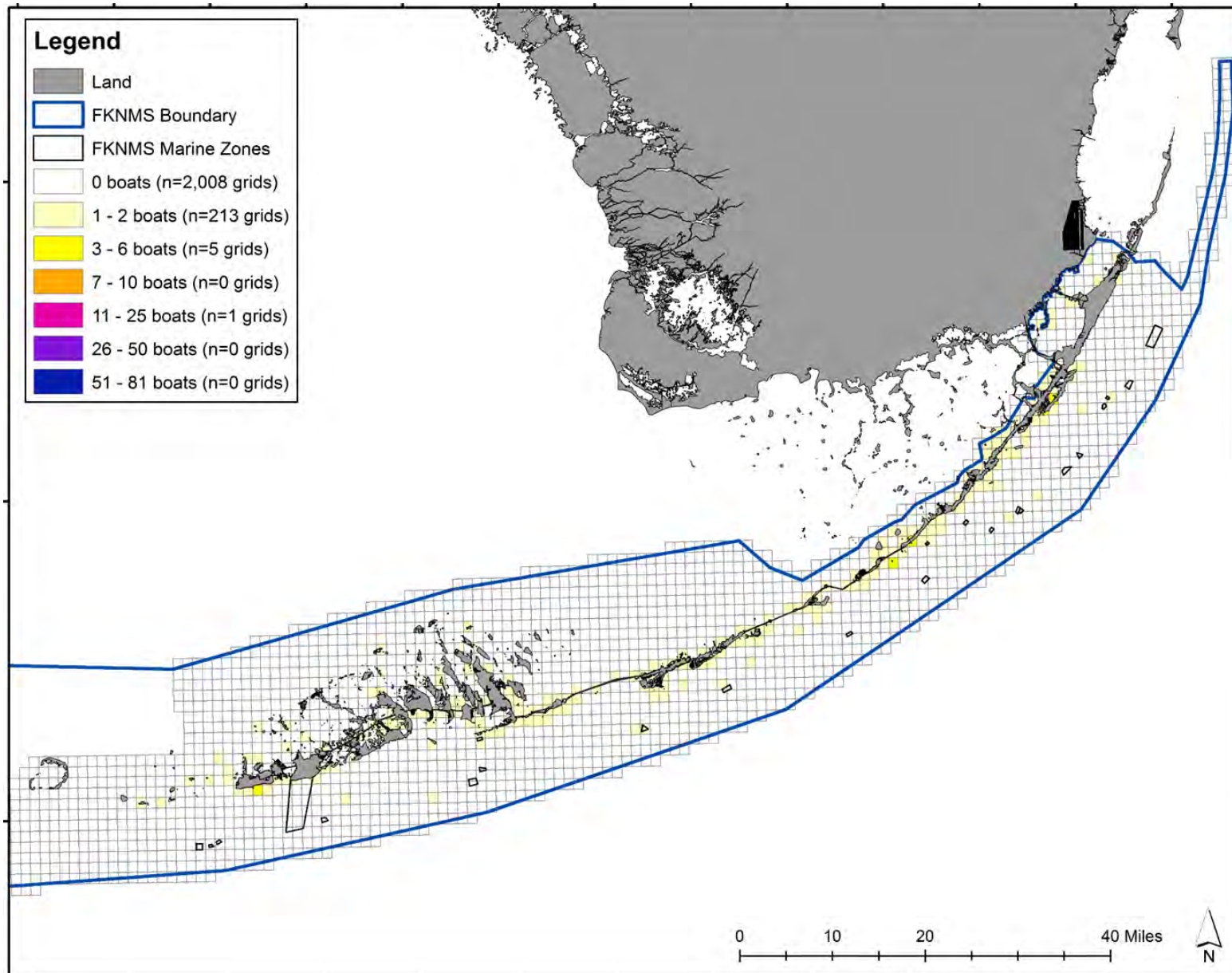


Figure 46 The average number of paddlecraft (kayaks, paddleboards, and/or canoes) per grid during all 2016-2017 surveys. (n = 29 flights, total boat count = 2310, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

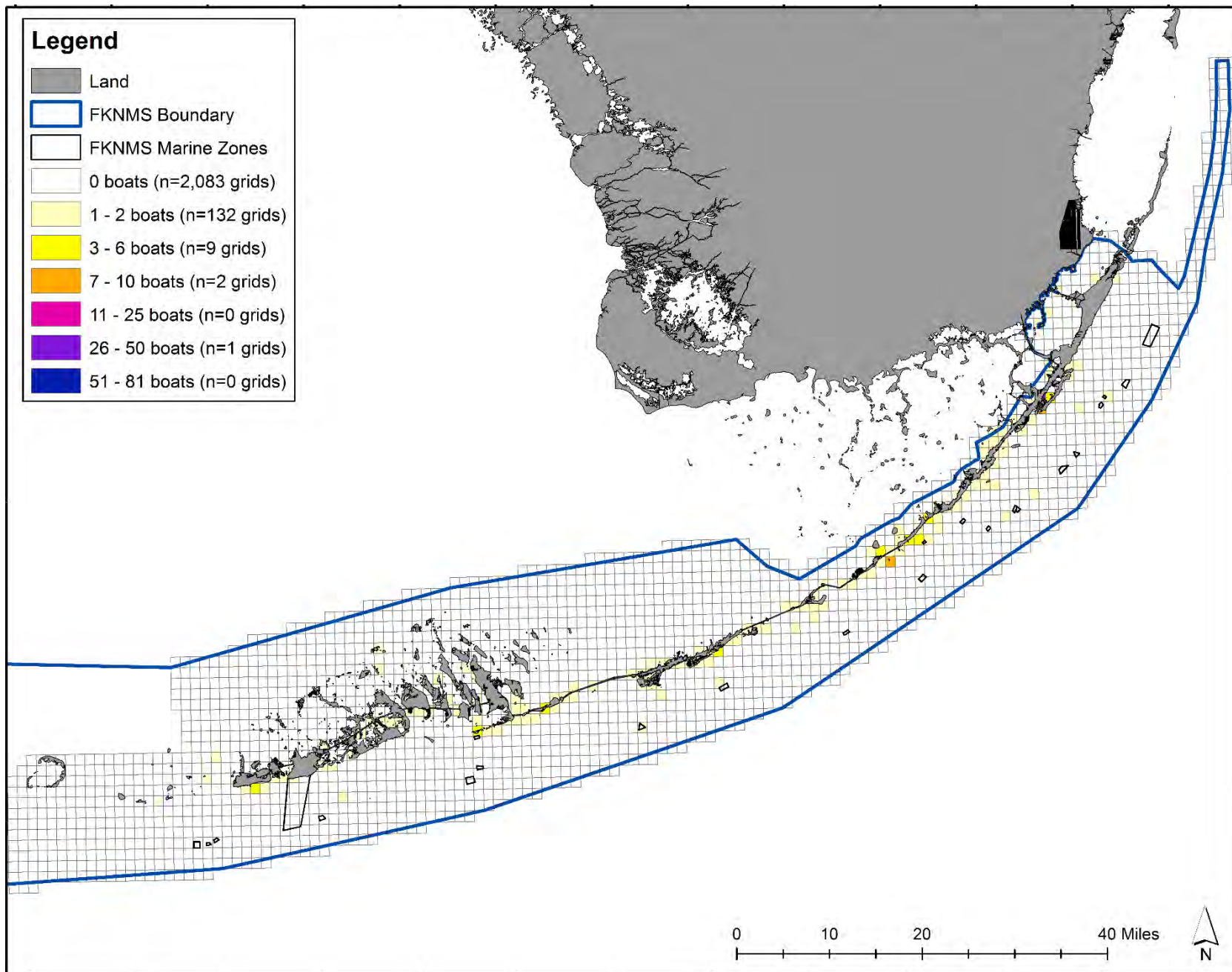


Figure 47 The average number of paddlecraft (kayaks, paddleboards, and/or canoes) per grid during surveys conducted at high-use (holiday and summer weekends) times. (n = 8 flights, total boat count = 1,157, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

