Survey of human activities at five seagrass sites on Fishers Island, New York

Fishers Island Seagrass Management Coalition

MPA Watch

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April 2021

Funded by a grant from the

Long Island Sound Funders Collaborative, Long Island Community Foundation

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ACKNOWLEDGEMENTS

Thank you to Angela Kemsley for helping the Fishers Island Seagrass Management Coalition get started and established with MPA Watch, and for flying from California to the East Coast in 2019 to do in-person trainings. We would also like to thank the Fishers Island community members who volunteered their time for this project.

Steve Arnott thanks the Fishers Island Seagrass Management Coalition for the award of a contract to work on the project.

The Fishers Island Seagrass Management Coalition is grateful for funding provided by the Long Island Sound Funders Collaborative at the Long Island Community Foundation.

INTRODUCTION

Seagrasses are a type of submerged aquatic vegetation, with seventy-two extant species occurring globally in temperate and tropical coastal waters. They are marine angiosperms (flowering plants) that grow as leafy "meadows" on sandy, sunlit areas of seabed, anchored within the sediment by a network of roots and rhizomes (Short et al., 2011).

Seagrasses provide many ecosystem services, defined as natural processes that directly or indirectly benefit wildlife and humans (De Groot et al., 2002; United Nations Environment Programme, 2020). On a global scale, they are an important component of blue carbon, a term that refers to the carbon stored in coastal and marine ecosystems. Although seagrasses cover less than 0.2% of the ocean floor, they store ~10% of the carbon sequestered by the oceans each year from the atmosphere, thereby helping to offset the effects of human carbon emissions (Nellemann et al., 2009; Fourqurean, 2012; Blue Carbon Initiative, 2021). Other ecosystem services vary depending on species and location, with more than a dozen being linked with *Zostera* meadows in the northern Atlantic, including nutrient sequestration (e.g., nitrogen removal), oxygen generation, provision of essential habitat for wildlife, including many economically important marine organisms, sediment accretion, seabed stabilization, education, recreation, and tourism (Nordlund et al., 2016).

Despite their importance, seagrasses have been declining worldwide for decades (Waycott et al., 2009). The history of seagrasses in Long Island Sound (LIS) is a case in point. Two species occur in the region: a dominant eelgrass species (*Zostera marina*), and a less common species, widgeon grass (*Ruppia maritima*), which is confined to more brackish areas. Seagrass meadows were common in shallow waters throughout most of LIS prior to the 1930s, but a widespread fungal disease at that time decimated many areas. In later decades, seagrasses were further impacted by eutrophication caused by nitrogen discharges from sewage and land runoff (Long Island Sound Study, 2004, 2006). Today, they are confined to the eastern portion of LIS (east of the Connecticut River), where water quality is more ocean-influenced, and less degraded, compared with western and central sections.

Of the seagrass meadows existing today within New York State waters, ~96% occur around Fishers Island (Bradley & Paton, 2018). Other areas of seagrass within New York State waters occur in embayments along the southern and eastern parts of Long Island, but they too have declined dramatically since the 1930s (New York State Seagrass Taskforce, 2009).

There is no federal legislation that directly protects seagrasses in the U.S., although they do receive some indirect protection under the Magnuson-Stevens Fishery Conservation & Management Act, because they are designated Essential Fish Habitat, and under the Clean Water Act, which regulates some discharges that harm seagrasses. At the state level, New York passed a Seagrass Protection Act (State of New York, 2012) that authorizes the New York State Department of Environmental Conservation (NYSDEC) to protect extant seagrass habitats, and to regulate coastal and marine activities that threaten seagrasses and restoration efforts. Methods of achieving this include: (i) designating seagrass management areas (SMAs), (ii) developing and adopting a management plan for each SMA, and (iii) consulting with local governments, recreational boaters, marine industries, fishermen, affected property owners and other stakeholders to effectively manage, protect and restore seagrasses.

More recently, the 2017-2027 New York Ocean Action Plan (3.2.3 Action 2) called for the implementation of seagrass management plans for designated SMAs, including the regulation of marine and coastal activities to protect seagrasses from further decline. The goals of the management plans are to ensure the ecological integrity and resilience of the ocean ecosystem, and to sustain the biodiversity and local economy that is inextricably linked with it (New York State Department of Environmental Conservation, 2017).

This report focuses on seagrass habitats in the coastal waters of Fishers Island, located at the eastern end of LIS. Co-management of SMAs, involving both state and community partners, has been proposed as an effective method of protecting Fishers Island seagrass habitats (Collier, 2016). Using this approach, the island's H.L. Ferguson Museum and the Fishers Island Conservancy, with the assistance of The Nature Conservancy (TNC), convened relevant community partners to form the Fishers Island Seagrass Management (FISM) Coalition in 2017.

The coalition comprises representatives from twenty community-based stakeholder groups that depend upon, interact with, or may affect the Island's marine and coastal habitats. It has built interest, support, and momentum within the local community, and has created a solid basis from which co-management and protection of the island's eelgrass ecosystems can be developed and implemented. The FISM Coalition has also developed working relationships with the NYSDEC and the Town of Southold (which Fishers Island is part of), both of which have encouraged the community in developing a seagrass management plan and delineating SMAs.

For marine protected areas to be effective, it is essential to identify activities that pose threats at a local scale so that management responses can be targeted appropriately (Unsworth et al., 2018). As part of this process, the FISM Coalition initiated a community-based monitoring program to collect data on the frequency of human activities in, and adjacent to, seagrass areas. The methodology for the monitoring program was developed in collaboration with MPA Watch (https://mpawatch.org), a California-based citizen science program that trains volunteers to monitor human uses of coastal natural resources using standardized scientific survey methods.

The goal of the Fishers Island MPA Watch program is to quantify the intensity and types of human activities occurring at five Fishers Island seagrass sites (selected based on local knowledge), both before and after the implementation of any management actions that may be taken. Additional goals are to identify where activities are most frequent (which sites), times when activities are most frequent (time of year, time of day, days of the week, holidays), and under what conditions they are most frequent (weather and tide conditions). The program was therefore specifically designed to provide information on potential threats to seagrasses posed by human activities occurring in the immediate vicinity of targeted seagrass meadows, with the aim of informing future management actions to reduce localized threats. It was not designed to address other potential local threats such as nearby land use activities, nutrient discharges or dredging, or more broad-scale threats such as climate change or invasive species. It is intended that results from the first stage of the monitoring program, as presented in this report, will provide essential information needed for developing and adopting a management plan for

Fishers Island seagrass habitats. The study also provides a benchmark for comparing against future survey data that may be acquired after implementing a management plan.

METHODS

Collection of human activities data

A detailed sampling guide was compiled for monitoring human uses of Fishers Island seagrass areas, based on established MPA Watch protocols (FISM Coalition & MPA Watch, 2019). Volunteers were trained to follow these guidelines when monitoring five sites on (or near) Fishers Island. Sites were chosen based on their proximity to seagrass meadows and their perceived popularity for use by the public. They included, from west to east: North Hill, Flat Hammock (a small island ~1 km north of Fishers Island), West Harbor, Eighth Hole, and East Beach (**Fig. 1**).

In brief, on each sampling event a volunteer (or pair of volunteers) collected data at a site by walking a set transect while counting and recording human activities on a standardized field data sheet. Volunteer name(s), site name, date, and start/end time were noted, and eight environmental variables (cloud cover, precipitation, air temperature, wind, tide level, visibility, and wave height) were scored categorically, based on the volunteer's best judgement (i.e., subjectively). Human activities were assigned to one of three main categories: on-shore activities (hereafter referred to as shore activities), offshore activities, and boating activities (see **Appendix 1** for a copy of the data sheet, which lists activity types under each of the three main categories). Shore activities were partitioned into sandy shore or rocky shore areas. Any activity that involved the removal of a natural resource was classified as consumptive (e.g., hand collection of biota, fishing), while all other activities were classified as non-consumptive.

For boating activities, additional vessel data were recorded on a separate boat data sheet, including vessel type (listed under commercial fishing, commercial non-fishing, or recreational), activity, and vessel position data (compass heading and distance from the observer's coordinates, determined with a hand-held GPS unit and range-finding binoculars) (see **Appendix 2** for further details).

Estimation of boat positions

Boat positions recorded on-site by volunteers were mapped using Google Earth Pro 7.3.3.7786 software after extrapolating latitude and longitude from their recorded distance and heading with respect to the observer's coordinates. Extrapolations were performed with internet software that implemented the "great-circle" calculation method (https://www.fcc.gov/media/radio/find-terminal-coordinates).

In addition to the boat positions recorded by field volunteers, boat positions were digitized from the historical timeline of satellite images available within Google Earth Pro. Only stationary boats (those without a visible wake) were recorded from the satellite images.

Air temperature data from the National Weather Service (NWS)

In addition to the subjective air temperature data recorded on-site by field volunteers, daily maximum and daily minimum air temperature data were downloaded from two nearby weather stations: Groton Airport, CT (~6 km north of Fishers Island) and Montauk Airport, NY (~20 km south) (National Weather Service, 2021). Daily temperature data were acquired for the periods May-Oct 2019 and May-Oct 2020, and the data were in close agreement between the two stations (mean absolute differences were ±1.9°F and ±3.4°F for maximum and minimum temperatures, respectively).

On dates when sampling events occurred, daily maximum air temperature values (averaged across Groton and Montauk) ranged from 59-87°F (mean = 76.1°F, SD = 6.6°F; **Fig. 2**). These data were categorized into three groups: "<70" (n = 2 and 5 sampling events in 2019 and 2020, respectively); "70s" (n = 23 and 5); and "80s" (n = 13 and 2).

Precipitation data from the National Weather Service (NWS)

Daily precipitation amounts (inches) were downloaded from Groton Airport and Montauk Airport weather stations for the same time periods as the air temperature data (National Weather Service, 2021). On days when precipitation occurred at one station, it usually occurred at the other (79% of cases, n = 129 precipitation days), and rain amounts were positively correlated between stations ($r = 0.78$, $p < 0.0001$). On days when sampling events occurred, precipitation was assigned as "no" if precipitation did not occur at either station, or "yes" if least one station experienced positive precipitation.

Tide data from the National Oceanic & Atmospheric Administration (NOAA)

Predicted times and heights of high and low waters were obtained for Silver Eel Pond, Fishers Island (National Oceanic and Atmospheric Administration, 2021). Using these data, the predicted tidal heights at the beginning, end and mid-point of each survey event were interpolated from a fitted sine function (**Fig. 3 A, B**). Sampling sites were assumed to have similar tides to Silver Eel Pond, based on local knowledge (an experienced local captain confirmed that tides at the five sampling sites occur within 30 min of each other; FISM Coalition, pers. comm., 1/11/2021). Mean predicted tidal heights (at the mid-point of each sampling event) were 22.1 cm (range: -2.9 to 53.9), 45.0 cm (9.4 to 75.5), and 86.6 cm (75.4 to 97.9) for sampling events that had been subjectively categorized by field volunteers as low, medium, and high, respectively (ANOVA, $p < 0.001$). Further examination of the NOAA predicted tidal height data showed that sampling events grouped more distinctly into either low or high tidal events, with a lack of mid-tide events (**Fig. 3 C**). This simpler low/high recategorization, based on the NOAA tide data, was used when testing relationships between tide and human activities.

Statistical analyses

All statistical analyses were performed using R (R Core Team, 2019) with RStudio (RStudio Team, 2018). A one-way ANOVA was used for comparing predicted tidal height data (NOAA tide data) against tide categories recorded by field volunteers (low, medium, and high). A Kruskal-Wallis test was used for comparing the duration of sampling events between sites (data were not normally distributed). Chi-squared goodness-of-fit tests were used for comparing counts of human activities among categorical explanatory variables. The null hypothesis of each chi-squared test assumed that the frequency of expected activities per explanatory category was proportional to the number of sampling events per category, and that the expected probability of an activity occurring per sampling event was equal across all sampling events. The default significance threshold for statistical tests was set at $\alpha = 0.05$. However, when chi-squared comparisons were made against temporal and environmental variables, a Bonferroni correction was applied to account for multiple testing (Whitlock & Schluter, 2015). The significance threshold was adjusted to $\alpha = 0.0125$ for temporal comparisons (0.05/4, since four temporal variables were tested: monthly time blocks, weekdays versus weekends, holidays versus non-holidays, and time of day). With environmental variables, the significance threshold was adjusted to $\alpha = 0.008$ (0.05/6, since six variables were tested: air temperature, cloud cover, precipitation, wind, tide, and visibility).

The performance of chi-squared tests was assessed by: (i) checking whether data met chi-squared assumptions, and (ii) calculating the statistical power of each test. To check compliance with chi-squared assumptions, the expected (null hypothesis) values per explanatory category were examined to see whether all categories had expected values > 1, and at least 20% of categories had expected values ≥ 5 (Whitlock & Schluter, 2015). Power analyses were performed using the R package *pwr* (Champely, 2020). By convention, power ≥ 0.8 is usually considered acceptable (i.e., 80% probability of detecting a *real* difference between groups), whereas power < 0.8 is considered low, or having a low probability of detecting any real difference (Whitlock & Schluter, 2015). Instances when test assumptions were violated, or when tests had low statistical power, are noted in the Results section. Full details of the chi-squared performance metrics are presented in **Appendix 3**.

RESULTS

Summary of sampling events

A total of 50 sampling events occurred during 2019 and 2020 (**Table 1**). They occurred on 31 unique sampling days, with 1-4 sampling events taking place per sampling day. Thirty-eight sampling events occurred in 2019 (20 sampling days) and 12 occurred in 2020 (11 sampling days). Forty-one sampling events were on weekdays (26 sampling days) and nine sampling events were on weekends (5 sampling days). Three sampling events occurred over the Labor Day weekend in 2019 (Sat 8/31 – Mon 9/2), one occurred over Memorial Day weekend in 2020 (Sat 5/23 – Mon 5/25), and one occurred on Fri July 3rd, 2020 (observed Independence Day holiday).

During 2019, sampling events were most frequent in August (n = 23) and September (n = 10), with a smaller number occurring in July (n = 3) and October (n = 2). In 2020, sampling events were more evenly spaced from May through October (1-5 sampling events per month), although no sampling took place in August (**Table 1**). Over the entire sampling period, sampling was more frequent at West Harbor (24 sampling events) compared with other sites (5-8 sampling events per location), probably because this site was the most convenient for volunteers to access (FISM Coalition, pers. comm., 2/11/2021).

Sampling events occurred between the hours of 8:32 am (earliest start time) and 5:15 pm (latest end time) and were most frequently from 11 am - 12 pm and 2 pm - 3 pm (**Fig. 4**). The mean duration of all sampling events was 20.5 minutes (range: 1-120 minutes) (**Fig. 5**), but duration differed between locations (Kruskal-Wallis test, $p < 0.001$). The difference was driven mainly by five sampling events during Sep-Oct 2019 at West Harbor, which were apparently performed as 1-hr (n = 2) or 2-hr (n = 3) observation periods, rather than the time taken to walk the transect while recording data (as described in the field manual). There was no difference in sampling duration among sites if these five sampling events ≥ 1-hr were ignored ($p = 0.224$; overall mean sampling event duration = 12.1 minutes, range = 1-48 minutes).

Since a prolonged sampling event presumably increases the probability of observing an activity, it is possible that long-duration (≥ 1-hr) sampling events may have biased comparisons among categories of interest (e.g., among sites, etc.). Therefore, any comparisons made in the analyses presented below were tested first using all available data, and again using just data from short-duration sampling events (i.e., without the five events ≥ 1-hr). The Results section mentions cases in which the conclusion of a statistical test was modified by omitting long-duration sampling events.

Summary of environmental variables

Table 2 summarizes the environmental variables recorded during sampling events or acquired from the NWS and NOAA. These data were used for exploring relationships between environmental variables and the human activities observed at each site. Note, however, that wave height was not explored because there was insufficient variation among sampling events (wave height = 0-2 ft in all except one sampling event). Also, NWS daily maximum air temperature, NWS precipitation, and NOAA tide data were explored in preference to their field recorded equivalents because: (i) NWS and NOAA data were more objective, (ii) maximum air temperature and cumulative precipitation throughout the day probably have a greater influence on daily human activities than a snapshot of conditions during a sampling event, and (iii) adverse conditions, such as a passing rainstorm, probably reduced the likelihood of a volunteer collecting data at that specific time of day. (n.b., only two sampling events occurred during precipitation, which is insufficient for statistical comparisons against non-precipitation events).

Summary of shore, offshore and boating activities

A total of 290 human activities were recorded from the 50 sampling events, ranging from 0-27 activities per sampling event (mean = 5.8, SD = 7.5, median = 3).

Of the 290 activities observed, 213 were shore activities (range = 0-20 per sampling event, mean = 4.26, SD = 5.78, median = 0.5), 30 were offshore activities (range = 0-6, mean = 0.60, SD = 1.28, median = 0), and 47 were boating activities (range = 0-9, mean = 0.94, SD = 2.00, median = 0). There was a significant difference between these three activity types in their frequency per sampling event ($\chi^2 = 211.5$, df = 2, $p < 0.0001$), with shore activities being most frequent and offshore activities being least frequent (**Fig. 6 A**). Activities, in general, were mostly non-consumptive, as opposed to consumptive (272 non-consumptive activities in total versus 18 consumptive activities; $\chi^2 = 222.5$, df = 1, $p < 0.0001$; **Fig. 6 B**).

Types of activities at different sites

When all activities were considered together (shore + offshore + boating), there was a significant difference in the frequency of activities among sites ($\chi^2 = 89.7$, df = 4, $p < 0.0001$; **Fig. 7 A**). West Harbor had the highest activity levels, followed by Flat Hammock, Eighth Hole, North Hill, and East Beach.

Shore activities (the most common activity type) followed a similar pattern – they were most frequent at West Harbor, intermediate at Flat Hammock and Eighth Hole, and infrequent at North Hill and East Beach ($\chi^2 = 87.1$, df = 4, $p < 0.0001$, **Fig. 7 B**).

With offshore activities, no difference in frequency was detected among sites ($\chi^2 = 6.2$, df = 4, $p = 0.182$; **Fig. 7 C**). However, offshore activities were relatively uncommon, which resulted in violations of chi-squared assumptions (four sites had expected values < 5) and low statistical power.

