Integrating the Florida Keys National Marine Sanctuary Research Permit Database with ArcGIS to Visualize Scientific Utilization Patterns

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INTRODUCTION

National Marine Sanctuaries are designated in specific areas to promote comprehensive management of their special ecological, historical, recreational, and aesthetic resources. The Florida Keys National Marine Sanctuary (FKNMS) was established by Congress in 1990 to preserve the Florida Keys' unique marine environments and resources, including the third largest barrier coral reef in the world, mangrove forests, seagrass beds, and the various maritime heritage resources resulting from centuries of shipwrecks. The FKNMS encompasses four National Wildlife Refuges (NWR), ten state parks, and shares boundaries with Biscayne, Everglades, and Dry Tortugas National Parks.

Because the FKNMS is the only sanctuary to entirely encompass a community and its management plan is designed to incorporate marine zoning as a way to manage human use, FKNMS issues the most permits in the system of National Marine Sanctuaries to cover a wide variety of activities that would otherwise be prohibited. The Superintendent may issue these permits if he/she finds that the activity will: further research or monitoring related to Sanctuary resources and qualities; further the educational value of the Sanctuary; further the natural or historical resource value of the Sanctuary; further salvage or recovery operations in connection with an air or marine casualty; assist in managing the Sanctuary; or otherwise further Sanctuary purposes, including facilitating multiple uses of the Sanctuary to the extent compatible with the primary objective of resource protection. In addition, Special Use Permits and Maritime Heritage Resources Permits are also available.

The Sanctuary issues about 60-70 research permits a year to various individuals in academia, government, and private businesses. Although a database of these permits is maintained via the Online Sanctuary Permitting, Reporting, and Evaluation sYstem (OSPREY), it does not provide a direct geospatial reference for these permits nor does it offer an easy form of comparison between permits. Therefore, this project expanded upon an earlier pilot study initiated in 2008 to integrate the Florida Keys National Marine Sanctuary research permit database with ArcGIS to visualize and examine scientific utilization patterns. Specifically, this project incorporated five years of research permitting data (2005-2009), which allowed me to examine time-series trends in scientific resource utilization patterns. In addition, I improved upon how these data were displayed within ArcGIS maps, making it easier for the permits managers to use.

Working through the National Ocean Service line office with the Office of National Marine Sanctuaries in Key West, Florida, I selected this project to build upon my educational introduction with the ArcGIS software. The need for scientists to utilize this software in creative solutions is growing. As a young scientist, I want to keep abreast of the newest technologies while still providing a useful service to the public. In addition, I desire to gain a better understanding of the complexity of managing human use in marine environments. The need to balance protection of delicate ecosystems with a high recreational and steady commercial marine reliance in the Keys creates an ongoing challenge for managers.

QUESTION/HYPOTHESIS

Because most scientific activities occurring within the Florida Keys National Marine Sanctuary are not exempt from the Sanctuary regulations, the FKNMS issues approximately 60-70 research-based permits a year to allow scientists to conduct their work. Despite the high species richness due to diverse community types, most consumptive research is known to focus on the vulnerable coral reefs. Generally, coral reef scientists keep their consumptive "foot print" to a minimum, but resource managers are beginning to monitor these activities to facilitate research collaboration if it results in reduced impact to the resources. As a result, the project tests whether ArcGIS can be used to assess spatial patterns in consumptive research within the FKNMS and evaluate trends in resource (taxonomic) utilization. In relation to the main hypothesis, this work will suggest whether or not scientists potentially miss out on collaborative opportunities based on their overlapping interests and/or spatial coverage. These two questions drive the need for the creation of visual aids to help resource managers reduce and/or reassess potential impacts.

