Limits of Acceptable Change Study in the NE Reserves and Culebra to support the development of management actions

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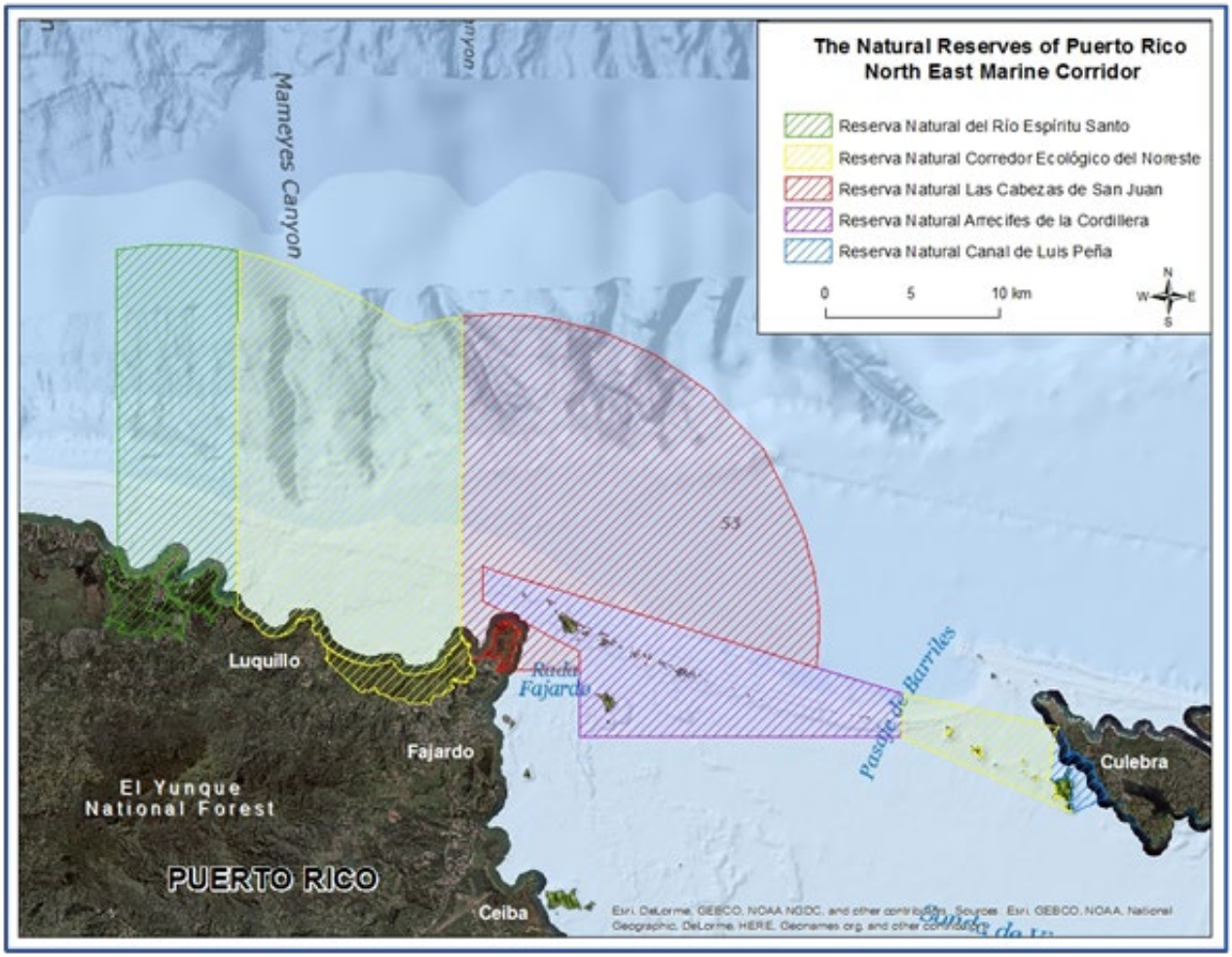

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Introduction

The Puerto Rico's Northeast Marine Corridor (NMC)[1] is a region designated as a conservation area network by the Puerto Rico Planning Board in 2016, and it has 122 existing conservation areas, including six large natural reserves, that create the basis for integrated management across the existing conservation initiatives (Figure 1). It stretches from the municipality of Rio Grande in the northwest, to Culebra in the northeast, with diverse coastal and marine habitats which are increasingly under threat from local, regional, and global activities (Pittman et al., 2017).

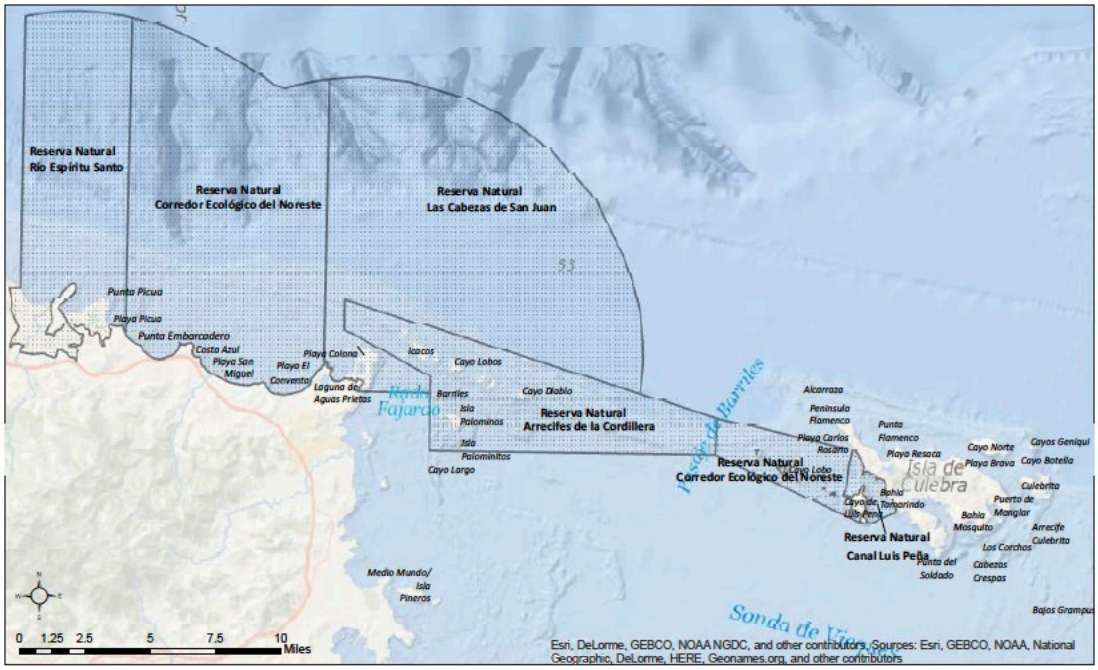

Figure 1: The Northeast Marine Corridor and Culebra protected area network (taken from Pittman et al., 2017)).

NMC habitats extend from the shoreline to deeper waters, including beaches, mangroves, sea grasses, coral reefs, and offshore waters. They provide important provisioning (fisheries), cultural (tourism), supporting (nutrient cycling), and regulating (shoreline protection) services adjacent to a densely populated coastline. The NMC also support a large part of the region's economy, as it derives from consumptive uses such as fishing (Shivlani and Matos-Caraballo, submitted) and non-consumptive (non-extractive) uses such as snorkeling, diving, boating, and beach visitation (Leeworthy, Schwarzmann et al. 2018). The habitats also define the social and cultural identity of adjacent coastal communities (Griffith and Pizzini 2002, Griffith, Valdés Pizzini et al. 2007).

Past work targeted the socioeconomic (and economic) characteristics of facets of the various communities and activities located adjacent to the NMC (Griffith, Valdés Pizzini et al. 2007, Matos-Caraballo and Agar 2011, Hernández-Delgado, Shivlani et al. 2014, Pittman, Jeffrey et al.

[1] Please note that the acronym "NMC" is used where the report refers to all six reserves; where the report focused on one or more of the reserves, those reserves are identified instead.

2017), fewer have focused specifically on identifying the uses and activities in the area and their relationships with the coastal and marine resources[2]. Also, with the exceptions of Pittman et al. (2017), Kågesten et al. (2015), and the Puerto Rico Coral Reef Monitoring Program, all of which focus on benthic habitats, areawide biophysical studies have been largely absent for the NMC.

This study assesses the NMC's users and respective use patterns based on user group surveys and interviews, analyzed through the lens of Limits of Acceptable Change (LAC) framework (McCool 1996) . The purpose of the study is to understand how to balance or achieve desired resource conditions with commercial and recreational users' demands and behavior. While the uses are well known and have been characterized by previous studies, visitor loads and activities, vessel boating patterns, and user and stakeholder views on resource conditions and changes are less well understood. This study intends to fill this gap to develop specific management recommendations for managing users and geographic areas of the NE Reserves and Culebra.

Methods

Based on an initial characterization conducted from 2018-19, four main user/stakeholder groups were identified as those that utilize the NMC resources. The overall approach adopted for the characterization, completed between 2019 and 2021, consisted of two methods chosen to optimize data collection from the four main user/stakeholder groups. Intercept surveys were used to query recreational boaters and visitors, and structured surveys were administered as interviews with commercial fishers and water-based operators (Bernard and Bernard 2013).

The study approach, survey instruments, and related methods were submitted to the Office of Management and Budget (OMB) for review and approval, which was obtained in 2019 for four surveys pertaining to recreational boaters, visitors, commercial fishers, and water-based operations. The OMB control number assigned was 0648-0775.

Intercept surveys

The study team determined that the best method by which to target boaters who undertook trips to the NMC would be to implement intercept surveys at the most popular public boat ramp in the region, located in La Croabas, Fajardo. The boat ramp receives vessels trailered from the local region and other areas. Key collaborators (NMC managers, commercial fishers, and recreational boaters that assisted with methodology planning) agreed that the Croabas boat ramp would be the most effective location to survey recreational boaters who utilize the NMC.

[2] It is noted however that other socioeconomic studies have been conducted in discrete parts of NMC. For example, Alfredo Montañez-Acuña conducted a series of focus groups with regional water-based operations on uses in the Luis Peña Canal No-Take Reserve, identifying key uses, areas of use, and management options within the marine reserve (Montañez-Acuña, 2017).

A digital version of the boater survey (which could be administered in either online or offline modes) was created, and all surveys were conducted in person using a tablet. To ensure that the survey did not have a bias because of different type of boaters using the NMC weekdays versus weekend days, equal numbers of survey sessions were held each month over weekdays and weekend days. Each intercept survey session was conducted for six hours, from 10 am to 4 pm, during which both departing and returning vessel operators were approach.

The study team selected five intercept sites to survey visitors in the NMC region. These sites included three beaches and two ports. The sites were selected to reach as many visitors as possible over a two-hour session, and all surveys were conducted using an online/offline version from a tablet. In the case of the beaches, the timing of the surveys was for two hours between 10 am to 2 pm. Thus, all survey sessions were completed by 12 pm or 4 pm. The port sessions were held according to the ferry schedules from Fajardo to Culebra and Vieques. The sessions started two hours before the expected departure of the ferry, and visitors were asked to participate as they entered the ferry terminal.

Structured surveys

The study used findings from a 2019 commercial fisher census (Shivlani and Matos-Caraballo, submitted) and the concessionaire list with permits to operate at La Cordillera Reefs Natural Reserve and Luis Peña Channel No-take Natural Reserve (and Carlos Rosario and Tamarindo beaches) to identify the total number of each group that utilizes the NMC. The fisher census estimates that 50 fishers utilized the region but not all consistently (i.e., year-round basis). Upon further discussions with fishers at fishing centers from Rio Grande to Naguabo, it was determined that 30 or fewer fishers rely on the NMC for their livelihoods. As per the operators, a mixture of emails, phone calls, and on-site visits were used to corroborate the total number of active operations from the concessionaire list. There were several unlicensed operations that either openly or clandestinely offered trips (Schleier, personal communication), but these were not included in the sample, which consisted of 18 operations.

Both the commercial fisher and water-based operator surveys were set up as online/offline instruments, and both types were administered in person with the respondent. Additional information provided by each fisher and operator was collected separately and used for the findings. Surveys took over half an hour (and extended at times to over an hour).

Results

This section summarizes the results for the LAC study in NE Reserves and Culebra (NMC) for each of the four main groups. It describes their uses as well as their views on resource conditions, perceptions concerning crowding and other conditions related to limits of acceptable change, and management preferences for improving resource conditions and addressing crowding.

Intercept surveys

Intercept surveys were initially plan to be implemented over the period of one year but due to the onset of the COVID-19 pandemic they were conducted over pre-set periods (four times/month) (Alreck and Settle 2003). The study team had to stop all field-based surveys with the onset of the COVID-19 pandemic, even before the Commonwealth of Puerto Rico officially announced its first lockdown in mid-March 2020.

The study team expected at first to recommence the intercept surveys when infection rates subsided, but given the high rate of transmissibility, coupled with the rise of the delta and omicron variants, the study team decided to err on the side of caution and decided to use only those surveys that were obtained over the intercept survey session between mid-2019 and early 2020.

It should be noted that, with the exception of the registered boater intercept survey session, the intercept approach worked very well, both in terms of response rates and the number of surveys completed by session. Visitors were open to participating in the survey and provided detailed information on uses, use patterns, and views on resource and crowding conditions.

Registered boaters

A total of 56 surveys were completed from June 2019 to January 2020, over 18 sessions. Only just over three surveys per session were conducted, and each session was six hours long (10 am to 4 pm). Pilot work had suggested that as many as 12 surveys could be conducted per session but given that one of the two ramps at the Fajardo boat ramp site has been damaged and was largely inoperable, fewer than expected registered boaters trailered their vessels to the site. Also, the active hurricane season, which resulted in the northeast coast being threatened by Hurricane Dorian in August and Tropical Storm Karen in September, and unfavorable wind conditions for large parts of late 2019, depressed ramp activity. The findings however were very useful in providing an overview on boaters' views on resource conditions and crowding in the northeast.

Over three quarters of those surveyed, or 76.8%, identified the Croabas boat ramp as their primary port; another 10.7% used an east coast port or ramp. The remainder used either north coast or west coast ports or ramps. Exactly half of those surveyed reported having a secondary port, and of the 28 respondents who identified their secondary ports by name, 75% of these ports were located in the east coast. This suggests that use is mainly local, in that boaters may change ports within a given coast, but they do not necessarily shift their use patterns across longer distances (i.e., across ports).

When asked about their primary zip code, 43% (n = 41) stated that they lived in northeastern Puerto Rico. A majority of non-east coast boaters using the ramp were from the metropolitan San Juan area (36.5%). Past work conducted with registered boaters at individual registration offices similarly determined that a majority of north coast registered boaters (58%; n = 269) and

all east coast registered boaters (n = 61) took trips to the east coast (Shivlani 2009)[3]. The NE Reserves and Culebra thus remain important recreational destinations for boaters from these two coasts, and while boaters may switch ports, they do so from within the east coast (ex., Fajardo or Ceiba) to access the aforementioned areas.

Over fourth fifths (83.9%; n = 56) of the registered boaters had owned their vessels for 10 years or less, and 51.8% had obtained a vessel in the past five years. The average amount of time that a boater had owned a vessel was just over 6-10 years (mean = 3.05, where 1 is less than one year, and 8 is over 30 years; SD = 1.90). By contrast, 44% (n = 56) had 16 or more years of boating experience (operating a vessel); the average experience reported was slightly under 16-20 years (mean = 4.86; SD = 2.39). Thus, while the years of vessel ownership reported is on average less than the vessel operating experience, the fact that respondents had been operating vessels for between 16-20 years on average showed that the sample likely held a considerable historical knowledge on boating-related issues.

Every boater (n = 56) surveyed reported owning a motorboat, averaging 21 feet in length (SD = 5.06) and 224 horsepower (SD = 213). Most vessels (92.8%) were less than 30 feet in length. This contrasts with the commercial fishing fleet reported for Puerto Rico which averaged less than 100 horsepower (Shivlani and Matos-Caraballo, 2022).

Boaters were asked to estimate the number of trips that they take per month, broken down into weekdays (Mondays to Fridays) and weekend days (Saturdays and Sundays). Responses were recorded based on total trips per month, separated as a maximum of 22 weekday trips/month and eight weekend trips/month. Over half of the sample (53.6%; n = 56) took weekday trips, and 89.3% took weekend day trips; also, 42.8% took both weekend and weekday trips. The average number of trips for weekdays (2.55 days; SD = 3.75) was very similar to that of weekend days (2.48 days; SD = 1.82), showing that while trips were taken during weekdays, these were less frequent and taken by fewer boaters than weekend day trips; in fact, boaters utilized an average of 11.6% of all weekdays available in a month compared to 31% of all weekend days available in a month. These findings reinforce anecdotal information provided by other stakeholders in this study, that crowding conditions worsen towards the end of the week (Medina, personal communication; Schleier, personal communication).

When asked about the trip profiles, the most frequent trip length reported was eight hours (44.6%; n = 56), and 76.7% stated that their trip lasted no longer than eight hours; the average trip length was 8.76 hours (SD = 4.74). Over a two-thirds of the respondents (69.6%) took three other passengers on a typical trip, and the average number was 3.88 (SD = 1.86) passengers plus a captain. Trip profiles indicate that boaters generally visit the NMC region in small groups (less than four persons) and spend the whole day out in the area. It should be noted that there

[3] It is noted that while the number of registered boaters surveyed was relatively low per session, the data collection team did spend 108 hours over a six-month period at the survey site. The relatively low rate of use suggests that the public ramp use is likely low compared to private marina or dock use to access the NMC.

were high ranges for both trip length (up to 24 hours) and number of persons per trip (10 or more); however, the high ranges represented 5% or less of the sample.

Respondents provided use information per area. It was expected that since the intercept surveys were conducted within the NMC region that boaters would likely show a strong affinity to the region. The following map (Figure 2) was used to determine if the NMC region (denoted as zones 2 and 3) represented the most important area, as measured by percentage of total use.

Figure 2: Puerto Rico use areas

Table 1: Boaters' areas of use in Puerto Rico

Area	Average use percentage (n = 56)
1	2.05 (13.4)
2	25.3 (39.7)
3	55.6 (39.0)
4	9.55 (17.0)
5	2.14 (11.4)
6	2.68 (9.29)
7	17.9 (8.17)

Use covered all areas in the sample, but average use percentages were highest on the east coast (Table 1). Respondents used Area 2 (the northern section of northeastern Puerto Rico) on average for 25.3% of all trips, and they used Area 3 (the NMC) for over half of all trips (55.6%). Area 4, south of the NMC, accounted for another 9.6% of all trips. Overall, 55.6% of all boaters surveyed reported using Area 3; when combined with Area 2, the percentage of users in the northeastern region increased to 80.9% of the sample. This shows that boaters using the Croabas ramp (and likely other access points in northeastern Puerto Rico) disproportionately focus their trips to NMC, and less so to the northwest or southeast.

When asked about crowding conditions in the most used areas, a majority (57%; n = 56) stated that the areas were either moderately or very crowded, leaving little to no space for boating-related activities. By contrast, only 8.9% identified their used areas as being open such that they have all the space they need to engage in their boating-related activities. This may be expected, as most of the boaters surveyed reported taking weekend day trips, which is when use can be expected to peak; however, another reason why crowding might be an issue is due to the preferred used areas (Areas 2 and 3, where most boaters take their trips.