Boating activities varied between sites ($\chi^2 = 48.5$, df = 4, $p < 0.0001$, **Fig. 7 D**), although the comparison was in slight violation of chi-square test assumptions (expected value for Flat Hammock was 4.7, rather than ≥5). Boating was frequent at Flat Hammock, West Harbor and Eighth Hole, but relatively infrequent at North Hill and East Beach.

Google Earth historical satellite images were used to further explore boating activities. The analysis was confined to images that simultaneously covered all five sites during the months July through December, since no boats were visible in images from months earlier in the year. A total of 87 stationary boats (those without a visible wake) were visible in thirteen images spanning 2006-2017. The frequency of boats differed between sites ($\chi^2 = 92.7$, df = 4, $p < 0.0001$). Boats were most frequent at West Harbor, intermediate at Flat Hammock and Eighth Hole, and least frequent at North Hill and East Beach (**Table 3**). These results are in general agreement with the pattern found from the site-based sampling, although West Harbor showed more boating activity than Flat Hammock and Eighth Hole in the satellite images.

<u>Types of shore activities</u>

The 213 shore activities observed throughout the study period fell into seven categories (**Table 4**). The most frequent activity was beach recreation (walking, resting, playing, etc., n = 182 activities), which was non-consumptive. Other non-consumption activities included animals being walked, either off-leash (n = 7) or on-leash (n = 3), wildlife watching (n = 4), and tide pooling (n = 2). Consumptive activities included hand collection of biota (the second most frequent shore activity, n = 12), and fishing (n = 3).

Of the 213 shore activities observed, 194 were on sandy shore areas while the remaining 19 activities were on rocky shore areas.

Types of offshore activities

Only 30 offshore activities were recorded during the fifty sampling events (**Table 5**). They fell into two non-consumptive categories: offshore recreation (swimming, body surfing, etc., n = 27 activities), and stand-up paddle boarding (n = 2).

Types of boating activities

A total of 47 boating activities were recorded during the fifty sampling events (**Table 6**). Boats were either anchored (n = 25 boats), underway (n = 12), or moored (n = 6) (status was not specified for the remaining 4 boats). Anchored boats were only observed at Flat Hammock (n = 14) and Eighth Hole (n = 11), whereas moored boats were only observed at West Harbor (n = 6).

Most of the boating activities were non-consumptive (n = 44), and included powerboats (n = 28), sailboats (n = 12), kayaks (n = 3) and a jet ski (n = 1). There were 3 consumptive boating activities, attributable to 2 recreational fishing boats (fishing with hook and line gear) and 1 commercial lobster boat (the latter was underway).

Thirty-seven of the survey-recorded boats had sufficient heading and distance data to estimate their positions, as well as the 87 stationary boat positions observed in from Google Earth Pro historical satellite images. Boat positions are shown in **Figs. 8-11**. Note that at Flat Hammock, Eighth Hole and North Hill, anchored boats were frequently located very near the shore, and on top of, or close to, seagrass meadows.

Relationships between activities and time periods

Variations in the frequency of activities per sampling event were analyzed with respect to time of year (separated into Jul-Aug 2019, Sep-Oct 2019, May-Jul 2020, and Sep-Oct 2020), weekdays versus weekends, holidays versus non-holidays, and time of day. Since chi-square tests were repeated four times on each activity type, the significance threshold of each test was adjusted to $\alpha = 0.0125$ (0.05/4).

The frequency of all activities (beach + offshore + boating activities) differed with time of year ($\chi^2 = 17.3$, df = 3, $p < 0.001$). They were more frequent during the earlier time blocks of the year (Jul-Aug 2019 and May-Jul in 2020) than the later time blocks (Sep-Oct of 2019 and 2020) (**Fig. 12 A**), although the pattern was less evident if long duration sampling events were included. All activities were also more frequent in the early afternoon (12-3 pm) versus other times of the day ($\chi^2 = 18.1$, df = 2, $p < 0.001$; **Fig. 12 C**), and there was some evidence that they were more frequent on holidays versus non-holidays, but only after long-duration sampling events (≥ 60 min) were removed from the analysis ($\chi^2 = 9.0$, df = 1, $p = 0.003$; **Fig. 12 C**). There was no discernable difference between weekends versus weekdays ($\chi^2 = 0.5$, df = 1, $p = 0.46$; **Fig. 12 B**).

The same analyses were repeated with just the shore activities, just the offshore activities, and just the boating activities. Shore activities varied in a similar manner to all activities. They were more frequent in the earlier months versus later months of the year ($\chi^2 = 15.3$, df = 3, $p = 0.002$ when long-duration sampling events were omitted; **Fig. 13 A**), and they more frequent on holidays versus non-holidays ($\chi^2 = 12.9$, df = 1, $p < 0.001$; **Fig. 13 C**). Shore activities were also least frequent during morning hours, but only after long-duration sampling events had been removed from the analysis ($\chi^2 = 39.9$, df = 2, $p < 0.001$; **Fig. 13 D**). Shore activities did not differ between weekdays and weekends ($\chi^2 = 0.1$, df = 1, $p = 0.77$; **Fig. 13 B**).

Offshore activities varied with time of day, being most frequent from 12-3 pm ($\chi^2 = 19.2$, df = 2, $p < 0.0001$; **Fig. 14 D**). They did not vary with respect to time of year ($\chi^2 = 2.4$, df = 3, $p = 0.49$; **Fig. 14 A**), weekday versus weekends ($\chi^2 = 0.6$, df = 1, $p = 0.45$; **Fig. 14 B**), or holidays versus non-holidays ($\chi^2 = 0.0$, df = 1, $p = 1.0$; **Fig. 14 C**). (Note, however, that chi-square assumptions were not met when testing time of year and holidays, and statistical power was generally low in comparisons of offshore activities – see **Appendix 3 A**).

Boating activities varied with time of day, being most frequent from 12-3 pm ($\chi^2 = 11.9$, df = 2, $p = 0.003$; **Fig. 15 D**). There was some evidence to suggest that boating activities varied with time of year ($\chi^2 = 15.4$, df = 3, p = 0.002), although chi-square assumptions were not met, and the effect weakened after long-duration sampling events were removed from the analysis (**Fig. 15 A**). Boating activities did not differ significantly between weekdays versus weekends ($\chi^2 = 0.3$, df = 1, p = 0.56; **Fig. 15 B**), or between holidays versus non-holidays ($\chi^2 = 5.2$, df = 1, p = 0.02; **Fig. 15 C**), although, in the latter case, chi-square test assumptions were not met.

Relationships between activities and environmental conditions

Variation in the frequency of activities was analyzed with respect to daily maximum air temperature (NWS data), cloud cover, precipitation (NWS data), wind, predicted tide level (NOAA data), and visibility. Wave height was not explored because it was recorded as 0-2 feet consistently across 49 of the 50 sampling events. Since chi-square tests were repeated six times on each activity type, the significance threshold of each test was adjusted to $\alpha = 0.008$ (0.05/6).

Analyses of all activities (shore + offshore + boating) revealed that their frequency increased with daily maximum air temperature ($\chi^2 = 19.7$, df = 2, p < 0.0001; **Fig. 16 A**), and that they were more frequent on cloud-clear days ($\chi^2 = 21.9$, df = 2, p < 0.0001; **Fig. 16 B**) without precipitation ($\chi^2 = 16.7$, df = 1, p < 0.0001), although the precipitation effect had less support after removing long-duration sampling events (**Fig. 16 C**). They were also frequent on breezy days but infrequent on windy days ($\chi^2 = 18.5$, df = 2, p = 0.0001; **Fig. 16 D**). Activities were not significantly related to tide or visibility (tide, short-duration sampling events: $\chi^2 = 4.90$, df = 1, p = 0.027, **Fig. 16 E;** visibility, short-duration sampling events: $\chi^2 = 5.0$, df = 1, p = 0.026, **Fig. 16 F**).

Shore activities were most frequent on days when air temperatures were ≥ 80°F ($\chi^2 = 11.7$, df = 2, p = 0.003; **Fig. 17 A**), and on cloud-clear days ($\chi^2 = 15.1$, df = 2, p < 0.001; **Fig. 17 B**) without precipitation ($\chi^2 = 11.4$, df = 1, p < 0.001; **Fig. 17 C**), although the relationship with precipitation was less evident when long-duration sampling events were removed from the analysis ($\chi^2 = 3.7$, df = 1, p = 0.055). Shore activities were also more frequent on breezy days versus calm or windy days ($\chi^2 = 18.1$, df = 2, p < 0.001; **Fig. 17 D**). Tide and visibility showed no significant relationships when the full dataset was considered. However, when long-duration sampling events were removed from the analysis, shore activities were more frequent during low tides ($\chi^2 = 15.6$, df = 1, $p < 0.0001$; **Fig. 17 E**).

Analyses of the relationships between offshore activities and environmental variables had poor statistical power (0.38-0.54) due to the relatively small number of offshore activities observed. Also, chi-squared assumptions were violated in comparisons against air temperature, cloud, wind, and visibility. Nevertheless, some graphical patterns were similar to those found with shore activities and all activities: offshore activities were apparently more frequent at higher air temperatures (**Fig. 18 A**), and on cloud-clear days (**Fig. 18 B**) without precipitation (**Fig. 18 C**). Tide and visibility had no apparent relationship with offshore activities (**Fig. 18 E-F**).

The analyses of boating activities had relatively low statistical power (0.67-0.78). However, boating activities were found to be more frequent on cloud-clear and partly cloudy days compared with cloudy days ($\chi^2 = 13.1$, df = 2, $p = 0.001$; **Fig. 19 B**), and more frequent on calm or breezy days compared with windy days ($\chi^2 = 10.7$, df = 2, $p = 0.005$; **Fig. 19 D**). They were not related to daily maximum air temperature ($\chi^2 = 5.9$, df = 2, $p = 0.051$; **Fig. 19 A**), precipitation ($\chi^2 = 1.4$, df = 1, $p = 0.234$; **Fig. 19 C**), tide ($\chi^2 = 0.06$, df = 1, $p = 0.455$; **Fig. 19 E**), or visibility ($\chi^2 = 1.0$, df = 1, $p = 0.324$; **Fig. 19 F**).

Performance of chi-squared tests

Chi-squared assumptions were not violated in any of the tests on shore activities, or on all activities (shore + offshore + boating). Statistical power was also very high (~1). Therefore, these analyses had a high probability of detecting any real differences that may have existed.

Chi-squared assumptions were, however, violated in 15 of the 24 tests performed on offshore activities (the least frequent type of activity), and 4 of the 24 tests on survey-recorded boating activities (the second least frequent activity type). The violations were attributable to some explanatory variable categories having expected values <5 (none of the analyses had expected values <1). Statistical power was low for offshore activities (mean power = 0.5, range = 0.36 – 0.78). With boating activities, the power of chi-squared tests was, on average, only slightly less than 0.8 (mean = 0.76, range = 0.66-0.93). In the separate analysis of boating activities that used historical satellite data, statistical power was high (0.98), and chi-squared assumptions were met. Complete information on chi-squared test violations and statistical power analyses are presented in **Appendix 3**.

In addition to chi-squared violations and low statistical power in some of the tests, other potential limitations to the analyses included:

1) The duration of sampling events was quite variable and differed significantly between sites, potentially causing bias because the likelihood of observing an activity presumably increases with sampling event duration. This issue was addressed by retesting data without 5 long-duration (≥60-min) sampling events (these 5 sampling events were apparently 1-hr or 2-hr observations periods, rather the time taken to walk a transect walks). The MPA Watch methods are designed to mitigate the effects of sampling duration, since volunteers are only supposed to count an event as they walk past it along the site's set transect.
2) Sampling events were not allocated randomly across sampling sites, time periods, or environmental categories. (e.g., West Harbor was sampled much more frequently than other sites; during some time-blocks, sampling occurred at some sites, but not others). This may have created bias in some of the comparisons presented.

CONCLUSIONS

Main findings from the monitoring program

Based on observations made by field volunteers using standardized MPA Watch protocols, human activities were identified and counted at five monitoring sites on Fishers Island during Jun-Oct 2019 (prior to the COVID-19 global pandemic), and May-Oct 2020 (during the pandemic). They were tested for relationships with spatial, temporal, and environmental variables.

Shore activities were the most frequent type of activity (e.g., relaxing or walking on the beach, tide pooling, etc.), followed by boating activities (mostly powerboats and sailboats), then offshore activities (swimming, stand-up paddle boarding). Most activities (94%) were non-consumptive. The only observed consumptive activities were hand-collection of shore biota (the second most frequent shore activity) and fishing, either from the shore or from a boat.

Results from the analyses of spatial variation showed that West Harbor was generally the most active site, especially for shore activities. Flat Hammock and Eighth Hole had intermediate levels of activities, while North Hill and East Beach were the least visited. There was a marked difference between the types of boating activities at West Harbor versus Flat Hammock and Eighth Hole. Most boats at West Harbor were moored in deeper areas away from the shore (**Fig. 10**), whereas those at Flat Hammock and Eighth Hole (and North Hill in satellite images) were mostly anchored very close to the shore, sometimes with one end pulled ashore and the other end anchored in areas of adjacent seagrass (**Figs. 8-9**).

Activities were related with three of the four temporal variables tested. When all activities were considered together (shore + offshore + boating), they were more frequent on holidays versus non-holidays, and in early afternoons (12-3 pm) rather than mornings or late afternoons. They were also more frequent during earlier time blocks of the years (Jul-Aug 2019 and May-Jul in 2020) than later time blocks (Sep-Oct of 2019 and 2020). There was no apparent difference in activity levels between weekdays and weekends. Analyses of shore activities alone showed similar relationships to all activities combined. With boating and offshore activities, some temporal relationships were similar, but they were generally less discernable due to smaller observation numbers.

Activities were related with five of the six environmental variables examined. In general, activities tended to be more frequent on days with warmer air temperatures, clear skies, and no rain, and on calm or breezy days rather than windy days (unsurprisingly, activities were more frequent when the weather was nice). Shore activities were more frequent at low tide than at high tide after some potentially confounding long-duration sampling events were removed from the analysis. Visibility was not related with activities, although no sampling events occurred during conditions of very low visibility.

Certain limitations to the analyses were identified. In some tests with offshore activities and (to a lesser degree) boating activities, chi-squared assumptions were violated and/or statistical power was low (see **Appendix 3**, which may also inform future monitoring efforts). Conclusions from most of the offshore and some of the boating analyses were therefore less robust compared with analyses of shore activities, and of all activities combined. The comparison of boating activities among sites based on satellite imagery was statistically more robust than the comparison using survey-recorded boating data. Results were comparable to on-site observations, although they indicated more boating activity at West Harbor than all other sites.

Another concern with the analyses arose from five sampling events that had a much longer duration than any of the others, which probably contributed to their relatively high activity counts. This was addressed by running the analyses both with and without the long-duration sampling events. In most cases, this did not change the outcome of tests, but there were some instances when it did (all activities versus holidays; shore activities versus time of day, precipitation, and tide; and boating activities versus month/year time bocks).

A further issue came from unequal sampling across sampling sites, and across some other categories of interest (e.g., unequal sampling of sites across different monthly time blocks), which may have introduced some bias. Future monitoring efforts could address this issue by allocating sampling events more evenly across explanatory categories of interest. Overall, however, most of the analyses had high statistical power and met chi squared test assumptions.

Identifying major threats to seagrass

Although human activities clearly have the potential to damage seagrass meadows, not all activities pose the same degree of threat. An important next step in protecting seagrass habitats around Fishers Island, therefore, is to associate types of human activities with the severity of threat that each one poses. Published seagrass studies from other U.S. and international areas provide insights into many of these aspects, but local observation and knowledge is probably of greater importance in identifying causes and effects. Ideally, any perceived associations should be verified with scientific field surveys to quantify and monitor the degree of damage in affected versus control areas of seagrass.

Based on the activities observed during the survey, boating probably poses the greatest threat to seagrass meadows at some of the sites studied. Abrasion, scarring and uprooting of seagrass by boats, propellors, anchors, anchor chains, and mooring chains can all cause localized, long-lasting damage to seagrass (e.g., Collins et al., 2010; Unsworth et al., 2017), although specialized conservation moorings have been designed to help prevent these effects (e.g., Parry-Wilson et al., 2019). At West Harbor, which had the highest level of boating activities, boats were moored rather than anchored, and they were generally located in deeper areas away from seagrass. Boating damage at West Harbor may be relatively limited, therefore, although mooring chains can still damage seagrass, so *in situ* observations are needed to verify whether this has occurred. At Flat Hammock and Eighth Hole, boats were anchored very close to the shore, and directly adjacent to, or in, seagrass meadows. Actions are likely needed at these locations to reduce boating-related damage. At North Hill and East Beach, boating activities were less prevalent, but even infrequent boating impacts have the potential to cause long-lasting local impacts (note that boats were visible at North Hill in satellite images), so some management actions may still be needed.

Offshore activities have the potential to damage seagrass, although they were the least frequent type of activity observed at the study sites. For example, offshore swimming activities may result in trampling, which can damage seagrass over time (Eckrich & Holmquist, 2000; Garmendia et al., 2017). It is also possible that some rarer types of offshore activities occur that were not recorded during the survey, but nevertheless have the potential of causing severe, localized damage. Shellfish harvesting, for example, can disturb or remove areas of seagrass and take a long time to recover (Alexandre et al., 2005). Local knowledge is needed to identify such threats, and to limit their potential effects.

Shore activities were the most frequent type of activity observed, and although they occur out of the water, they still have the potential to impact nearby seagrass meadows. For example, beach activities have been identified as a major source of plastic debris in some areas (Portman & Brennan, 2017), resulting in the accumulation of plastics in seagrass (de los Santos et al., 2021; Unsworth et al., 2021; Sanchez-Vidal et al., 2021), and consumption of plastics by marine fauna associated with seagrasses (Remy et al., 2015). Actions to minimize the input of marine debris from shore activities would therefore help protect adjacent areas of seagrass and associated fauna at frequently visited sites. Similar measures to reduce potential impacts of discarded fishing line, or commercial fishing gear (e.g., traps, pots, and nets), would also be beneficial (Orth et al., 2017).