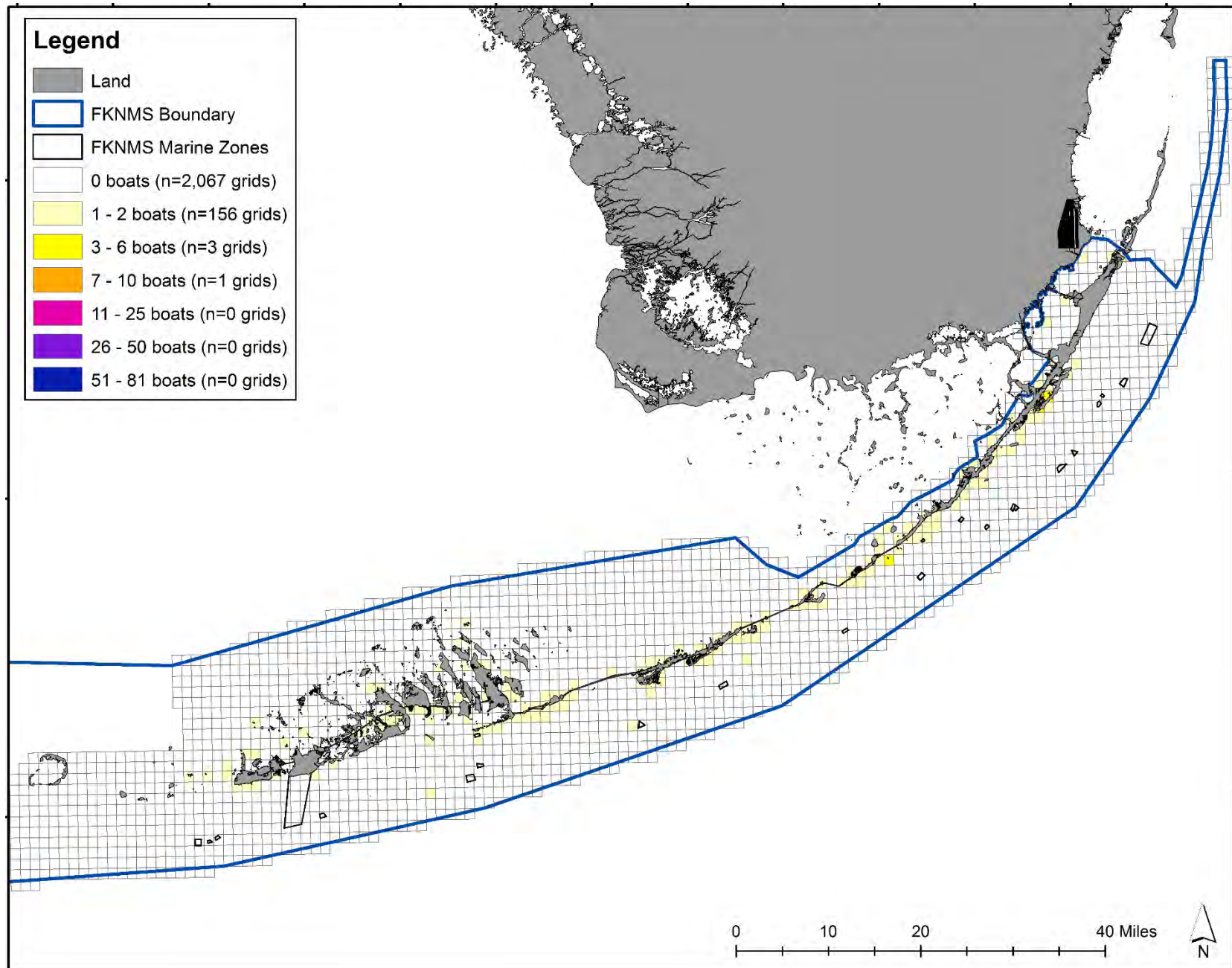


Figure 48 The average number of paddlecraft (kayaks, paddleboards, and/or canoes) per grid during surveys conducted at low-use times (winter weekdays and weekends and summer weekdays). (n = 19 flights, total boat count = 1,007, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

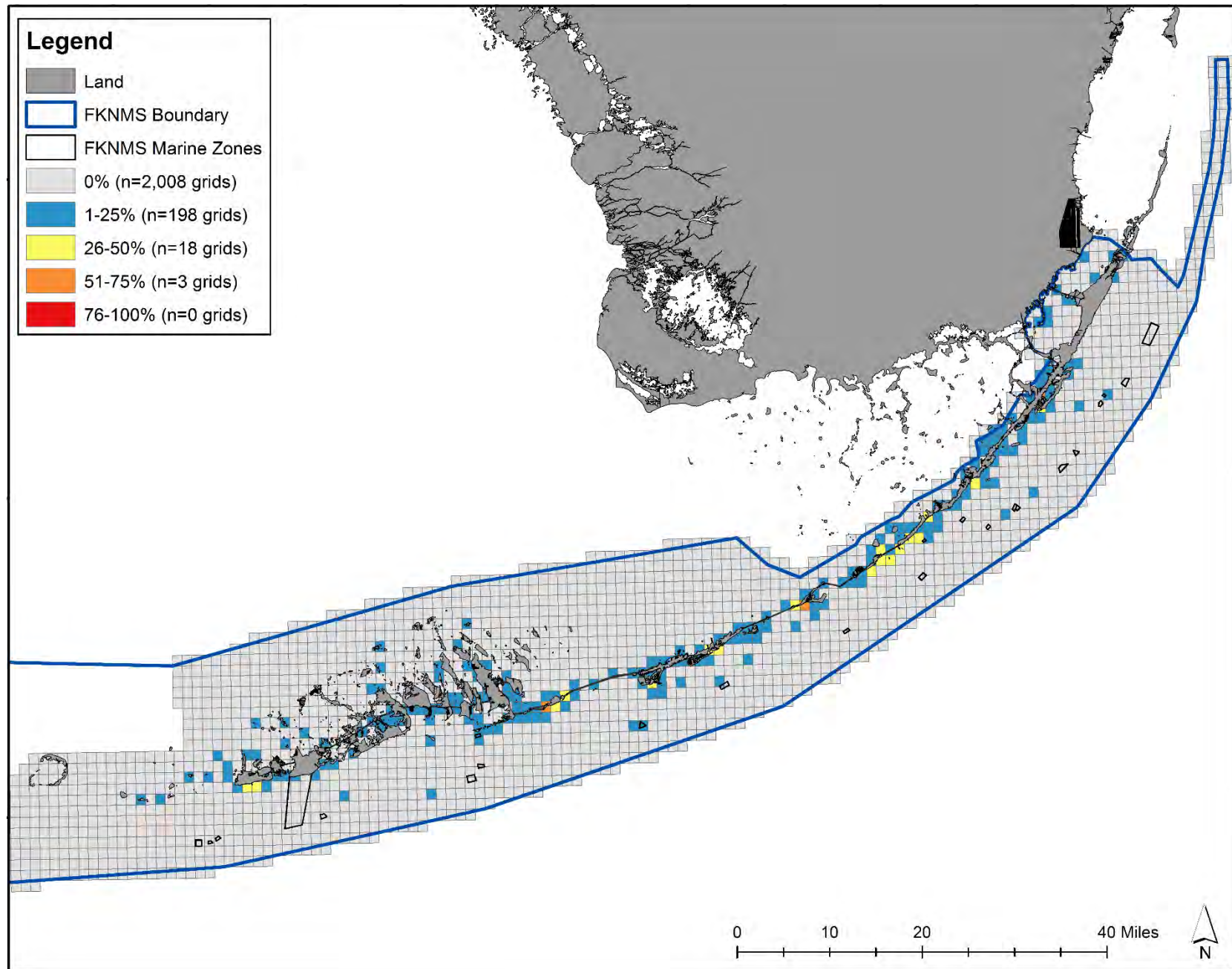


Figure 49 Map depicting the percent of time grids were occupied by paddlecraft (kayaks, paddleboards, and/or canoes) during all 2016-2017 surveys. (n = 29 flights, total boat count = 2310, total grids = 2,227). FKNMS marine zones are depicted using the same color or scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