Table 2: Boaters' trip activities (n= total sample)

Activity	Almost every trip (%)	Most trips (%)	Half of trips (%)	Few trips (%)	Never (%)	n
Fishing (line)	15.4	11.5	5.77	9.62	57.7	52
Spearfishing	11.8	0	1.96	1.96	84.3	51
Diving	4.08	20	2.04	2.04	91.8	49
Snorkeling	20.8	6.25	8.33	1.04	54.2	48
Swimming	22.4	0	0	2.04	75.5	49
Water-skiing	0	0	0	2.08	97.9	48
Cruising	81.8	5.45	0	9.09	3.64	55
Visiting keys and beaches	79.6	7.41	0	7.41	5.56	54

Boaters did not engage much in on-water activities, such and diving, snorkeling, and swimming, for which only around a fifth or a quarter of the respondents participated almost in every trip or on most trips (Table 2). Also, only 26.9% of respondents reported fishing on most or all trips, compared to 57.7% who stated that they do not fish at all; a much larger majority, or 84.3%, stated that they do not spearfish. Thus, consumptive uses in the areas used (including the NMC) were not very popular. Instead, boaters most often engaged in cruising (87% of all or most trips) and visiting keys and beaches (87% of all or most trips). Use patterns in the region, as determined by Shivlani (2009), consist of boaters most cruising eastward from one of the primary northeastern ports to anchor on popular keys such as Icacos and Palomino, and cruising and visiting keys and beaches remain the most important activities for boaters.

Table 3: Number of other boaters viewed and tolerated, by activity, (n = total sample; standard deviations in parentheses).

Activity	Number of other vessels viewed on a typical trip, where 1 = 1-5 and 7 = over 30	n	Number of other vessels tolerated	n	Number of other visitors tolerated	n

Fishing (line)	1.63 (1.71)	24	6.65 (20.8)	23	2.78 (5.07)	23
Spearfishing	1.5 (1.73)	12	8.14 (26.2)	14	8.79 (27.2)	13
Diving	2.3 (1.95)	10	10.8 (29.3)	11	13.3 (34.7)	8
Snorkeling	3.0 (2.05)	22	19.9 (34.3)	14	26.2 (38.1)	11
Swimming	5.25 (2.34)	12	23.0 (40.3)	10	29.7 (47.5)	7
Water-skiing	2.17 (2.40)	6	13.9 (34.5)	8	14.4 (37.3)	7
Cruising	5.23 (2.38)	53	88.3 (70.8)	39	94.2 (71.8)	38
Visiting keys and beaches	5.47 (2.23)	49	89.7 (71.1)	38	95.7 (72.1)	37

As shown in Table 3, boaters experienced different levels of crowding, depending on activity type. Thus, those activities that were reported as the most popular, namely cruising and visiting keys and beaches, were the same ones that elicited the highest number of vessels observed. On average, boaters saw over 21-25 other vessels (mean = 5.23) while cruising and between 21-25 and 26-30 other vessels (mean = 5.47) while at keys and beaches. Consumptive and most in-water activities showed less crowding, such that boaters reported viewing between 1-5 and 6-10 vessels (mean = 1.63 for line fishing; mean = 1.5 for spearfishing) while they were line fishing or spearfishing.

Boaters showed a distinct difference in tolerance levels based on activity type. While engaged in fishing activities, for example, boaters stated that they tolerated only over six vessels and less than three other fishers on average while they were engaged in line fishing. Fishers also reported viewing between 1-5 and 6-10 vessels, suggesting that boaters are very likely to move based on average congestion conditions. Similarly, while spearfishing, boaters only tolerated eight other vessels and less than nine other divers; given that reported use conditions average between 1-5 and 6-10 other spearfishing vessels observed, is likely this may result in boaters moving. Tolerance levels were generally much higher for cruising and visiting keys and beaches. Boaters stated that they tolerate almost 90 vessels while cruising and visiting keys and beaches before they are inclined to find another location. Based on the fact that boaters reported viewing just over 21-25 other vessels while cruising and between 21-25 and 26-30 other vessels while visiting keys and beaches, crowding is likely not a concern for these activities. The reasons for these differences in tolerances is likely a function on the impacts that other users have on the activity. Thus, consumptive uses such as fishing are not amenable to a high density of users where catch rates may be negatively impacted. Similarly, spearfishers may want to have an area to themselves to maximize catches and safety. Conversely, nonconsumptive uses that result in the aggregation of boaters who can engage in social activities together and in close proximity may actually be preferred over seeking more quiet areas, as shown by the high tolerance totals of other boats and visitors that respondents stated that they would accept while cruising or visiting keys and beaches. Thus, there is no singular tolerance total as defined by the sample, and levels are likely to vary considerably based on activity type.

Table 4: Impact by activity type (n= total sample).

Activity	No impact (%)	Very minor impact (%)	Minor impact (%)	Moderate impact (%)	Major impact (%)	n
Number of other vessels in the area	14.5	16.4	14.5	1.82	52.7	55
Number of other users in the area	16.4	18.2	18.2	10.9	36.4	55
Behavior of vessel operators	5.46	3.64	7.27	7.27	76.4	55
Music from other vessels	10.9	3.64	3.64	9.09	72.7	55
Trash from other vessels	0	1.82	5.46	0	92.7	55

Boaters were generally aware that most boating activities, especially when practiced improperly, significantly impact trip quality (Table 4). In fact, apart from the number of other users in a given area, all other activities were perceived as having major impacts to trip quality. Behavior, which is manifested in the volume and type of music played, boating etiquette, and trash retention, was the main complaint. Boaters felt that others abused their privileges by creating hazardous conditions, playing music unfit for families, and throwing trash into the water, and that these abuses all had major impacts. Trash was almost universally condemned as a major impact (92.7% agreeing) and none of the respondents felt that trash had no impact.

Table 5: Resource conditions (n = total sample).

Resource	Excellent (%)	Good (%)	Neutral (fair) (%)	Poor (%)	Very poor (%)	Don't know (%)	n
Water clarity	70.9	14.5	10.9	1.82	1.82	0	55
Marine biodiversity	22.2	27.8	25.9	9.26	0	14.8	55
Marine life size	14.8	27.8	27.8	13.0	0	16.7	54
Marine life abundance	14.8	27.8	27.8	13.0	0	16.7	54

Coral diversity and abundance	5.56	24.1	16.7	22.2	7.41	24.1	54
Coral health	5.56	22.2	13.0	22.2	13.0	24.1	54
Quality of beaches	76.4	16.4	5.46	0	0	1.82	55

Boaters were generally very satisfied with the condition of two resources: Water clarity and beach quality. As shown in Table 5, over 85% of those surveyed felt that water clarity was either excellent or good. An even greater percentage, or 92.8%, rated beach quality as excellent or good. Because boaters reported engaging mainly in cruising and visiting beaches and keys, it is important from the perspective of user satisfaction that related conditions (i.e., how transparent the water is, as a proxy for water quality, and the quality of beaches) were rated as being in excellent to good condition. This also suggests that the NMC provide the cultural ecosystem benefits that boaters value. There were some concerns raised by boaters related to coral reefs; that is, while a large percentage of respondents did not know how coral diversity, abundance, and health were faring, almost 30% felt that coral diversity and abundance was poor or very poor, and over a third (35.2%) felt that coral health were between poor and very poor. Most boaters did not engage with benthic resources, as 92% and 54% never participate in diving and snorkeling, respectively. Thus, the views concerning coral reef conditions may be more a result of education and awareness rather than direct observation.

In summary, over 87% (n = 56) engaged in cruising and almost three quarters (73.2%) visited beaches and keys. Almost a third (32.1%) reported line fishing, and 11% fished with a speargun. Only 3.6% either free dived or used SCUBA for non-consumptive uses, and 19.6% participated in snorkeling. These show that boaters likely use the NMC mostly for the beaches in the Cordillera Reserve and Natural Area (RNA) keys (ex., Icacos, Palomino) and for cruising within the region; consumptive activities, especially vessel-based, line fishing, are important only for a subset of boaters who likely use the NMC for its coral reef fisheries.

Visitors

A total of 754 visitors participated in the visitor intercept study, from May 2019 to February 2020. As stated in the methodology, four sessions were to be held per month (two weekday and two weekend day sessions) across five sites. An irregular ferry schedule and strong hurricane season in 2019 both led to a later than expected start to conducting visitor surveys at ferry sites in Culebra and Vieques. Also, several hurricane threats and poor weather led to the postponement of beach survey sessions. Finally, the impending threat of COVID-19 shut down all data collection in March 2020. Overall, the study team completed 67 sessions, completing an average of 11.3 surveys per session.

Almost two thirds of visitors (62.5%; n = 754) provided zip code or other primary location data. Most of the visitors providing such data were from Puerto Rico (57%; n = 472), followed by visitors from the mainland US (36.7%) and overseas visitors (6.4%). Within Puerto Rico visitors, almost half (47.1%) were from a local or adjacent community, including Ceiba, Culebra, Fajardo and Luquillo. San Juan and other municipalities in the metropolitan area provided 18.4% of Puerto Rican visitors, with the remainder originating mainly from western inland and southeastern coastal communities. Very few visitors arrived from western or southwestern municipalities. This shows that Puerto Rican visitation to the NMC region is largely driven by local residents and metropolitan tourists, and less so from other municipalities. Also, it should be noted that if other results are considered from within the survey that ask about residency, then it is likely that over 68% of the sample consisted of Puerto Rican residents; it is just that a smaller proportion provided zip code or other primary location data.

US-based visitors arrived from 33 states and the District of Columbia, mostly from New York (representing 7.2% of all visitors, and 17% of all non-Puerto Rican visitors), followed by Virginia, Florida, Illinois, and Massachusetts (all of which represented 2% of total visitors). Foreign visitors, arriving from four continents, comprised 6.4% of all visitors and 15% of all non-Puerto Rican visitors; Mexico and Spain led all other countries in terms of visitor totals.

A majority of the visitors fell into the second youngest cohort (18-30 years old), representing over a third (35.5%; n = 747) of the sample. The next two age groups (31-40 years and 41-50 years) comprised 25.2% and 18.2% of the sample. The average age was 3.35 (or between 31-40 and 41-50 years) (SD = 1.37), meaning that the visitors surveyed were slightly older than the 31-40 year group.

The average number of visitors per trip in the sample was 4.03 (SD = 2.70; n = 666), including the survey respondent. The median group size was three visitors, but a few visitors reported consisting of 15 or more persons in their groups.

As might be expected, local residents and visitors from other parts of Puerto Rico mainly took day trips (86.4%). Over 81% of US-based visitors stated that they were staying for one or more nights, as did 86.7% of foreign visitors[4]. Of the visitors who provided additional information on their trip, the most frequent number of nights to be spent in Puerto Rico was two nights (17.4%; n = 201), followed by three or five nights (13.9% each), and one night (11.9%); almost 7% stated that they would spend 30 or more nights in Puerto Rico. On average, visitors stated that they planned to spend 6.2 nights (SD = 7.04).

[4] In the case of several US-based and almost all of the foreign visitors, it is likely that they misinterpreted the question to mean whether the trip to the northeastern Puerto Rico is to be a day or overnight trip; the data collection team always clarified this question when asking it of visitors, but some respondents may not have completely understood the question.

When asked if this represented their first trip to Puerto Rico, 68.3% (n = 735) stated they are residents. Among non-resident visitors, 12% were making their first trip to Puerto Rico, and the remainder (19.7%) were repeat visitors. Most of those returning for a trip (74%; n = 81) had been to Puerto Rico no longer than two years prior; thus, repeat visitation is an important phenomenon among non-residents.

Activities and resource conditions

As shown in Table 6, the most important activities were relaxation (91%) and spending time at beaches (88.8%) in the NMC. While 21.2% of the sample reporting taking culture-based activities, very few visitors engaged in water-based activities. The most popular of these were visiting one or more of the bioluminescent bays (11.3%), shore snorkeling (4.1%) and kayaking (3.2%). These rates of participation for snorkeling were much lower than those reported by a 2018 visitor valuation study (Leeworthy, Schwarzmann et al. 2018), but it should be noted that that data for snorkeling use included only non-residents. In the present effort, if only non-residents are considered, then the snorkeling from shore rate increases to over 12% (and over 22% for foreign visitors).

Table 6: Activities in the NMC region (n = total sample)

Activity	Engagement (%)	n
Relaxation	91.0	741
Beaches	88.8	741
Snorkeling from shore	4.13	741
Snorkeling from a vessel	0.80	741
Diving from shore	0.40	741
Diving from a vessel	0.13	741
Kayaking	3.20	741
Cultural activities	21.2	741
Visiting the bioluminescent bays	11.3	741
Fishing from shore	1.07	741
Fishing from a vessel	0.80	741
Hiking	15.1	741
Surfing	1.62	741
Cruising on a vessel	1.21	741

When asked about the main reason for their visit, 44% identified beaches and 41.4% stated that they were in the region for relaxation. Activities related to coastal and marine resources other than visiting beaches were either not identified or were not very important. What this suggests is that the visitors are largely motivated by the region's beaches for their trips, but that other activities – such as snorkeling, bioluminescent bay visits, kayaking, and hiking – are 'add-ons' to the primary activity. It should also be noted that most visitors do not have access to vessels and thus rely on water-based operations to be able to snorkel, dive, or fish in the NMC.

Table 7: Reasonable number of visitors, by activity type (n = total sample; standard deviation in parentheses)

Activity	Number of visitors, where 1 = 1-5 visitors and 7 = more than 30 visitors*	n
Visiting a beach	5.46 (2.16)	732
Snorkeling	3.35 (2.25)	562
Diving	2.91 (2.17)	483
Kayaking	3.67 (2.25)	592
Surfing	2.99 (2.31)	342
Hiking	5.28 (2.26)	659
Fishing	2.56 (2.28)	498
Spearfishing	2.01 (2.06)	435
Visiting a bioluminescent bay	4.26 (2.35)	432

* Number of visitors, where 1 = 1-5 visitors, 2 = 6-10 visitors, 3 = 11-15 visitors, 4 = 16-20 visitors, 5 = 21-25 visitors; 6 = 26-30 visitors, and 7 = over 30 visitors.

Visitors held nuanced views on what they considered a reasonable number of visitors per site or by activity (Table 7). Visitors generally called for low number of visitors within the same area when engaged in consumptive activities, such as fishing (mean = 2.56, between 6-10 and 11-15 fishers) and spearfishing (mean = 2.01, 6-10 spearfishers). By contrast, the sample felt that other more social activities that are non-consumptive can allow for higher visitor concentrations. Visitors, for example, felt that beaches can have between 21-25 and 26-30 visitors without being crowded. These findings are important because they demonstrate that visitors perceive no single reasonable limit for different kinds of uses, and that preferences are to likely considerable use-specific requirements (ex., do more users augment the activity experience to a high threshold, is there a bell curve for certain uses, and do other uses require stricter limits based on resource scarcity?).

Visitors were next asked to share their experiences based on the activities in which they most recently engaged. With respect to beaches, composed of 62.3% (n = 752) of the sample, the beaches visited were Playa Seven Seas in Fajardo (22.3%), Playa Monserrate in Luquillo (17.1%), and Playa Sun Bay (31.9%), Playa Caracoles (19%), and Playa Esperanza (8.0%) in Vieques. Visitors also spent time in other beaches in the region, including Culebra, Ceiba, and Fajardo.

Table 8: Beach conditions, as reported by percentage (n = total sample)

Beaches	1 – excellent	2 – good	3 – fair	4 – poor	5 – very poor	n
Facilities	45.8	19.6	18.2	8.38	8.07	644
Cleanliness	51.2	27.6	14.5	4.78	1.85	648
Space	78.0	13.5	5.34	2.35	7.85	637
Crowding	79.1	11.5	7.19	1.60	0.64	626
Natural resource conditions	67.1	22.7	7.90	2.05	0.16	633

The average number of other visitors that the sample reported viewing was between 16-20 and 21-25 on the top three beaches visited, or 5.49 (on a scale where 1 = no other visitors and 11 = over 50 other visitors; SD = 3.44; n = 651). As shown in Table 8, visitors rated the beaches they visited very highly. Almost two thirds of the visitors rated facilities as good or excellent, with almost 90% providing rating all other conditions as good or excellent. Crowding was not perceived as an issue, and the space available was considered ample. When asked if the number of visitors should be reduced, only 6.6% of the respondents felt that limits should be imposed; 91% disagreed with the proposal, arguing that neither space nor crowding presented an issue that needs to be managed.

Table 9: Snorkeling conditions, as reported by percentage (n = total sample)

Snorkeling	1 – excellent	2 – good	3 – fair	4 – poor	5 – very poor	Don't know	n
Water clarity	59.4	25	12.5	0	3.13	0	32
Fish diversity	28.1	37.5	15.6	6.25	9.37	0	32
Amount of fish	22.6	32.3	22.6	19.4	3.23	0	31
Fish size	21.9	34.4	31.3	3.13	9.37	0	32
Coral conditions	15.6	12.5	18.8	21.9	12.5	18.8	32
Crowding	28.1	15.6	37.5	15.6	3.13	0	32

Over 14% (n = 752) of the sample took a snorkel trip, either on a tour or from the shore. Almost two thirds (66.2%; n = 104) considered themselves as novice snorkelers, while 29.2% identified themselves as intermediate snorkelers. Only 6.7% stated that they were experts, in that they had been snorkeling several times and felt completely comfortable in the water. Visitors saw an average between 5-10 and 11-15 snorkelers on their trip (mean = 2.69, where 1 = no other snorkeler, and 11 = over 50 snorkelers; SD = 1.96; n = 32).

Visitors were asked to rate their snorkeling trip (the three sites provided were shore-based snorkeling within the NMC, Luis Peña Channel No-take Reserve, and the La Cordillera Reefs Natural Reserve). Due to the low rate of responses per site, the results were pooled together. As shown in Table 9, visitors generally enjoyed the sites for the water clarity, which 84.4% rated as excellent or good, followed by fish diversity (65.6% rated as excellent or good), fish size (56.3% rated as excellent or good), and amount of fish (54.9% rated as excellent or good). Only 28.1% rated coral conditions as good or excellent, and a plurality (34.4%) rated them as poor or very poor. Interesting, coral conditions was the only condition for which a segment of the respondents chose to provide a "don't know" response. Finally, less than a majority ranked crowding positively (43.7% rated it as excellent or good), and 58.1% stated that the number of snorkelers should be reduced. These findings are important because they show that there is a

divergence between visitors' views on resource conditions (which are very positive) and those on crowding conditions and the need to reduce users in a given snorkel site.

Only 19 visitors reported taking a diving or fishing trip, and most elected not to provide more information on these activities. As shown by the 2018 visitor profile study conducted in Puerto Rico (Leeworthy, Schwarzmann et al. 2018), participation rates in diving and fishing are very low and in this study, 2.5% or fewer visitors participated in either activity (and even fewer provided trip data). One recommendation to obtain such water-based activity information is to set up a concessionaire-specific survey that can be self-administered at the end of a trip.

Table 10: General resource conditions, as reported by percentage (n = total sample)

Resource	1 – excellent	2 – good	3 – fair	4 – poor	5 – very poor	Don't know	n
Beaches	51.9	32.4	11.4	3.23	0.40	0.67	744
Mangroves	11.1	28.0	10.0	2.84	2.70	45.4	740
Seagrasses	10.7	30.0	15.0	2.48	1.65	40.2	727
Water clarity	45.0	33.5	16.0	2.69	2.02	0.81	743
Plastics on the coast and ocean	28.7	44.3	17.8	6.76	1.35	1.08	740
Other garbage – cans, bottles – on beaches	25.8	45.5	21.3	5.01	1.36	1.08	738
Coral reefs	5.67	24.0	11.5	2.02	0.94	55.9	741
Fish and invertebrates	6.55	34.2	12.8	1.77	0.55	44.1	733

Visitors provided their views on the conditions of natural resources that they had viewed in their most recent trip (Table 10). They felt that many resources were in excellent or good conditions, including beaches (74.3%) and water clarity (78.5%), and that pollution from land-based sources and via recreational activities was generally doing well. However, visitors could not attest to the conditions of most of the major ecosystems/habitats in the region, and 45.4%, 40.2%, and 55.9% felt that they didn't have sufficient knowledge to assess the status of mangroves, seagrasses, and coral reefs, respectively. Also, 44.1% of the respondent felt ill-equipped to assess fisheries conditions.