There are many potential threats to seagrasses around Fishers Island, other than those posed by human activities in the immediate vicinity of seagrass areas. Some of these issues require action at a regional, national, or international scale (e.g., climate change effects), but many will depend on local management actions targeting a range of specific, localized threats. Based on findings from this study, protections against some harmful site-based activities seems warranted, but protection against other threats will likely also be necessary. It will be important, therefore, to evaluate and resolve other potential local issues, such as fertilizer runoff, septic tank leakage, shoreline construction practices, dredging, etc., to fully protect Fishers Island seagrass meadows.

RECOMMENDATIONS

The public is generally unaware of the considerable benefits to society that seagrasses provide. There is growing momentum at the local level on Fishers Island (FISM Coalition, Fishers Island Conservancy), at the state level (New York State Seagrass Protection Act; New York State Senate, 2012), and at the international level (United National Environmental Programme, 2020) in promoting their ecological and economic importance, and in reversing their widespread, long-term decline. Many of these changes depend on decision at the local level. Actions taken by the FISM Coalition are therefore crucial in spearheading the protection of seagrass habitats around Fishers Island, while at the same time contributing towards their wider scale protection.

Based on the findings from this report, and in discussion with members of the FISM Coalition, the following recommendations are made:

Near-term

1) Provide educational signs at popular seagrass shore areas (and other frequented areas) on Fishers Island to help inform the public of the benefits and importance of the island's seagrass habitats, engage public support in protecting them, and inform the public of ways to help minimize human impacts on them.
2) Assess seagrass boating damage, or potential for damage, at sites identified with high levels of boating activity. Make site-specific plans to eliminate or minimize boating damage and, if necessary, test different methods of achieving this, such installing buoys to guide boats away from sensitive areas or providing facilities such as seagrass-friendly moorings. Once evaluated, install the appropriate facilities, make boaters aware of them (e.g., signs), and encourage boaters to comply accordingly.
3) Assess seagrass shore areas for trash-related problems, and provision of waste disposal facilities. Ensure the provision of convenient, wind- and bird-proof disposal facilities at popular seagrass shore areas for collecting trash and discarded fishing line. Facilities should be serviced regularly, and the public encouraged to use them. Arrange and/or support beach cleanup events in areas identified as problematic.

4) Assess other potential local threats to Fishers Island seagrasses (other than on-site human activities) such as nearby land use patterns, runoff, nutrient inputs, dredging activities, etc. Make management plans to address any identified issues.
5) Support existing water quality monitoring programs on Fishers Island, which are needed for collecting important long-term management data such as water temperature, salinity, turbidity, and nutrient levels.
6) Review the methodology used for collecting human activities data to ensure statistical rigor of future monitoring efforts. For example, where possible, allocate sampling effort randomly across treatments of interest (sites, time periods, etc.) to minimize sampling bias. Review methods of minimizing potential sampling bias introduced by variation in sampling event duration. Ensure appropriate statistical power when evaluating less frequent activities that may be of interest (the power analyses presented in Appendix 3 provides some general guidance). Under the category "hand collection of biota", make additional notes of biota being collected if they appear to be destructive; make notes of any observed damage occurring to seagrass, or potential for damage; make notes of trash or marine debris observed at sites; consider whether a boat-based survey of human activities is feasible and/or needed, and whether it would provide additional value to existing shore-based surveys of human activities.
7) Perform future human activity surveys so that long-term changes can be compared against benchmark data presented in this report, especially in response to any management actions taken.

<u>Longer-term</u>

8) If feasible, conduct in-water field surveys to assess and monitor the health of seagrass habitats in areas deemed vulnerable to damage due to frequent activities (e.g., areas of high boating activity), and compare them against control, low activity areas.
9) Identify any other areas of Fishers Island seagrass habitat that may be vulnerable to damage from human activities. For example, conduct satellite imagery analyses of boating activities

in or near mapped seagrass meadows (New York State Department of Environmental Conservation, 2018) to identify other areas vulnerable to boating damage.

10) Assess the potential benefits of additional, convenient methods of monitoring human activities at seagrass sites with high activity levels (e.g., time-lapse video surveys).

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TABLES

Table 1. Number of sampling events performed at each site, by year and month.

Year	Month	North Hill	Flat Hammock	West Harbor	Eighth Hole	East Beach	TOTAL
2019	Jul	-	1	1	-	1	3
	Aug	5	3	6	5	4	23
	Sep	1	1	6	1	1	10
	Oct	-	-	2	-	-	2
2019 Total		6	5	15	6	6	38
2020	May	-	-	3	-	-	3
	Jun	-	-	1	-	-	1
	Jul	-	-	5	-	-	5
	Sep	-	-	-	1	1	2
	Oct	-	-	-	1	-	1
2020 Total		0	0	9	2	1	12
TOTAL		**6**	**5**	**24**	**8**	**7**	**50**

Table 2. Summary of environmental variables, their categorizations, and number of sampling events (n) assigned to each environmental category (nd indicates sampling events with no data). Variables with an asterisk were analyzed for relationships with activity counts. Air temperature and precipitation data from the National Weather Service (NWS), and tide data from the National Oceanographic and Atmospheric Administration (NOAA), were downloaded from publicly accessible web sites (see Methods section). Variables recorded on-site were categorized subjectively by volunteer samplers. NWS and NOAA variables were categorized by grouping recorded numerical values.

Data source		Variable	Category	n
On-site sampling	*	Clouds	Clear	26
			Partly cloudy	7
			Cloudy	14
			nd	3
	*	Wind	Calm	8
			Breezy	33
			Windy	9
	*	Visibility	Perfect	42
			Limited	8
			Shore only	0
		Air temperature	Cool	4
			Mild	18
			Warm	16
			Hot	12
		Precipitation	No	47
			Yes	2
			nd	1
		Tide	Low	15
			Medium	25
			High	9
			nd	1
		Wave Height	0-2ft	46
			2-4ft	1
			4-6ft	0
			6+ft	0
			nd	3
NWS	*	Air Temperature	<70	7
			70s	28
			80s	15
	*	Precipitation	No	32
			Yes	18
NOAA	*	Tide	Low	24
			High	26

Table 3. Number of stationary boats (those without a wake) visible at each site in Google Earth Pro historical satellite images. Year and month refer to dates associated with each image.

Year	Month	North Hill	Flat Hammock	West Harbor	Eighth Hole	East Beach	**TOTAL**
2006	Aug	1	0	11	0	0	**12**
2006	Oct	0	0	8	0	0	**8**
2006	Nov	0	1	0	0	0	**1**
2008	Jul	1	0	11	0	0	**12**
2008	Oct	0	0	0	0	0	**0**
2009	Sep	0	0	1	0	0	**1**
2010	Dec	1	9	7	11	0	**28**
2011	Sep	0	5	4	0	0	**9**
2011	Nov	1	0	3	1	0	**5**
2014	Aug	1	0	6	1	2	**10**
2016	Oct	0	0	0	0	0	**0**
2016	Dec	0	0	0	0	0	**0**
2017	Sep	0	0	1	0	0	**1**
TOTAL		**5**	**15**	**52**	**13**	**2**	**87**

Table 4. Number of shore activities recorded during sampling events, by site and activity type. Numbers separated by a comma represent activity counts on sandy and rocky shores, respectively. n: number of sampling events.

Shore Activity	Consumptive	North Hill n = 6	Flat Hammock n = 5	West Harbor n = 24	Eighth Hole n = 8	East Beach n = 7	**Total Sandy, Rocky n = 50**	**Grand Total n = 50**
Beach recreation	No	0, 0	0, 10	146, 0	24, 0	2, 0	**172, 10**	**182**
Hand collection of biota	Yes	0, 0	0, 7	5, 0	0, 0	0, 0	**5, 7**	**12**
Animals off leash	No	0, 0	0, 0	2, 0	4, 0	1, 0	**7, 0**	**7**
Wildlife Watching	No	0, 0	0, 0	4, 0	0, 0	0, 0	**4, 0**	**4**
Animals on leash	No	0, 0	0, 0	2, 0	1, 0	0, 0	**3, 0**	**3**
Shore fishing (hook & line)	Yes	0, 0	0, 0	3, 0	0, 0	0, 0	**3, 0**	**3**
Tidepooling	No	0, 0	0, 0	0, 1	0, 1	0, 0	**0, 2**	**2**
Total Sandy, Rocky		**0, 0**	**0, 17**	**162, 1**	**29, 1**	**3, 0**	**194, 19**	**213**
Grand Total		**0**	**17**	**163**	**30**	**3**	**213**	**213**

Table 5. Number of offshore activities recorded during sampling events, by site and activity type. n: number of sampling events.

Offshore Activity	Consumptive	North Hill n = 6	Flat Hammock n = 5	West Harbor n = 24	Eighth Hole n = 8	East Beach n = 7	**Total n = 50**
Offshore Recreation (e.g. swimming, bodysurfing)	No	3	4	16	4	0	**27**
Stand Up Paddle Boarding	No	0	0	3	0	0	**3**
Total		**3**	**4**	**19**	**4**	**0**	**30**

Table 6. Number of boating activities recorded during sampling events, by site and activity type. All vessels were recreational, except for one commercial lobster boat. n: number of sampling events; dash represents zero.

Activity	Vessel	Consumptive	North Hill n = 6	Flat Hammock n = 5	West Harbor n = 24	Eighth Hole n = 8	East Beach n = 7	**Total n = 50**
Anchored	Powerboat	No	-	9	-	9	-	**18**
	Sailboat	No	-	5	-	-	-	**5**
	Jetski	No	-	-	-	1	-	**1**
	Fishing boat (fishing, hook & line)	Yes	-	-	-	1	-	**1**
	Total Anchored		**0**	**14**	**0**	**11**	**0**	**25**
Moored	Sailboat	No	-	-	4	-	-	**4**
	Powerboat	No	-	-	2	-	-	**2**
	Total Moored		**0**	**0**	**6**	**0**	**0**	**6**
Underway	Powerboat	No	1	2	3	1	-	**7**
	Kayak	No	-	-	3	-	-	**3**
	Sailboat	No	-	-	1	-	-	**1**
	Commercial lobster boat (not fishing)	Yes	-	-	-	1	-	**1**
	Total Underway		**1**	**2**	**7**	**2**	**0**	**12**
Unknown	Sailboat	No	-	1	1	-	-	**2**
	Powerboat	No	-	-	1	-	-	**1**
	Fishing boat (fishing, hook & line)	Yes	-	-	1	-	-	**1**
	Total Unknown		**0**	**1**	**3**	**0**	**0**	**4**
	Total Non-Consumptive		**1**	**17**	**15**	**11**	**0**	**44**
	Total Consumptive		**0**	**0**	**1**	**2**	**0**	**3**
Grand Total			**1**	**17**	**16**	**13**	**0**	**47**

FIGURES

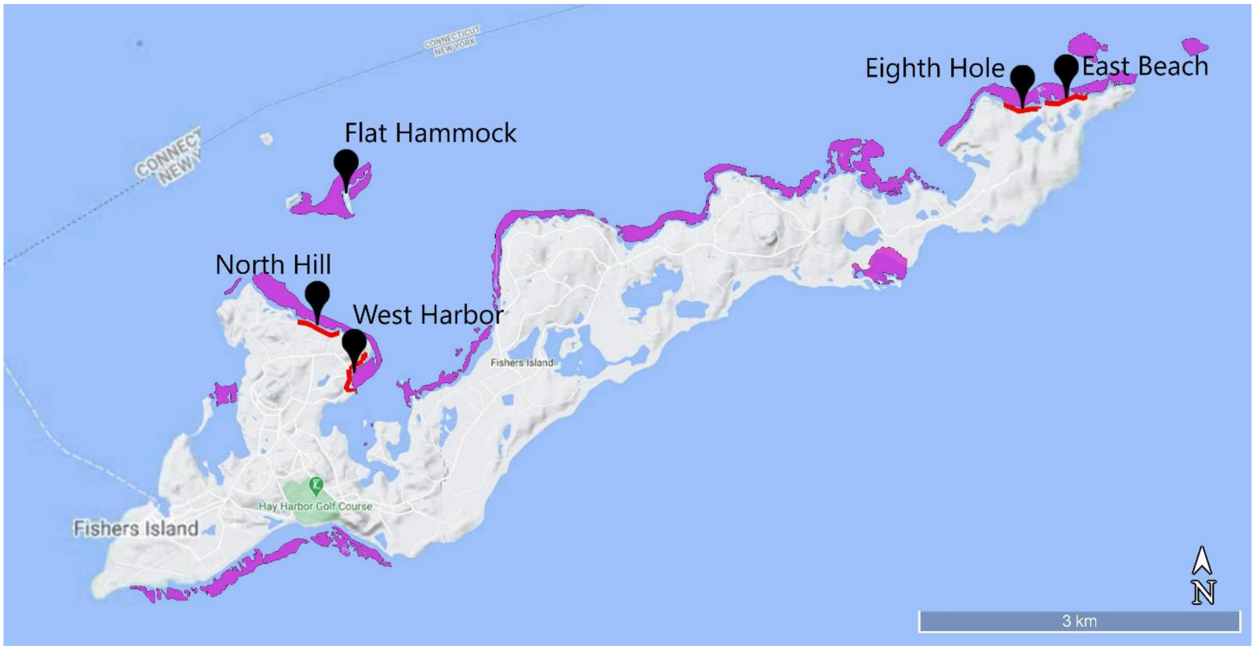

Fig. 1. Map showing locations of the five seagrass sites where human activities were monitored. Red lines show transects that were walked during sampling events (note: Flat Hammock was observed from the North Hill transect). Purple areas represent mapped areas of seagrass (New York State Department of Environmental Conservation, 2018).

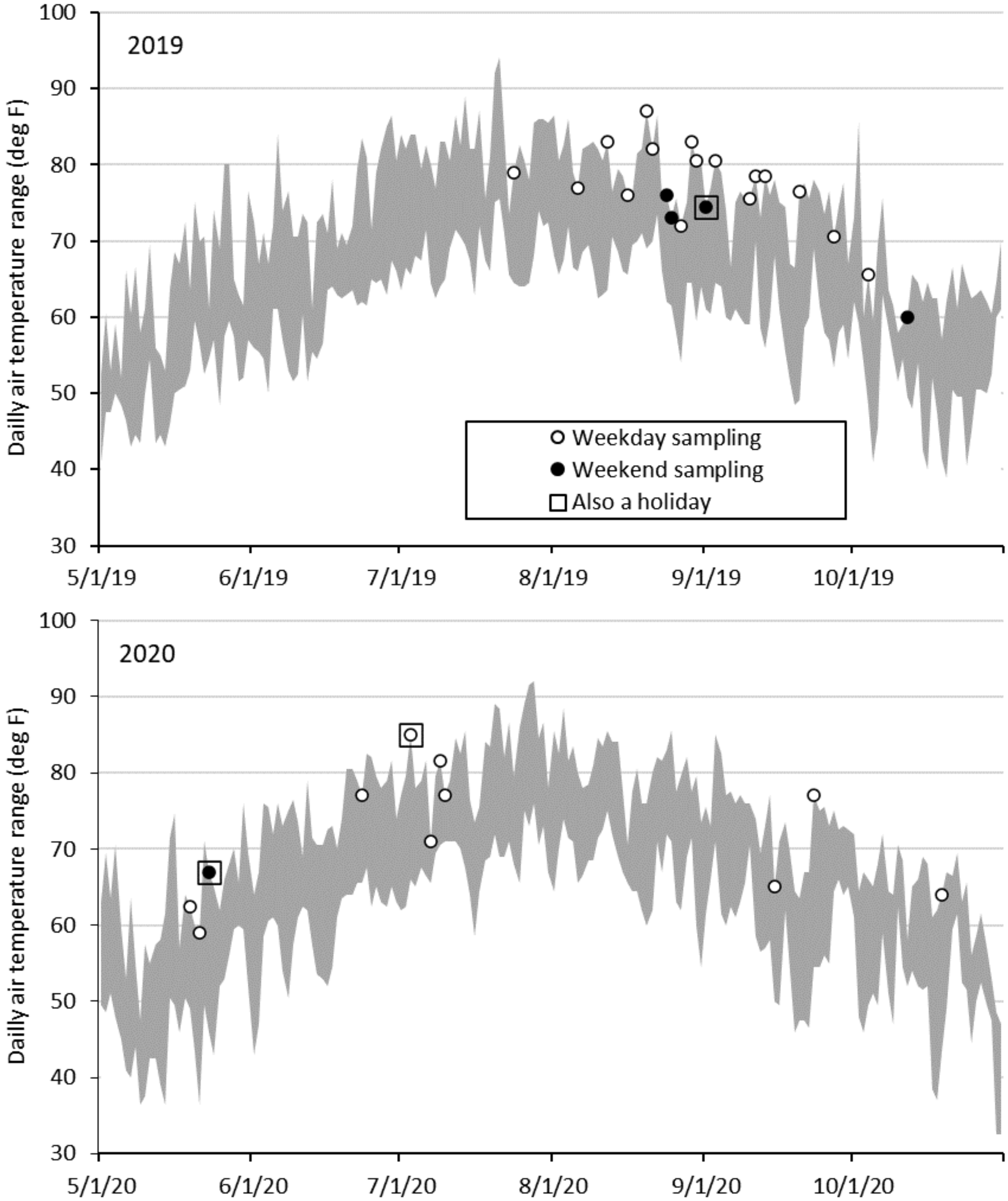

Fig. 2. Daily range in air temperature values (gray areas) from May-October 2019 and 2020, based on daily maximum and minimum air temperature values (NWS data). Symbols indicate days on which sampling events occurred (see legend; symbols are placed on that day's maximum air temperature). Sampling occurred on 31 different days (some days had multiple sampling events).