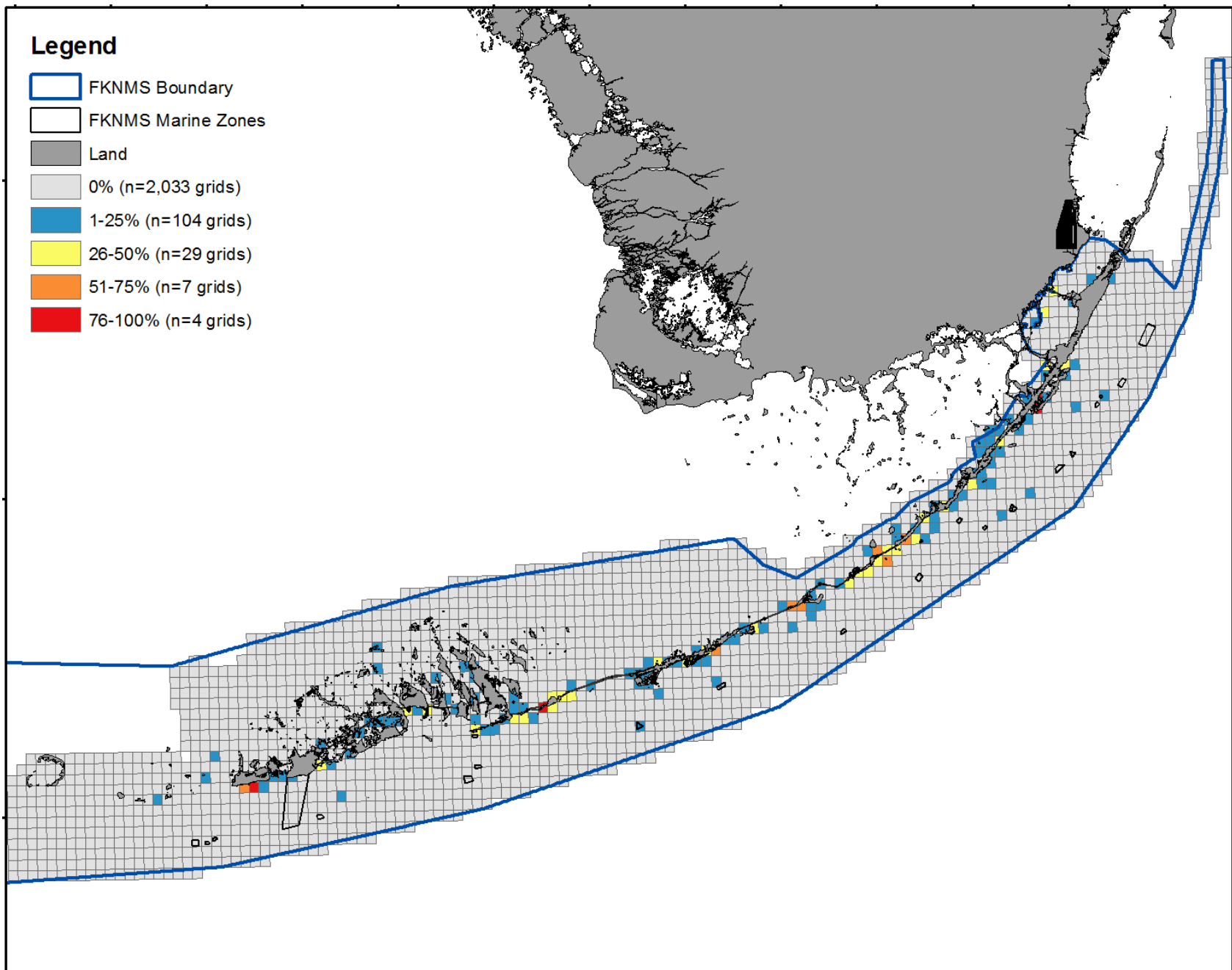


Figure 50 Map depicting the percent of time grids were occupied by paddlercraft (kayaks, paddleboards, and/or canoes) during surveys conducted at high-use (holiday and summer weekends) times. (n = 8 flights, total boat count = 1,157, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

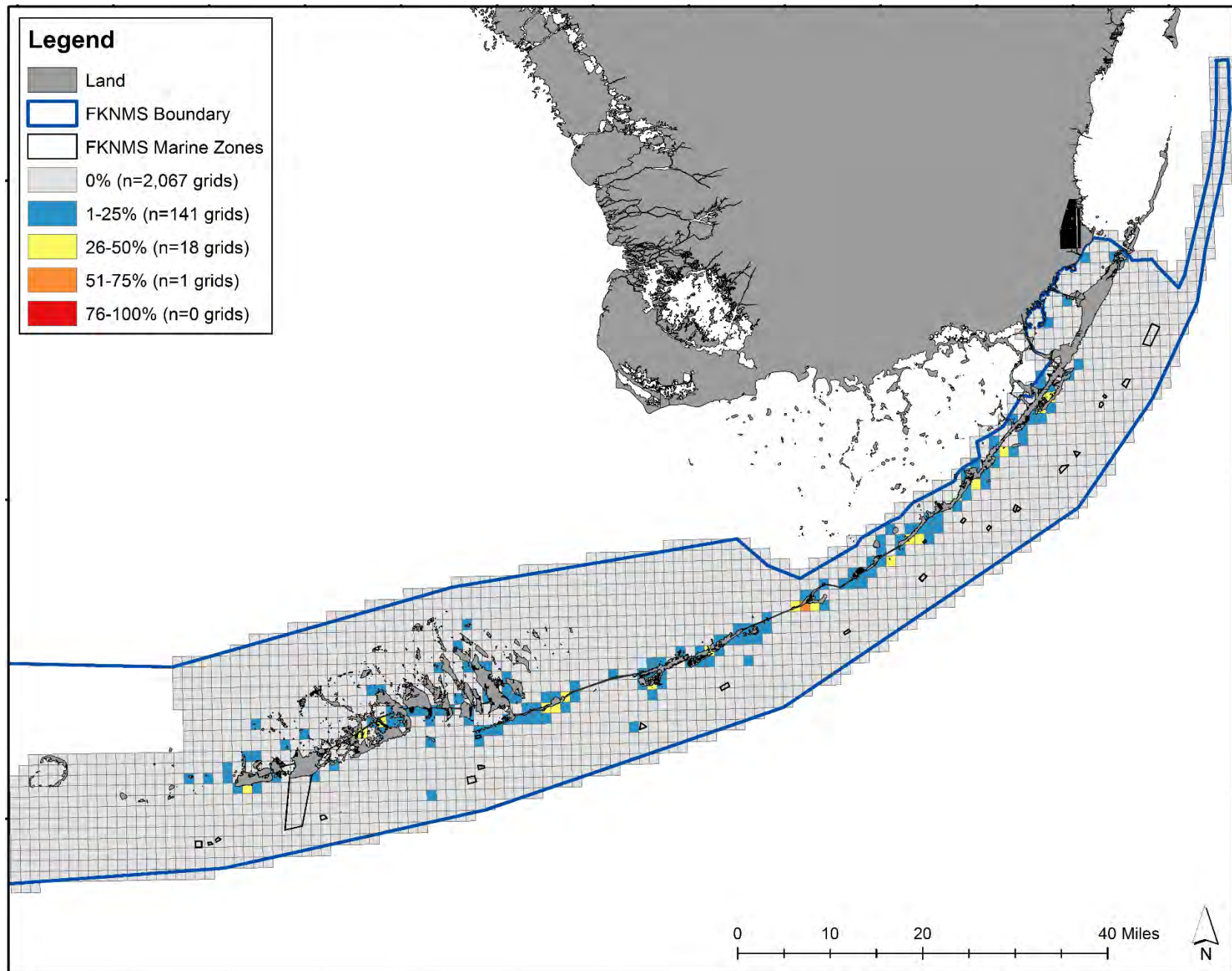


Figure 51 Map depicting the percent of time grids were occupied by paddlecraft (kayaks, paddleboards, and/or canoes) during surveys conducted at low-use times (winter weekdays and weekends and summer weekdays). (n = 19 flights, total boat count = 1,007, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