Return visit conditions

Activity-based crowding was not a significant issue for visitors, as only 27.9% (n = 745) reported seeing more visitors than they had expected. A slightly higher percentage, or 29.4%, felt the

opposite, that they had seen fewer or much fewer visitors than they had expected. Also, 42.7% stated that they saw the number of visitors they had expected. It is possible that if the plurality that stated seeing the number of visitors they expected starts to feel otherwise (i.e., dissatisfied with the crowding conditions), overall visitor satisfaction may commence to decline; that is, there is enough ambivalence among the visitors to recommend that crowding should be tracked for changes in visitor perceptions, especially for those uses that can only support low numbers of users per site (ex., fishing, diving, snorkeling).

Table 11: Importance of resources/conditions for return visit, as reported by percentage (n = total sample)

Resource/condition (%)	Very important	Important	Somewhat important	Not very important	Not important at all	n
Beach quality	82.8	14.6	0.94	0.54	0.13	742
Condition of natural resources, such as mangroves and corals	63.8	27.4	4.35	3.40	1.09	735
The amount of coastal pollution, such as plastics and garbage	80.3	17.7	0.95	0.54	0.54	740
Crowding and congestion	39.4	24.0	18.6	10.6	7.45	738
The amount of noise, especially music	29.3	23.7	17.8	13.1	16.1	738
Trip costs in terms of lodging, activities	20.9	26.8	18.2	16.4	17.7	742

As shown in Table 11, natural resource conditions were the most important for visitors when considering a return trip. For example, 82.8% of visitors rated beach quality as a very important determinant in whether they would make a return trip, compared to only 20.9% who rated trip costs as very important. Similarly, visitors ranked the physical attributes of the NMC as the most important factors for a return trip, including the condition of coastal and marine resources (63.8% rated as very important) and the amount of coastal, land-based and vessel-based pollution (80.3% rated as very important). Crowding and noise pollution were not perceived as very important, but almost two-thirds of visitors did rate crowding and congestion as important or very important (63.4%).

Finally, when asked about which factor would most influence their willingness to return for a trip to the NMC region, 52.3% (n = 735) stated that the beach quality would determine if they make a repeat trip. Almost a quarter, or 22.9%, of the sample selected marine resource conditions as the primary factor in making a repeat trip. By contrast, factors such as crowding, sound, and trip costs were selected by only 2% or fewer visitors, showing that social factors are less important based on the fact that visitors showed a high threshold for total visitors at a beach, which was their top ranked activity. Beachgoers, who dominated the present study,

have a less direct relationship to the region's coastal and marine resources than might consumptive users such as fishers and spearfishers and those who prioritize water-based activities. Nevertheless, given at 22.9% made a future trip contingent on the quality of marine resources suggests that visitors do value these resources even if they do not utilize them as much as they do the region's sandy beaches.

Stakeholder interviews

Stakeholder interviews were structured, in-person surveys that were conducted via census sampling of the two main stakeholder groups: Commercial fishers and water-based operations. The steps taken, as described in the methods, were to identify the total number of members in each of the two groups via a number of approaches specific to each group and then to contact all members to explain the research and promote participation in the study.

All stakeholder interviews were conducted after the delta variant had declined in Puerto Rico because these were to be in-person interviews. It should be noted that due to the COVID-19 pandemic, overall participation in both groups declined somewhat, but the study team was able to contact and recruit a majority of members in each group.

Commercial fishing operations

Fieldwork commenced in 2019 in support of identifying the dedicated set of fishers who use the NMC on a year-round basis with a plan to complete fisher surveys over the spring and summer of 2020. However, the onset of the pandemic delayed the fisher surveys by over one year.

The initial characterization of use, conducted with 146 east coast fishers to identify areas of use, estimated that while between 26-50 fishers used the northeastern and southern sections of the La Cordillera Reefs Natural Reserve and Culebra, use was most pronounced in areas south of the NMC region (Figure 3). Based on these findings and follow-up discussions with fishing center leaders and key informants in ports in Rio Grande, Luquilo, Fajardo, Ceiba, Naguabo, Culebra, and Vieques, it was determined that a maximum of 30 fishers use the NMC region on a year-round basis; that is, the initial research determined that more fishers (as many as 50 operations) may fish the region on a sporadic basis, but dedicated use tends to occur south of the study region.

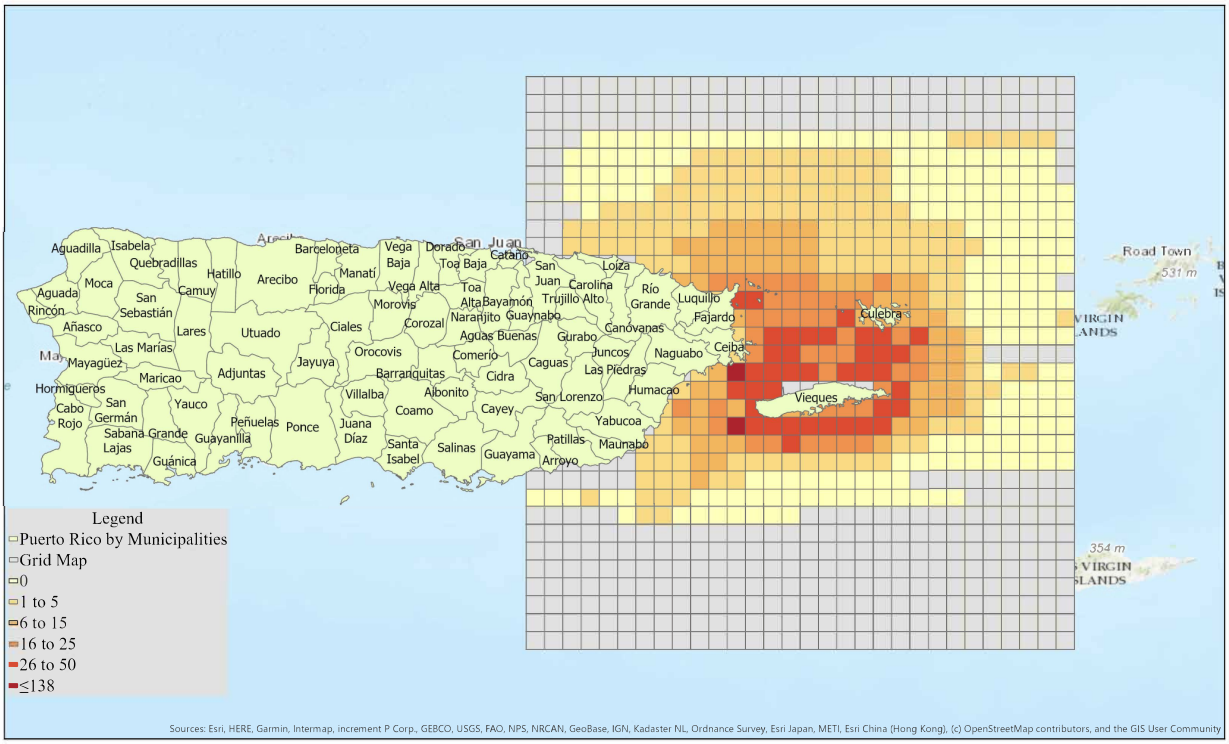

Figure 3: Commercial fishing on Puerto Rico's east coast (taken from Shivlani and Matos-Caraballo, submitted)

The team contacted all 30 fishers who use the region, from Luquillo to Ceiba, and interviewed 21 fishers, representing 70% of the fleet that utilizes the NMC on a dedicated basis. Nine fishers did not participate in the study, of whom several stated that they had not returned to fishing on a full-time basis since the COVID-19 pandemic and others who refused to participate due to other reasons.

All of the 21 fishers who participated in the study were part of full-time operations; that is, the respondents accessed their respective fishing ground year-round and depended mainly on fishing as a primary source of income. Among the respondents, two thirds (67%) were captains, 14% were divers, and 19% were crew members/helpers.

Fishers accessed the NMC region from a number of northeastern and eastern ports, from Rio Grande to Ceiba. Only one fisher stated having a secondary port; otherwise, a majority of the sample fished year-round from their primary port. This shows that there is not much movement of fishers, who tend to be very conservative in their movements (due to a combination of variable trip costs and productivity of known fishing grounds); thus, it is unlikely that fishers other than those surveyed seasonally or periodically access the NMC region.

The fishers surveyed had been fishing the region on average for 30.6 years (SD = 14.7; n = 16), with the range of experience spanning from between 10 years and over 60 years. A majority of the respondents were 60 years or older (52.2%; n = 21), and those 51 years or older represented 90.3% of the sample.

Fishing was an important income source to the respondents who, on average, depended on selling seafood for an average of 80.1% (SD = 28.0; n = 21) of their household income. Also, while not all fishers relied on their harvest for household consumption (57.1% sold all catch), 43% took home an average of 4.57% (SD = 6.79; n = 21) of their total landings. It should be noted that fishers take home mainly the low value species (Agar, Waters et al. 2008) while selling the high value catch.

Vessel, gear, and species information

Fishers provided information on vessel and gear characteristics, as related to the most recent fishing year, and on targeted species. Because the sample included crew and divers, not all fishers reported owning a vessel. The average number of vessels held by 75% of the respondents was 1.21 (SD = 0.43). The vessels used were generally longer (mean = 37 feet; SD = 13.9; n = 15) than vessels used in the overall Puerto Rican fishery, which averaged 20.7 feet (Shivlani and Matos-Caraballo, submitted). A majority of the vessels had combination wood-fiberglass hulls (80%; n = 15), and the remainder had fiberglass hulls. Vessels generally used one (outboard) engine (mean = 1.07 engines; SD = 0.26; n = 15), exhibiting moderate fishing power (i.e., horsepower averaged 82.3 hp (SD = 15.8), and the largest engines were listed as having 115 hp).

Fishers provided present value (in 2021 dollars) for their vessel hulls, engines, and electronic equipment. The minimum was $6,500 and the maximum was $28,600 (n = 15). The average present value of the vessel and associated equipment was $17,123 (SD = 6816).

The gears that fishers held ranged from fixed, passive gear such as fish traps, lobster traps, and vertical lines and active gear such as dive equipment and fishing lines. The fishery is highly diversified in the northeast, where fishers deploy a number of different gears to harvest a mix of fish and invertebrate species (Shivlani and Matos-Caraballo, submitted). Within the present sample, 27.8% (n =18) used more than one gear, whereas 50% used handlines, 44.4% used dive gear, 33% used vertical line gear, 22% used fish and/or lobster traps, and 11% used nets (nets were the only gear that was not fished by itself and instead was always a secondary gear to another gear type). The average replacement cost of the gear, which does not include labor costs (most fishers build their own gear), was estimated at $6587 (SD = 11951; n = 18). There was considerable variability in the replacement costs because gear types such as traps were disproportionately more expensive compared to others such as dive gear and especially line gear.

Fishers provided their annual operating expenses, as determined by vessel repair and maintenance costs and gear repair and rebuilding costs. Vessel replacement costs averaged $811 (SD = 775; n = 9), consisting of hull repairs, engine maintenance, and vessel equipment replacement. Gear repair and rebuilding costs averaged $500 (SD = 292; n = 11), and these varied depending on the gear type, where certain gears (lines, weights, hooks, etc.) needed to be replaced whereas others (traps, nets) could be repaired.

The sample identified the three most important gears that are used in the NMC region (i.e., the gears that the fishers ranked between trap, line, net, and dive gear). Overall, 42.9% (n = 21) ranked vertical line gear most frequently among the top three gears, followed by fish and lobster traps (38.1%), handlines (38.1%) and dive gear (38.1%), and nets (14.3%). In terms of the top ranked gear, fishers identified dive gear most frequently (38.1%), followed by vertical line gear (33.3%) and handline gear (28.6%). Given the shallow depth and coral and other hardbottom habitats available to fishers in the NMC region, gears amenable to those habitats (ex., dive and line gear) are disproportionately important. The exception is the vertical line gear, which is fished in much deeper water (Agar and Shivlani 2016), and is likely utilized in the northern sections of the region.

Fishers provided use information using Figure 2, from which they selected areas where they usually fish. Area 3 represented the NMC, and other areas of note included Area 2 (north of the NMC) and Area 4 (south of the NMC). Within these areas, fishers reported taking 187 trips (SD = 54.8; n = 19) per year, with most targeting shallow-water reef fish (76.2%), spiny lobster (66.7%), queen conch (42.9%), and deep water snappers and groupers (33.3%).

Table 12: Fisher use, by area (n = total sample; standard deviations in parentheses)

Area	Average use percentage – Gear 1 (n = 21)	Average use percentage – Gear 2 (n = 21)
1	4.31 (19.6)	4.31 (19.6)
2	51.9 (27.1)	16.4 (27.0)
3	43.8 (27.3)	14.8 (27.9)
4	2.38 (10.9)	0.00 (0.00)
5	0.00 (0.00)	0.00 (0.00)
6	0.00 (0.00)	0.00 (0.00)
7	0.00 (0.00)	0.00 (0.00)

As shown in Table 12, fishing occurred mainly along the northeast and east coasts. The area north of the NMC (Area 2) generated more use than any other area, accounting for 52% of the primary gear utilized by fishers. Area 3, which comprises the NMC, accounted for much of the remainder of the primary gear use (43.8%).

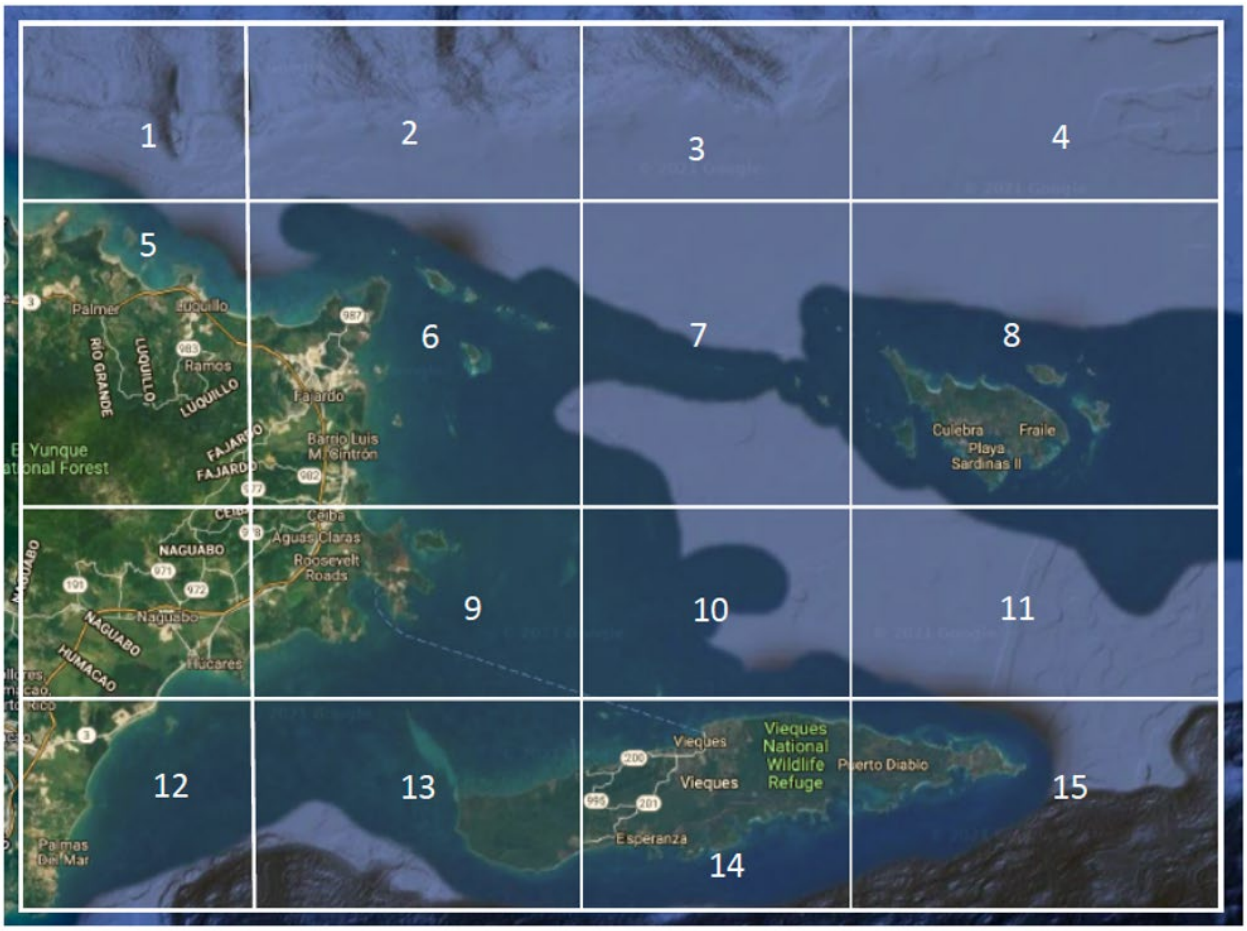

Figure 4: Area of use, NMC region

Next, the sample was asked about their use of zones within and adjacent to the NMC region (Figure 4). A majority of fishers fished zones 2 and 3, located north of the La Cordillera Reefs Natural Reserve a RNA, and zone 6, which encompasses the western half of La Cordillera Reefs Natural Reserve (Table 13). Zones 6 and 7, representing the eastern half of the La Cordillera Reefs Natural Reserve and Culebra were also used but by fewer fishers. Similarly, the western side of the NMC, denoted by zones 1 and 5, was also utilized but by 30% or fewer fishers. Use did not extend much into areas south of the La Cordillera Reefs Natural Reserve, although as shown in Figure 3, that part of eastern Puerto Rico is very heavily utilized by fishers from other east coast ports.

Table 13: Zone fished within and around NMC (n = total sample)

Zone	Fishers reporting use (%) (n = 20)
1	30
2	75
3	55
4	0
5	22.2

6	52.6
7	31.6
8	15.8
9	21.1
10	21.1
11	0
12	0
13	5.56
14	0
15	0

When asked about the importance of various natural and socioeconomic conditions that influence their decision as to whether and where to take a fishing trip, fishers identified weather (76.2%) as the most important factor, followed by fuel cost (52.4%) (Table 14). Crowding, bait costs, and the availability of preferred habitat were less important, confirmed by the weighted averages; however, the averages also demonstrate the crowding conditions are the least important factor used by fishers in deciding whether to take a trip and where to go. This suggests that crowding may not be a significant factor in the region, at least from a fisheries perspective; this can be further corroborated that the NMC region mapping exercise, which determined that fewer than 50 fishers (and more likely up to 30 fishers) utilize the region on a *consistent* basis (Figure 4). Furthermore, when asked about the number of vessels that they see while fishing, respondents estimated that there are less than four vessels on average (mean = 3.86 vessels; SD = 3.15; n = 21) in their immediate area, which is less than half (mean = 9.1 vessels; SD = 10.1; n = 20) as many vessels that fishers stated that they would tolerate before switching to another area. The optimal number of vessels that fishers felt should operate around them in their fishing area is just under five vessels (mean = 4.95 vessels; SD = 4.29; n = 20), which was also below the average number of vessels that fishers reported seeing at present. It is likely that fishers spread out use based on the number of vessels that they encounter in a fishing ground, such that crowding is not as pervasive as an intra-group phenomenon as it might be as across groups. This may also help explain the reason why commercial fishing use is not as prolific in the heart of the NMC region, which has a number of other user types, including visitors, whose activities are more amenable to crowded conditions; in fact, discussions with fishers and past research in region with fishery and other stakeholders (Hernández-Delgado, Shivlani et al. 2014) both demonstrated that many commercial fishing operations deliberately avoid tourism-dominated areas, including the shallower sections of the NMC (ex., zone 8).

Table 14: Factors influencing fishing trip location and timing (n = total sample)

Factor	1 – Most important	2	3	4	5 – Least important	n	Weighted average*
Weather	76.2	0.0	0.0	0.0	23.8	21	1.95
Fuel cost	52.4	19.1	14.3	4.8	9.5	21	2.00

Bait cost	15.0	35.0	20.0	25.0	5.0	20	2.70
Crowding	15.0	30.0	20.0	25.0	10.0	20	2.85
Preferred habitat	15.0	40.0	20.0	10.0	15.0	20	2.70

** Weighted average is based on total respondents for a particular question, where the average is based on the importance of a factors (1 = most important and 5 = least important.*

Fishers evaluated how crowding may affect fishery conditions and habitats across a number of factors (Table 15). Only a quarter or less felt that it would have major to moderate effects (ranks 4 and 5) on the amount of fish available for capture or catch-per-unit-effort. Even fewer fishers (10%, ranks 4 and 5) believed that crowding would lead to higher use conflicts or lack of space. The condition that over a third agreed might suffer major effects is habitat damage.