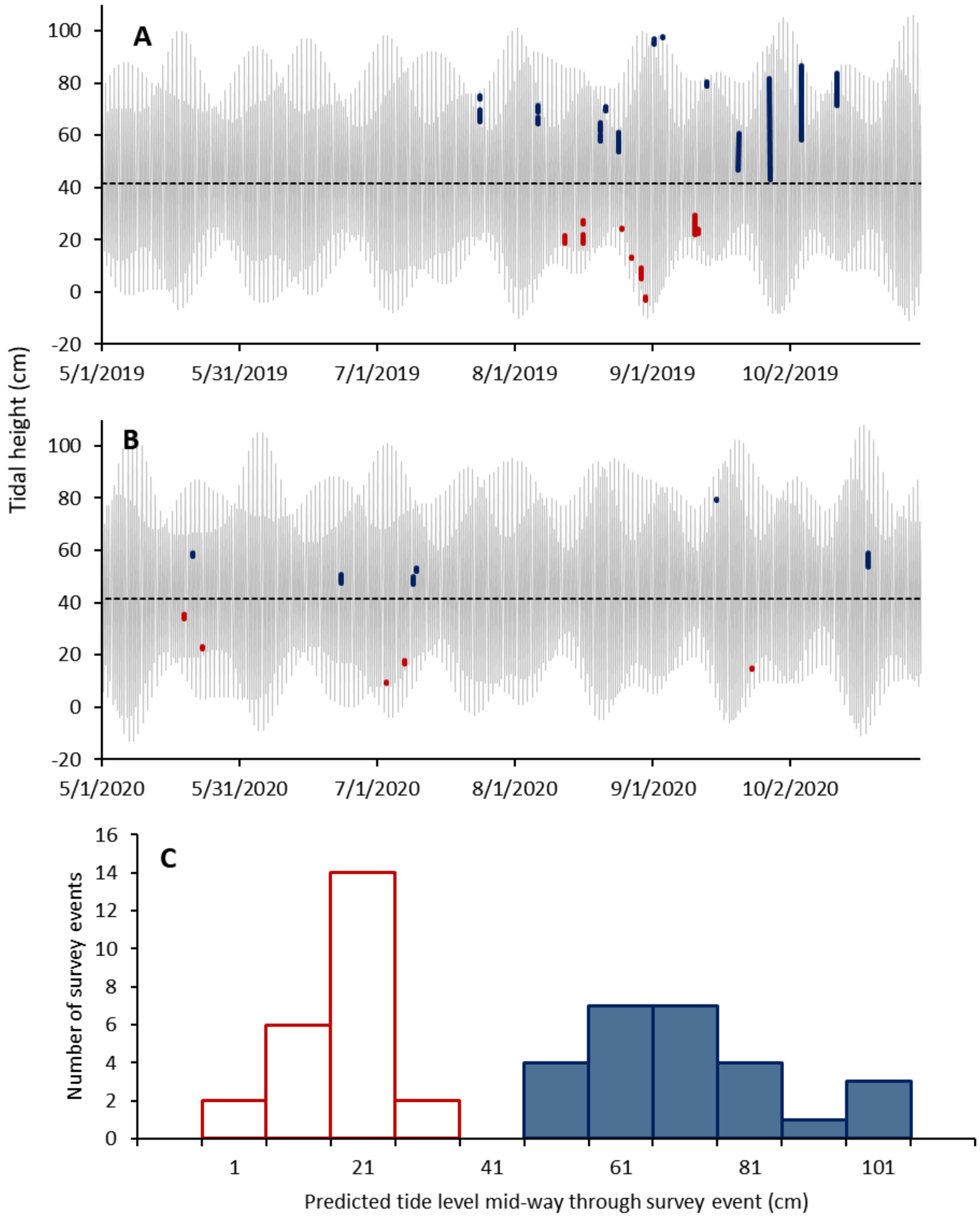

Fig. 3. Predicted tidal heights at Silver Eel Pond, Fishers Island (gray lines) during sampling years 2019 (A) and 2020 (B). Blue ("high tide") and red ("low tide") marks represent range of predicted tidal heights during each sampling event (length of each mark depends on the sampling event duration). The horizontal black dash line represents the mean predicted tidal height (41.4 cm) from 1/1/2019 through 12/31-2020. (C) Frequency of predicted tide levels mid-way through sampling events. Red bars: "low tide" sampling events; blue filled bars: "high tide" sampling events.

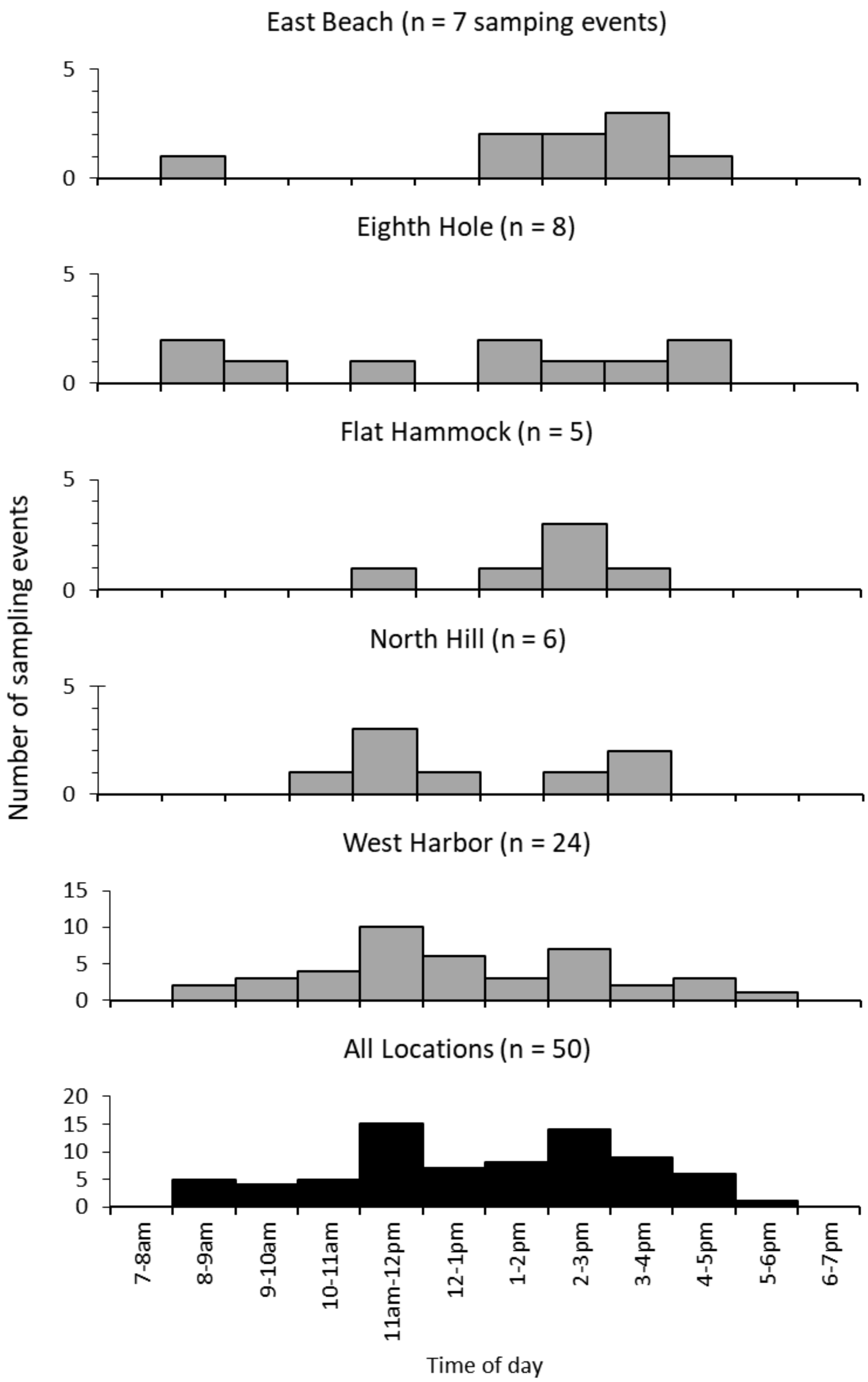

Fig. 4. Time of day when sampling events occurred at each of the five sampling sites, and at all sites combined. (Note: plots show the number of sampling events overlapping time of day split into 1-hr blocks; some sampling events overlapped more than one 1-hr block).

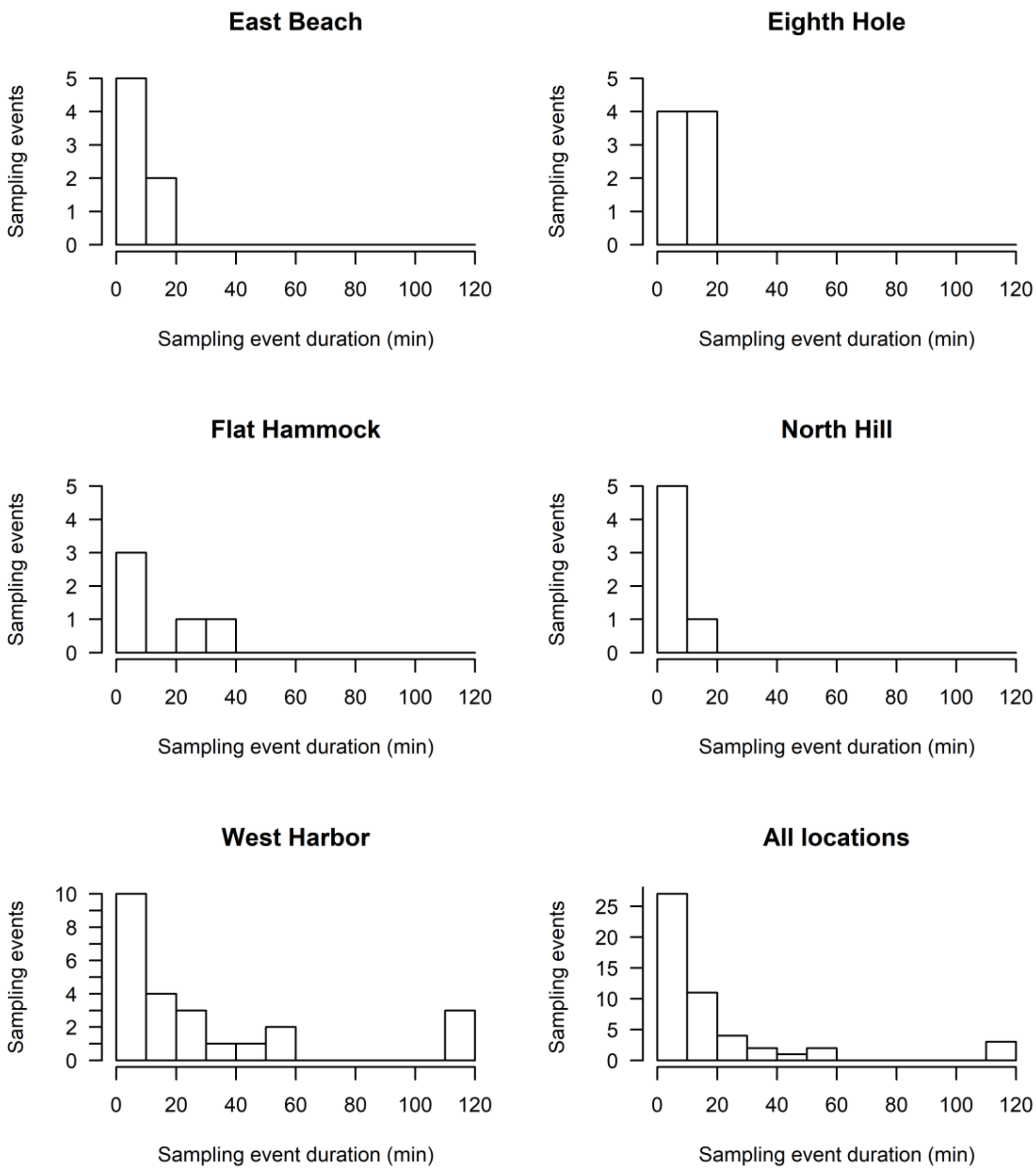

Fig. 5. Duration of sampling events at each sampling site, and all sites combined.

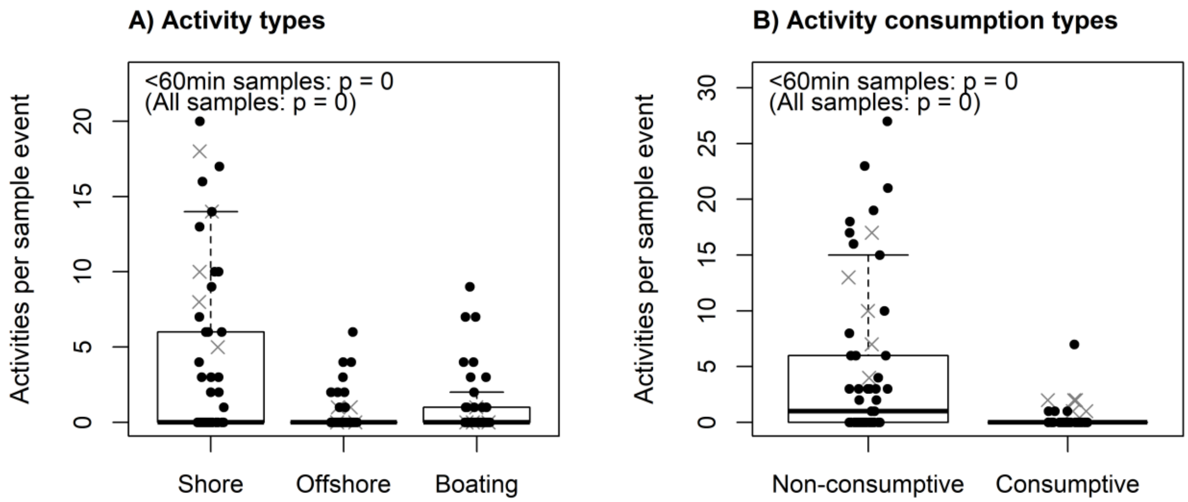

Fig. 6. (A) Comparison of shore, offshore and boating activities per sampling event. (B) Comparison of non-consumptive and consumptive activities per sampling event. Plots show data from all sampling events (n = 50).

Interpretation of plots: Boxplots show the median (dark horizontal line), inter-quartile range (box) and range of non-outliers (whiskers: data within median ± 1.5xIQR), based on short-duration (<60 min) sampling events. Raw data are shown as symbols (circles: sampling events lasting < 60-min; crosses: sampling events lasting ≥ 60-min; data are scattered horizontally to reduce overlap). Chi-squared tests compared the frequency of activities among x-axis categories. Tests were performed using only sampling events < 60-min (circles only; top p-value), and with all available data (circles and crosses; bottom p-value).

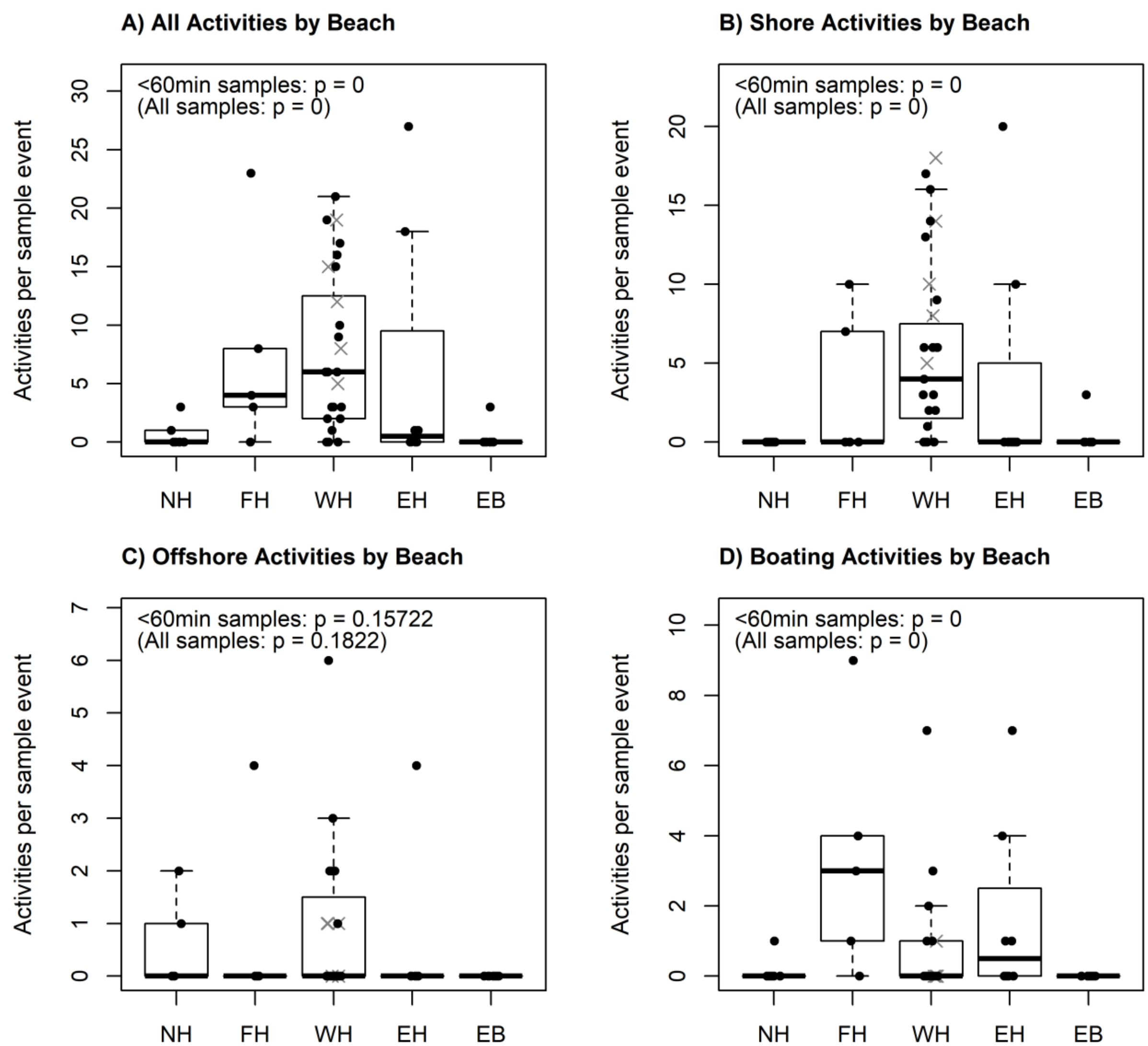

Fig. 7. Comparison of activities among sampling sites. (A) All activities (shore + offshore + boating). (B) Shore activities. (C) Offshore activities. (D) Boating activities. Sites are ordered west-to-east: NH, North Hill; FH, Flat Hammock; WH, West Harbor; EH, Eighth Hole; EB, East Beach). Note: The chi-square assumption of expected ≥ 5 per category was violated when comparing offshore activities (expected = 3.6, 3.0, 4.8, 4.2 NH, FH, EH, EB, respectively) and when comparing boating activities (expected = 4.7 at FH). The Bonferroni corrected α for tests shown is p = 0.0125.