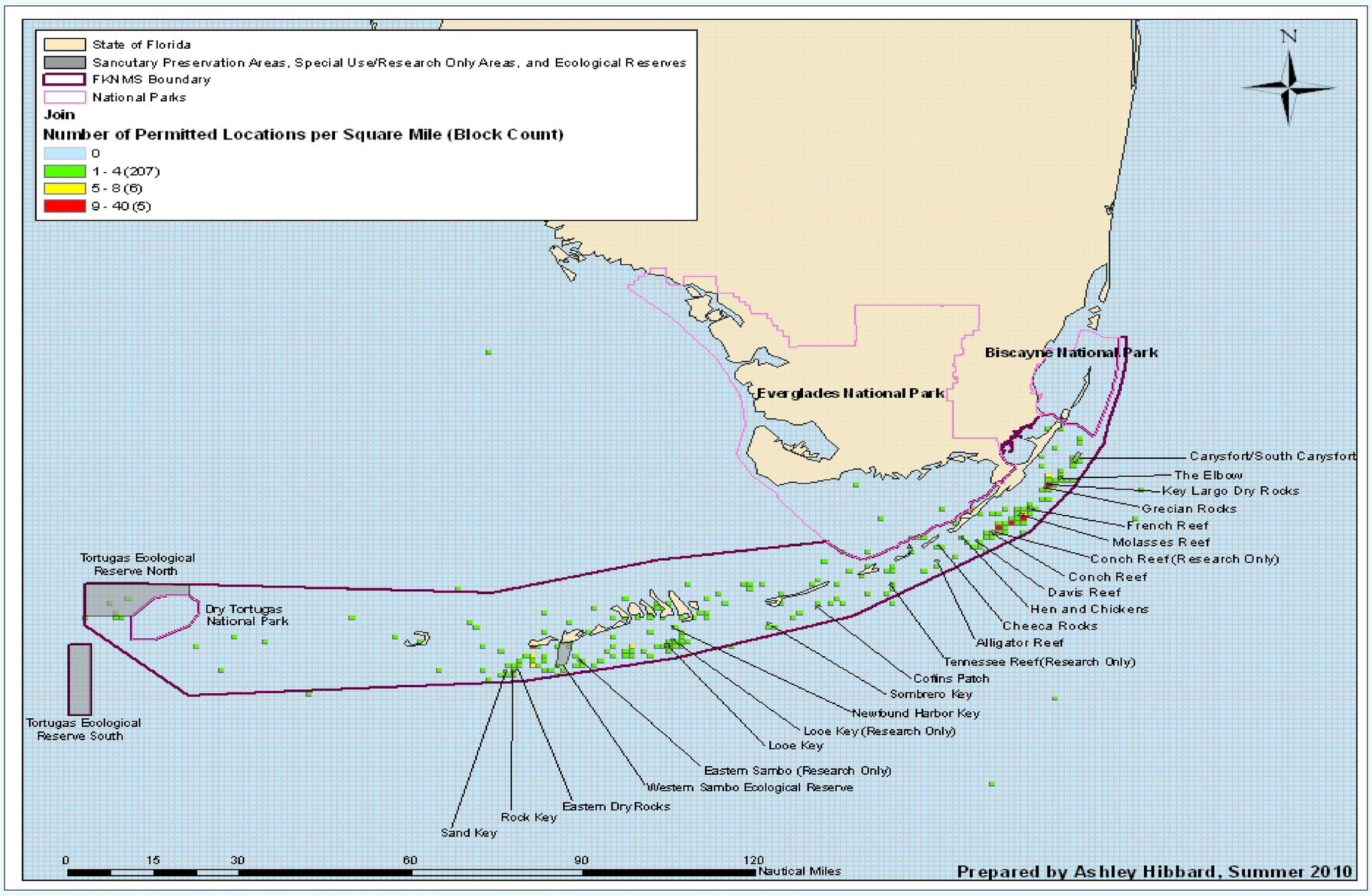

Figure 1. Distribution of permitted research locations within the Florida Keys National Marine Sanctuary from 2005-2009, displayed as number per square mile with a graduated color system.