Watersports – Personal Watercraft (PWCs)

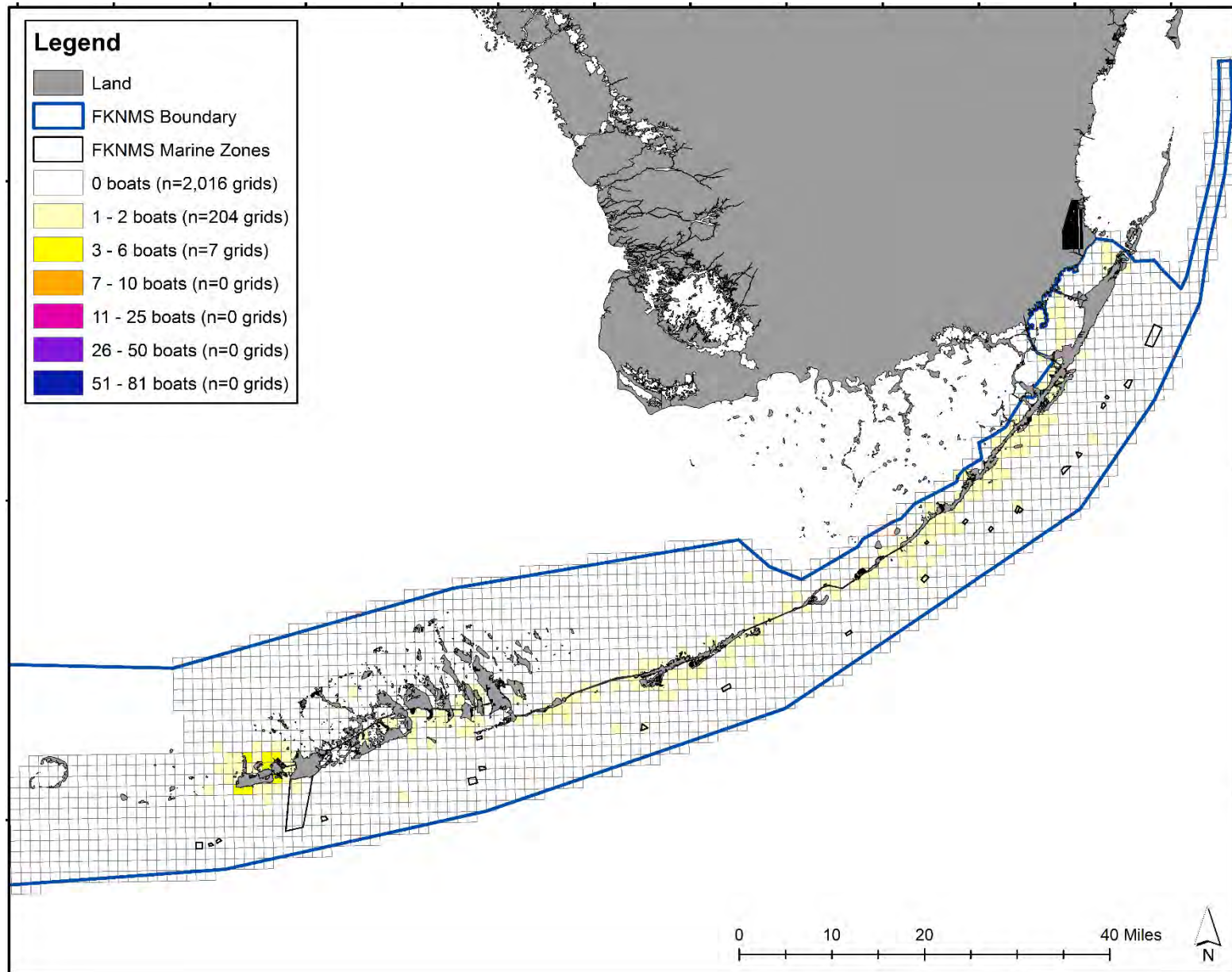


Figure 52 The average number of personal watercraft (PWC) per grid during all 2016-2017 surveys. (n = 29 flights, total boat count = 1914, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

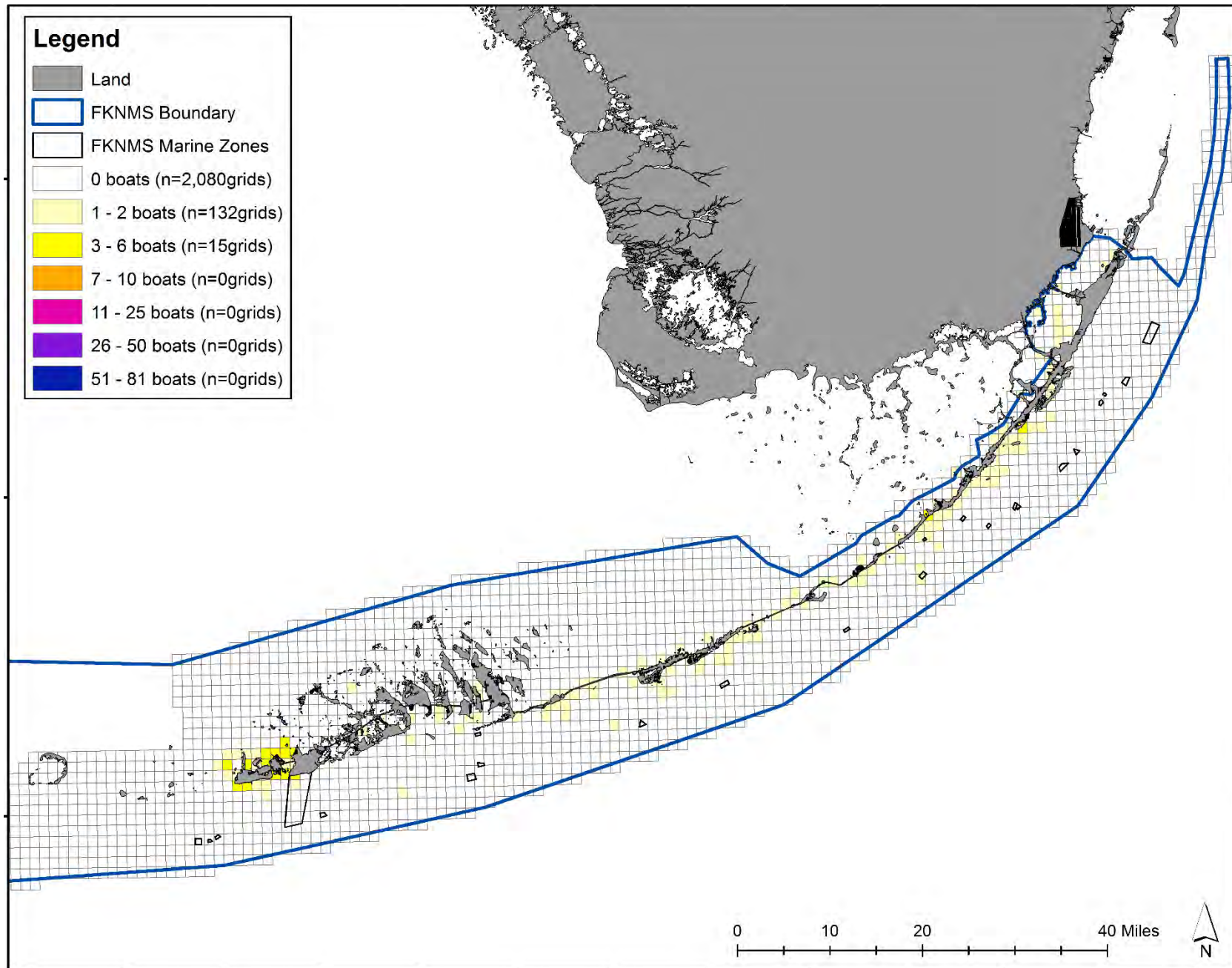


Figure 53 The average number of personal watercraft (PWC) per grid during surveys conducted at high-use (holiday and summer weekends) times. (n = 8 flights, total boat count = 852, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