Interpretation of plots: Boxplots show the median (dark horizontal line), inter-quartile range (box) and range of non-outliers (whiskers: data within median ± 1.5xIQR), based on short-duration (<60 min) sampling events. Raw data are shown as symbols (circles: sampling events lasting < 60-min; crosses: sampling events lasting ≥ 60-min; data are scattered horizontally to reduce overlap). Chi-squared tests compared the frequency of activities among x-axis categories. Tests were performed using only sampling events < 60-min (circles only; top p-value), and with all available data (circles and crosses; bottom p-value).

Fig. 8. Boat positions at Flat Hammock. White circles show position of stationary boats from Google Earth historical (2006-2017) satellite images. Red labels show the boat positions estimated from data recorded during sampling events. “A”: Anchored boats, “U”: boats underway.

Fig. 9. Boat positions at Eighth Hole and East Beach. White circles show position of stationary boats from Google Earth historical (2006-2017) satellite images. Red labels show the boat positions estimated from data recorded during sampling events. “A”: Anchored boats, “U”: boats underway.

Fig. 10. Boat positions at West Harbor. White circles show position of stationary boats from Google Earth historical (2006-2017) satellite images. Red labels show the boat positions estimated from data recorded during sampling events. “M”: Moored boats, “U”: boats underway, Symbol without letter: status not recorded.

Fig. 11. Boat positions at North Hill. White circles show position of stationary boats from Google Earth historical (2006-2017) satellite images. Red labels show the boat positions estimated from data recorded during sampling events. "U": boat underway.

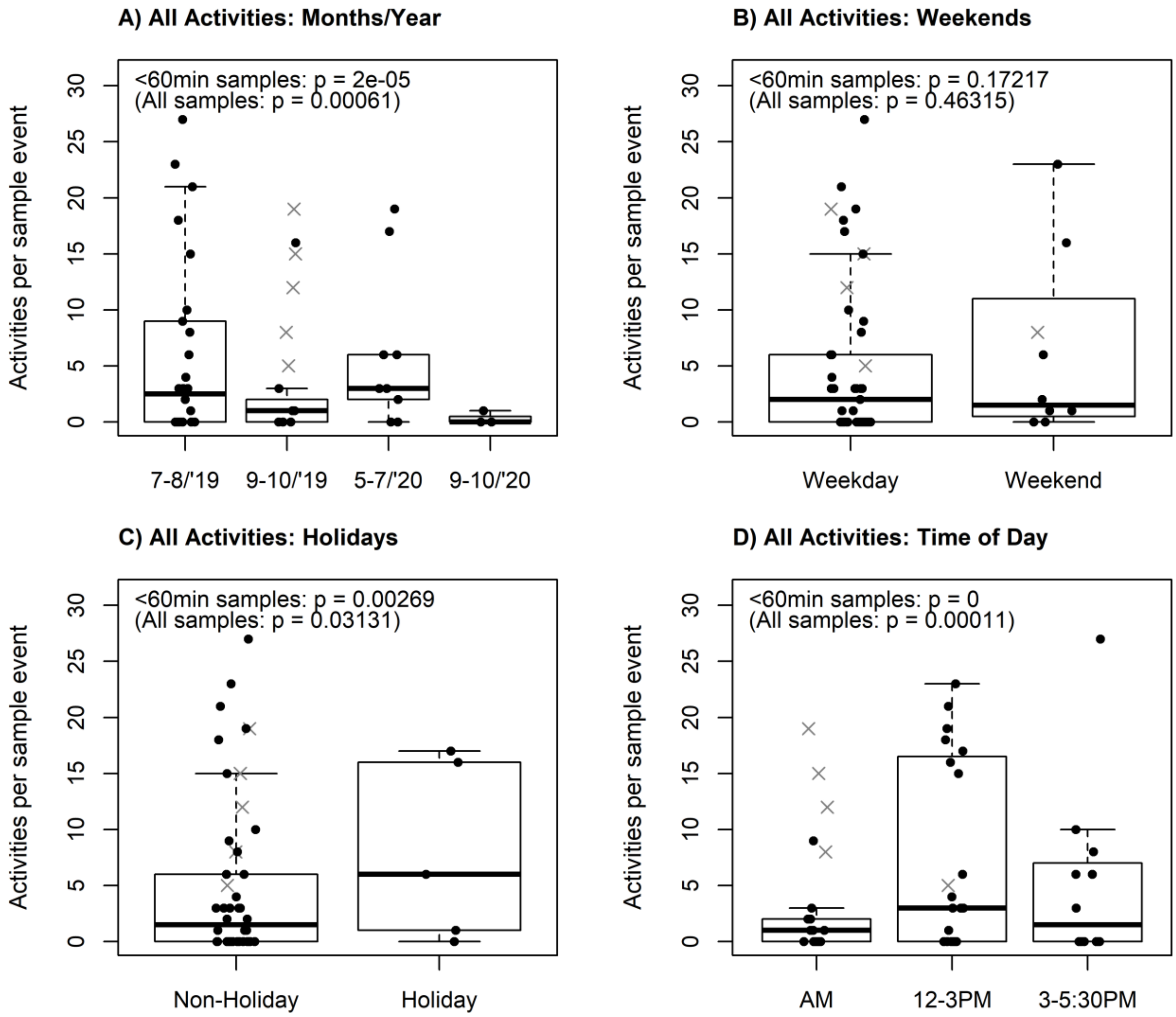

Fig. 12. Comparison of all activities (shore + offshore + boating activities) per sampling event with respect to the categorized temporal variables. (A) Month and year time blocks. (B) Weekdays versus weekends. (C) Non-holidays versus holidays. (D) Time of day. The Bonferroni corrected α for tests shown is p = 0.0125.

Interpretation of plots: Boxplots show the median (dark horizontal line), inter-quartile range (box) and range of non-outliers (whiskers: data within median ± 1.5xIQR), based on short-duration (<60 min) sampling events. Raw data are shown as symbols (circles: sampling events lasting < 60-min; crosses: sampling events lasting ≥ 60-min; data are scattered horizontally to reduce overlap). Chi-squared tests compared the frequency of activities among x-axis categories. Tests were performed using only sampling events < 60-min (circles only; top p-value), and with all available data (circles and crosses; bottom p-value).

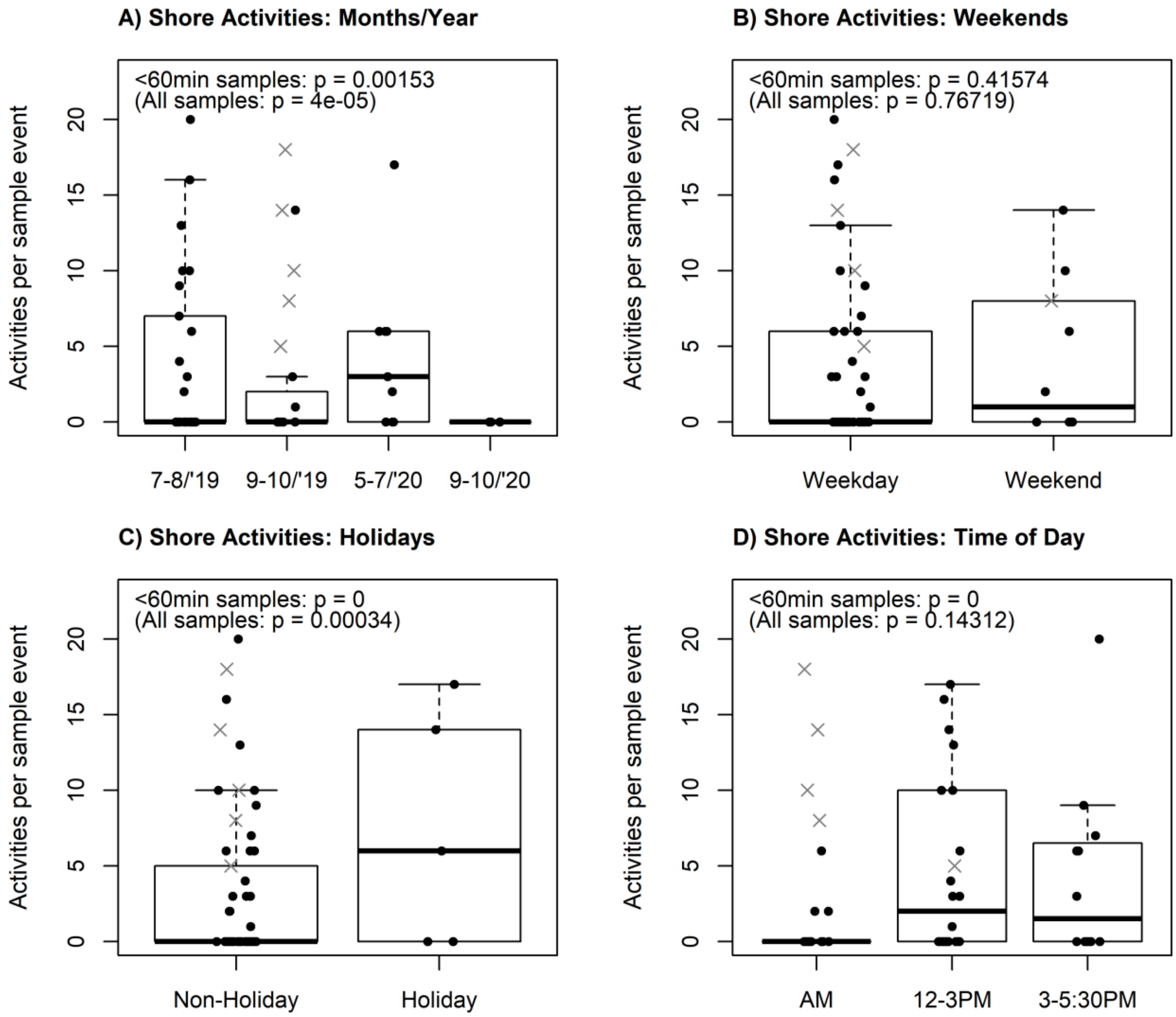

Fig. 13. Comparison of shore activities per sampling event with respect to the categorized temporal variables. (A) Month and year time blocks. (B) Weekdays versus weekends. (C) Non-holidays versus holidays. (D) Time of day. The Bonferroni corrected α for tests shown is p = 0.0125.

Interpretation of plots: Boxplots show the median (dark horizontal line), inter-quartile range (box) and range of non-outliers (whiskers: data within median ± 1.5xIQR), based on short-duration (<60 min) sampling events. Raw data are shown as symbols (circles: sampling events lasting < 60-min; crosses: sampling events lasting ≥ 60-min; data are scattered horizontally to reduce overlap). Chi-squared tests compared the frequency of activities among x-axis categories. Tests were performed using only sampling events < 60-min (circles only; top p-value), and with all available data (circles and crosses; bottom p-value).

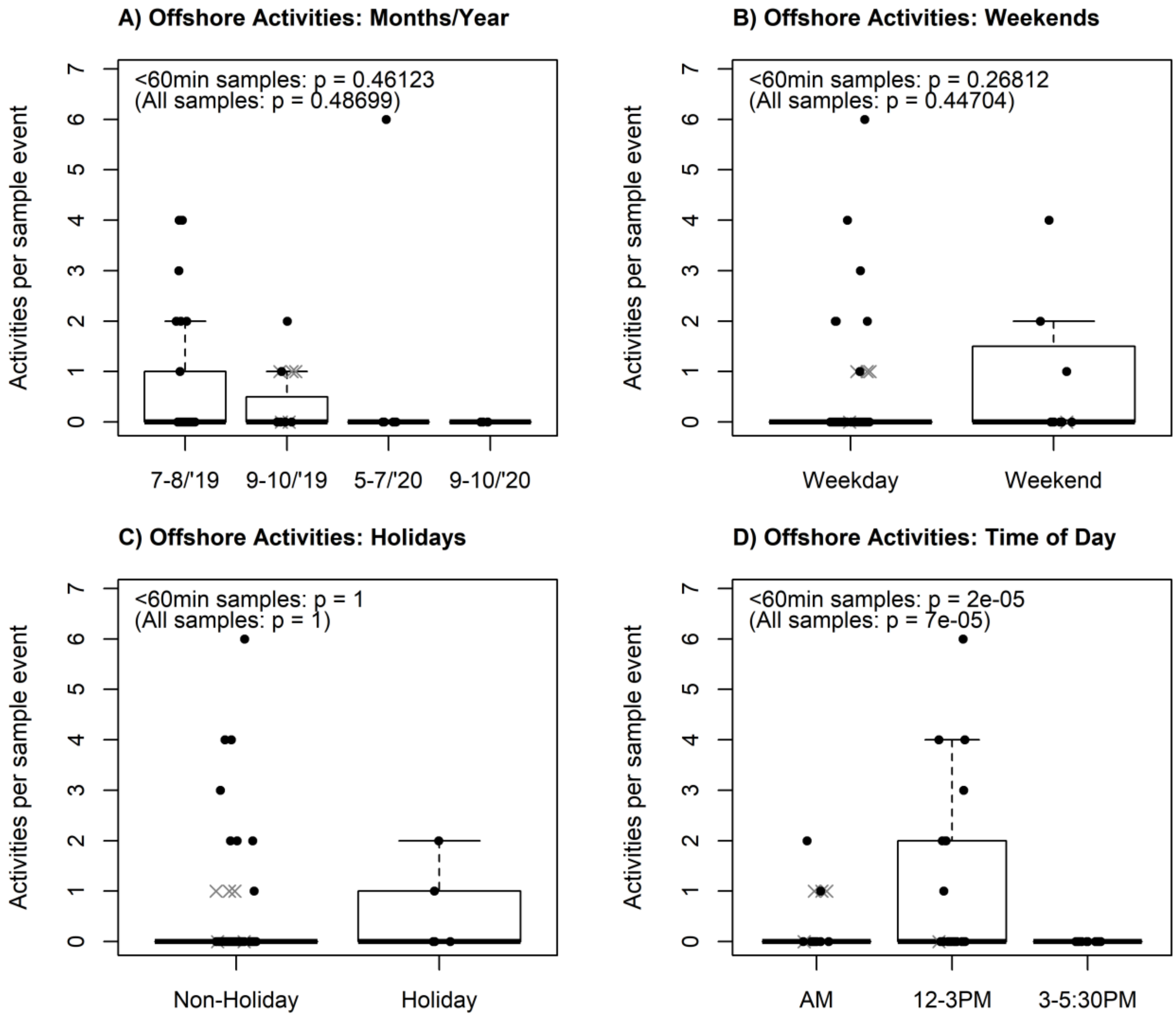

Fig. 14. Comparison of offshore activities per sampling event with respect to the categorized temporal variables. (A) Month and year time blocks. (B) Weekdays versus weekends. (C) Non-holidays versus holidays. (D) Time of day. Note: The chi-square assumption of expected ≥ 5 per category was violated when comparing month and year time blocks (expected = 1.8, Sep-Oct 2020), holidays (expected = 3, holidays), and weekends (expected = 4.8). The Bonferroni corrected α for tests shown is p = 0.0125.

Interpretation of plots: Boxplots show the median (dark horizontal line), inter-quartile range (box) and range of non-outliers (whiskers: data within median ± 1.5xIQR), based on short-duration (<60 min) sampling events. Raw data are shown as symbols (circles: sampling events lasting < 60-min; crosses: sampling events lasting ≥ 60-min; data are scattered horizontally to reduce overlap). Chi-squared tests compared the frequency of activities among x-axis categories. Tests were performed using only sampling events < 60-min (circles only; top p-value), and with all available data (circles and crosses; bottom p-value).

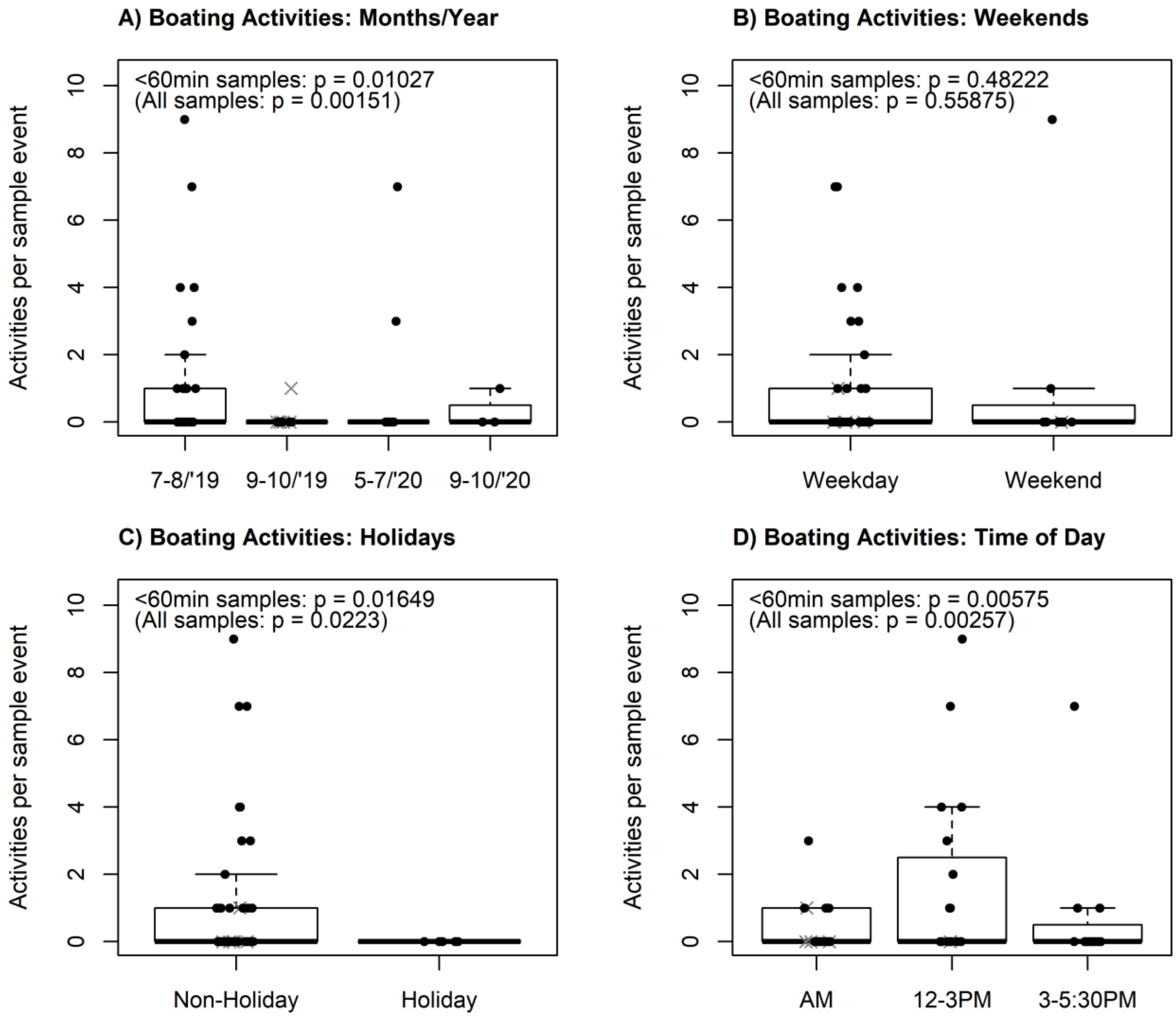

Fig. 15. Comparison of boating activities per sampling event with respect to the categorized temporal variables. (A) Month and year time blocks. (B) Weekdays versus weekends. (C) Non-holidays versus holidays. (D) Time of day. Note: The chi-square assumption of expected ≥ 5 per category was violated when comparing month and year time blocks (expected = 2.8, Sep-Oct 2020), and holidays (expected = 4.7, holidays). The Bonferroni corrected α for tests shown is p = 0.0125.