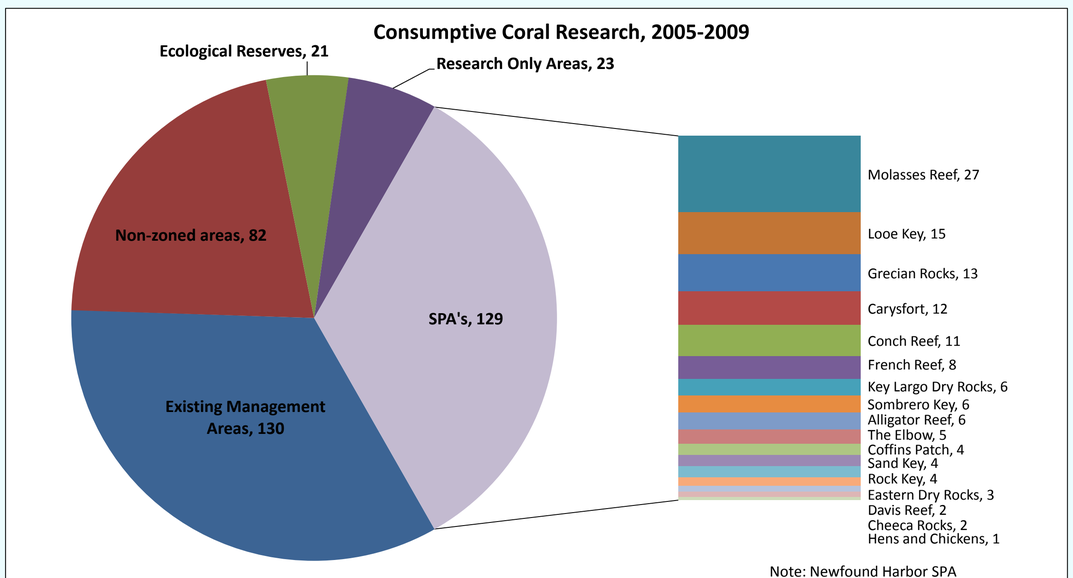

Figure 2. Total number of consumptive coral research permits issued from 2005-2009, divided by type of location.

PREDICTION

Based on the pilot project completed for research permits issued in 2007 and outside research in FKNMS management documents (such as the Comprehensive Science Plan and the Revised Management Plan), I hypothesize that ArcGIS is a useful tool to assess spatial patterns in consumptive research within the FKNMS. Likewise, because of my working knowledge of the software, I believe this geodatabase will prove especially useful when incorporating a multi-year and multi-interest dataset into the program. In addition, I predict that the software's wide range of tools will allow for a thorough assessment of taxonomic utilization. Because coral reef research is widespread throughout the FKNMS, occurring in all zoned areas (e.g., Sanctuary Preservation Areas, Research Only Areas, Ecological Reserves, etc.) and along the Reef Tract (e.g., Sand Key, Pelican Shoal, Coffins Patch, Grecian Rocks, etc.), I predict that some scientists are potentially missing out on collaborative opportunities, based on their overlapping interests and/or spatial coverage, because they do not possess an awareness of each other's research. In addition to lost opportunities, this suggests that overlap could result in overuse in certain areas of the Sanctuary, especially the protected marine zones.

MATERIALS

A Dell Precision 370 workstation was provided for access to the suite of ArcGIS Version 9.2 software, including ArcMap, ArcCatalog, and ArcGlobe. The formatting of the OSPREY permitting database lent itself to data organization and analysis through Microsoft Office Excel 2007. Poster creation relied on a combination of ArcMap and Microsoft Office PowerPoint 2007. Though the preparation of new permit shapefiles resulted from information obtained through OSPREY, many of the Marine Protected Areas (MPA) and Florida land shapefiles already existed in the FKNMS geodatabase. All ArcGIS maps depict a low resolution Florida land shapefile because it provides the least amount of distraction from the permitting data, which stands as the focus of this project.