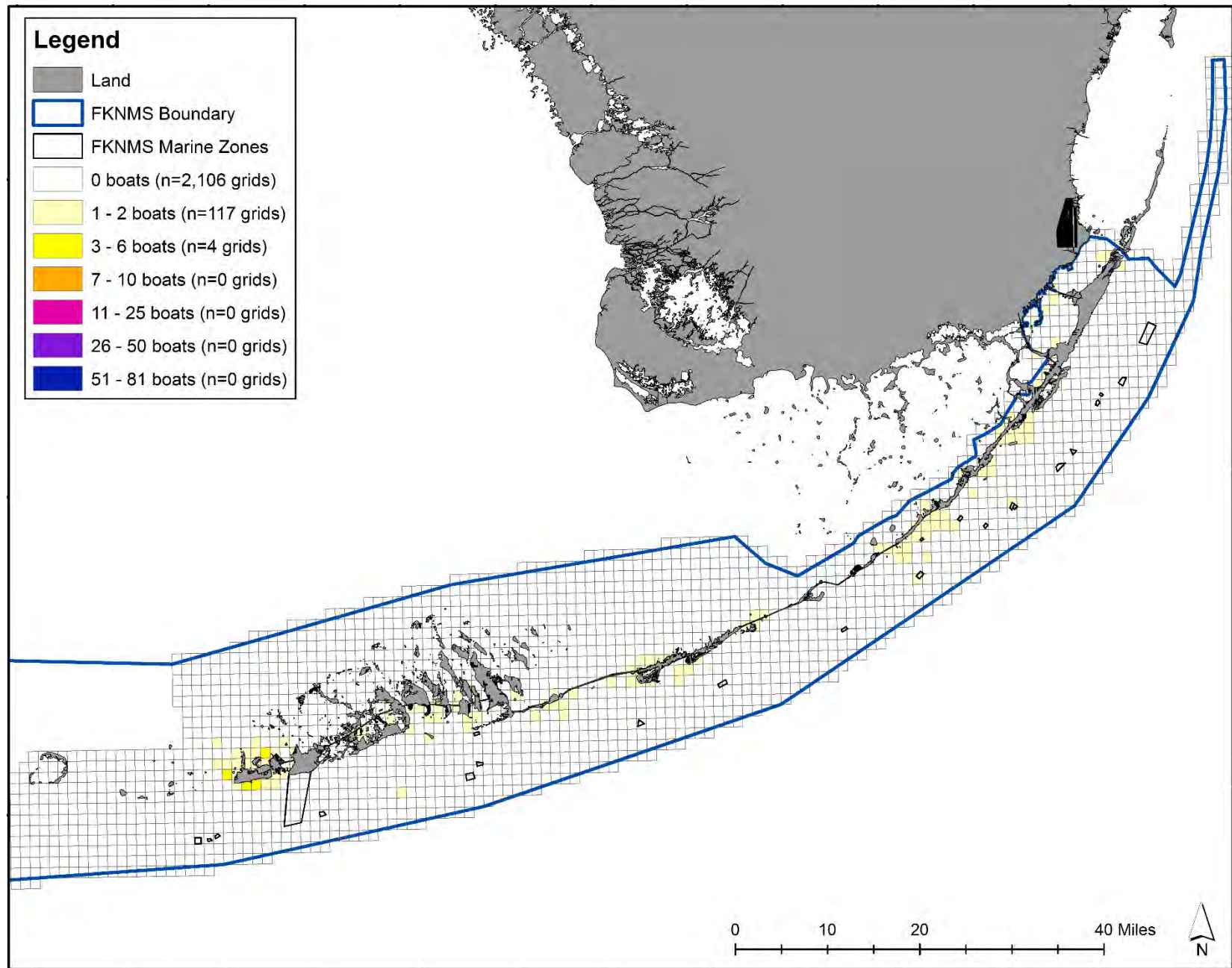


Figure 54 The average number of personal watercraft (PWC) per grid during surveys conducted at low-use times (winter weekdays and weekends and summer weekdays). (n = 19 flights, total boat count = 951, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

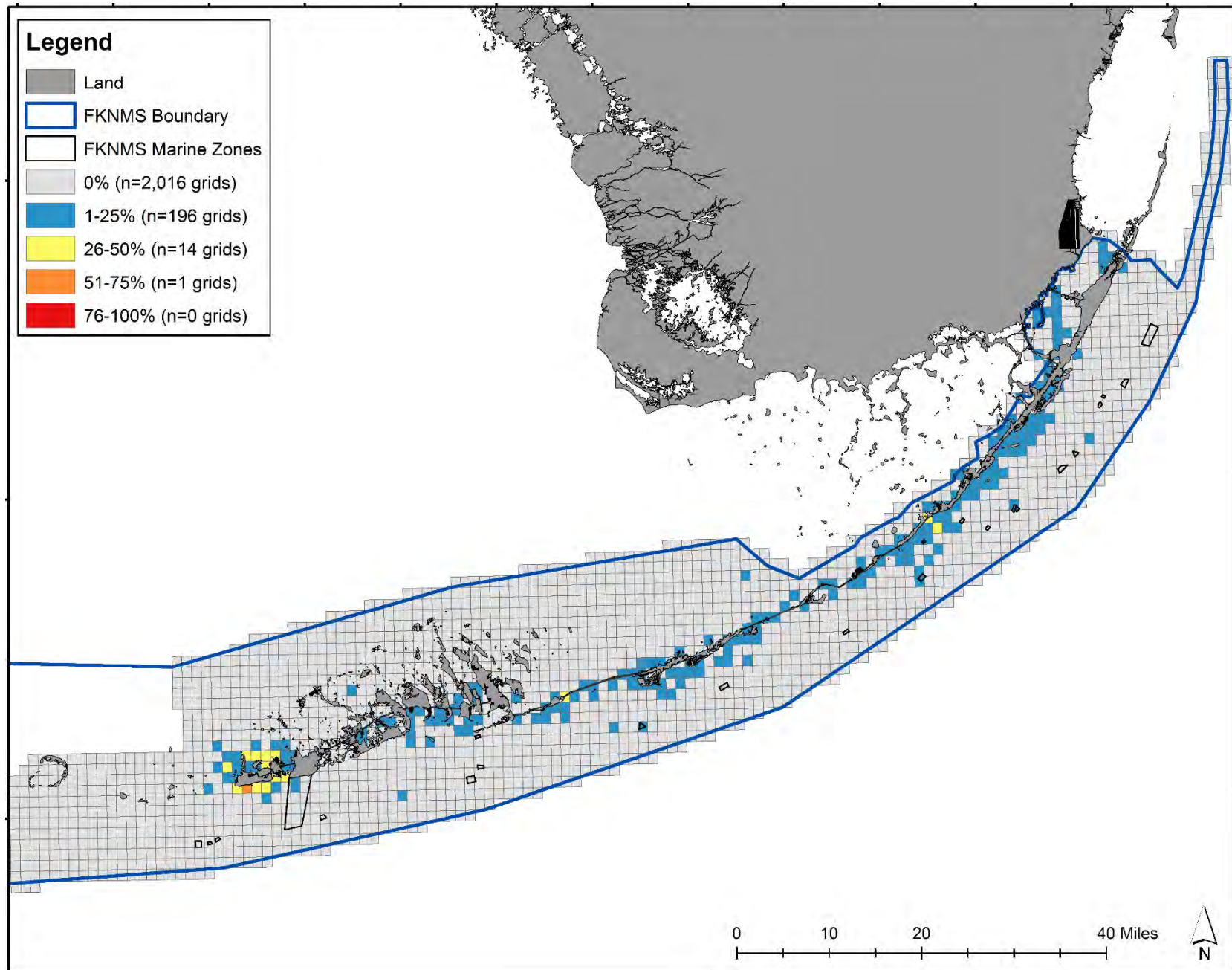


Figure 55 Map depicting the percent of time grids were occupied by personal watercraft (PWC). (n = 29 flights, total boat count = 1914, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