Table 15: Crowding effects on fisheries conditions, in percentage (n = total sample)

Factor	1 – Minor effect	2	3	4	5 – Major effect	n
Fewer fish available for capture	35.0	25.0	25.0	15.0	0.0	20
Lower catch rates	25.0	25.0	25.0	20.0	5.0	20
Higher intra and inter-group conflicts	50.0	30.0	10.0	10.0	0.0	20
Lack of space between vessels	50.0	30.0	10.0	10.0	0.0	20
Habitat damage	14.3	23.8	23.8	33.3	4.76	21

When asked about other user groups (and their own user groups) and the impacts they presented, none of the user groups were perceived as representing much of an impact (Table 16). For example, only 19% felt that recreational fishers generated moderate or major impacts (ranks 4 and 5). No other group was identified by more than 14% of the sample to be responsible to moderate or major impacts. It is likely that already existing use separation, i.e., where fishers avoid tourism areas such as the waters around Palomino and Icacos (two heavily visited keys in the western half of the La Cordillera Reefs Natural Reserve), is responsible for a form of de facto zoning.

Table 16: Impact of user groups on fishing activities, in percentage (n = total sample)

Factor	1 – Minor impact	2	3	4	5 – Major impact	n
Recreational fishers	28.6	33.3	19.1	9.52	9.52	21
Other commercial fishers	23.8	38.1	38.1	0.0	0.0	21
Recreational divers	28.6	38.1	19.1	9.52	4.76	21
Other commercial divers	28.6	33.3	28.6	4.76	4.76	21
Catamarans/large charters	28.6	42.9	14.3	9.52	4.76	21
Small charters (six or fewer passengers)	28.6	42.9	23.8	0.0	4.76	21
Private vessels	28.6	42.9	23.8	0.0	4.76	21

Fishers also provided their views on coastal and marine resource conditions, focusing on nearshore habitats such as mangroves and seagrasses and marine habitats such as coral reefs and other hardbottom areas (Table 17). Most fishers felt that a majority of the resources were in fair (rating = 3) or good (rating = 2) condition. None of the resources, apart from water clarity and quality, were rated as in excellent condition, but fishers did not agree either that fisheries and habitats were in decline (i.e., in poor to very poor condition). When asked to identify the resource that had declined the most in the region, a plurality of fishers selected fish and fisheries (38.1%), followed by queen conch (33.3%) and spiny lobster (14.3%); together, these three important commercial fishery resources accounted for almost 86% of the resources identified as having declined the most. These findings cohere well with past research findings on overfishing in Puerto Rico (Ault, Smith et al. 2008, Baker, Appeldoorn et al. 2016), and show that while fishers may believe that resources are being managed well presently, the fishers are also aware that several of these resources have undergone significant reductions in abundance. The primary reason given for the resource decline was contamination emanating from land-based sources of pollution, which 52.4% identified. Another 38.1% of the fishers blamed extreme events resulting from a changing climate for resource decline.

Table 17: Coastal and marine resource conditions, in percentage (n = total sample)

Resource	1 – Excellent condition	2	3	4	5 – Very poor condition	Resource that has most declined	n
Fish and fisheries	0.0	42.9	38.1	14.3	4.76	38.1	21
Spiny lobster	0.0	31.6	63.2	5.26	0.0	14.3	19
Queen conch	0.0	10.5	73.7	10.5	5.3	33.3	19
Coral reefs	0.0	31.6	57.9	5.26	5.26	4.76	19
Seagrasses	0.0	40.0	50.0	5.0	5.00	0.0	20
Mangroves	0.0	38.1	61.9	0.0	0.0	4.76	21
Hardbottom	0.0	35.0	65.0	0.0	0.0	0.0	21
Water quality	14.2	38.1	38.1	0.0	9.52	0.0	21
Water clarity	19.1	33.3	38.1	0.0	9.52	4.76	21

Most fishers (85.7%) believed that the numbers of other user groups are acceptable at present levels and that their totals should not be reduced; all fishers argued that commercial fishers and commercial divers are acceptable at present levels and should not be reduced. However, even among the minority that would prefer a reduction in the number of other user groups, these fishers did not provide a preferred reduction percentage.

Finally, fishers rated a series of management strategies as related to zoning, education and awareness, enforcement, and limits on vessels and harvest totals (Table 18). All respondents rejected any type of zoning, with 84% or higher percentages of fishers not in favor of no entry,

no fishing, and use-specific zones. By contrast, fishers generally favored education and outreach activities, which 85% considered as most preferred or moderately preferred (ratings = 4 and 5), and over 90% were in favor of enforcement of existing rules and regulations. Limits on either vessel or fishing totals were largely rejected, with 70% in opposition (ratings = 1 and 2). Other studies have found similar findings among fishers (Agar and Shivlani 2016, Agar and Shivlani 2016, Agar, Shivlani et al. 2019), where respondents have argued that effective regulations already exist, and what is needed is better enforcement of those regulations.

Table 18: Fishers' management preferences, in percentage (n = total sample)

Management action	1 – Least preferred	2	3	4	5 – Most preferred	n
No entry/no use zones	31.6	47.4	21.1	0.0	0.0	19
No fishing zones	31.6	47.4	21.1	0.0	0.0	19
Areas zoned by use	26.3	47.4	26.3	0.0	0.0	19
Education and awareness	0.0	5.0	10.0	5.0	80.0	20
Enforcement	0.0	0.0	9.52	4.76	85.7	21
Limits on vessel totals	15.0	55.0	20.0	0.0	10.0	20
Fishing quotas	15.0	55.0	20.0	0.0	10.0	20

Water-based operations

Water-based operations are comprised of concessionaires licensed by the Commonwealth of Puerto Rico to undertake sanctioned trips to La Cordillera Reefs Natural Reserve and Luis Peña Channel No-take Natural Reserve (including Carlos Rosario and Tamarindo beaches). The team identified several other operations that offered trips within the NMC region both prior to and after the COVID-19 pandemic but, given the ephemeral and illegal nature of these operations, these were not included in the survey effort. However, information concerning the types and characteristics of these non-licensed operations was collected to assess the effects that these operations may have on the overall industry and on use in the region.

The study team used the list of 25 concessionaires authorized to take trips to the various reserves. After reviewing the list, the team determined that there was a total of 19 concessionaires (as there were several operators who hold licenses for both the La Cordillera Reefs Natural Reserve and Luis Peña Channel No-take Natural Reserve). The team contacted the entire list and completed a total of 16 surveys; of the three that did not participate, two indicated to have no time to conduct the interview and the other could not be reached.

All 16 operations surveyed took trips from marinas or ramps in Fajardo, Ceiba, or Culebra. Only two operations reported having a secondary port, and only one of those ports was outside the NMC region. This shows that most of the operators are local and focus solely on the NMC for their activities and livelihoods.

The operations had been in existence for 18.9 years (SD = 11.7; n = 16) on average, and 75% had at least a decade of taking trips on the region. Half of the operators surveyed were

between 31-40 years old, and 31.3% were between 51-60 years old. Those between 41-50 years old comprised 12.5% of the sample, and only one dive operator was older than 60 years old.

The sample owned and operated an average of 2.31 vessels (SD = 2.50; n = 16), with the range being from one vessel to nine vessels. As shown in Table 19, there was a wide variety of vessels that operate in the NMC. The primary vessel for most operations was a powerboat, which made up over 58% of all vessels. In a few cases, the primary vessel was a catamaran or sailboat, and one operation offered powerboat rentals. Catamarans were the largest vessel type, averaging 39 feet in length, and these could hold almost twice as many passengers (49.2) as powerboats (26.2). Powerboats were the only type of vessel on which certain operators offered dive trips, and all other vessel types were equipped for snorkel trips. Crew totals varied as well, with catamarans having the highest crew total (3.6 crew members), due likely to the fact that catamarans catered to the largest groups; some respondents who operated catamarans stated that their vessels had much higher capacities, but most operate at lower limits (maximum = 80 passengers).

Table 19: Concessionaire vessel types and characteristics averages (n = total sample)

Characteristic	Rental powerboat	Powerboat	Catamaran	Sailboat	n
Length (feet)	13 (0.0)	32.8 (8.88)	39 (9.90)	N/A	34
Capacity of passengers	4 (0.0)	26.2 (22.7)	49.2 (19.0)	12.5 (9.19)	36
Number of divers	0.0 (0.0)	10.2 (14.3)	0.0 (0.0)	0.0 (0.0)	36
Number of snorkelers	4.0 (0.0)	26.0 (24.1)	49.2 (19.0)	9.5 (13.4)	36
Crew	0.0 (0.0)	2.84 (1.46)	3.6 (1.14)	2.5 (0.71)	36
Percentage of total (%)	22.2	58.3	13.9	5.56	36

Only 31.3% (n = 16) of the operators rented kayaks or paddleboards. Those that did rent out such equipment did so either as part of a package tour (ex., kayak rentals as part of a catamaran/powerboat tour) or for nearshore and Bio Bay tours. None of the operators rented personal watercraft.

When asked about trip profiles (on their top three vessels), operators stated that they work year round, taking an average of 1.61 trips (SD = 0.84; n = 26) daily. There was considerable variation between operators, in that just over half took a daily trip, whereas 15.4% took three or more trips per day. The former tended to take long-distance, mixed trips (ex., snorkel and beach visits to Culebra from Fajardo or Ceiba), and the latter worked as water taxis, shuttling passengers to keys adjacent to the northeastern mainland. Trips consisted of 21.9 passengers (SD = 19.2), and 77% of operators allowed snorkeling (or have snorkel tours) and 15.4% allowed

diving on their trips (diving occurred as part of a mixed trip, which also included snorkelers. The average number of snorkelers per trip was 26.7 (SD = 19.5; n = 20), which was almost twice as high as the average number of divers (mean = 14.8 divers; SD = 7.08; n = 4).

Operators estimated the frequency at which they offered different activities and services. On average, the sample took snorkeling trips on 68.8% (SD = 43.3; n = 16) of all trips, followed by kayaking (mean = 20.6% of all trips; SD = 37.4; n = 16), water taxi services (mean = 19.4% of all trips; SD = 40.1; n = 16), and diving (mean = 6.56% of all trips; SD = 17.0; n = 16). Operators did not offer consumptive use trips, such as spearfishing or hook and line fishing, in the NMC. When considering only operators who offered other activities and services, snorkeling occurred on 91.7% (SD = 16.3; n = 12) of trips; similarly, diving occurred on 35% (SD = 26.0; n = 3) of trips, kayaking on 66.0% (SD = 38.6; n = 5) of trips, and water taxi services on 77.5% (SD = 45.0; n = 5) of trips.

All operators reported that they give a pre-trip talk/presentation, and all talks include a section on water safety, emergency procedures, and related matters. Three quarters of the respondents stated that they provide information on the marine ecosystem, how to avoid touching corals and other sensitive habitats, and how to maintain buoyancy in the water to avoid making contact with the marine resources. A few operators added that they closely monitor their clients in the water for both their safety and the sanctity of the marine resources, and others stated that they do not allow the use of fins that may otherwise result in snorkelers walking on reefs.

Operators provided use information using Figure 1, where Area 3 represented the NMC, and other areas of note included Area 2 (north of the NMC) and Area 4 (south of the NMC). As shown in Table 20, the area most frequently used by the sample was Area 3, which represents the NMC; almost all use (96%) occurred within that area, with the only area reporting use being Area 4, south the NMC. These results show the importance of the NMC to the concessionaires, who largely rely on the region's keys and marine resources for their livelihoods. Two operators did relate that they had operations in other parts of Puerto Rico (including San Juan and the southeastern coast), but the data presented here relate to those trips that originate from within the NMC; moreover, even if those off-site activities are considered, these decrease average use in the NMC by less than one percent, again reinforcing the importance of Area 3 to the operators.

Table 20: Water-based operator use, by area, average percentages (standard deviations in parentheses)

Area	Average use percentage (n = 16)
1	0.00 (0.00)
2	0.00 (0.00)
3	95.6 (17.5)
4	4.38 (17.5)
5	0.00 (0.00)
6	0.00 (0.00)

7	0.00 (0.00)

Also, operators were shown Figure 4 that divided the NMC and environs into 15 zones, and they identified uses in which they participated by zone (Table 21). Use was concentrated in two zones, Zone 6 and Zone 8, which had more a combined 40% use by activity. Zone 6 encompasses the western keys of Icacos and Palomino and nearshore snorkeling sites, and Zone 8 includes Luis Peña Canal No-take Reserve and adjacent beaches. While beach visitation was lower in Zone 8, likely due to the further distance, the region did attract considerable snorkeling. Other areas, both in and around the NMC, were mostly largely left unvisited; when compared to fishing uses, which were spread around the various zones, it appears the operator uses are highly specific and attract a large percentage of operators to discrete zones. The aforementioned zones, due to their high use, were also disproportionately identified by operators as high use and congestion areas. In fact, 87.5% of operators identified the western side of the La Cordillera Reefs Natural Reserve as a high traffic and crowded zone, compared to 56.3% who felt that Culebra was very heavily visited.

Table 21: Zones visited within and around the NMC, in percentages

Zone, % reporting (n = 16)	Visiting keys/beaches	Snorkeling	Diving	High use/ conflict/congestion
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0
6	37.5	43.8	6.25	87.5
7	0.0	0.0	0.0	6.25
8	12.5	37.5	6.25	56.3
9	21.1	0.0	0.0	6.25
10	21.1	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0
13	6.25	6.25	0.0	18.8
14	0.0	0.0	0.0	6.25
15	0.0	0.0	0.0	6.25

When asked about the factors that influence their decision on whether or where to take a trip, operators pointed to weather (87.5%) as the most important element that would influence their decision to take a trip (Table 22). By contrast, the distance to location was not much of a factor, likely due to the fact that trips are taken to one of a few sites in the aforementioned zones. A majority of the respondents pointed to congestion (50% rating the issue as 1 or 2, most important or moderately important) as an important factor, but a similar percentage (43.8%) felt that it was either the least important or less important factor. Finally, operators felt that site conditions are not that important, as 62.5% considered them as least important or less

important; this finding needs to be qualified, as many respondents added that site conditions are already factored in prior to a trip, and others pointed out that there are not many alternatives to the main destinations, especially as related to the keys and beaches.

Table 22: Factors influencing operator trip location and timing

Factor (%)	1 – Most important	2	3	4	5 – Least important	n
Weather	87.5	0.0	6.25	0.0	6.25	16
Distance to location	6.25	0.0	6.25	0.0	87.5	16
Congestion	25.0	25.0	6.25	18.8	25.0	16
Site condition	25.0	12.5	0.0	18.8	43.7	16

Operators were asked to consider vessel totals and concentrations in three separate questions. First, they were asked about the maximum number of vessels that they would tolerate in an area before moving to another location. Second, they were asked to estimate the average number of vessels they usually see in the areas where they take their trips. Third, they were asked to provide the number of vessels they believed are suitable for the areas that they take visitors.

The operators who worked as water taxis did not provide a number that they tolerate, as their activities are not affected as much by recreational space as they are by having space to dock their vessel (i.e., an area to embark and disembark passengers). The water taxis also didn't want to provide a total that they felt is suitable, but those that did believed that there should be no more than 30 vessels in a given area. The operators who took dive trips stated that they would tolerate an average of six other boats where they take their divers, and that they see only about half as many vessels in those areas; they felt that having four other vessels in a dive site would be suitable. The operations that had the most competition for space, both in terms of vessels and visitors, were the larger motorboats and catamarans that took trips to the western keys and nearshore areas (for snorkeling-beach visitation combination trips). Most of these operations estimated that they see an average of 50 vessels in the region where they operate. However, a majority of these larger operators did not provide an upper limit of other vessels that they would consider unacceptable before changing locations, and most also did not provide a suitable total per site. Instead, most of these larger operators argued that space to anchor or moor their vessel is more important than the total number of other vessels. This view aligns closely with the views of visitors who engaged in beach tourism, who stated that crowding is not an issue as long as space is available, i.e., it is not the number of other visitors as much as it is the activities in which they are engaged. It is also clear that certain activities, such as diving and snorkeling require more space, and that those operators may be more amenable to vessel management; however, with respect to mass tourism locations such as Icacos, operators' concerns are likely mostly related to visitor safety and anchorage or mooring availability.

Table 23: Changes in use intensity by user group

User group (%)	1 – Much less use	2	3	4	5 – Much more use	n
Recreational fishers	13.3	0.0	60.0	13.3	13.3	15
Commercial fishers	14.3	14.3	42.9	21.4	7.14	14
Recreational divers	35.7	7.14	42.9	7.14	7.14	14
Commercial divers	23.1	15.4	46.2	7.69	7.69	13
Catamarans/large charters	0.0	0.0	12.5	37.5	50.0	16
Small charters (six or fewer passengers)	0.0	0.0	0.0	25.0	75.0	16
Private vessels	0.0	0.0	6.67	13.3	80.0	15

Most operators felt that while commercial fishing uses, consisting of commercial fishers and divers, had declined (28.6% reporting much less use or less use for commercial fishers and 38.5% for commercial divers), the use among catamarans and large charters and small charters had increased (87.5% for large charters and 100% for small charters) (Table 23). Similarly, 93.3% felt that private vessels had increased in the region. These findings suggest that operators potentially perceive more competition from cohorts and from other recreational users than they do from commercial fishers. The number of fishers did decline in the region following Hurricane Maria and present totals do represent a long-term decline (Shivlani and Matos-Caraballo, submitted); conversely, anecdotal information points to an increase in both recreational vessels and unlicensed concessionaires (Schleier, personal communication), both of which compete with the operators in terms of areas visited and activities in which they engage.

Table 24: Impact of user groups on coastal and marine resources

User group (%)	1 – Minor impact	2	3	4	5 – Major impact	n
Recreational fishers	40.0	13.3	20.0	0.0	26.6	15
Commercial fishers	42.9	7.14	14.3	7.14	28.6	14
Recreational divers	66.7	6.67	20.0	6.67	0.00	15
Commercial divers	64.3	7.14	21.4	0.0	7.14	14
Catamarans/large charters	6.25	0.0	43.8	18.8	31.3	16
Small charters (six or fewer passengers)	0.0	6.25	18.8	6.25	68.8	16
Private vessels	0.0	0.0	12.5	18.8	68.8	16

As shown in Table 24, operators' views on the impact that other user groups have on the coastal and marine environment varied considerably and tended to track their views on how they believe use intensities have shifted as per user group. Thus, among those groups, namely commercial fishers and divers, that operators did not believe had increased their effort

recently, the majority views were that these groups present a major impact. However, among those groups that operators believed had increased their effort (small charters and private vessels), most operators (75% or greater) felt that these groups had major or moderate impacts to the coastal and marine environment.