PROCEDURE

Because this project is an expansion of a pilot study completed in 2008, the OSPREY database was queried for research permits issued from 2004-2009 for the FKNMS. The query results were exported as Microsoft Excel worksheets separated by year so that the data could be further investigated and formatted to ensure compatibility with ArcGIS. Although the data included comprehensive descriptions of each permitted research project, only information relevant to the current study was used. This allowed for a division of the permits into consumptive and nonconsumptive research. Consumptive research results in the taking of some resource from the Sanctuary; for example, coral mucus samples or even core samples constitute consumption, whereas temporary deployment of equipment on the seafloor represents nonconsumptive research because it does not destroy any part of the resource.

An ArcGIS geodatabase was created in order to visualize scientific utilization patterns within the FKNMS. Existing shapefiles were used to build the base map for this project, but a new "point" shapefile was created using the permit data from 2005-2009 within the Excel spreadsheet. Data from 2004 was sparse in the OSPREY database, so that year remains absent from the analysis. To generate the necessary shapefile, the aforementioned spreadsheet was modified so that the research locations listed in each permit had corresponding GPS coordinates. For those research permits that listed a particular FKNMS zone, as opposed to an exact GPS coordinate, a second Excel file was created to qualify those "polygon" data. To analyze all consumptive research data, I created an additional variable to indicate the activity type as consumptive or non-consumptive.

The most challenging variable of the project resulted from permits that listed only a general location for the research activities. When a permitted research area was listed as "Sanctuary-wide" or "non-zoned areas within the Sanctuary," I could not create a location for it; randomly generating a polygon at this scale would be too inexact and may have created additional problems in the analysis. After combining the five years of consumptive research locations, a graduated color map was created in ArcMap. Sampling tools allowed for the FKNMS to be sectioned into blocks measuring one square nautical mile by using a fishnet/polygon vector grid. After plotting the research points on the map, a spatial join between the points layer and the fishnet layer resulted in a count of the number of points per grid block. The count was displayed as a graduated color system, with each block being assigned a particular color based on the number of uses for consumptive research in the five year period.

My second map used regional pie charts to visualize the spatial distribution of consumed resources for various areas of study. As each permit was assigned a primary interest based on the focus of the research (e.g. coral, seagrass, sediments, invertebrates, etc.), the main type of consumptive research could be visually depicted by Keys regions. A chart also provides totals of research interests over the five year period.

RESULTS

The majority of permitted research occurring in the range of 2005-2009 was consumptive in nature – a total of 61.93% of all research permits issued. However, the same majority of consumptive research was very low impact, only taking coral mucus samples or collecting fish larvae.

A non-analytical, visual interpretation of the spatial distribution of FKNMS research activity showed some clustering of research activity (Figure 1). The middle and lower Keys showed research locations to be widely dispersed, whereas the upper Keys showed research activities concentrated into a few distinct areas. The upper part of the Sanctuary, including the Key Largo National Marine Sanctuary Existing Management Area (EMA) and nearby Sanctuary Preservation Areas (SPA), namely Conch Reef, Davis Reef, Molasses Reef, Carysfort, The Elbow, French Reef, and Grecian Rocks, had a higher concentration of research sites. Several of the SPAs in this area, such as Carysfort, Molasses Reef, French Reef, and Conch Reef, had more than fifteen research sites in a five-year period. For example, within Molasses Reef there were thirty-eight research sites, twenty-seven of which were related to coral research. Likewise, within in the Western Sambo Ecological Reserve in the Lower Keys, there were sixteen research sites, where eight of these were related to non-consumptive coral research.

The majority of research focused on coral ecology. Generally, coral research occurring in the FKNMS covered a variety of topics, including reproductive biology and early-life development, microbial community organization and development, health and disease, bioindicators, zooxanthallae, restoration, genomics, and benthic communities. A cursory examination of where consumptive coral research occurred between 2005-2009 revealed that the majority of effort was generally within SPAs and EMAs (Figure 2). Of these areas, the majority of coral research occurred in the Upper Keys, which is most likely due to the high density of reefs (both barrier and patch) in that area along with easier access from mainland Florida. In addition to coral, there were also several permits issued whose research focused on fish, including research on reef fish, snapper and grouper (Figure 3).