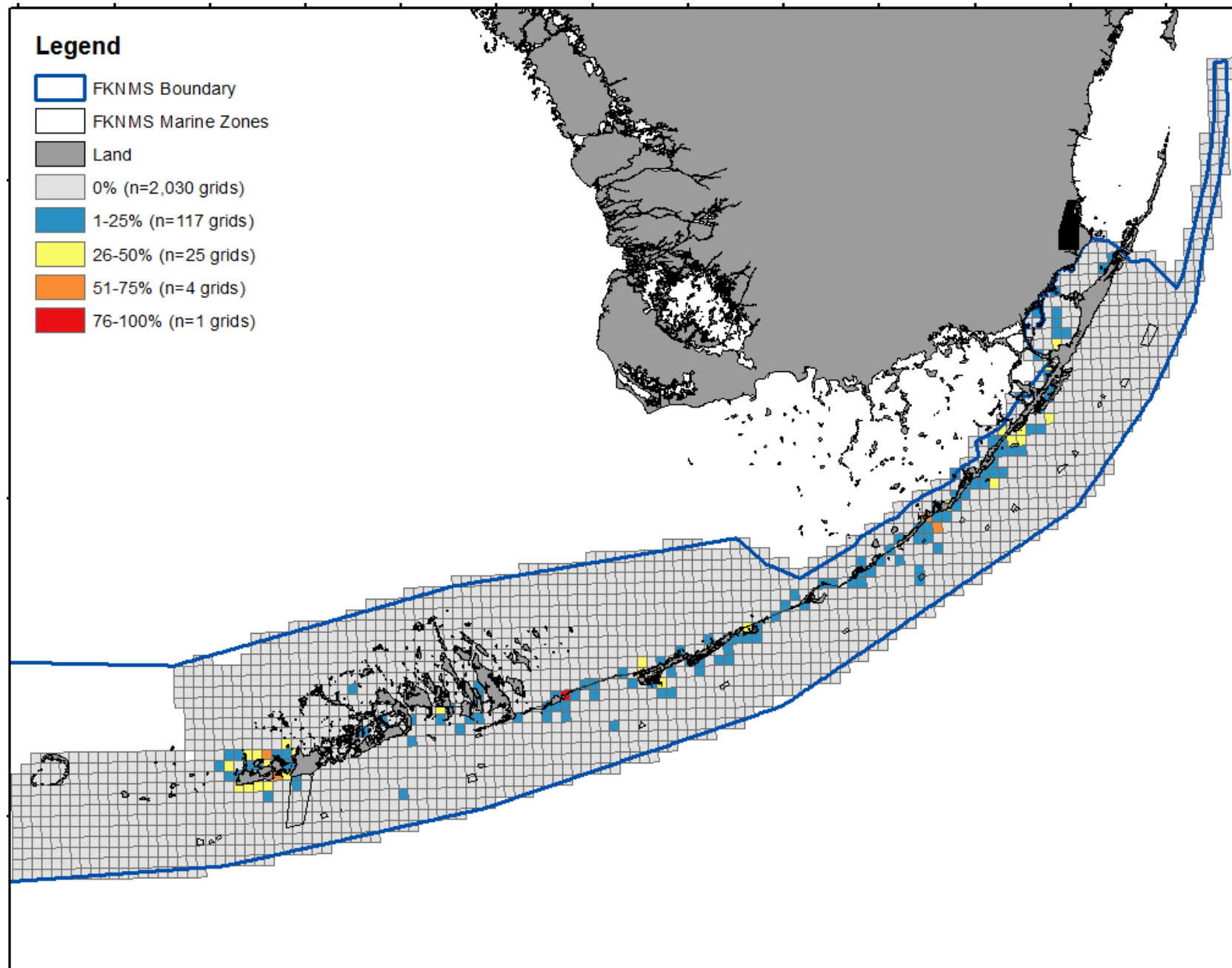


Figure 56 Map depicting the percent of time grids were occupied by personal watercraft (PWC) during surveys conducted at high-use (holiday and summer weekends) times. (n = 8 flights, total boat count = 852, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

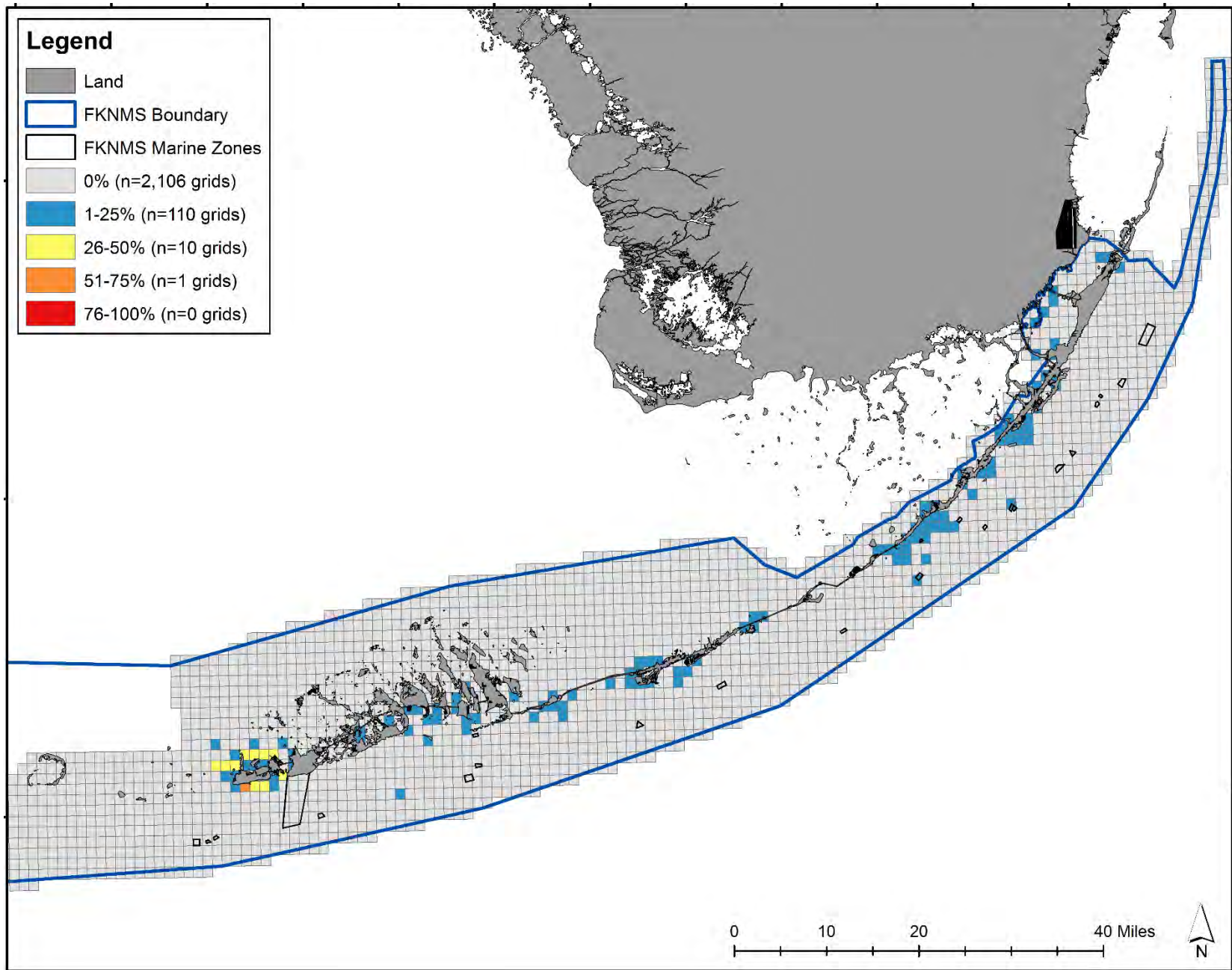


Figure 57 Map depicting the percent of time grids were occupied by personal watercraft (PWC) during surveys conducted at low-use times (winter weekdays and weekends and summer weekdays). (n = 19 flights, total boat count = 951, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for occupancy but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