Table 25: Operator views on resource conditions, in percentage (n = total sample)

Resource (%)	1 – Excellent condition	2	3	4	5 – Very poor condition	n
Fish and fisheries	0.0	20.0	26.7	20.0	33.3	15
Spiny lobster	7.14	7.14	50.0	7.14	28.6	14
Queen conch	0.0	0.0	30.8	15.4	53.8	13
Coral reefs	0.0	6.67	20.0	46.7	26.7	15
Seagrasses	46.7	20.0	0.0	20.0	13.3	15
Mangroves	50.0	0.0	50.0	0.0	0.0	14
Hardbottom	0.0	100	0.0	0.0	0.0	4
Water quality	60.0	6.67	20.0	0.0	13.3	15
Water clarity	56.3	18.8	12.5	6.25	6.25	16

Table 26: Operator views on resource trends, in percentage (n = total sample)

Resource (%)	1 – Much better	2	3	4	5 – Much worse	n
Fish and fisheries	0.0	15.4	15.4	15.4	53.8	13
Spiny lobster	0.0	0.0	14.3	35.7	50.0	14
Queen conch	0.0	0.0	7.69	38.5	53.8	13
Coral reefs	0.0	6.67	6.67	20.0	66.7	15
Seagrasses	14.3	21.4	35.7	7.14	21.4	14
Mangroves	0.0	0.0	50.0	0.0	50.0	14
Hardbottom	0.0	0.0	75.0	0.0	25.0	4
Water quality	6.67	0.0	73.3	6.67	13.3	15
Water clarity	6.25	0.0	75.0	12.5	6.25	16

As shown in Table 25 and Table 26, operators felt that most fishery resources were in poor to very poor condition (fish and fisheries = 53.3%, ratings = 4 and 5; queen conch = 69.2%; ratings = 4 and 5), with the exception of spiny lobster. With respect to nearshore sources, especially seagrasses and mangroves, a majority of operators agreed that these resources were in stable to excellent condition. Coral reefs were perceived as doing poorly, as almost three quarters of the sample rated them as being in poor to very poor condition (ratings = 4 and 5). Water quality and clarity were considered in to be mostly excellent to good condition by most respondents. In terms of resource trends, operators were generally pessimistic about fishery resources, which a majority felt were getting worse or much worse. Similarly, the group felt that coral reefs had deteriorated considerably, as 97% of those surveyed consider coral reefs to have gotten worse or much worse over time. Given the bleaching events and past and emerging diseases (especially the stony coral tissue loss disease), operators show a high level of concern for one of

the most important resources they rely upon. Finally, it should be noted that only a small minority of the operators believed that any of the resources had improved over time; the prevailing view was that in cases such as water clarity and quality, hardbottom habitats, and mangroves, these resources have maintained their present status, thereby preventing a decline rather than showing improvement. When asked about which resource they believed had most declined in the NMC region, 56.2% (n = 16) identified coral reefs, followed by queen conch (18.8%) and spiny lobster (12.5%). Just under a third (31.3%; n = 16) stated that the decline was a result of overfishing and due to an increase in the number of users, including smaller (illegal) charters.

Table 27: Operator preferences for changes in user groups, in percentage (n = total sample)

User group	Increase	Remain the same	Decrease	n	Preferred % change	n
Recreational fishers	0.0	85.7	14.3	14	-40.0 (28.3)	2
Commercial fishers	0.0	100	0.0	14	0.0 (0.0)	14
Recreational divers	0.0	100	0.0	14	0.0 (0.0)	14
Commercial divers	64.3	7.14	21.4	0.0	7.14	3
Catamarans/large charters	0.0	35.7	64.3	14	-60.0 (18.7)	9
Small charters (six or fewer passengers)	0.0	35.7	64.3	14	-66.7 (19.4)	9
Water taxis	0.0	85.7	14.3	14	-50.0 (0.0)	2
Private vessels	0.0	33.3	66.7	15	-59.0 (16.0)	10

When asked about their preferences for changes in totals that they believed should be considered for various user groups (Table 27), operators were largely in favor of either reducing existing totals or maintaining those totals. In some cases, only a small number of respondents provided their views on particular groups (ex., commercial fishers, water taxis), whereas the majority felt that they did not have sufficient information to provide a meaningful total. Half the operators considered that three private vessels (59% reduction), catamarans and large charters (60% reduction), and small charters (66.7% reduction) should be reduced. Several of the respondents added that the concessionaries, as these are now organized, represent the optimal total and, in some cases, the operations could reduce the total number of passengers they take out to these areas. Others felt that private vessels are a major source of impacts in the nearshore areas because of groundings due to lack of local knowledge and conditions, anchoring on hardbottom and other sensitive habitats, and sound pollution and trash; moreover, several private vessels offer tours to the NMC, which is illegal but not well enforced. Overall, more than two-thirds of operators (68.8%; n = 16) supported some type of a limit on the total number of users in the NMC, suggesting that the industry is mostly in favor of addressing total use (see Table 28). The operator community is mostly in favor of addressing emerging and largely unregulated uses that are causing certain changes to their industry (ex., reducing visitor loads in specific areas).

Most operators (81.3%; n = 16) agreed that corals would serve as the best indicator for the NMC's ecological health, followed by water quality (25%) and water clarity, fisheries (including spiny lobster) (18.8%). Several respondents added that the local reefs are being mistreated via trampling, touching, and anchoring, and that there are die-off events resulting from algal overgrowth in some areas. Given the importance of reefs to many of the operators who take snorkel trips, corals were often highlighted as the resource that is most at peril and the one that should be closely monitored.

Table 28: Operators' management preference, in percentage (n = total samples

Management action (%)	1 – Least supported	2	3	4	5 – Most supported	n
No entry/no use zones	66.7	0.0	6.67	6.67	20.0	15
No fishing zones	18.5	0.0	0.0	0.0	81.3	16
Areas zoned by use	6.67	0.0	33.3	13.3	46.7	15
Education and awareness	0.0	0.0	12.5	6.25	81.3	16
Enforcement	0.0	0.0	0.0	0.0	100	16
Limits on vessel totals	6.25	0.0	25.0	25.0	43.8	16
Daily limits on visitors by zone	12.5	12.5	25.0	18.8	31.3	16
Commercial operator licenses	6.25	0.0	0.0	0.0	93.8	16
No anchor zones	0.0	0.0	6.25	0.0	93.8	16
Rotating zones	37.5	12.5	12.5	12.5	25.0	16

Operators were presented with a series of management actions that could be undertaken in the NMC to improve resource and/or crowding conditions (Table 28). There was support for particular types of zones, especially those that disallowed all extractive uses (81.3% in strong support) and no anchor zones (93.8% in strong support), with lower but still majority support for daily limits on visitors by zone (50.1% in strong or moderate support) and an overall zoning strategy (60% in strong or moderate support); however, operators opposed no entry/no use zones (66.7% in least support) that would affect their access. Respondents universally and strongly supported improvements in enforcement, which was among the most important issues that operators raised in discussion, and there was strong majority support for requiring all commercial operators to be licensed (likely due to the prevailing concerns over illegal water taxis and tour operators in the NMC). These results show that zoning as a general strategy, and especially as particular zone types, enjoys considerable support among the operator community, who views the management approach as a means by which to separate out uses (ex., fishing and tourism), as has been implemented in other areas (Shivlani and Suman 2000, Lynch, Wilkinson et al. 2004). Also, there are some management actions that can be taken which are broadly supported (both within fisher and water-based operator samples), especially education and awareness to impart best practices across various stakeholder groups and visitors, effective enforcement of existing regulations (ex., controlling illegal fishing, trips, and tours), and mandatory licenses to be able for commercial operators to access the NMC.

Finally, operators identified uses that should be allowed (or not) in the 15 zones within the NMC (from Figure 4), in terms of whether the zone should be closed to all uses, closed to extractive activities, or prioritized for tourism. As shown in Table 29, operators felt that most of the NMC, particularly the northern section, should be open for all activities. There was generally less support for having zones not allow any extractive uses, partly because there is not much commercial fishing that occurs in the most visitor-dense zones, and the preference was more towards having certain zones being prioritized for tourism activities. A majority of all operators agreed that such a priority should be extended to Zone 6 (the western half of the La Cordillera Reefs Natural Reserve) and Zone 8 (the waters surrounding Culebra). These results show that inter-group conflicts are minimal, mainly because operators do not face much competition for resources or space from commercial fishers in the areas where they take their trips; however, operators do compete with each other, illegal charters, and private vessels, and setting up certain tourism-priority areas may give the concessionaires priority use of these very heavily used zones.

Table 29: Operator zone type preferences, in percentage (n = total sample)

Zone, % reporting (n = 16)	Priority for tourism activities	No extractive activities	No uses or activities
1	0.0	0.0	0.0
2	0.0	0.0	0.0
3	0.0	0.0	0.0
4	0.0	0.0	0.0
5	0.0	12.5	0.0
6	81.3	12.5	0.0
7	6.25	6.25	0.0
8	62.5	12.5	0.0
9	12.5	6.25	0.0
10	0.0	0.0	0.0
11	6.25	0.0	0.0
12	0.0	0.0	0.0
13	18.8	6.25	0.0
14	12.5	6.25	0.0
15	6.25	6.25	0.0

Conclusions

The study, despite being truncated due to the onset of the COVID-19 pandemic, was able to achieve its objectives of characterizing the major stakeholder groups and visitors, in terms of their use patterns, views on resource conditions, and management preferences for addressing

crowding and congestion, environmental sustainability, and visitor satisfaction. The study also obtained information on how stakeholders felt regarding resources that could serve as ecosystem and socioeconomic indicators, which can be applied in support of management decisions that affect conservation and use in the NMC.

Recreational boaters

Two key findings from the recreational boater survey are related to resource use and socioeconomic (crowding) perceptions: The first is that boater activities focus mainly on non-consumptive uses; and the second is that boaters have a high tolerance for other vessels in their immediate vicinity. As determined by past work with recreational boaters in the region (Shivlani 2009, Hernández-Delgado, Shivlani et al. 2014), use is highly concentrated in limited areas. The prevailing use pattern involves boaters using ramps or marinas to access the NMC from northeastern ports (Fajardo and Ceiba, mainly) and to either travel south towards Cayo Piñero off Ceiba (10 miles) or, more often, to the smaller keys located three miles due east (Icacos) or 5.6 miles southeast (Palomino) from the northeastern coast. Those who want to visit Culebra to snorkel on the west side in the Luis Peña Canal No-take Reserve, visit the northern beaches, or to go to the eastern side to the island of Culebrita, need to travel 23 miles or more to reach the island.

The most important activities for boaters, as reported by the sample, in the NMC were cruising and cruising (87.5% participation on almost very or most trips) and visiting keys and beaches (87%). Only 26.9% reported line fishing on almost every or most trips, which was the most prolific consumptive activity. What this suggests is that recreational boaters likely do not compete for resources with other NMC stakeholders, namely commercial fishers. Also, low fishing rates means that recreational boaters also do not likely interfere with water-based operations, i.e., fishing on top of divers or snorkelers.

Also, although recreational boaters engage in activities within areas that attract high numbers of private and commercial vessels (and visitors), boaters surveyed in the study did not report feeling crowded. For example, while participating in cruising and visiting keys and beaches, boaters stated that they viewed an average of 5.2 and 5.5 other vessels, respectively; however, the respondents stated that they were willing to tolerate as many as 88 vessels while cruising and 90 vessels while visiting keys and beaches. Thus, the recreational boaters' views on crowding were in some ways positive, in that they did not perceive any negative effects from crowding until very high totals. There may even be a pull factor which attracts more boaters in specific areas to congregate and socialize, a phenomenon observed in other areas during peak times, such as parts of Biscayne National Park on Columbus Day regattas (Ault, Smith et al. 2005). This is not to state that recreational boaters were not negatively impacted by other vessels, as 52.7% and 36.4% considered having too many vessels and visitors, respectively, as a major impact; however, it was more so the behavior and activities of other vessels that generated the most impacts. Loud music (72.7%), poor etiquette (76.4%), and trash from other vessels (92.7%) were all behaviors (independent of crowding) that elicited the strongest responses.

These findings show that crowding conditions in the NMC, as perceived by the recreational boating community, are activity-specific, and thus are likely best addressed across stakeholders that participate in the same activity. The results also demonstrate that limits in specific areas that attract and incentivize crowding need to be established acknowledging that crowding is not a disservice for visitors. Of course, measures related to safety and benthic resource protection must be prioritized, but management needs to do so by accepting that congestion is the users' expectation when visiting these areas.

Visitors

Among the most relevant findings from the visitor study was that visitors from both Puerto Rico and elsewhere (mainland US and foreign countries) mostly did not engage in water-based activities. The most important activity found to drive NMC tourism and can serve as a key indicator for visitor satisfaction is beach tourism, which corroborates with other recent visitor research in Puerto Rico (Leeworthy, Schwarzmann et al. 2018).

The NMC (as much of coastal Puerto Rico) attracts tourists mainly for its beaches. Just under 89% of the sample reported spending time on a beach during their visit, compared to 1.1% who went fishing, 4.1% who went snorkeling from shore, and 0.40% who went diving from the shore. Also, only 1.1% and 0.8% reported fishing from the shore or a vessel, respectively. These results show that beaches, among all other coastal and marine resources, influence visitation, and that beach quality and amenities likely determine visitor views on trip satisfaction instead of other coastal and marine resource conditions. For visitors, crowding consisting of up to 30 other beachgoers in their area was considered acceptable, and 91% opposed use/visitor total limits. Similar to recreational boaters, limited crowding may in fact have pulled visitors to beaches rather than causing them to find other locations.

When asked about what factors would influence a repeat visit, 97% considered beach quality as being a very important or important factor, outranking all other ecological and socioeconomic factors except for coastal pollution such as plastics and garbage (98% rating it as a very important or impactor factor); however, coastal pollution was tied very closely to beaches, in that visitors considered it more as an aesthetic than environmental issue (i.e., in that coastal pollution impeded beach activities and took away from the viewshed). Indeed, when asked about which factor would most influence a return visit, a majority of visitors identified beach quality.

Commercial fishers

The study determined that commercial fishing use is limited in the NMC, and that most commercial fishers avoid areas heavily utilized for recreational purposes, resulting in a de facto zoning, or use separation, arrangement. Thus, setting limits on commercial fishing use in the

NMC or establishing activity-specific zones may be relatively straightforward and in fact would likely represent the formalization of existing norms.

Commercial fishers relied on more on the area north of the NMC for both of their top two gears (52% for gear 1; 16% for gear 2) than they did on the NMC (44% for gear 1; 15% for gear 2). While 53% of the fishers did report using the western side of the La Cordillera Reefs Natural Reserve and 31% the eastern side of the La Cordillera Reefs Natural Reserve, the most popular zones by total use – reported by 75% and 55% of the respondents – were both located north of the La Cordillera Reefs Natural Reserve. Even when they did use the La Cordillera Reefs Natural Reserve, commercial fishers pointed out that in the areas that they fish (located east of the popular sandbars and keys) usually have less than four other vessels, which is below half their tolerance threshold. Also, fishers did not believe that any of the other user groups affected their fishing activities or that present rates of crowding impacted harvest totals or rates or led to use conflicts.

Although fishers did not express much support for zoning, with 73% or more of the respondents against no use, no fishing, or use-specific zones, this is likely because fishers are concerned about losing access to areas that they currently fish and not because of the high tourism use areas that they actively avoid. If zoning were to be implemented such that use separation reinforces the status quo and even adds other coral-dominated sites (see Hernandez-Delgado et al., 2014), fishers will (a) not lose much, if any, fishing grounds and (b) eliminate any incidental use conflicts.

Water-based operators

The most important findings from water-based operators related to their views on other user groups, namely illegal charters and private vessels, and their willingness to support spatial conservation measures. These results demonstrate that while operators rely disproportionately on access to the NMC, they are willing to accept certain use conditions that are in support of sustainable tourism; however, given the operators' concerns on illegal charters and a rising recreational boater base, the support is contingent on management mandating licenses for all commercial operators and requiring that all vessels, and especially private vessels, exercise best practices (ex., maintain safe distances from other vessels, respect others, and avoid groundings and other impacts on marine resources).

Most operators used very discrete zones, focusing on shallow sandbanks, keys, and beaches for general (ex., sun and fun tours) trips and on reefs and hardbottom habitats for more specialized snorkel and dive trips. There was also considerable specialization in the stakeholder group, in that the concessionaires worked as water taxis, general tour operators, dive and snorkel operators, luxury tour operators, and vessel rental centers; this likely reduces direct competition in an otherwise crowded marketplace. Notwithstanding these efforts to focus on specific uses and visitors, respondents stated that water operator uses have increased (in both large and small charters), and 93.3% estimated that private vessel use was either higher or

much higher than in the past. Over 87% also believed that the increasing private vessel use had resulted in moderate to major impacts to coastal and marine resources.

While a majority of the sample favored zoning in general, support depended on the types of zones to be established. Thus, over four fifths supported no fishing zones, and 94% supported no anchor zones, but there was little support for no entry/no use zones (27%) and rotating zones (38%). It could be argued that these results demonstrate a bias, in that the preferred options prioritize operator access; but, operators also did favor other management actions that may affect access, including daily limits on visitors by zone (50% support) and limits on vessel totals (69%). Also, two thirds supported visitor management and limits.

Inter-group views on existing conditions and crowding

Table 30 shows that for crowding was not an issue for any of the groups. The tolerance/encounter ratio was much higher for recreational boaters than for visitors and commercial fishers, such that boaters estimated that they could tolerate over 16 times the number of vessels they encounter while visiting keys and beaches. This is due to the nature of the activity and habituation of crowding conditions. The northeastern region has five large marinas and several guarderias (boat storage areas), including Ceiba's iconic Puerto del Rey marina, the largest in the Caribbean. The marina has over 1,000 slips and 650 dry stack spaces. Given the number of local vessels and the vessels trailered in from the San Juan metropolitan area, recreational boaters likely encounter dozens of other vessels on the water and in the popular keys and beaches.

For visitors and commercial fishers, the number of other visitors or vessels they encounter, respectively, are closer to their tolerance thresholds than as determined for recreational boaters. However, neither group expressed discontent with the number of other users. Visitors ranked their beach visits as the most frequent activity in which they engaged, a large majority (84%) rated beaches as in either excellent or good condition. Similarly, commercial fishers generally discounted crowding as an important factor in terms of harvest, catch rates, or use conflicts. Fishers also tended to fish further away from the most popular tourist areas, so they actively reduced their exposure to crowding conditions.

Operators are a heterogeneous group, consisting of those who take sun and sand tours of the La Cordillera Reefs Natural Reserve beaches, others who focus on dedicated snorkel and dive trips, and others who specialize in kayak and small motorboat excursions. There are also those operators who work mainly as water taxis, offering occasional custom charters. The operator types have different use patterns and space requirements and thus have varied views on what level of use represents crowding. However, most operators agree that crowding is equally, if not more, a function of behavior than of vessel or user densities.

Table 30: Inter-group stated encounters and tolerance

Views	Primary activity	Vessels /users encountered	Vessels/users tolerated	Tolerance/encounter ratio
Recreational boaters	Visiting keys and beaches	5.47 vessels	89.7 vessels	16.3
Visitors	Visiting beaches	20.5 visitors	25.5 visitors	1.24
Commercial fishers	Fishing	3.86 vessels	4.95 vessels	1.28
Water-based operators	Varied by operator	Varied by activity	Varied by activity	Tolerance varied, but is dependent on behavior more than total vessels/users

Resource and social indicators

The limits of acceptable change (LAC) approach is an important lens via which to identify and evaluate the uses and issues facing the NMC. The approach consists of four components expanded into nine steps established to improve uses in managed areas (McCool 1996). The premise of LAC is that use is an integral part of the system (akin to the ecosystem-based approach to management), and that there exist a range of acceptable resource and social conditions that can be parameterized to evaluate if these fall within acceptable ranges and to identify management actions to maintain or achieve the conditions. Within the LAC approach, it is important to develop standards (ex., appropriate resource and social indicators) that can be measured to determine whether conditions fall within an acceptable range . If a standard's threshold is breached, the role of management is to identify and prioritize alternatives to redress the breach and restore the area to below the indicator threshold, i.e., below LAC.

The NMC is an ecologically complex and socioeconomically diverse region, containing vulnerable coastal and marine habitats that provide key ecosystem services. Among these services are provisioning services that local commercial fishers capture in the form of valuable finfish and invertebrates, and the cultural services enjoyed by visitors and on which the commercial operators depend for their livelihoods. The nearshore habitats serve as important nursery grounds for commercial fisheries and fish that divers and snorkelers enjoy viewing, providing essential supporting ecosystem services. But, both global impacts from climate change and local stressors resulting from unsustainable fishing practices and use-based habitat damage can undermine the functionality of the region's ecosystem and attendant ecosystem services.