CONCLUSION

This project showed that even from a non-analytical approach, GIS can be used to assess spatial patterns of both consumptive and non-consumptive research within FKNMS. The success of not only displaying permitted locations on a map, but identifying "hot spots" of high consumption *and* heavy use will allow Sanctuary resource managers the insight to reduce permitting to these areas of high interest. This could effectively spread the research footprint to more of the Florida Keys or encourage the sharing of data between scientists to reduce the overall human impact on the reef. The results indicate that the prediction of ArcGIS's success in analyzing multi-year data points holds true.

When examining research within the SPAs, the majority of the consumption occurring between 2005-2009 targeted corals, but only at low impact by collecting mostly coral larvae. However, one must consider that the focus of this research spanned a wide variety of topics and it was rare to find research on the same or similar topics within the same SPA or nearby areas. Therefore, there was not a large amount of overlap between research permit locations and fields of study; as a result, the likelihood that scientists were missing collaborative opportunities in that five-year period is low. This result is surprisingly opposite of the author's prediction. Considering the high overlap of permitted locations, especially in the upper Keys, the thought that a high density of research all focused on entirely different topics seemed counterintuitive to me. However, realizing that biodiversity and species richness on coral reefs ranks higher than most other tropical ecosystems, I see the issue to be more of human impact on the area and less of a research collaboration effort.

Although this is the second attempt at visualizing scientific utilization patterns within the FKNMS, these data are representative of a five-year period in the Sanctuary's twenty-year existence. It would be beneficial for the reef managers to expand this geodatabase to include all permits issued by the Sanctuary from the past and in subsequent years. From an interpretive standpoint, it was difficult to determine the best method for visualizing and analyzing the data because research permit locations varied between points and general areas (polygons). Creating randomized points is not the best representation of research in 'general areas', especially for larger areas like the Key Largo National Marine Sanctuary EMA. Some of the permits were issued for "Sanctuary-wide" research or "non-zoned areas within the Sanctuary," which made it impossible to quantify or reduce to a polygon. It is recommended that the PI's provide data as specific sites and/or specific coordinates when research permits are issued. Understanding the nature of field research, however, indicates that PI's may need to search for adequate collection sites for their data. Thus, the best solution would be to require exact coordinates of research locations in the submitted final report; this would effectively take care of two of the issues addressed in this project: devising a more effective method of displaying data on maps and increasing compliance with permit conditions.

This project possesses the potential for further investigation and to become another tool in the management of marine protected resources. The impact of human use (in the form of research activities) on smaller spatial scales, and over longer time-frames improves the pilot project, but reviewing the cumulative effects of research is still a challenging task. Without a spatial representation of permitted research, the OSPREY database cannot track the use of an area. In terms of permitting, both geography and consumption can be improved upon. "Tagging" research permits with set key words can help make the transition from an online database to a visual depiction easier. The combination of improving the FKNMS permitting system, along with establishing a spatially based representation of research, will aid resource managers in keeping the fine balance between protecting the delicate marine ecosystem and controlling human productivity and enjoyment in the Florida Keys National Marine Sanctuary.