Lobster Seasons Opening Days

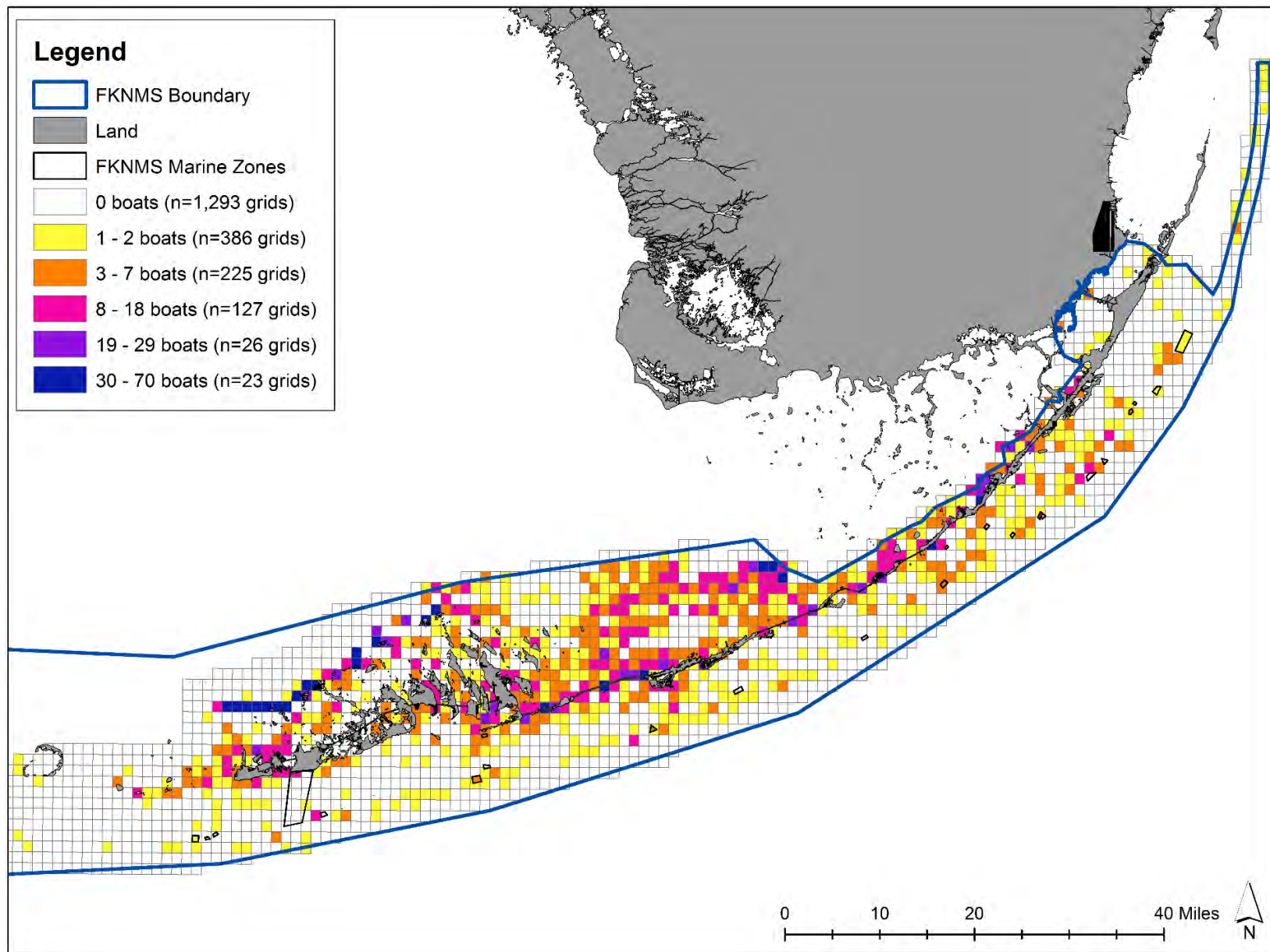


Figure 58 Number of boats observed per grid during Lobster Sport Season 2016 (July 27-28, 2016). (n= 1 flight, total boat count = 4818, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

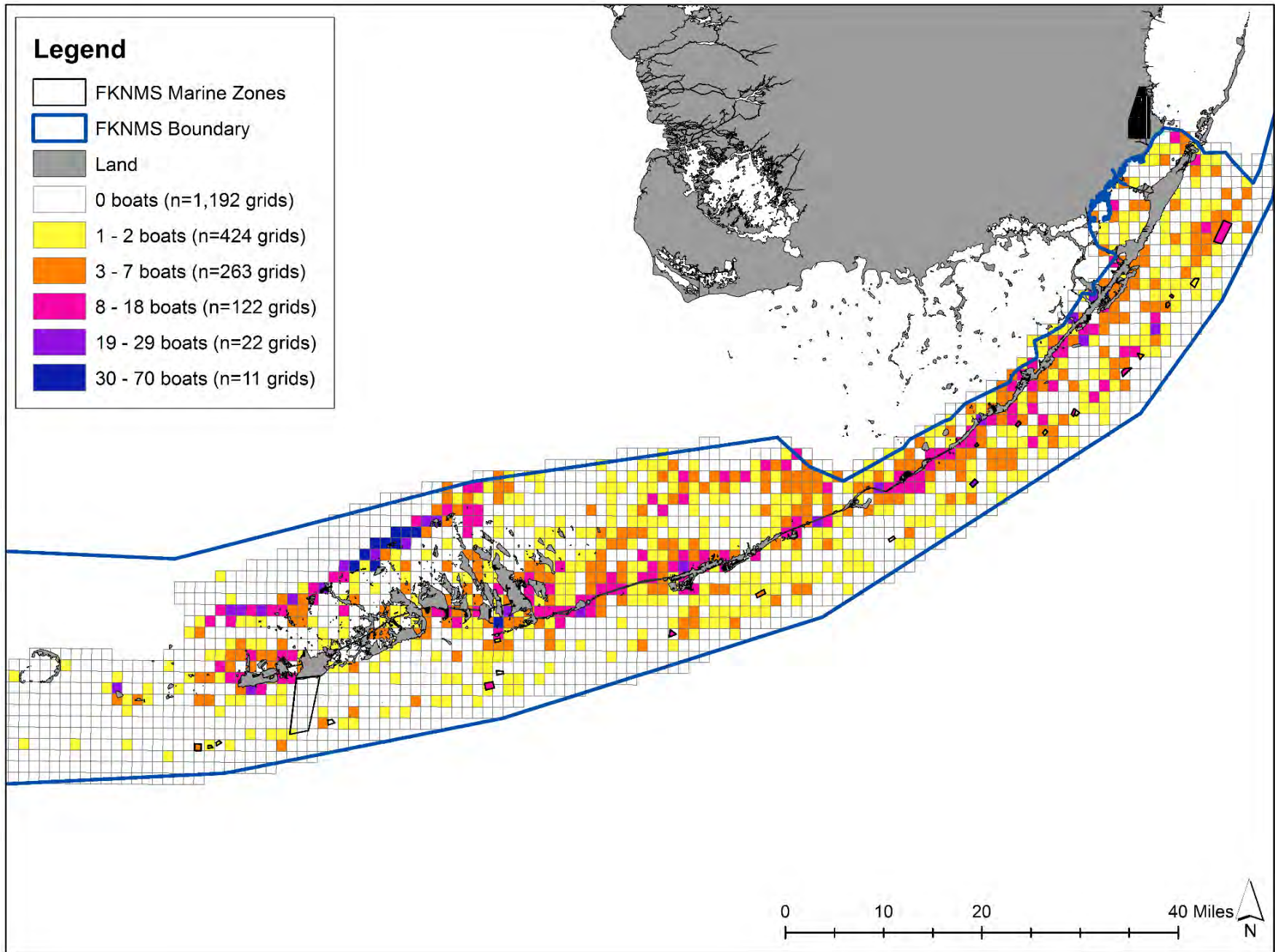


Figure 59 Number of boats observed per grid during Lobster Season Opening Day 2016 (August 6, 2016). (n= 1 flight, total boat count = 4096, total grids = 2,227). FKNMS marine zones are depicted using the same color scheme for average boat counts but are not included in the grid counts. Each grid represents 1 square latitude and longitude minute, which is approximately 1 square nautical mile.