By characterizing the main user groups that rely on, recreate in, and benefit from the NMC, the study was able to identify the appropriate resource and social indicators specific to each user

group that can be measured to assess the region's health. The study also determined which alternatives would be acceptable to the various user groups in addressing those conditions that have surpassed their limits. It is important to emphasize that the indicators represent user group priorities and, as such, may not reflect underlying resource conditions; however, these indicators, especially as they relate to use, conflict, and resources, are important gauges of user group perceptions and, eventually, satisfaction.

For recreational boaters, crowding is clearly not a constraint and does not apply to their views on social carrying capacity. However, boater behavior and practices are important to boater satisfaction and are perceived as mostly negative. As recreation returns to the region following the pandemic (as noted by several commercial fishers and operators in their interviews), use is likely to increase in previously heavily visited keys and beaches. While the use totals may not impact boater satisfaction, negative behaviors such as loud music, poor boater etiquette, and disregard for coastal and marine resources may further exacerbate impacts already reported by a majority of boaters. Thus, it would be important to monitor the number of conflicts observed and reported (citations, boater exit surveys) to determine whether there exists a correlation between recreational boater totals (especially high concentrations in popular sites) and the number of conflicts. Options for action may include limiting use by moorings or other vessel limit schemes (defined carrying capacity), upgrade enforcement and/or develop NMC-specific boater education material and programs (malleable carrying capacity), or a combination of both limits and enforcement and education approaches.

For visitors, whose major activity in and adjacent to the NMC is beach recreation, do not perceive present levels of visitation as a constraint. However, beach quality and amenities together influence visitor satisfaction, i.e., beaches are comprised of the space the offer, the level of cleanliness maintained, the availability of facilities, and the quality of surrounding natural resources. Monitoring beach quality and amenities as a series of inter-connected indicators or as a composite can be used to determine changes in visitor satisfaction, which in turn may affect the likelihood of a return visit. Options for action (many of which are already in place) should focus on maintaining beach quality, as it relates to promoting beach cleanliness among visitors, and monitoring the quality of intertidal and subtidal, nearshore natural resources. Options for action may include ecological recovery programs (ex., sea grass recovery zones, mangrove replanting, subtidal cleanups, etc.), programs focused on visitors to improve best practices (ex., preference of recyclable material over single use plastics, proper trash removal, avoidance of trampling on seagrasses and other fragile benthic resources, etc.).

For commercial fishers, whose activities are largely spatially separated from recreational users, the most important resource condition is the availability of fishery resources for their livelihoods. The NMC may play a secondary but important role in addressing this condition, by protecting nursery habitats and managing coral reefs and other hardbottom communities. NMC is not charged with fisheries management and thus cannot directly oversee fisheries in its boundaries; the NMC can however work with fishers and DNER to monitor changes in landings in NMC-associated and NMC-dependent species. Options for management may be to actively protect either juveniles and/or adults of commercial species via spatial tools (i.e., adding to the

Luis Peña Canal No-take Reserve) or to work with DNER and fishers to identify NMC-specific actions (ex., output measures related to size limits, quotas, and total allowable catch (Cochrane and Garcia 2009)). Fishers have become increasingly wary with the top-down measures (Shivlani and Matos-Caraballo, submitted) and argue that they have not benefited from most fishery measures, especially spatial management actions (Agar, Shivlani et al. 2019). However, the commercial fisher survey findings show that NMC use is restricted to a small number of participants who only infrequently use nursery areas and coral reefs in the western La Cordillera Reefs Natural Reserve; thus, spatial restrictions, especially if these are identified and set up with fisher and other stakeholder participation (see, for instance, Delaney (2003)), can yet be implemented in important NMC habitats.

For water-based operators, the resources on which they depend for their livelihoods comprise the most important condition. The resources themselves vary based on operator type and size. The largest operators rely mainly on the adjacent keys, sandbars, and beaches to conduct sun-and-sand tourism activities. Crowding and related social constraints are important but given that the passengers are generally not offended by high use area, social conditions that may matter most are those related to private vessel behaviors and practices. Snorkel and dive operators are more constrained by space, but they do not find much crowding in the areas where they operate; instead, the main concern that they face is a degrading resource base, especially corals (Pittman, Jeffrey et al. 2017). Finally, water taxis do not often engage directly in activities and are mostly involved in transporting passengers from mainland Puerto Rico to one of the keys in La Cordillera Reefs Natural Reserve RNA. Their primary concern is the social condition related to a normalization of illegal water-taxis and charters, which undermine their operations due to poor or no enforcement. Vessel behaviors and practices can be monitored for both large operators and for recreational boaters, as both groups have the same concerns. Coral and associated resources are already monitored in the La Cordillera Reefs Natural Reserve and Culebra Reserve under the Puerto Rico Coral Reef Monitoring Program (PRCRMP)[5], and operators could be recruited to provide local ecological knowledge on dive and snorkel sites on a periodic basis. Illegal operator totals and activities could be monitored by identifying such operators via internet searches, on-the-ground data collection from the main ports, and information provided by operators. One important connection across all the operator types is the availability of local knowledge, which can be collected in a formal manner (i.e., periodic surveys) to determine changes in in conditions. Management actions to address changes in conditions clearly need to be tailored. Boater behavior and impacts may likely need to be addressed via a mix of enforcement upgrades and enforcement efforts, as well as with the required use of mooring buoys to limit recreational boaters at specific locations. A deterioration in coral conditions may require both use limits (ex., based on coral cover trends, disease outbreaks, and bleaching, habitat damage, diver and snorkeler perception, etc.) and no-take zones to reduce local stressors. Finally, illegal charters will require a reassessment of the management approach as per the types and number of concessionaires suitable for the region. If illegal charters continue to rise, these in part represent a demand (i.e., more visitors) that is met by those free riding on the licensed concessionaires. The unlicensed effort also takes away

[5] https://www1.usgs.gov/obis-usa/ipt/resource?r=prcrmp_database.

from being able to accurately estimate numbers of visitors and types of tours being taken in the NMC. Thus, it is important that any alternative to consider whether the concessionaire base should be increased, both to meet visitor demand and to maintain resource conditions.

Recommendations

1. Continue to monitor the number of conflicts observed and reported by boaters and citations to determine whether there is a causal relationship between crowding in popular sites and the number of conflicts.
2. Continue to conduct in-person, visitor intercept surveys along key sites (beaches, ferry docks) to evaluate visitor satisfaction as it relates to trip quality, resource conditions, crowding, and marine litter.
3. Continue to conduct self-administered visitor surveys with visitors taking trips on concessionaire vessels to evaluate visitor views on trip quality, resources conditions, in-water crowding, vessel crowding, noise, and marine litter.
4. Continue to conduct self-administered, registered vessel operator surveys to determine operators' uses by area and related views on resource conditions, congestion, noise, and marine litter.
5. Working with DNER, monitor changes in landings/harvest of NMC-associated and NMC-dependent species to determine long-term trends in species harvest and resource conditions.
6. Working with PRCRMP, monitor coral and associated habitat conditions in the NMC.
7. Working with concessionaires, monitor reef conditions for disease, bleaching, and other mechanical damage to set up recovery zones that limit visitor use where conditions deteriorate.
8. Facilitate communication with concessionaires and marinas to receive input on conflicts with recreational boaters.
9. DNER should consider being more specific when granting authorizations which should include places of authorization (without generalizing by natural reserve), and create categories of type of activity.
10. Estimate the total number of visitors taken to NMC by concessionaire type and activity to compare trends in visitor perceptions (recommendations 2 and 3) and visitor loads, resource conditions (recommendation 5).
11. Continue monitoring the amount and types of non-permitted NMC operations, via internet searches, on-the-ground data collection from the main ports, and information provided by operators, to evaluate options to increasing the concessionaire base and/or to upgrade enforcement.
12. Consider establishing a mandatory anchoring buoy system in most visited areas to avoid crowding.

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Appendix 1: Initial Characterization of the Northeast Reserves users and user patterns

Initial Characterization of the Northeast Reserves users and user patterns

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Introduction

Puerto Rico's Northeast Marine Corridor (NMC)[6], which stretches from the municipality of Rio Grande in the northwest to Culebra in the northeast, comprises a mosaic of diverse coastal and marine habitats which are increasingly under threat from a multitude of local, regional, and global activities (Pittman et al., 2017). The NMC was designed as a conservation area network by the Puerto Rico Planning Board in 2016, encompassing 122 existing conservation areas, including six large natural reserves, and creating the basis for integrated management across the existing conservation initiatives.

A set of connected habitats extend from the shoreline to deeper waters, including swaths of sandy beaches, mangrove forests and islands, sea grasses, hardbottom habitats, coral reefs, and pelagic waters. These habitats provide important provisioning (fisheries), cultural (tourism), supporting (nutrient cycling), and regulating (shoreline protection) services adjacent to a densely populated coastline. The habitats effectively support a large part of the region's economy, as it derives from consumptive uses such as fishing and nonconsumptive uses such as snorkeling, diving, boating, and beach visitation; the habitats also define the social and cultural identity of coastal communities, whether these are organized as fishing centers and villages or as tourism-dominated (and dependent) sites.

While several past studies have considered the socioeconomic (and economic) characteristics of facets of the various communities and activities located adjacent to the NMC and Culebra, fewer have focused specifically on the region's human dimensions – effectively on the types and relationships of uses with the region's coastal and marine environments. Similarly, areawide biophysical studies have been largely absent for the NMC and Culebra region, with the notable exceptions of Pittman et al. (2017) and Kågesten et al. (2015), which focus on benthic habitats.

This study represents the initial characterization of the NE area user and user patterns based on existing bio-physical and socio-economic data analyzed through the lens of a Limits of Acceptable Change framework. The purpose is to: First, develop a socioeconomic characterization of the most relevant and recent, human dimensions studies, reports, and other work conducted in the region, especially as these relate to conditions in the post-Hurricane Maria period (i.e., post-September 2017); and second, to develop a biophysical characterization as it relates to the NMC and Culebra habitats and their conditions, associated fauna, and ecological function. The region was hit very hard by the 2017 hurricane, and traditional activities such as commercial fishing and tourism both were severely impacted and, in some cases, permanently changed; habitats and associated fauna were damage and their functions were in several cases greatly impaired. These need to be considered as part of a new 'baseline' for the region, and the study should be considered as a combined biophysical and

[6] Please note that the terms "NE (Northeast) area" and "Northeast Marine Corridor (NMC)" are used interchangeably in this document. These refer to the study area as described above.

socioeconomic characterization of the region, given the socio-ecological nature of interactions that shape the NMC and Culebra, its habitats, and its human environment.

NMC biophysical dimensions

The biophysical dimensions of the NMC are dominated by a series of inter-connected habitats, commencing from the shoreline, across a series of cays, and extending into offshore waters. Shoreline habitats include a variety of sandy, forested, and rocky coastlines subject to relatively low tidal range (less than a meter), although it should be noted that sea level has been rising at 2.04 mm per year since the 1960s and represents a long-term threat to the NMC coast via flooding, surge, and erosion events (Runkle et al., 2018). These inter-tidal habitats are important nursery grounds for a variety of finfish and invertebrates, and these also provide essential ecosystem services as related to shoreline protection and nutrient cycling.

Subtidal coastal environments consist of a mixture of soft-bottom and hard-bottom habitats, consisting of bare muddy and sandy bottoms, seagrass beds, hard-bottom communities, and coral reefs, among others (Miller and Lugo, 2009). These different habitats, which can be found as a continuum from a singular habitat type to a mixed habitat type, host a variety of marine communities, including most of the region's most valuable fisheries and protected species. The NMC's coral reefs are centers of high biodiversity, containing a large variety of fish and invertebrate guilds across various trophic levels and generating high levels of productivity in an otherwise nutrient poor system (Pittman et al., 2017; Miller and Lugo, 2009).

Kågesten et al. (2015) completed a shallow-water (0-35 meter) benthic mapping study of northeastern Puerto Rico and Culebra in which they developed a classification scheme for benthic habitats and a summary of benthic habitats by area, among other activities. The overall map that the study generated covered 744 square kilometers of benthos via a multi-resolution depth model that combined aerial photography, satellite imagery, and underwater video and photos. The main habitat types in the NMC characterized by the study, which are discussed in more detail below, were mangroves, seagrasses, softbottom algae, coral reefs, sand, mud, artificial habitats, and unknown types (Figure 1). Deeper waters (below 30 meters) are less well studied (Pittman et al., 2017), especially mesophotic reefs and sea grasses down to 100 meters and 127 meters, respectively. It should be noted that no area-wide studies have been conducted to assess changes in biological cover since the 2017 hurricane season; this represents a significant information gap, especially when area-specific studies on various coastal and marine habitats have shown significant damage across many biological cover classes. Hurricane Maria, for example, damaged and smothered several nearshore areas (Matos et al., forthcoming; Matos, personal communication), effectively changing habitats as it crossed the Commonwealth in September 2017.

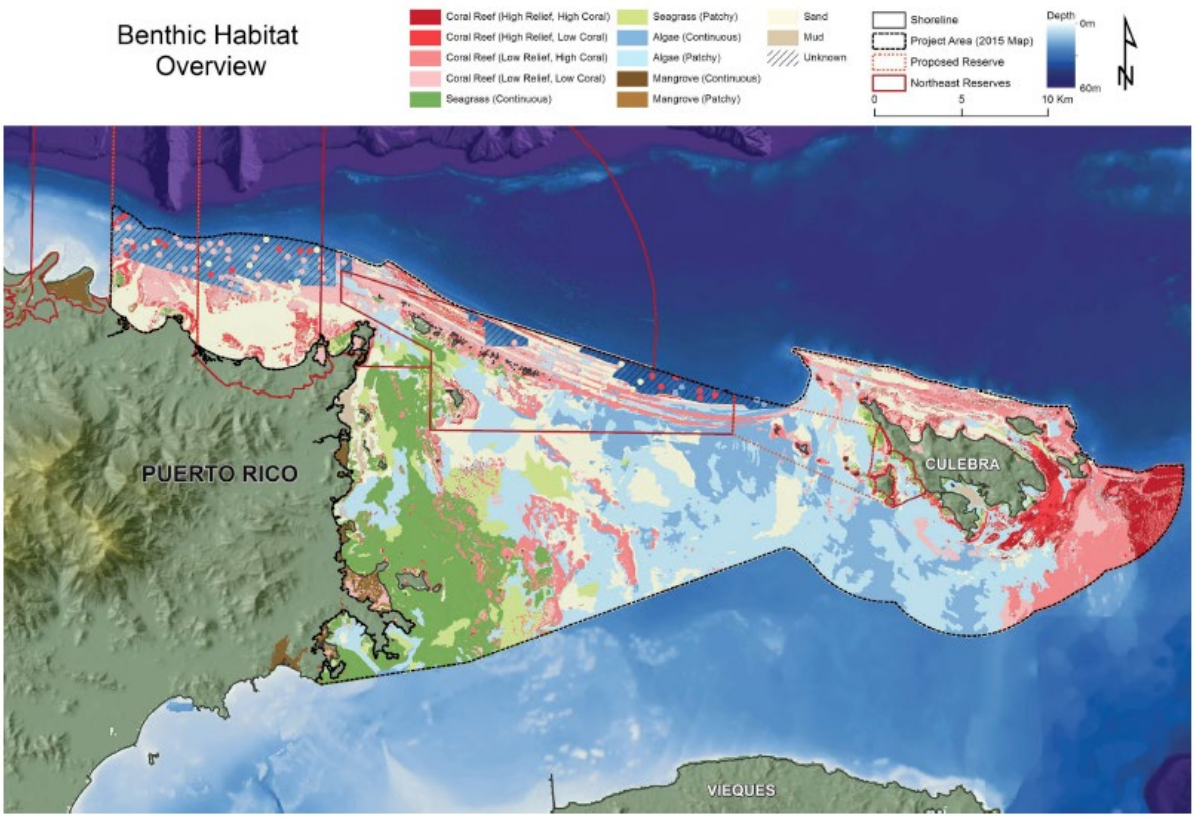

Figure 5: Benthic habitats of northeastern Puerto Rico and Culebra (Kågesten et al., 2015)

Moreover, chronic factors, comprised of land-based source of pollution, fisheries, and climate change, represent a long-term threat to the integrity and function of the NMC biophysical environment (NOAA, 2016). . These ongoing activities, along with episodic impacts resulting from hurricanes and other storm events, reshape the NMC habitats, resulting in drastic changes in species abundance and distribution. With the advent of a new coral disease (stony coral tissue loss disease) spreading across the western Caribbean (Weil et al., 2019), it remains unclear how that event may further change the abundance and distribution of the region's corals.

Mangroves

Of the four genera of mangroves found in Puerto Rico, the one that is most commonly associated with the water's edge is the red mangrove (*Rhizophora mangle*), although both black mangroves (*Avicennia germinans*) and white mangroves (*Laguncularia racemosa*) are also found in the same habitats, but usually a bit further inland (Miller and Lugo, 2009). If considered as part of the region's marine habitat, the emergent vegetation that red mangroves represent comprises only 0.59% (or 4.3 square kilometers) of northeastern Puerto Rico and Culebra; by contrast, a 2008 study estimated that there were 8,323 square kilometers of mangroves across the Commonwealth (Gould et al., 2008). Thus, the extent to which mangroves comprise the NMC depends on whether the area landward of the spring high tide

zone is considered as part of the NMC. Both Pittman et al. (2017) and Kågesten et al. (2015) consider only subtidal and intertidal mangroves as part of the NMC and northeastern Puerto Rico, respectively.

Mangroves have suffered considerable losses in Puerto Rico, first with agricultural development over the past 200 years and then due to urban development in the 1960s and 1970s (Martinuzzi et al., 2009). Since 1972, the Commonwealth of Puerto Rico has protected mangroves, and additional protections have been afforded via the several protected zones in the NMC, including the large natural reserves and over a hundred smaller conservation areas. Hurricanes Irma and Maria in 2017 did damage mangroves across the entire island; Branoff (2019) determined a 22% total mortality a year following the 2017 hurricane season in mangrove forests in north-central Puerto Rico. Similarly, Griffey et al. (2019) reported an average of 33% height loss among Puerto Rican mangroves, with areas close to Hurricane Maria's landfall reaching as much as 65% height loss.

As in other parts of Puerto Rico, mangroves in the NMC serve as nursery grounds for many of the region's finfish and invertebrates (Appeldoorn et al., 2009; Pittman et al., 2007; Mumby et al., 2004). Mangrove channels and related subtidal areas also harbor protected species such as the West Indian manatee (*Trichechus manatus manatus*). Various species spend parts of life histories in mangroves before completing ontogenetic migrations to deeper water, making mangroves an essential fish habitat that maintains connectivity (and sustainability) over the larger coastal ecosystem (Serafy et al., 2015; Jones et al., 2010). While NMC mangroves have been largely protected against harvest (for firewood) and cutting (for development), these habitats are endangered by the adjacent development activities which result in pollution, sedimentation, and fishing pressure (NOAA, 2016).

Seagrasses

Seagrasses, in continuous and patchy meadows, comprised 123.5 square kilometers of the northeastern Puerto Rico and Culebra benthos (Kågesten et al., 2015) in the mid 2010s, which represented 16.6% of the region's total area. Much of the seagrass was found as a continuous habitat, especially as nearshore shoals, with a smaller percentage found as patchy habitat.

There are five genera of native seagrasses found in Puerto Rico (Miller and Lugo, 2009), of which the most common is turtle grass (*Thalassia testudinum*). The other species include manatee grass (*Syringodium filiforme*), sea vine (*Halophila decipiens*), six-leaved grass (*H. engelmannii ascherson*), and shoal grass (*Halodule beaudettei*). Another species of prevalence is the invasive sea vine (*H. stipulacea*), which competes with native sea grasses and actually recovered better than native species following the 2017 hurricane damage to Culebra's sea grass communities (Hernandez-Delgado et al., 2020).