Interpretation of plots: Boxplots show the median (dark horizontal line), inter-quartile range (box) and range of non-outliers (whiskers: data within median ± 1.5xIQR), based on short-duration (<60 min) sampling events. Raw data are shown as symbols (circles: sampling events lasting < 60-min; crosses: sampling events lasting ≥ 60-min; data are scattered horizontally to reduce overlap). Chi-squared tests compared the frequency of activities among x-axis categories. Tests were performed using only sampling events < 60-min (circles only; top p-value), and with all available data (circles and crosses; bottom p-value).

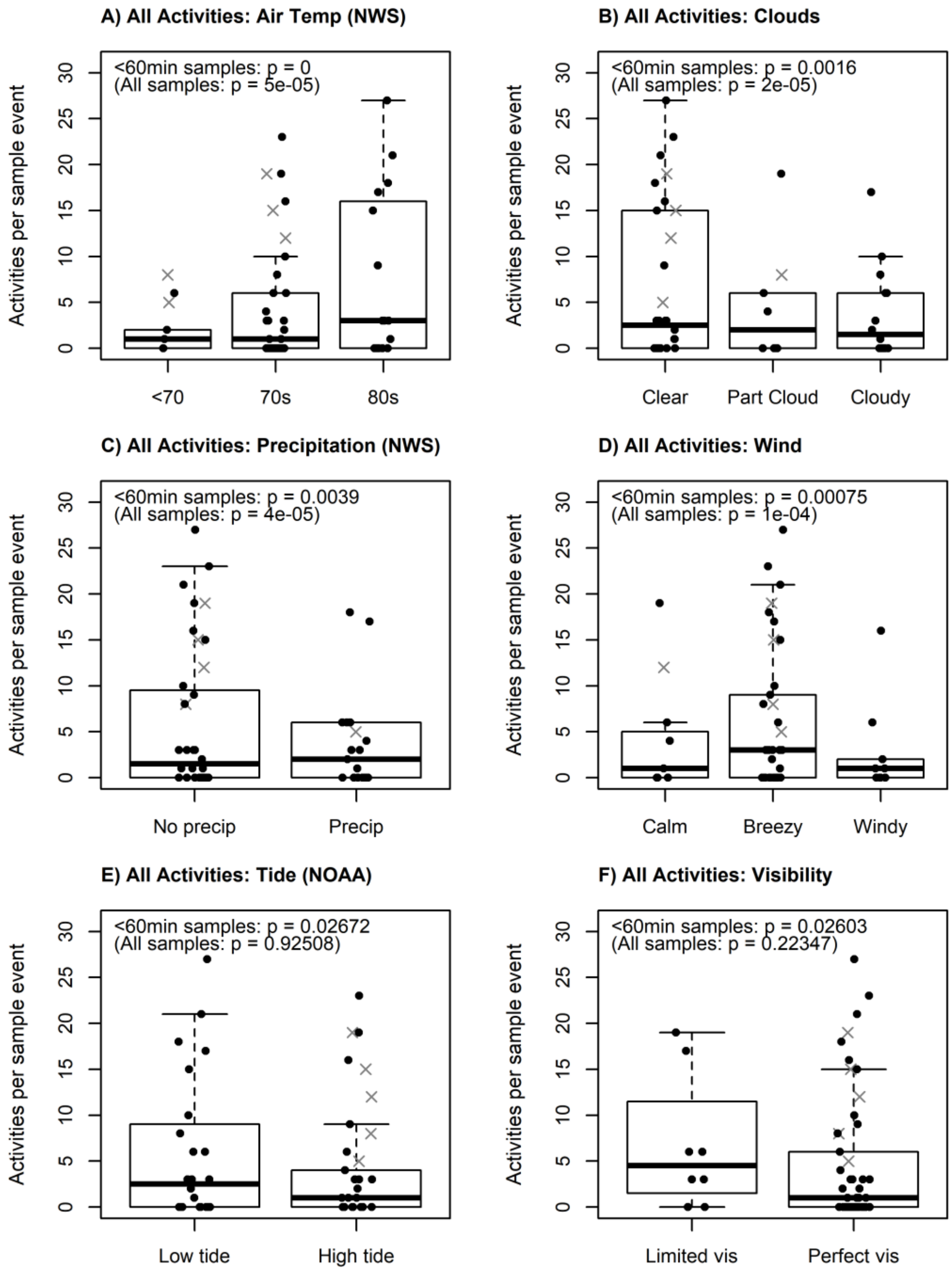

Fig. 16. Comparison of all activities (shore + offshore + boating) per sampling event with respect to environmental variables. (A) Daily maximum air temperature. (B) Cloud cover. (C) Precipitation. (D) Wind. (E) Tide. (F) Visibility. The Bonferroni corrected α for tests shown is $p = 0.008$.

Interpretation of plots: Boxplots show the median (dark horizontal line), inter-quartile range (box) and range of non-outliers (whiskers: data within median ± 1.5xIQR), based on short-duration (<60 min) sampling events. Raw data are shown as symbols (circles: sampling events lasting < 60-min; crosses: sampling events lasting ≥ 60-min; data are scattered horizontally to reduce overlap). Chi-squared tests compared the frequency of activities among x-axis categories. Tests were performed using only sampling events < 60-min (circles only; top p-value), and with all available data (circles and crosses; bottom p-value).

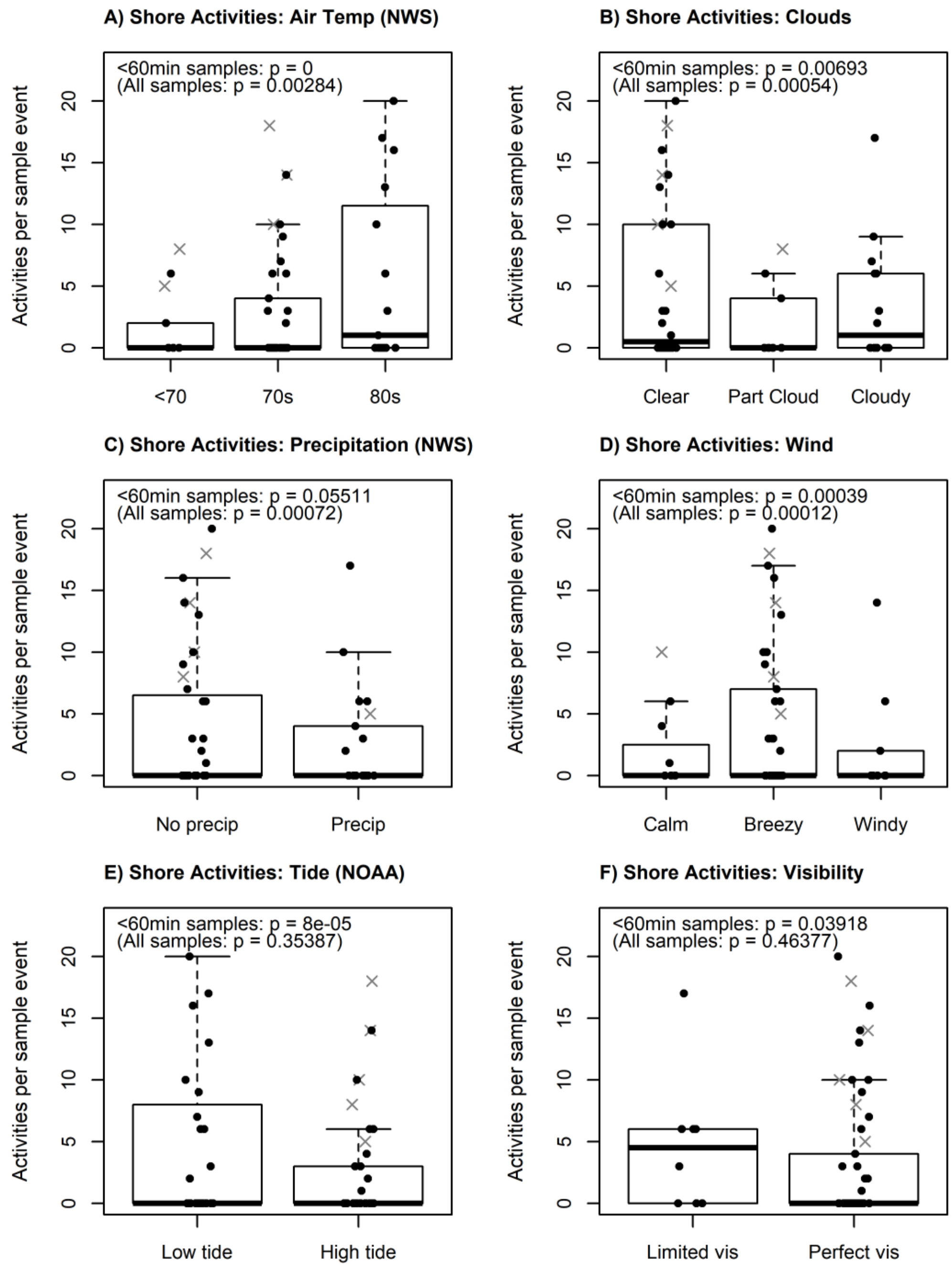

Fig. 17. Comparison of shore activities per sampling event with respect to environmental variables. (A) Daily maximum air temperature. (B) Cloud cover. (C) Precipitation. (D) Wind. (E) Tide. (F) Visibility. The Bonferroni corrected α for tests shown is $p = 0.008$.

Interpretation of plots: Boxplots show the median (dark horizontal line), inter-quartile range (box) and range of non-outliers (whiskers: data within median ± 1.5xIQR), based on short-duration (<60 min) sampling events. Raw data are shown as symbols (circles: sampling events lasting < 60-min; crosses: sampling events lasting ≥ 60-min; data are scattered horizontally to reduce overlap). Chi-squared tests compared the frequency of activities among x-axis categories. Tests were performed using only sampling events < 60-min (circles only; top p-value), and with all available data (circles and crosses; bottom p-value).

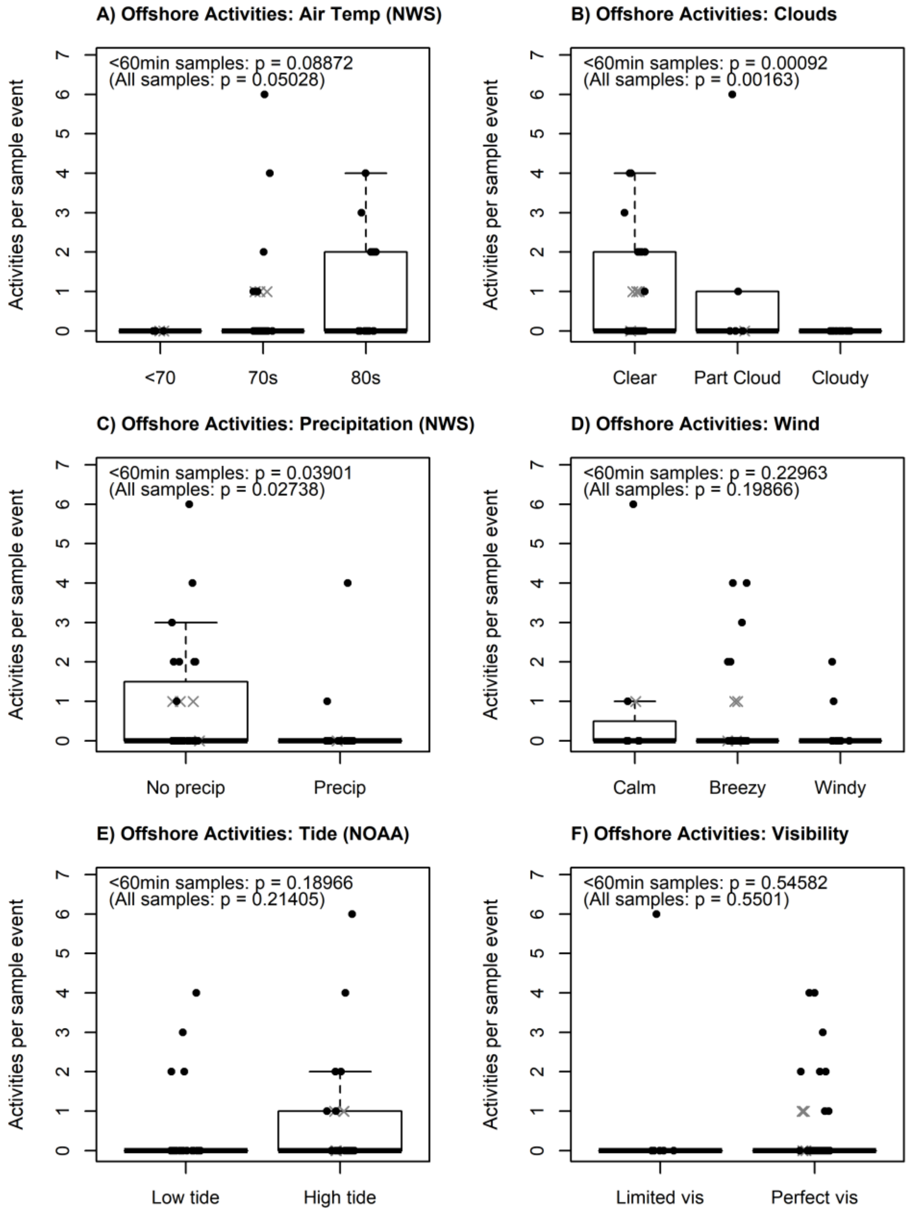

Fig. 18. Comparison of offshore activities per sampling event with respect to environmental variables. (A) Daily maximum air temperature. (B) Cloud cover. (C) Precipitation. (D) Wind. (E) Tide. (F) Visibility. Note: The chi-square assumption of expected ≥ 5 per category was violated when comparing air temperature (expected = 4.2, <70 deg F category), clouds (expected = 4.5, part cloud), wind (expected = 4.8, calm), and visibility (expected = 4.8, limited). The Bonferroni corrected α for tests shown is p = 0.008.

Interpretation of plots: Boxplots show the median (dark horizontal line), inter-quartile range (box) and range of non-outliers (whiskers: data within median ± 1.5xIQR), based on short-duration (<60 min) sampling events. Raw data are shown as symbols (circles: sampling events lasting < 60-min; crosses: sampling events lasting ≥ 60-min; data are scattered horizontally to reduce overlap). Chi-squared tests compared the frequency of activities among x-axis categories. Tests were performed using only sampling events < 60-min (circles only; top p-value), and with all available data (circles and crosses; bottom p-value).