ACKNOWLEDGEMENTS

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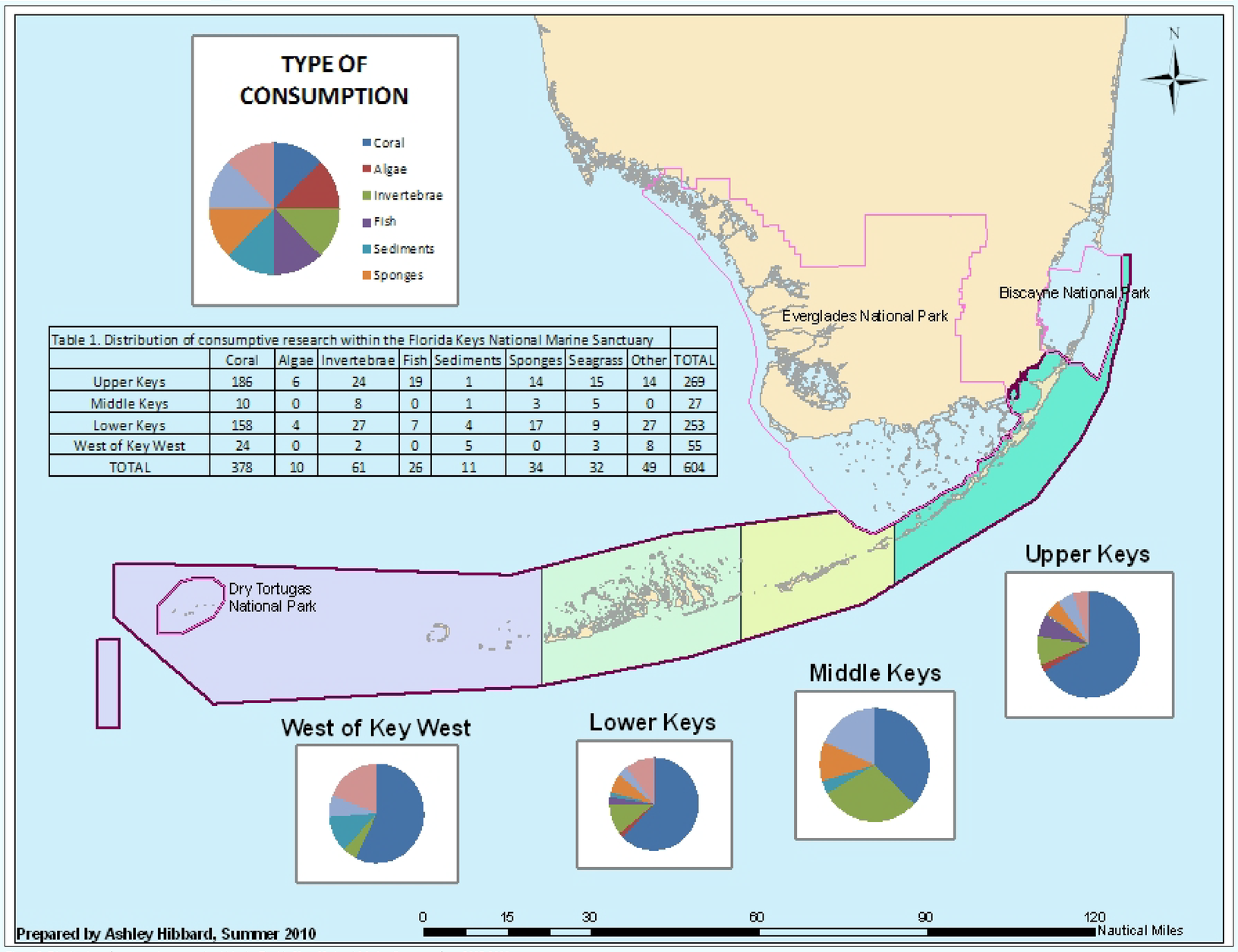

Table 1. Distribution of consumptive research within the Florida Keys National Marine Sanctuary

	Coral	Algae	Invertebrae	Fish	Sediments	Sponges	Seagrass	Other	TOTAL
Upper Keys	186	6	24	19	1	14	15	14	269
Middle Keys	10	0	8	0	1	3	5	0	27
Lower Keys	158	4	27	7	4	17	9	27	253
West of Key West	24	0	2	0	5	0	3	8	55
TOTAL	378	10	61	26	11	34	32	49	604

Figure 3. Distribution of consumptive research within the Florida Keys National Marine Sanctuary from 2005-2009.