Seagrasses are highly productive habitats, providing a variety of ecosystem benefits, including serving as a source of food for grazers, enriching the food chain with detritus (which can comprise 95% of total production), providing shelter for a number of marine fauna and

substrate for epibionts, developing stable structures that reduce the effects of storms and consolidate underlying sediment, among others (Miller and Lugo, 2009). Sea grasses are also important habitats for a variety of finfish and invertebrates, and in Puerto Rico, sea grasses host queen conch (*Lobatus gigas*), one of the island's most valuable fisheries (Agar and Shivlani, 2017). Matos et al. (2019) reported higher rates of commercial diver decompression sickness following the decimation of sea grass meadows in southwestern Puerto Rico following Hurricane Maria; the loss of conch habitat led divers to adopt riskier diving behavior. Also, seagrasses in the NMC and Culebra provide essential habitat for the region's protected species, including the West Indian manatee and five species of sea turtles (Leatherback (*Dermochelys coriacea*), Hawksbill (*Eretmochelys imbricata*), Green (*Chelonia mydas*), and Loggerhead (*Caretta caretta*) sea turtles) (Pittman et al., 2017).

While little is known of the trends in seagrass distribution along the entire NMC and especially in deeper waters, the flora are heavily impacted in nearshore areas by vessels (propeller scarring, blowouts), visitor impacts (trampling, sedimentation), coastal development (sedimentation, shading), and land-based sources of pollution (sedimentation, eutrophication, toxins) (Pittman et al., 2017). Also, extreme events such as hurricanes have wiped out parts of or entire meadows. Hernandez-Delgado et al. (2020) reported extensive damage from Hurricanes Irma and Maria on sea grass communities in Culebra from sedimentation impacts resulting in burial and death, and physical damage causing scarring and exposed structures subject to further erosional events; overall, the rapid assessment estimated that over 20% of Culebra's sea grass communities had been lost to the 2017 hurricanes.

Corals

A total of 69 shallow-water, reef-building (scleractinian) corals across 13 families are found in Puerto Rico (Ballantine et al., 2008), and since 2014, seven of those species have been listed as threatened under the US Endangered Species Act (NOAA Fisheries, 2014). The reef-building corals are complemented by 46 shallow-water, soft (alcyonarian) corals, 260 fish species, and 500 marine algae (Ballantine et al., 2008). The north coast is generally poor in hardbottom communities, but due to a wider shelf that commences off northeastern Puerto Rico (in the NMC), there are offshore reefs with well-defined reef zones. However, these communities are also highly stressed, due to a combination of land-based runoff and river discharges. Fringing reefs dominate reef formation in eastern Puerto Rico, with high, variable cover on offshore islands and low cover in shallow areas off the mainland.

In their detailed mapping effort, Kågesten et al. (2015) estimated that as a biological cover class, live coral comprised only 0.18% of the NMC and Culebra; however, as a habitat, coral reefs (consisting of hard corals, soft corals, and hardbottom algae communities) covered almost a quarter (23.6%) of the region. Coral reef cover was highest around Culebra and within the Cordillera Natural Reserve, with the highest relief and highest cover off eastern Culebra. Lower relief and cover reefs were located along the Cordillera cay chain and off the eastern mainland, with patch reefs located along the northern extent of the NMC.

The region's reefs have been greatly impacted by a variety of land-based impacts, overfishing, and climate change. Hernandez-Delgado et al. (2006) reported a phase shift in Luis Peña Canal Natural Reserve from coral to algal dominance following several years of environmental degradation resulting in nutrient runoff, sewage discharges, and sediment loads. River-based nutrient and fecal discharges serve as chronic stressors to nearshore coral reefs and are pronounced along population centers, such as northeastern Puerto Rico (Ramos-Scharron et al., 2015; Larsen and Webb, 2009). Historic overfishing in coral reef ecosystems has required stricter regulatory measures, ranging from increased minimum size limits, seasonal and/or time-area closures, marine reserves, quotas, and more recently, dedicated access measures (Agar and et al., 2019). However, many stocks remain heavily exploited, and fishing effort – which declined after Hurricanes Irma and Maria in 2017 – has rebounded in the years following the storm (Matos-Caraballo, personal communication).

The 2017 historic hurricane season had significant impacts on Puerto Rico's coastal and marine habitats, and coral reefs suffered considerable damage (NOAA, 2019). An estimated 11% of the Commonwealth's corals were impacted by the storms, with certain areas experiencing a total loss. Due in part to the track of Hurricane Maria, corals in the NMC and Culebra were amongst the hardest hit, with an average of 13% coral colony damage in the region. Pillar coral (*Dendrogyra cylindrus*), a species listed under the US Endangered Species Act, was the most impacted coral, as 77% of surveyed colonies showed damage. Other listed species, such as elkhorn (*Acropora palmata*), staghorn (*A. cervicornis*), and lobed star coral (*Orbicella annularis*) all exhibited damage to between 37-45% of their colonies. The concern facing these damaged colonies is that the colonies may become increasingly stressed and thus more vulnerable to disease, herbivory, and competition. To address this concern, NOAA has the led the effort to reattach 5,400 fragments of broken colonies at 32 sites, including several sites in the NMC.

Climate change represents a global, existential threat for the NMC and Culebra coral reefs. The 2005 mass-bleaching event resulted in a widespread coral mortality event in 2006, affecting 52 reef-building species across the commonwealth (Garcia-Sais et al., 2008). Hernandez-Delgado et al. (2006) reported bleaching in 80-97% of leeward reef corals along the east coast, with lower bleaching percentages at reefs with stronger water circulation. A white plague-type disease killed 20-60% of living coral in survey sites in the east coast, affecting all key, reef-building species. Diseases in fact have played a significant role in now threatened species, especially acroporids, which have suffered from a white patch disease since the 1990s. Since 2019, another disease has emerged. The stony coral tissue loss disease (SCTLD), first reported in South Florida in 2014, is a generalist disease that is transmitted across species and is virulent (Weil et al., 2019). The disease has affected over 20 of the 45 reef building corals found in Florida, and it can lead to between two-thirds to complete colony mortality within weeks to months (FDEP, 2018). In November 2019, an outbreak was identified in a reef off Culebra, with an increase in disease prevalence to 74% by December 2019 (Weil et al., 2019).

Other habitats

The other main habitats in the NMC and Culebra, as determined by Kågesten et al. (2015), consisted of softbottom algae, sand, mud, and artificially created areas. Of these, softbottom algae comprised over a third of all NMC and Culebra habitats (33.9%), followed by sand (17.5%). Mud and artificially created areas comprised less a combined 0.7% of the total area. Softbottom algae tended to colonize sandy areas or rhodoliths (benthic marine algae), which are important hotspots that can serve as seedbanks and grounds for microalgae and macroalgae species instrumental in conferring ecosystem resilience (Fredericq et al., 2019).

Also, rhodolith reefs, consisting of brown algae, sponges, and various reef building corals, have been reported in waters deeper than 40 meters off western Puerto Rico (Ballantine et al., 2009); however, given the data gaps concerning mesophotic reefs in the NMC and Culebra, these and other deeper reef types (ex., deep terrace and drop-off wall types, as described by Garcia-Sais et al. (2008)) remain largely understudied in the region (Pittman et al., 2017). These deeper reefs are also important to a variety of larger predators, serving as habitats for commercially important grouper and snapper species, and parts of these habitats may also function as spawning aggregation sites (Garcia-Sais et al., 2008).

Marine fauna

Due to the variety of habitats and high levels of productivity, the NMC and Culebra are a hotspot for marine fauna, hosting hundreds of species of fish and invertebrates and an array of marine mammals and reptiles (namely sea turtles). The fauna utilize the different habitats for parts or all of their life histories, whether that relates to marine turtle nesting, marine mammal residency, or spawning, nursery, foraging, and migrations among fish and invertebrates. Also due to its productivity, the region is an important commercial and recreational fishery and marine tourism center, hosting a mainly artisanal, multispecies, multi-gear fishery and a well-established network of water-based operations (Hernandez-Delgado et al., 2014; Shivlani, 2009). Management authority for these fauna is spilt across Commonwealth and US federal government agencies, with the Puerto Rico Department of Environmental Resources (DNER) carrying out Commonwealth laws and US Fish and Wildlife Service (FWS) and NOAA Fisheries implementing federal wildlife and fisheries regulations.

A total of 448 coral reef fish species are found in Puerto Rican waters, including in the NMC and Culebra, compared to a total of 751 marine fish in the region (Froese and Pauly, 2019). Many species, especially those associated with reef-related fisheries, are considered overfished or fully exploited (Ault et al., 2008). While a large variety of fin fish are harvested, especially with fish trap gear that targets many reef fish species (Agar et al., 2008), there are highly valued species that have been heavily fished and which exhibit depressed or slowly recovering populations. These include both shallow and deep-water groupers and snappers, which play an important role as higher level trophic predators to maintain top-down control in their respective food webs, and parrotfish, which perform the key task of grazing on macroalgae to promote coral integrity in many reef habitats (Mumby et al., 2006). Most grouper species have been identified as overfished and undergoing overfishing, most snapper species as experiencing or in an unknown status, and parrotfish as undergoing overfishing (CFMC, 2011).

Hernandez-Delgado et al. (2014) reported very low concentrations of apex predators in the Cordillera Natural Reserve, representing a long-term decline from 1997-2012 of fishery-targeted species and especially after two strong bleaching events in 1998 and 2005 that resulted in mass coral mortalities. The study also found that herbivores had increased to encompass most of the total fish biomass inside the reserve, and that lionfish (*Pterois volitans*) populations had increased in recent years, coinciding with declines in groupers and snappers. Similarly, another study (Hernandez-Delgado et al., 2006) found declines in reef fish inside the Luis Peña Canal No-Take Reserve from 2002 to 2004 following a few years of rapid recovery inside reserve boundaries following its 1999 designation. Similar declines have been observed in other marine reserves in Puerto Rico (Schärer-Umpierre et al., 2014).

There are an estimated 2,183 species of marine invertebrates across eight phyla, with mollusks, comprised of 1,176 species, accounting for more than half of all Puerto Rican marine invertebrates (Weil, 2005). Other invertebrates include 171 species of cnidarians, of which there are 116 species of anthozoans (a class that includes corals, octocorals, zoanthids and anemones). Crustaceans are represented by 342 species, including brachyurans (crabs), macrurans (shrimps and lobsters), and anomurans (hermit crabs), among others. There are also 165 species of echinoderms, 131 species of bryozoans, 129 species of annelids, and 61 species of sponges. Endemism, while more common in Puerto Rican terrestrial systems, is exceedingly rare in its marine system, and no marine invertebrates are considered endemic to the NMC and Culebra. Marine invertebrates occupy almost every marine habitat off the Commonwealth, with many species occupying many different habitats. Some, such as corals and spongers, are wholly sessile in their mature stages whereas others, including annelids and crustaceans, are largely mobile as adults.

Several marine invertebrates are of high economic value, especially spiny lobster (Panulirus argus) and queen conch (*Lobatus gigas*) which are found in a variety of shallow-water NMC and Culebra habitats. Spiny lobster is harvested both inshore and on reef and other hardbottom habitat, whereas queen conch is collected from seagrass and other softbottom areas (CFMC, 1996). Spiny lobster is not presently overfished (Medley, 2019), but queen conch is heavily overexploited and is managed using a variety of closed season, daily trip limits, and area closures to manage the vulnerable fishery. There is also a common octopus (*Octopus vulgaris*) fishery that exists throughout Puerto Rico, but less than a combined 10% of the total landings are harvested by commercial divers in the north and east coasts (Rodriguez-Ferrer et al., 2017b).

There are 18 marine mammals that are residents in or pass through Puerto Rican waters (Weil, 2005). Of the resident species, the West Indian manatee (*Trichechus manatus manatus*) is the only species of Sirenians in Puerto Rico, and it is protected under the US Endangered Species Act and Marine Mammal Protection Act and jointly managed by the FWS and DNER. The island-wide population was estimated at 300 individuals in 2010 (UNEP, 2010), and Collazo et al. (2019) state that the average minimum estimate across different surveys through 2014 was 386 +/- 89 individuals. The spatial distribution of manatees in the NMC and Culebra is uneven, in

that the Collazo et al. (2019) study found that while manatees were sighted as far east as Culebra, none were sighted along the Cordillera Natural Reserve and from Fajardo to Culebra; by contrast, highest concentrations were found in a hotspot along the western edge of the NMC, in Rio Grande. Manatees in Puerto Rico face similar challenges as they do in other parts of their range, with seagrass habitat loss, fishery gear entanglement, and – in particular – vessel collisions playing a combined role to impact their population (Pittman et al., 2017).

Among whales, including baleen whales and toothed whales and dolphins, most species are transitory to Puerto Rican waters and are found either occasionally or along migratory routes during particular times of a year. Overall, a total of 17 species (four baleen, 13 toothed) have been reported for Puerto Rico, US Virgin Islands, and British Virgin Islands. The most common resident species is the bottlenose dolphin, a common, coastal dolphin species found around the entire island (Rodriguez-Ferrer et al., 2017a; Mignucci-Giannoni et al., 1989). Coastal bottlenose dolphins in the NMC and Culebra mostly represent a nearshore ecotype that in the northwestern Atlantic is found within 34 kilometers and in waters less than 34 meters in depth (Torres et al., 2003). While previous marine mammal stock assessments have not determined an island-wide population estimate or population trends, a study conducted in south and west Puerto Rico using mark-recapture methods to compare changes in the number of individuals determined that the bottlenose dolphin population had declined in the area by 60% to 127 individuals from 2001 to 2015 (Rodriguez-Ferrer et al., 2017a). While the study could not confirm the source of the decline, as to whether it was related to mortality, movement, or a combination of both factors.

There are four main species of sea turtles (Leatherback (*D. coriacea*), Hawksbill (*E. imbricata*), Green (*C. mydas*), and Loggerhead (*C. caretta*) sea turtles) that frequent Puerto Rican waters, and all but the Loggerhead sea turtle nest in Puerto Rico. Loggerhead sea turtles are found only in Puerto Rican waters, and these sighting are mostly limited to the northeast and southeast coasts (USFWS, 2018d). Leatherback sea turtles are the largest of all sea turtle species, growing to 2.4 meters in length and weighing as much as 900 kilograms (USFWS, 2018c). While mainly pelagic, leatherbacks do nest in many Puerto Rican beaches, especially in the west, north, and east. In the NMC and Culebra region, leatherbacks nest in and around Fajardo and Culebra beaches. Green sea turtles also frequent Puerto Rico either in transit or for coastal foraging, but the species tends to nest in few beaches across the Commonwealth; the most popular nesting site in the northeast is Culebra (USFWS, 2018a). Hawksbill sea turtles, unlike other pelagic species, are generally coastal and tend to favor coral reefs and shallow coasts; in Puerto Rico, hawksbills are found across the island but tend to favor discrete nesting areas in the southeast, north, and northwest (USFWS, 2018b). The species nests in the northeast in Culebra.

All sea turtles found in and around Puerto Rico (and along other parts of their ranges) face similar challenges, namely vessel collisions, fishery gear entanglement, pollution (especially plastic pollution), and poaching (NMFS, 2009). On land, sea turtles are especially vulnerable, as debris, development, and lighting can block nesting females and misorient hatchlings, leading to aborted nesting attempts and high hatching mortality rates, respectively. All sea turtle species that frequent Puerto Rico are listed as endangered under the ESA (NMFS, 2009), and

both green and hawksbill sea turtles have designated critical habitat in and off Culebra, where the beaches and coastal waters as key nesting and foraging habitats, respectively (USFWS 2018a; USFWS, 2018b).

Sea turtle populations have generally followed a positive to stable trend in Puerto Rico. Leatherbacks, for example, nest mainly in the Fajardo area in the NMC and in Culebra, and sites there increased from four nests in the late 1970s to almost 900 by the 2000s (NMFS/USFWS, 2012). Similarly, hawksbill populations were listed as increased, based on nesting in coastal areas, including Culebra (NMFS/USFWS, 2013). The 2017 hurricane season affected sea turtles in the region, resulting in mortalities, reduced nesting, and changes in foraging behavior (Matley et al., 2019; Crespo Feliciano, 2018; Leibach, 2017); measures taken by governmental agencies and conservation groups focused mainly on coastal responses, especially as related to the protection and restoration of nesting beaches. For example, the Federal Emergency Management Agency (FEMA), in conjunction with Commonwealth and other federal agencies, undertook steps to prevent impacts to Culebra and other significant nesting sites, including the prohibition of night activities to minimize light pollution, prevention of the use of heavy machinery during the summer nesting season, a ban on alteration of beach features, and the implementation of a beach monitoring plan (FEMA, 2018). While nesting did recover albeit to lower levels than before the storms, especially in those areas least impacted by the storm (ex., Mona Island off western Puerto Rico) (Crespo-Feliciano, 2018), more research is needed in the NMC and Culebra, in particular, to estimate the long-term impacts of overall mortalities and nesting disruptions.

NMC human dimensions

The NMC is an essential part of the region's economy and identity. Densely populated, the NMC's coast is dominated by an urban fringe consisting of the towns of Rio Grande, Luquillo, Fajardo, and Ceiba. Within and between these towns are several public and private marinas, piers and boat ramps, and beaches, all of which serve as launching points for a portion of the over 60,000 registered vessels in Puerto Rico (personal communication, Perez-Prado).

Puerto Rico experienced a sharp decline in population over the 2010-2018 period, and especially following the devastating effects of Hurricanes Irma and, in particular, Maria. The population, which stood at 3.73 million in 2010, declined to 3.19 million in 2018, representing a decline of 14.3% (US Census, 2019). Due to the significant effects to the island's infrastructure in the NMC, most coastal and marine economies, including fishing and tourism, effectively collapsed in the months following Hurricane Maria. While fishing communities had recovered to resume commercial fishing in most of the NMC region by 2018, levels of participation and effort remained much lower than before the storm; in some areas, fish houses (villa pesqueras) remained closed. Also, discussions with NMC area water-based operations in 2018 revealed that visitation totals remained at 50% of their pre-hurricane peaks even a year after the storm. Thus, in many ways, 2019 represented a new socioeconomic baseline (year 0) for the NMC region.

Fishing

Fishing is an important component of the socioeconomics in the region, and the activity is practiced from discrete commercial fishing centers and their respective communities and more diffusely by recreational fishing interests, consisting of shoreline anglers, spearfishers, and vessel-based fishers. Effort emanates both from locations adjacent to the NMS and from other parts of the island. In the former case, commercial fishing operations, fishing charters, and recreational fishers reside in these locations and perennially target NMC species. In the latter case, fishers from other parts of the island travel to the NMC on a seasonal basis to take fishing trips, either on their own or rented vessels or on fishing charters. Depending on the species, different NMC habitats are targeted by fishers. Reef fish, spiny lobster, and octopus are mainly targeted in or near coral reefs and related habitats, flats fish and queen conch are landed along sea grasses and other soft bottom habitats, and offshore fin fish are caught in pelagic waters.

Recreational fishing

The Commonwealth of Puerto Rico does not require a recreational fishing license. In 2010, Puerto Rico's Department of Natural and Environmental Resources (DNER) developed a licensing system, but this has not yet been implemented (Bacchiocchi et al., 2017). Instead, the territorial government utilizes mainly size and bag limits and time-area closures for popular species by which to address fishing effort. Recreational fishery regulations extend from the shoreline to nine nautical miles for territorial waters and through the federal exclusive economic zone (EEZ) to 200 nautical miles (except where waters are shared by other states).

Several reef fish species are closed to all fishing every year during their peak spawning seasons (ranging from December to February, February to April, and April to June), and spawning areas across territorial and federal waters are closed either on seasonal or permanent bases (CFMC, 2017). These include the Luis Peña Canal No-Take Reserve, located off eastern Culebra, which is closed year-round to all fishing. Recreational take limits are based on individual and vessel quotas, such as recreational fishers and vessels can harvest up to five and 15 reef fish per trip/day, respectively. Spiny lobster and queen conch, both of which are harvested mainly via diving, have lower take limits. Recreational fishers may harvest up to three lobster or conch per trip, and vessels can harvest up to 10 lobster or 12 conch per trip. Species are also subject to minimum size limit requirements, and these range from a total length for most reef fish, carapace length for spiny lobster, and shell length for queen conch.