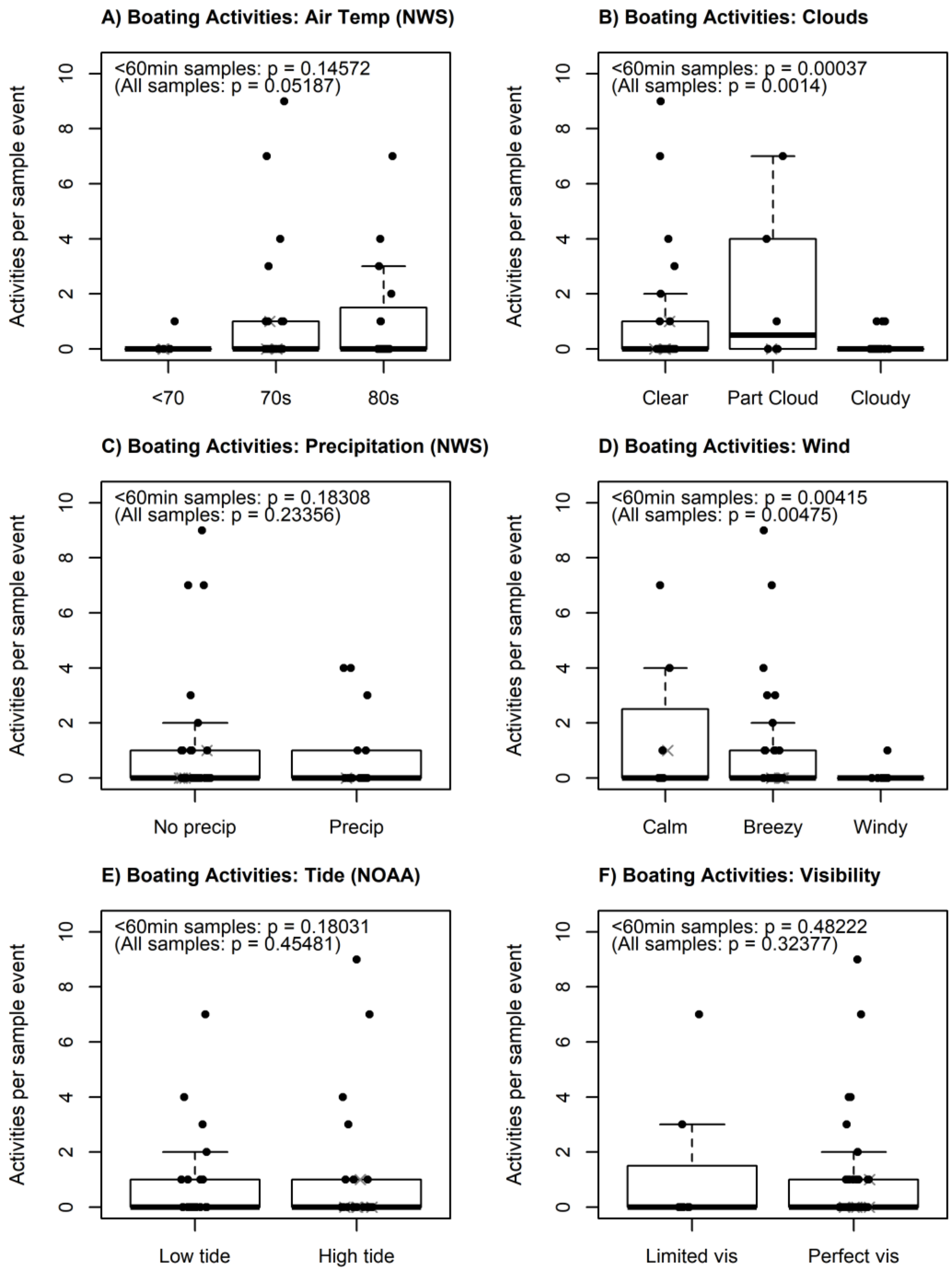

Fig. 19. Comparison of boating activities per sampling event with respect to environmental variables. (A) Daily maximum air temperature. (B) Cloud cover. (C) Precipitation. (D) Wind. (E) Tide. (F) Visibility. The Bonferroni corrected α for tests shown is p = 0.008.

Interpretation of plots: Boxplots show the median (dark horizontal line), inter-quartile range (box) and range of non-outliers (whiskers: data within median ± 1.5xIQR), based on short-duration (<60 min) sampling events. Raw data are shown as symbols (circles: sampling events lasting < 60-min; crosses: sampling events lasting ≥ 60-min; data are scattered horizontally to reduce overlap). Chi-squared tests compared the frequency of activities among x-axis categories. Tests were performed using only sampling events < 60-min (circles only; top p-value), and with all available data (circles and crosses; bottom p-value).

Appendices

Appendix 1. MPA Watch field data sheet used by field volunteers. (Some variables were not explored in this report: “Wave Height” was almost always 0-2 ft; “Beach Status” was always open; “Did you observe” options were mostly never observed). Weather and tide station data from national agencies were used in preference to the air temperature, precipitation and tide data recorded on field data sheets.

Fishers Island Seagrass Management (FISM) Coalition
Human Uses Monitoring Data Sheet

Name(s):		Date: ___/___/_______	Transect ID:
Start Time:	End Time:	Clouds: clear (0%)/ partly cloudy (1-50%)/ cloudy (>50%cover)	Precipitation: yes / no
Air Temperature: cold / cool / mild / warm / hot		Wind: calm / breezy / windy	Tide Level: low / med / high
Visibility: perfect / limited / shore only		Beach Status: open / posted / closed	Wave Height: 0-2ft 2-4ft 4-6ft 6ft+

On-Shore Activities	Sandy	Rocky Intertidal
Beach Recreation (walking, resting, playing, etc. NOT tidepooling)		
Wildlife Watching		
Domestic animals on-leash (count human as beach rec)		
Domestic animals off-leash (count human as beach rec)		
Driving on the Beach		
Tide-pooling (not collecting)		
Collecting (things that are alive or were alive, e.g., shells)		
Shore-based fishing – hook and line		
Shore-based fishing – other (describe gear in comments)		

Off-Shore Activities (Non-Boating)	
Offshore Recreation (e.g., swimming, bodysurfing)	
Surfing/Boogie Boarding/ Windsurfing	
Stand Up Paddle Boarding	
Non-Consumptive SCUBA and snorkeling	
Spear Fishing (free diving or SCUBA)	
Other Consumptive Diving (e.g., nets, poles, traps)	

Boating	Recreational		Commercial		Unknown	
	Inactive	Active	Inactive	Active	Inactive	Active
Boat Fishing – Line						
Boat Fishing – Trap						
Boat Fishing – Other (Describe gear in comments)						
Unknown Fishing Boat						
Kayak/Canoe/Rowboat						
Dive Boat						
Work Boat (e.g., Bay Constable, research, Coast Guard)						
Commercial Fishing Charter (6+ people)						
Private Powerboat						
Sailboat						
Ferry (e.g., Popeye, contracted ferries, Ferry District boats)						
Other Boating (e.g., jet ski, party boat)						

Comments

Did you observe: ☐ scientific research; ☐ education; ☐ beach closure; ☐ large gatherings (e.g., beach cleanup); ☐ enforcement activity

Appendix 2. MPA Watch boat data sheet used by field volunteers.

Human Uses Monitoring: BOAT USE Data Sheet

Vessel #	Time	Lat/Long	Compass Heading	Distance (yds)	Vessel Type	Vessel	Activity	Notes
1		N.						
		W.						
2		N.						
		W.						
3		N.						
		W.						
4		N.						
		W.						
5		N.						
		W.						
6		N.						
		W.						
7		N.						
		W.						
8		N.						
		W.						
9		N.						
		W.						
10		N.						
		W.						
11		N.						
		W.						
12		N.						
		W.						

VESSEL	Vessel Types			Activity	Comments
	Commercial Fishing	Comm. Non-Fishing	Recreational		
	Commercial Fishing Charter (6+ people) Lobster Boat Trap Fishing Boat Line Fishing Boat Net Fishing Boat (Purse, gillnet) Other	Ferry (Popeye, contracted ferries, Ferry District boats) Work Boat (Bay Constable, research, Coast Guard) Charter (Whale, Diving, Ecotour) Cargo Ship Other	Sport Fishing Boat Power Boat Sailboat Dive Boat Kayak/ Canoe/ Rowboat Other (party boat, jet ski)	Fishing Not Fishing Anchored Underway Moored Other (Diving, spearfishing)	

Appendix 3. Chi-squared assumptions and power analysis

Each chi-squared test performed was checked for compliance with chi-squared assumptions, and the statistical power of the test was calculated.

Chi-squared tests compare observed counts per explanatory category against expected counts from a null hypothesis scenario. The test assumes that all explanatory categories should have an expected count >1, and at least 20% of explanatory categories should have an expected count ≥5 (Whitlock & Schluter, 2015). The former assumption was never violated, but the latter sometimes was. Violations are reported in the tables A-C, below.

Statistical power refers to the probability (from 0 to 1) of detecting a true difference between explanatory categories (should one really exist), based on the samples acquired and chi-squared test conditions. In general, the power of a test will decline (i.e., will be less statistically rigorous):

- If low numbers of activities are counted,
- If the number of explanatory variable categories is large (e.g., it is generally more difficult, or requires more sampling effort, to detect a difference between many of categories than between a few categories),
- If the statistical threshold of the chi-squared test is reduced (e.g., when applying a Bonferroni correction factor to the p-value to account for repeated testing),
- If the magnitude of the difference between explanatory categories you are trying to detect is small (bigger differences between categories are easier to detect, resulting in higher power). An effect size index (*w*) is used in the power analysis function to modify the magnitude of the difference effect. In the power analyses presented here, *w* was set at 0.5, or a "large" difference, according to Cohen (1988).

By convention, power ≥ 0.8 is usually considered acceptable when performing a statistical test, whereas a test with power < 0.8 is considered to have low power, or a low probability of detecting a real difference, should one exist in the system (Whitlock & Schluter, 2015).

Three tables are presented below:

A. Chi-square tests comparing temporal variables (Bonferroni adjusted significance threshold, $\alpha = 0.0125$).
B. Chi-square tests comparing environmental variables (Bonferroni adjusted significance threshold, $\alpha = 0.008$).
C. Chi-squared tests between sites, and between consumptive versus non-consumptive activities (significance threshold, $\alpha = 0.05$).

Appendix 3 A. Violation of chi-squared assumptions and power analyses for chi-square tests comparing temporal variables. In these tests, a Bonferroni correction factor was applied to account for the fact that each type of activity was re-tested against four separate temporal variables (significance threshold adjusted to $\alpha = 0.05/4 = 0.0125$). Number of explanatory variable categories that violated chi-squared assumptions, and tests with power < 0.8, are shown in red.

Type of activity being tested	Sampling events included in analysis	Number of activities observed	Explanatory variable tested	Explanatory categories	Power	Categories with Expected < 5
shore	all	213	months/years	4	1.00	
			weekends	2	1.00	
			holidays	2	1.00	
			time of day	3	1.00	
	duration < 60 min	158	months/years	4	1.00	
			weekends	2	1.00	
			holidays	2	1.00	
			time of day	3	1.00	
offshore	all	30	months/years	4	0.41	1
			weekends	2	0.60	
			holidays	2	0.60	1
			time of day	3	0.48	
	duration < 60 min	27	months/years	4	0.36	2
			weekends	2	0.54	1
			holidays	2	0.54	1
			time of day	3	0.43	
boating	all	47	months/years	4	0.67	1
			weekends	2	0.82	
			holidays	2	0.82	1
			time of day	3	0.73	
	duration < 60 min	46	months/years	4	0.66	1
			weekends	2	0.81	
			holidays	2	0.81	
			time of day	3	0.72	
all	all	290	months/years	4	1.00	
			weekends	2	1.00	
			holidays	2	1.00	
			time of day	3	1.00	
	duration < 60 min	231	months/years	4	1.00	
			weekends	2	1.00	
			holidays	2	1.00	
			time of day	3	1.00	

Appendix 3 B. Violation of chi-squared assumptions and power analyses for chi-square tests against environmental variables, where a Bonferroni correction factor was applied to account for the fact that each type of activity was re-tested against six separate temporal variables (significance threshold adjusted to α = 0.05/6 = 0.008). Tests with power < 0.8 are shown in red. Number of explanatory variable categories that violated chi-squared assumptions, and tests with power < 0.8, are shown in red.

Type of activity being tested	Sampling events included in analysis	Number of activities observed	Explanatory variable tested	Explanatory categories	Power	Categories with Expected < 5
shore	all	213	air temp	3	1.00	
			clouds	3	1.00	
			precipitation	2	1.00	
			wind	3	1.00	
			tide	2	1.00	
			visibility	2	1.00	
	duration < 60 min	158	air temp	3	1.00	
			clouds	3	1.00	
			precipitation	2	1.00	
			wind	3	1.00	
			tide	2	1.00	
			visibility	2	1.00	
offshore	all	30	air temp	3	0.43	1
			clouds	3	0.43	1
			precipitation	2	0.54	
			wind	3	0.43	1
			tide	2	0.54	
			visibility	2	0.54	1
	duration < 60 min	27	air temp	3	0.38	1
			clouds	3	0.38	1
			precipitation	2	0.48	1
			wind	3	0.38	
			tide	2	0.48	
			visibility	2	0.48	1
boating	all	47	air temp	3	0.69	
			clouds	3	0.69	
			precipitation	2	0.78	
			wind	3	0.69	
			tide	2	0.78	
			visibility	2	0.78	
	duration < 60 min	46	air temp	3	0.67	
			clouds	3	0.67	
			precipitation	2	0.77	
			wind	3	0.67	
			tide	2	0.77	
			visibility	2	0.77	
all	all	290	air temp	3	1.00	
			clouds	3	1.00	
			precipitation	2	1.00	
			wind	3	1.00	
			tide	2	1.00	
			visibility	2	1.00	
	duration < 60 min	231	air temp	3	1.00	
			clouds	3	1.00	
			precipitation	2	1.00	
			wind	3	1.00	
			tide	2	1.00	
			visibility	2	1.00	

Appendix 3 C. Violation of chi-squared assumptions and power analyses for chi-squared tests with no Bonferroni correction factor applied (significance threshold of α = 0.05). Number of explanatory variable categories that violated chi-squared assumptions, and tests with power < 0.8, are shown in red.

Type of activity being tested	Sampling events included in analysis	Explanatory variable tested	Explanatory categories	Number of activities observed	Power	Categories with Expected < 5
shore	all	beach	5	213	1.00	
offshore				30	0.57	4
boating				47	0.79	1
all				290	1.00	
shore	duration < 60 min	beach	5	158	1.00	
offshore				27	0.52	4
boating				46	0.78	
all				231	1.00	
shore	all	consumption	2	213	1.00	
offshore				30	0.78	
boating				47	0.93	
all				290	1.00	
shore	duration < 60 min	consumption	2	158	1.00	
offshore				27	0.74	
boating				46	0.92	
all				231	1.00	
boating, satellite images	all	beach	5	87	0.98	

Appendix 4. Raw human activity data collected by field volunteers.

Appendix 4 A. Sampling event locations, general conditions, and temporal variables.

Beach	Date	Sample ID	Start Time	End Time	Duration [min]	Volunteer ID	Beach Status	Research Group(s)	Education Group(s)	Gatherings	Enforcement Activity	Weekend	Holiday
North Hill	08/06/19	29566	12:43	12:50	7	F	Open	No	No	No	No	No	No
	08/12/19	29454	14:48	15:00	12	F & C	Open	No	No	No	No	No	No
	08/16/19	29550	15:50	15:57	7	F	Open	No	No	No	No	No	No
	08/20/19	29627	11:13	11:23	10	J	Open	No	No	No	No	No	No
	08/25/19	29624	10:54	11:00	6	J	Open	No	No	No	No	Yes	No
	09/01/19	29721	11:43	11:47	4	J	Open	No	No	No	No	Yes	Yes
Flat Hammock	07/24/19	35518	14:03	14:28	25	F & A	Open	No	No	No	No	No	No
	08/12/19	29455	14:48	14:50	2	F & C	Open	No	No	No	No	No	No
	08/16/19	29549	15:20	15:26	6	J	Open	No	No	No	No	No	No
	08/24/19	29625	13:57	14:31	34	J	Open	No	No	No	No	Yes	No
	09/01/19	29722	11:22	11:23	1	J	Open	No	No	No	No	Yes	Yes
West Harbor	07/24/19	29242	14:03	14:28	25	F & A	Open	No	No	No	No	No	No
	08/06/19	29374	12:30	12:37	7	F	Open	No	No	No	No	No	No
	08/12/19	29453	13:14	13:50	36	K	Open	No	No	No	No	No	No
	08/12/19	29447	14:11	14:40	29	F & C	Open	No	No	No	No	No	No
	08/16/19	29548	16:04	16:15	11	J	Open	No	No	No	No	No	No
	08/20/19	29626	11:29	11:43	14	J	Open	No	No	No	No	No	No
	08/25/19	29623	11:06	11:12	6	J	Open	No	No	No	No	Yes	No
	09/01/19	29720	11:58	12:07	9	J	Open	No	No	No	No	Yes	Yes
	09/03/19	29725	13:00	13:25	25	F & B	Open	No	No	No	No	No	No
	09/10/19	31337	14:45	15:33	48	B	Open	No	No	No	No	No	No
	09/13/19	31332	9:00	10:00	60	B	Open	No	No	No	No	No	No
	09/20/19	31333	11:00	12:00	60	B	Open	No	No	No	No	No	No
	09/27/19	31334	10:00	12:00	120	B	Open	No	No	No	No	No	No
	10/04/19	31335	12:00	14:00	120	B	Open	No	No	No	No	No	No
	10/12/19	31336	9:00	11:00	120	B	Open	No	No	No	No	Yes	No
	05/19/20	32804	11:48	11:58	10	G	Open	No	No	No	No	No	No
	05/21/20	32815	11:10	11:19	9	G	Open	No	No	No	No	No	No
	05/23/20	32816	15:50	16:00	10	G	Open	No	No	No	No	Yes	Yes
	06/23/20	33317	14:30	14:44	14	H & D	Open	No	No	Yes	No	No	No
	07/03/20	33203	14:10	14:20	10	G	Open	No	No	No	No	No	Yes
	07/07/20	33205	17:05	17:15	10	G	Open	No	No	No	No	No	No
	07/09/20	33204	16:30	16:42	12	G	Open	No	No	No	No	No	No
	07/10/20	33316	11:45	11:50	5	H & D	Open	No	No	No	No	No	No
	07/10/20	33206	14:13	14:22	9	G	Open	No	No	No	No	No	No
Eighth Hole	08/21/19	29564	16:05	16:06	1	F	Open	No	No	No	No	No	No
	08/25/19	29619	11:43	11:56	13	E	Open	No	No	No	No	Yes	No
	08/27/19	29622	13:26	13:31	5	E	Open	No	No	No	No	No	No
	08/29/19	29716	14:15	14:30	15	F	Open	No	No	No	No	No	No
	08/30/19	31979	15:59	16:15	16	E	Open	No	No	No	No	No	No
	09/11/19	30007	13:35	13:40	5	F	Open	No	No	No	No	No	No
	09/23/20	33905	8:32	8:39	7	I	Open	No	No	No	No	No	No
	10/19/20	34112	8:53	9:05	12	I	Open	No	No	No	No	No	No
East Beach	07/24/19	29254	15:00	15:11	11	F & A	Open	No	No	No	No	No	No
	08/21/19	29562	15:58	16:05	7	F	Open	No	No	No	No	No	No
	08/27/19	29621	13:10	13:22	12	E	Open	No	No	No	No	No	No
	08/29/19	29717	14:08	14:15	7	F	Open	No	No	No	No	No	No
	08/30/19	31978	15:50	15:57	7	E	Open	No	No	No	No	No	No
	09/11/19	30006	13:27	13:35	8	F	Open	No	No	No	No	No	No
	09/15/20	33907	8:39	8:44	5	I	Open	No	No	No	No	No	No

Appendix 4 B. Sampling event locations, dates, and environmental variables. Black cells indicate no data recorded.