Appendix B

Table 1. Counts of boats observed per flight by activity. Day type: WD = winter weekday, WE = winter weekend, SD = summer weekday, SE = summer weekend, Holiday = day that fell on a Holiday weekend, Lobster = lobster opening day.

Flight Date	Day Type	Boat Counts								
		Wind (mph)	Comm. Diving	Fishing	Comm. Fishing	Sandbar	Water-sports	Anchored	Running	Grand Total
2/2/16	WD	12.1	22	242	26	0	62	352	444	1148
2/6/16	WE	14.2	11	275	19	0	20	286	371	982
3/12/16	WE	20.6	9	145	9	0	52	257	307	779
3/26/16	WE	9.6	165	627	12	265	215	226	830	2340
3/30/16	WD	12.9	68	276	23	28	68	227	469	1159
4/2/16	WE	16.8	84	333	4	144	107	135	436	1243
4/4-5/2016	WD	12.3	127	377	3	29	60	196	368	1160
4/9/16	WE	13.5	99	545	3	47	181	188	495	1558
5/12/16	SD	7.1	127	424	0	31	109	197	400	1288
5/14/16	SE	7.5	309	750	2	369	243	263	785	2721
5/29/16	Holiday	4	518	567	1	1200	507	309	917	4019
6/4/16	SE	11.5	73	377	2	251	203	233	499	1638
6/10/16	SD	7.1	164	403	0	54	124	232	410	1387
6/20/16	SD	21.4	23	144	0	35	62	189	142	595

7/2/16	Holiday	9.9	368	370	0	535	242	203	735	2453
7/9/16	SE	7.3	357	344	1	404	271	211	577	2165
7/27-8/2016	Lobster	11.7	3300	63	3	38	93	251	1070	4818
7/31/16	SE	10.6	169	194	1	244	187	203	464	1464
8/6/16	Lobster	12.5	2109	143	11	291	241	241	1059	4096
8/20/16	SE	5.7	650	370	17	251	251	290	629	2459
8/23/16	SD	8.5	155	130	34	22	73	248	252	914
9/3/16	Holiday	10.9	380	311	21	357	211	250	622	2152
9/11/16	WE	9.8	94	192	3	76	95	256	289	1005
9/29/16	WD	3.2	120	132	36	37	80	253	272	930
11/4/16	WD	12.6	61	234	26	17	94	238	371	1041
11/5/16	WE	10.8	92	282	20	47	132	277	412	1262
12/1/16	WD	10	35	239	40	8	55	248	301	926
12/29/16	WD	6.3	333	867	20	71	331	275	927	2824
1/21/17	WE	15.5	24	552	18	64	168	260	495	1581
Grand Total			10046	9908	355	4915	4537	6994	15348	52107

Appendix C

Table 2. Events that occurred in the Florida Keys during the survey period (<http://www.fla-keys.com/calendar>). Dates in bold indicate dates when aerial survey flights took place.

Date	Event	Category	Location
Jan. 31-Feb. 11, 2016	Paddle with the Authors from Key Largo to Key West	Paddling	Florida Keys
Feb. 14-15, 2016	Islamorada Bartenders Sailfish Open	Fishing	Islamorada
Feb. 26-27, 2016	Spring Backcountry Fly Championship Series	Fishing	Islamorada
Mar. 5-6, 2016	2016 Charity Annual Billfish Blast	Fishing	Key Largo
Mar. 11-12, 2016	REEF Lionfish Derby for Divers	Diving	Islamorada
Apr. 2-3, 2016	Naval Air Station Key West 2016 Southernmost Air Spectacular	General	Key West
Apr. 22-23, 2016	REEF presents: Dive for the Fishes Weekend	Diving	Key Largo
May. 11-15, 2016	Kamp Key West	General	Key West
May. 21, 2016	Key West Ladies' Dolphin Championship	Fishing	Key West
Jun. 5-10, 2016	42nd Annual Don Hawley Invitational Tarpon Tourn.	Fishing	Islamorada
Jun. 10-11, 2016	Fourth Annual Ladies Dolphin Tourn.	Fishing	Islamorada
Jun. 17-19, 2016	Guy Harvey Outpost Inaugural Blazing Mako Tourn. & Festival	Fishing	Islamorada
Jun. 20-24, 2016	Gold Cup Tarpon Tourn.	Fishing	Islamorada
Jun. 24-26, 2016	Marathon Super Boat Grand Prix	Boat Races	Marathon
Jun. 25-26, 2016	Get Into Your Sanctuary Celebration	Diving	Florida Keys
Jul. 4-6, 2016	Poor Boys Tarpon Fly Tourn.	Fishing	Islamorada
Aug. 13, 2016	Inaugural Florida Keys Poker Paddle	Paddling	Florida Keys
Aug. 20-23, 2016	Coral Spawning Night Dives	Diving	Key Largo
Sep. 9-11, 2016	Robert James Sales S.L.A.M. Celebrity Tourn.	Fishing	Key West
Sep. 16-18, 2016	17th Annual Herman Lucerne Memorial Backcountry Fishing Champ.	Fishing	Islamorada
Sep. 17, 2016	Fourth Annual Islamorada Swim for Alligator Lighthouse	Swim	Islamorada
Sep. 20-23, 2016	Project Healing Waters Fly Fishing	Fishing	Islamorada
Sep. 22-25, 2016	Maverick Boat Group Funament Owner's Tourn.	Fishing	Islamorada
Sep. 22-25, 2016	Marathon International Bonefish Tournament	Fishing	Marathon
Sep. 23-25, 2016	Take Stock in Children Backcountry Challenge	Fishing	Key Largo
Sep. 30-Oct. 1, 2016	9th Annual Mad Dog Mandich Inshore & Offshore Fishing Classic	Fishing	Islamorada
Oct. 7-9, 2016	Robert James Sales Baybone Celebrity Tourn.	Fishing	Islamorada
Oct. 14-15, 2016	15th Annual Casting for Cats Fishing Tourn.	Fishing	Islamorada
Oct. 15-16, 2016	Fifth Annual Standup Paddle Invitational 2016	Paddling	Islamorada
Oct. 29-30, 2016	Fall Backcountry Fly Champ. Series	Fishing	Islamorada
Nov. 4-6, 2016	Robert James Sales Redbone Celebrity Tourn.	Fishing	Islamorada
Nov. 6-13, 2016	35th Annual Key West World Champ. Races	Boat Races	Key West
Nov. 10-12, 2016	Cheeca Lodge & Spa All-American Backcountry Tourn.	Fishing	Islamorada

Dec. 1-4, 2016	Islamorada Sailfish Tourn.	Fishing	Islamorada
Jan. 9-15, 2017	Florida Keys Paddle Challenge	Paddling	Florida Keys
Jan. 15-20, 2017	30th Annual Quantum Key West Race Week 2017	Boat Races	Key West