Beach	Date	Sample ID	Air Temp [fieldsheet]	Max Air Temp [NWS]	Min Air Temp [NWS]	Clouds	Precipitation [fieldsheet]	Precipitation [NWS, inches]	Precipitation [NWS]	Wind	Tide [fieldsheet]	Tide [NOAA, cm]	Tide [NOAA]	Visibility	Wave Height
North Hill	08/06/19	29566	Warm	77	70s	Cloudy	No	0.015	Yes	Breezy	Medium	69.6	High	Limited	0-2ft
	08/12/19	29454	Hot	83	80s	Clear	No	0	No	Breezy	Low	19.5	Low	Perfect	0-2ft
	08/16/19	29550	Mild	76	70s	Cloudy	No	0	No	Breezy	Medium	21.4	Low	Perfect	0-2ft
	08/20/19	29627	Warm	87	80s	Clear	No	0	No	Breezy	Medium	59.6	High	Perfect	0-2ft
	08/25/19	29624	Mild	73	70s	Cloudy	No	0.015	Yes	Windy	Medium	24.2	Low	Perfect	0-2ft
	09/01/19	29721	Mild	74.5	70s	Clear	No	0	No	Windy	High	96.8	High	Perfect	0-2ft
Flat Hammock	07/24/19	35518	Hot	79	70s	Partly Cloudy	No	0.025	Yes	Calm	Medium	68.0	High	Perfect	
	08/12/19	29455	Hot	83	80s	Clear	No	0	No	Breezy	Low	18.9	Low	Perfect	0-2ft
	08/16/19	29549	Mild	76	70s	Cloudy	No	0	No	Breezy	Medium	27.0	Low	Perfect	0-2ft
	08/24/19	29625	Mild	76	70s	Clear	No	0	No	Breezy	Medium	57.2	High	Perfect	0-2ft
	09/01/19	29722	Mild	74.5	70s	Clear	No	0	No	Windy	High	96.9	High	Perfect	0-2ft
West Harbor	07/24/19	29242	Hot	79	70s	Partly Cloudy	No	0.025	Yes	Calm	Medium	68.0	High	Perfect	
	08/06/19	29374	Warm	77	70s	Cloudy	No	0.015	Yes	Breezy	Medium	66.1	High	Limited	0-2ft
	08/12/19	29453	Hot	83	80s	Clear	No	0	No	Breezy	Low	20.1	Low	Perfect	0-2ft
	08/12/19	29447	Hot	83	80s	Clear	No	0	No	Breezy	Low	18.0	Low	Perfect	0-2ft
	08/16/19	29548	Mild	76	70s	Cloudy	No	0	No	Breezy	Medium	19.5	Low	Perfect	0-2ft
	08/20/19	29626	Warm	87	80s	Clear	No	0	No	Breezy	Medium	63.6	High	Perfect	0-2ft
	08/25/19	29623	Mild	73	70s	Cloudy	No	0.015	Yes	Windy	Medium	23.5	Low	Perfect	0-2ft
	09/01/19	29720	Mild	74.5	70s	Clear	No	0	No	Windy	High	95.2	High	Perfect	0-2ft
	09/03/19	29725	Hot	80.5	80s	Clear	No	0	No	Calm	High	97.9	High	Perfect	0-2ft
	09/10/19	31337	Warm	75.5	70s	Partly Cloudy	No	0	No	Calm	Low	25.2	Low	Perfect	0-2ft
	09/13/19	31332	Warm	78.5	70s	Clear	No	0	No	Calm	High	80.9	High	Perfect	0-2ft
	09/20/19	31333	Warm	76.5	70s	Clear	No	0	No	Breezy	Low	53.9	High	Perfect	0-2ft
	09/27/19	31334	Warm	70.5	70s	Clear	No	0	No	Breezy	Medium	64.5	High	Perfect	0-2ft
	10/04/19	31335	Mild	65.5	<70	Clear	No	0.04	Yes	Breezy	Medium	75.5	High	Perfect	0-2ft
	10/12/19	31336	Mild	60	<70	Partly Cloudy	No	0	No	Breezy	High	81.5	High	Perfect	0-2ft
	05/19/20	32804	Mild	62.5	<70	Partly Cloudy	No	0	No	Windy	Medium	35.3	Low	Perfect	0-2ft
	05/21/20	32815	Warm	59	<70	Clear	No	0	No	Breezy	Medium	58.4	High	Perfect	0-2ft
	05/23/20	32816	Mild	67	<70	Cloudy	No	0.72	Yes	Breezy	Medium	22.7	Low	Limited	0-2ft
	06/23/20	33317	Warm	77	70s	Partly Cloudy	No	0	No	Calm	Low	49.0	High	Limited	0-2ft
	07/03/20	33203	Warm	85	80s	Cloudy	No	0.245	Yes	Breezy	Medium	9.4	Low	Limited	0-2ft
	07/07/20	33205	Mild	71	70s	Cloudy	No	0.095	Yes	Windy	Medium	17.2	Low	Limited	0-2ft
	07/09/20	33204	Warm	81.5	80s	Clear	No	0	No	Breezy	Low	48.1	High	Perfect	0-2ft
	07/10/20	33316	Mild	77	70s			0.035	Yes	Breezy	Medium	52.5	High	Limited	0-2ft
	07/10/20	33206	Cool	77	70s	Cloudy	Yes	0.035	Yes	Windy	High	77.0	High	Limited	2-4ft
Eighth Hole	08/21/19	29564	Hot	82	80s	Clear	No	0.27	Yes	Breezy	Medium	69.7	High	Perfect	0-2ft
	08/25/19	29619	Cool	73	70s	Cloudy	Yes	0.015	Yes	Windy	Low	23.1	Low	Perfect	0-2ft
	08/27/19	29622	Mild	72	70s	Cloudy	No	0	No	Calm	Medium	13.0	Low	Perfect	0-2ft
	08/29/19	29716	Hot	83	80s	Clear	No	0.015	Yes	Breezy	Low	6.4	Low	Perfect	0-2ft
	08/30/19	31979	Warm	80.5	80s	Clear	No	0	No	Breezy	Low	-2.9	Low	Perfect	0-2ft
	09/11/19	30007	Warm	78.5	70s	Clear	No	0	No	Breezy	Low	22.7	Low	Perfect	0-2ft
	09/23/20	33905	Mild	77	70s	Clear	No	0	No	Breezy		14.9	Low	Perfect	0-2ft
	10/19/20	34112	Cool	64	<70		No	0	No	Breezy	Medium	56.9	High	Perfect	0-2ft
East Beach	07/24/19	29254	Hot	79	70s	Partly Cloudy	No	0.025	Yes	Breezy	High	74.4	High	Perfect	
	08/21/19	29562	Hot	82	80s	Clear	No	0.27	Yes	Breezy	Medium	70.2	High	Perfect	0-2ft
	08/27/19	29621	Mild	72	70s	Cloudy	No	0	No	Calm	Medium	13.2	Low	Perfect	0-2ft
	08/29/19	29717	Hot	83	80s	Clear	No	0.015	Yes	Breezy	Low	8.2	Low	Perfect	0-2ft
	08/30/19	31978	Warm	80.5	80s	Clear	No	0	No	Breezy	Low	-2.3	Low	Perfect	0-2ft
	09/11/19	30006	Warm	78.5	70s	Clear	No	0	No	Breezy	Low	23.6	Low	Perfect	0-2ft
	09/15/20	33907	Cool	65	<70		No	0	No	Breezy	High	79.2	High	Perfect	0-2ft

Appendix 4 C. Sampling event locations, dates, and counts shore activities.

			Non-Consumtion Sandy Shore				Non-Consumtion Rocky Shore		Consumption Sandy		Consumption Rocky Shore		
Beach	Date	SurveyID	Animals, off leash	Animals, on leash	Beach Recreation	Wildlife Watching	Beach Recreation	Tide-pooling	Hand Collection of Biota	Shore Fishing	Hand Collection of Biota	Tide-pooling	TOTAL
North Hill	9/1/2019	29721	0	0	0	0	0	0	0	0	0	0	**0**
	8/25/2019	29624	0	0	0	0	0	0	0	0	0	0	**0**
	8/20/2019	29627	0	0	0	0	0	0	0	0	0	0	**0**
	8/16/2019	29550	0	0	0	0	0	0	0	0	0	0	**0**
	8/12/2019	29454	0	0	0	0	0	0	0	0	0	0	**0**
	8/6/2019	29566	0	0	0	0	0	0	0	0	0	0	**0**
Flat Hammock	9/1/2019	29722	0	0	0	0	0	0	0	0	0	0	**0**
	8/24/2019	29625	0	0	0	0	10	0	0	0	0	0	**10**
	8/16/2019	29549	0	0	0	0	0	0	0	0	7	0	**7**
	8/12/2019	29455	0	0	0	0	0	0	0	0	0	0	**0**
	7/24/2019	35518	0	0	0	0	0	0	0	0	0	0	**0**
West Harbor	7/10/2020	33206	0	0	0	0	0	0	0	0	0	0	**0**
	7/10/2020	33316	0	0	0	0	0	0	0	0	0	0	**0**
	7/9/2020	33204	0	0	3	0	0	0	0	0	0	0	**3**
	7/7/2020	33205	0	0	6	0	0	0	0	0	0	0	**6**
	7/3/2020	33203	0	1	16	0	0	0	0	0	0	0	**17**
	6/23/2020	33317	0	0	6	0	0	0	0	0	0	0	**6**
	5/23/2020	32816	0	1	5	0	0	0	0	0	0	0	**6**
	5/21/2020	32815	0	0	2	0	0	0	0	0	0	0	**2**
	5/19/2020	32804	0	0	0	0	0	0	0	0	0	0	**0**
	10/12/2019	31336	0	0	6	1	0	0	1	0	0	0	**8**
	10/4/2019	31335	0	0	3	1	0	0	1	0	0	0	**5**
	9/27/2019	31334	1	0	14	1	0	0	1	1	0	0	**18**
	9/20/2019	31333	0	0	12	0	0	0	1	1	0	0	**14**
	9/13/2019	31332	1	0	6	1	0	0	1	1	0	0	**10**
	9/10/2019	31337	0	0	0	0	0	0	0	0	0	0	**0**
	9/3/2019	29725	0	0	1	0	0	0	0	0	0	0	**1**
	9/1/2019	29720	0	0	14	0	0	0	0	0	0	0	**14**
	8/25/2019	29623	0	0	2	0	0	0	0	0	0	0	**2**
	8/20/2019	29626	0	0	6	0	0	0	0	0	0	0	**6**
	8/16/2019	29548	0	0	8	0	0	1	0	0	0	0	**9**
	8/12/2019	29447	0	0	13	0	0	0	0	0	0	0	**13**
	8/12/2019	29453	0	0	16	0	0	0	0	0	0	0	**16**
	8/6/2019	29374	0	0	3	0	0	0	0	0	0	0	**3**
	7/24/2019	29242	0	0	4	0	0	0	0	0	0	0	**4**
Eighth Hole	10/19/2020	34112	0	0	0	0	0	0	0	0	0	0	**0**
	9/23/2020	33905	0	0	0	0	0	0	0	0	0	0	**0**
	9/11/2019	30007	0	0	0	0	0	0	0	0	0	0	**0**
	8/30/2019	31979	3	0	16	0	0	1	0	0	0	0	**20**
	8/29/2019	29716	1	1	8	0	0	0	0	0	0	0	**10**
	8/27/2019	29622	0	0	0	0	0	0	0	0	0	0	**0**
	8/25/2019	29619	0	0	0	0	0	0	0	0	0	0	**0**
	8/21/2019	29564	0	0	0	0	0	0	0	0	0	0	**0**
East Beach	9/15/2020	33907	0	0	0	0	0	0	0	0	0	0	**0**
	9/11/2019	30006	1	0	2	0	0	0	0	0	0	0	**3**
	8/30/2019	31978	0	0	0	0	0	0	0	0	0	0	**0**
	8/29/2019	29717	0	0	0	0	0	0	0	0	0	0	**0**
	8/27/2019	29621	0	0	0	0	0	0	0	0	0	0	**0**
	8/21/2019	29562	0	0	0	0	0	0	0	0	0	0	**0**
	7/24/2019	29254	0	0	0	0	0	0	0	0	0	0	**0**
TOTAL			**7**	**3**	**172**	**4**	**10**	**2**	**5**	**3**	**7**	**0**	**213**

Appendix 4 D. Sampling event locations, dates, and counts offshore activities.

			Non-Consumption		
Beach	Date	SurveyID	Offshore Recreation (swimming, etc.)	Stand-Up Paddle Boarding	**TOTAL**
North Hill	8/6/2019	29566	0	0	**0**
	8/12/2019	29454	2	0	**2**
	8/16/2019	29550	0	0	**0**
	8/20/2019	29627	0	0	**0**
	8/25/2019	29624	0	0	**0**
	9/1/2019	29721	1	0	**1**
Flat Hammock	7/24/2019	35518	0	0	**0**
	8/12/2019	29455	0	0	**0**
	8/16/2019	29549	0	0	**0**
	8/24/2019	29625	4	0	**4**
	9/1/2019	29722	0	0	**0**
West Harbor	7/24/2019	29242	1	0	**1**
	8/6/2019	29374	0	0	**0**
	8/12/2019	29447	2	0	**2**
	8/12/2019	29453	3	0	**3**
	8/16/2019	29548	0	0	**0**
	8/20/2019	29626	2	0	**2**
	8/25/2019	29623	0	0	**0**
	9/1/2019	29720	2	0	**2**
	9/3/2019	29725	0	0	**0**
	9/10/2019	31337	0	0	**0**
	9/13/2019	31332	0	1	**1**
	9/20/2019	31333	0	1	**1**
	9/27/2019	31334	0	1	**1**
	10/4/2019	31335	0	0	**0**
	10/12/2019	31336	0	0	**0**
	5/19/2020	32804	0	0	**0**
	5/21/2020	32815	0	0	**0**
	5/23/2020	32816	0	0	**0**
	6/23/2020	33317	6	0	**6**
	7/3/2020	33203	0	0	**0**
	7/7/2020	33205	0	0	**0**
	7/9/2020	33204	0	0	**0**
	7/10/2020	33206	0	0	**0**
	7/10/2020	33316	0	0	**0**
Eighth Hole	8/21/2019	29564	0	0	**0**
	8/25/2019	29619	0	0	**0**
	8/27/2019	29622	0	0	**0**
	8/29/2019	29716	4	0	**4**
	8/30/2019	31979	0	0	**0**
	9/11/2019	30007	0	0	**0**
	9/23/2020	33905	0	0	**0**
	10/19/2020	34112	0	0	**0**
East Beach	7/24/2019	29254	0	0	**0**
	8/21/2019	29562	0	0	**0**
	8/27/2019	29621	0	0	**0**
	8/29/2019	29717	0	0	**0**
	8/30/2019	31978	0	0	**0**
	9/11/2019	30006	0	0	**0**
	9/15/2020	33907	0	0	**0**
TOTAL			**27**	**3**	**30**

Appendix 4 E. Sampling event locations, dates, and counts boating activities.

			Non-Consumption										**Consumption**			
			Anchored			Moored		Underway			Unknown		Anchored	Underway	Unknown	
				Power		Power			Power		Power		Sport Fishing	Commercial	Sport Fishing	
Location	Date	Survey ID	Jet Ski	Boat	Sailboat	Boat	Sailboat	Kayak	Boat	Sailboat	Boat	Sailboat	Boat	Lobster Boat	Boat	**TOTAL**
North Hill	8/6/2019	29566	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	8/12/2019	29454	0	0	0	0	0	0	1	0	0	0	0	0	0	**1**
	8/16/2019	29550	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	8/20/2019	29627	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	8/25/2019	29624	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	9/1/2019	29721	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Flat Hammock	7/24/2019	35518	0	3	0	0	0	0	0	0	0	1	0	0	0	**4**
	8/12/2019	29455	0	1	1	0	0	0	1	0	0	0	0	0	0	**3**
	8/16/2019	29549	0	1	0	0	0	0	0	0	0	0	0	0	0	**1**
	8/24/2019	29625	0	4	4	0	0	0	1	0	0	0	0	0	0	**9**
	9/1/2019	29722	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
West Harbor	7/24/2019	29242	0	0	0	0	0	0	0	0	0	1	0	0	0	**1**
	8/6/2019	29374	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	8/12/2019	29447	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	8/12/2019	29453	0	0	0	0	0	2	0	0	0	0	0	0	0	**2**
	8/16/2019	29548	0	0	0	0	0	0	1	0	0	0	0	0	0	**1**
	8/20/2019	29626	0	0	0	0	0	0	0	0	0	0	0	0	1	**1**
	8/25/2019	29623	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	9/1/2019	29720	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	9/3/2019	29725	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	9/10/2019	31337	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	9/13/2019	31332	0	0	0	0	0	0	0	0	1	0	0	0	0	**1**
	9/20/2019	31333	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	9/27/2019	31334	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	10/4/2019	31335	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	10/12/2019	31336	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	5/19/2020	32804	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	5/21/2020	32815	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	5/23/2020	32816	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	6/23/2020	33317	0	0	0	1	2	1	2	1	0	0	0	0	0	**7**
	7/3/2020	33203	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	7/7/2020	33205	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	7/9/2020	33204	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	7/10/2020	33206	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	7/10/2020	33316	0	0	0	1	2	0	0	0	0	0	0	0	0	**3**
Eighth Hole	8/21/2019	29564	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	8/25/2019	29619	0	0	0	0	0	0	0	0	0	0	0	1	0	**1**
	8/27/2019	29622	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	8/29/2019	29716	0	3	0	0	0	0	1	0	0	0	0	0	0	**4**
	8/30/2019	31979	1	6	0	0	0	0	0	0	0	0	0	0	0	**7**
	9/11/2019	30007	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	9/23/2020	33905	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	10/19/2020	34112	0	0	0	0	0	0	0	0	0	0	1	0	0	**1**
East Beach	7/24/2019	29254	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	8/21/2019	29562	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	8/27/2019	29621	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	8/29/2019	29717	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	8/30/2019	31978	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	9/11/2019	30006	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	9/15/2020	33907	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TOTAL			**1**	**18**	**5**	**2**	**4**	**3**	**7**	**1**	**1**	**2**	**1**	**1**	**1**	**47**