There are three main types of recreational fisheries sectors in Puerto Rico: shoreline angling; private vessel angling (and diving); and charter fishing. The Northeast Marine Corridor (NMC) affords locations and habitats for all three sectors (Lilyestrom, personal communication). A sizeable proportion of the estimated 109,000 recreational anglers in Puerto Rico (based on a 2010-2016 average) utilize the NMC, based on the popularity of the region as a marine tourism

center[7]. Leeworthy et al. (2018) determined that almost 1.2 million person-days were spent in northeastern Puerto Rico and the islands of Culebra and Vieques; while reef and offshore fishing were not as important as other water-based activities, higher percentages of visitors participated in these activities in the northeastern Puerto Rico than elsewhere on the island.

NOAA's Marine Recreational Information Program (MRIP) data for Puerto Rico show that participation in recreational fishing has varied considerably over the past few years, and that trips have decreased considerably over the past two decades. Total estimated trips ranged from 351,000 trips in 2012 to 668,000 trips in 2017, averaging just over 500,000 trips per year from 2010-2017. By contrast, anglers took an average of 1.06 million trips over the 2000-2009, demonstrating a sharp decline in recreational fishing participation in Puerto Rico. Fishing trips were most often taken at the shoreline, which averaged 254,000 trips over the 2010-2017 period. Fishing from private vessels was also very popular, averaging 245,000 trips over the same period. Recreational fishing was also shown to be important to residents, as this cohort represented an average of 91% of the total number of participants in the recreational sector over the 2010-2016 period. The types and numbers of fish caught depended on the sector, such that private vessels targeted mainly reef fish, charters targeted dolphin and other offshore species, and shore-based anglers targeted a mix of coastal migratory species, reef fish, and bait fish.

While there are several coastal locations available for shoreline fishing in the NMC (see, for example, Pittman et al., 2017), field-based research for this project determined that shoreline fishing occurs on an infrequent basis. Stakeholders who were interviewed in the various coastal communities did identify hotspots such as beaches and hardened shorelines (ramps, piers, etc.) that are utilized by anglers, but the stakeholders also clarified that effort is sporadic and not concentrated in any particular area. Also, a recent visitor study conducted in the region estimated that only 2.9% of all fishing trips/days in the NMC region were conducted from the shore (Leeworthy et al., 2018).

Recreational fishing effort in the NMC region, as estimated by the number of recreational vessels and their attendant infrastructure (marinas, ramps, boatyards), most often occurs from private vessels. There are an estimated 60,000 registered vessels in Puerto Rico (Perez Prado, personal communication), but the number that primarily operate within the NMC and the percentage of those vessel whose operators engage in recreational fishing activities is unknown. A pervious boating study found that private vessel operators who visited northeastern and eastern Puerto Rico, including much of the NMC, only occasionally fished from their vessels. Thus, while recreational fishing may comprise an important activity in terms of its overall impacts, it infrequently is the main activity for recreational vessel operators.

[7] All recreational fishery data, unless cited otherwise, is obtained from the Marine Recreational Information Program of the National Oceanic and Atmospheric Administrations. URL: https://www.fisheries.noaa.gov/recreational-fishing-data/recreational-fishing-data-and-statistics-queries

Charter fishing represents another source of recreational fishing effort in the NMC. Field-based research for this project determined that 26% of the 103 water-based operations identified in the NMC region (or which visit the NMC on a regular basis) are either dedicated charter fishing operations or offer/facilitate fishing activities, such as spearfishing, lobster diving, fish collection, etc. Charter fishing operations extend from Rio Grande to Culebra, and most operators are located in the Luquillo-Fajardo-Naguabo corridor. A previous study by Hernandez-Delgado et al. (2014) found that NMC use by surrounding charter operations was high, in that operations relied disproportionately on the region for their trips. Charter operations also tend to be flexible in their trip types, in that several offer multiple activities, including visiting keys, snorkeling, and fishing, over the same trip.

Commercial fishing

Fishers from villa pesqueras (fish houses) in Rio Grande, Fajardo, Ceiba, Culebra, Vieques, and occasionally Naguabo and Loiza, participate in a multi-species fishery across the NMC using one or more (as many as four, in some cases) gear types (Agar et al., 2019; Hernandez-Delgado et al., 2014). Species targeted include reef fishes, coastal pelagic fin fish, offshore fin fish, crustaceans, and mollusks. Gear types include a variety of line-based gear, ranging from the number of hooks used, depth fished, and soak times, several variations of traps (fish traps, lobster traps, deep-water snapper traps), SCUBA for spearfishing fin fish and collecting spiny lobster and queen conch, and different types of nets (from small cast nets to large seines).

Field-based research for this project in the post-Hurricane Maria period determined that there is a maximum of 90 active fishing operations that reside adjacent to and regularly fish within the NMC (Leon, personal communication). It should be noted that this total is dynamic, and that a combination of push and pull factors (fishery prices and abundance, opportunity costs associated with other employment, migration, etc.) and regulatory requirements may change the number of active participants. Of the 15 fishing centers listed by DNER for the municipalities adjacent to the NMC, field-based research determined that six of these were no longer active (or at least not rebuilt) as of late 2018. Effort from these centers had either shifted to nearby centers, or the operations had exited the fishery. For example, in late 2018, half of the operations in Hucares (Naguabo) had not returned to the fishery due to hurricane-related damages to the port, their vessels, and their homes. Similarly, the villa pesquera in Playa de Los Machos (Ceiba) remained abandoned due to hurricane damage through the end of 2018.

Due to the availability of reef and related habitats, there are a variety of gear deployed in the region (Matos-Caraballo and Agar, 2011; Shivlani and Koeneke, 2011); These include traps used for reef fish and spiny lobster, longline gear for various fish species, vertical line gear for deep water snappers, dive gear to collect conch, target spiny lobster, or to spear reef fish, and a variety of shallow and mid-water nets for bait fish, reef fish, and spiny lobster. There has been a trend towards dive gear in the overall fishery (Agar and Shivlani, 2017), and that is also the case for eastern Puerto Rican fishing communities. This is in part due to the availability of higher value species (spiny lobster and queen conch) by dive gear, as well as the lower investment

costs relative to trap or other passive gear. A NOAA funded study determined that dive and trap gear use was highest in the eastern NMC area, especially in the Cordillera Natural Reserve and Culebra corridor, whereas the highest line gear use was isolated in deeper waters off the central NMC and around Culebra (Koeneke, 2011; Shivlani and Koeneke, 2011).

Due to the highly localized nature of most fishing operations (Koeneke, 2011), commercial fishing in the NMC is often tailored to suit the available habitat; thus, as mentioned previously, due to the paucity of shelf habitat off northern Puerto Rico, fishers from western fishing ports of Loiza and Rio Grande deploy mainly line gear and target mid to deep water fin fish. As coral reefs and associated habitats increase in abundance, especially along the Cordillera-Culebra corridor off northeastern Puerto Rico, fishing operations diversify their gear types, using trap, dive, and line gears (by trip and season on the same operation, if it uses multiple gear) to maximize harvest of fin fish and invertebrates.

The main species harvested in the NMC are reef-related species such as spiny lobster, queen conch, and reef fish, offshore pelagics such as dolphin, wahoo, and tuna, and coastal species consisting of bait fish, coastal migratory species, and nearshore reef fish (Agar et al., 2019). As described in the section concerning recreational fishing, commercial fishing is regulated by time-area closures, seasonal closures, bag limits, and size restrictions. These include time-area and seasonal closures for a variety of reef fish, including the permanent closure of all fishing in the Canal Luis Peña No-Take Reserve off Culebra, and the seasonal closure of queen conch (which are subject to a vessel trip maximum during the open season).

Fishing operations usually consist of a captain and one crew member, although this depends on the type of fishery targeted and gear deployed. Handline fishers (those who fish using a monofilament line with one or more hooks in waters less than 200 feet) from eastern ports such as Croabas and Puerto Real in Fajardo take only one crew member and at other times fish alone; this is because they tend to take short, day trips and use minimum gear. Others who use fish and/or lobster traps use at least one crew member to assist with piloting the vessel and/or pulling gear, which is done using either manual or hydraulic wrenches. Dive operations tend to use the highest number of crew, using one member to pilot the vessel, and two to three divers to fish the area (Agar and Shivlani, 2017).

The main market for NMC landed seafood is San Juan and the metropolitan area (Leon, personal communication). The market effectively collapsed in the months following Hurricane Maria in September 2017, due to a combination of flattened demand, lack of access to fishing ports, lack of refrigeration, and damages to transportation infrastructure, as well as a decline in fishery participation. While the commercial fishery has rebounded in terms of participation, and there are as many as 1,100 licensed operations (Matos-Caraballo, personal communication) in Puerto Rico in the year following the hurricane, the impacts to fishing centers and ports in the NMC region remain profound. Areas such as Vieques, Naguabo, and Ceiba were devastated, with impacts to fishing ports and infrastructure, and these have yet to recover. In some cases, fishers have migrated to other communities, while others have left the industry altogether (Shivlani and Matos-Caraballo, in preparation).

Water-based operations

Water-based operations are tied directly to tourism, namely coastal and marine tourism. As demonstrated by Leeworthy et al. (2018), reef-based tourism represents an important component of Puerto Rico's tourism economy; in 2016-17, over a third (33.9%) of the over 3.45 million recreating visitors reported participating in one or more reef-based activities. The rates of reef visitation were highest in northeastern Puerto Rico (which the study defined as the region between San Juan to the west, Fajardo the east, and Humacao to the southeast). The reef-based activities in which most visitors participated included swimming (73.1%), snorkeling from shore (10.0%), snorkeling from a boat (11.1)%, visiting bioluminescent bays (6.2%), kayaking (5.4%), paddle boarding (and related boarding activities) (4.98%), and diving (1.03%). Less important to visitors in northeastern Puerto Rico were consumptive activities, such as reef fishing, inshore fishing, and spear fishing, for which participation rates did not exceed 0.79%.

Water-based operations in the NMC consist of multiple-activity charters that offer one or more activities over a trip. Field-based research determined that of the 103 water-based operations identified that utilize the NMC, almost two thirds (65%) offer some combination of snorkel trips (cruising, kayaking, and/or beach visits), 26% specialize in fishing trips (although several also offer combination fishing and in-water activity trips), 24% take SCUBA trips, 23% offer kayak trips, 16% are sailboat operations, and 8% specialize in trips to one of the bioluminescent bays (off Fajardo and Vieques). Overall, 90% of the operators offer more than one type of trip, likely to maximize clientele and income.

Previous studies (Shivlani, 2009; Hernandez-Delgado et al., 2014) in the region found that water-based operations focused primarily on the Cordillera to Culebra area for their trips. Shivlani (2009) conducted a census survey with water-based operations in Fajardo and Ceiba, which determined that all the operations in the two ports used the reserve as a primary destination, and that operations took an average of 370 trips per year. Trips taken by the largest operations (i.e., catamarans that can carry more than 100 passengers per trip) within the reserve were most often taken to the western side, with the islands (cayos) of Palomino and Icacos being the most popular stops (Figure 2). Operations with more than one vessel tended to diversify their trips, with the larger vessel (> 20 passengers) taking trips to the western side, and the smaller vessel (< 20 passengers) taking trips to the eastern side, including Culebra and Vieques. Small charters were more likely to use the more remote parts of the reserve and the eastern NMC, as these would be most sensitive to crowding conditions. The study also determined that consumptive use (angling, spear fishing, lobster diving), was less important than nonconsumptive use (snorkeling, diving, beach visitation), and that only 3% of all trips taken to the reserve involved fishing; fishing charters, which comprised 20% of the operations, instead tended to diversify their trips, catering to nonconsumptive options, and fishing trips tended to occur north of the reserve (and outside the NMC).

Following Hurricane Maria, water-based operations suffered considerably due to a combination of physical impacts to their vessels, marinas, and related infrastructure and slackened demand

due to hurricane impacts and recovery, visitor perceptions concerning the Commonwealth's infrastructure, and outmigration that reduced the local visitor pool. The Puerto Rico Tourism Company (PRTC) determined that there were 2.25 million arrivals (based on lodging occupancy rates) in 2017; that total decreased to 1.77 million arrivals in 2018, representing a decline of 21% in the year following Hurricane Maria (PRTC, 2019). While certain sectors, such as the cruise ship calls and cruise passenger totals, quickly recovered, the NMC water-based tourism took much longer. Similarly, the island's population decline (Kaske, 2018), which predated but was exacerbated by Hurricane Maria, led to a smaller pool of local visitors who could be expected especially over the summer months.

Field-based research conducted as part of this project determined that visitation rates for water-based operators in the Fajardo-Ceiba area for the winter and spring of 2018 were lower than 50% of expected totals over the high season. As visitation rates improve (January 2019 lodging rates were 66.5% higher from January 2018, or 174,000 vs. 105,000 visitors), it is expected that the water-based operations in the NMC will recover accordingly. However, It remains unclear the overall impact that the decline in the resident population will have on visitation rates, especially over summer months.

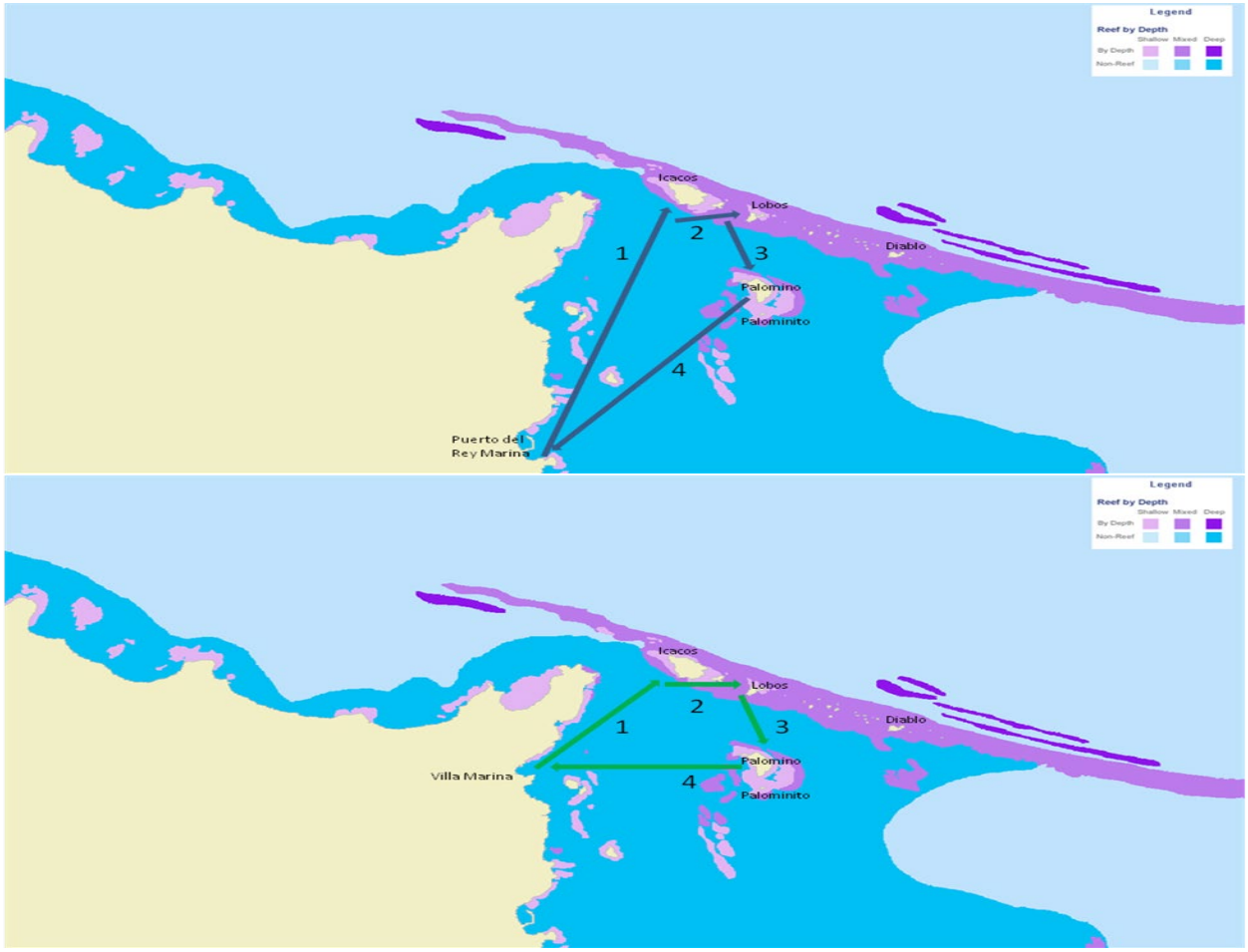

Figure 6: Large water-based operation use patterns in La Cordillera RNA, from Villa Marina (Fajardo) and Puerto del Rey (Ceiba) (Shivlani, 2009)

Recreational private vessels

Recreational (private) vessel operators represent a major stakeholder in the NMC region. The operators straddle a variety of different uses, ranging from cruising, visiting islands and beaches, snorkeling, diving, water-skiing, and fishing, among others. Some of these uses can be in conflict with others. Vessels can compete with each other for the same location for similar or different uses, and activities from one set of vessels can impact those of another set of vessels.

There are over 60,000 registered vessels in Puerto Rico (a 2012 boating survey by the US Coast Guard determined that there were 65,000 registered vessels that year), but the active total may have changed since Hurricane Maria (Perez-Prado, personal communication). It is unclear how many of the active vessels use the NMC, but given the proximity of the region to the San Juan metropolitan area and because several of the island's largest marinas are located in northeastern Puerto Rico, it is likely that the NMC hosts consistent boating activity; for example, the Puerto del Rey marina, located in Ceiba, has 1,000 wet slips and 400 drydock spaces (www.puertodelrey.com). The other marinas in Fajardo can collectively accommodate over 1,000 vessels in wet slips, with space for many more vessels in drydock. Vessels enter the region from ports located adjacent to and within the NMC, including the adjacent San Juan metropolitan area from the west and Humacao from the southeast, as well as private and public marinas in Rio Grande, Fajardo, Ceiba, Naguabo, and the islands of Culebra and Vieques. There is only one boat ramp that is operating after Hurricane Maria in the NMC region, and it is located in Fajardo (Croabas). Another boat ramp, located in Luquillo, is no longer in operation. Thus, recreational vessel operators can either travel to the NMC from adjacent ports, enter the NMC from private or public marinas located within the NMC, or trailer their vessels from other locations to the Fajardo boat ramp.

In an earlier study conducted with 102 registered vessel operators in northeastern Puerto Rico (Shivlani, 2009), 72% reported the eastern NMC as their primary destination. Their main activities in La Cordillera RNA and adjacent areas were visiting beaches and keys, cruising and swimming, followed by line fishing and snorkeling. The two most popular areas to visit were the islands of Palomino and Icacos, which 92% and 81% of the respondents reported visiting, respectively. The study determined that for the trips taken in the La Cordillera RNA, distance from port played a role in the areas visited, such that islands located further offshore were less often visited compared to those closer to port (Figure 3). Among those operators who took trips to Culebra, the most popular destination was Luis Peña No-Take Channel Reserve; in Vieques, the most popular destination was the western beach (which provides excellent sandy anchorage) of Punta Arenas. Similarly, using commercial satellite data representing 18 days from 2015 to early 2016, Battista and Husted (2017) found higher rates of vessel use (i.e., number of vessels) in summer versus winter months and identified Ensenada Honda (a popular

anchorage off southern Culebra) and islands in La Cordillera RNA as the two main hotspots, attracting between 10-20 vessels and 5-10 vessels, respectively.

It remains unclear whether recreational vessel uses and use patterns have changed since the 2017 hurricane season. Given its overall size and likely use footprint over the NMC region, a comprehensive recreational vessel study is important to establish a baseline on how vessel operators access the NMC, the uses in which the operators engage, the impacts that their activities may represent, and operators' preferred management options to improve resource quality.

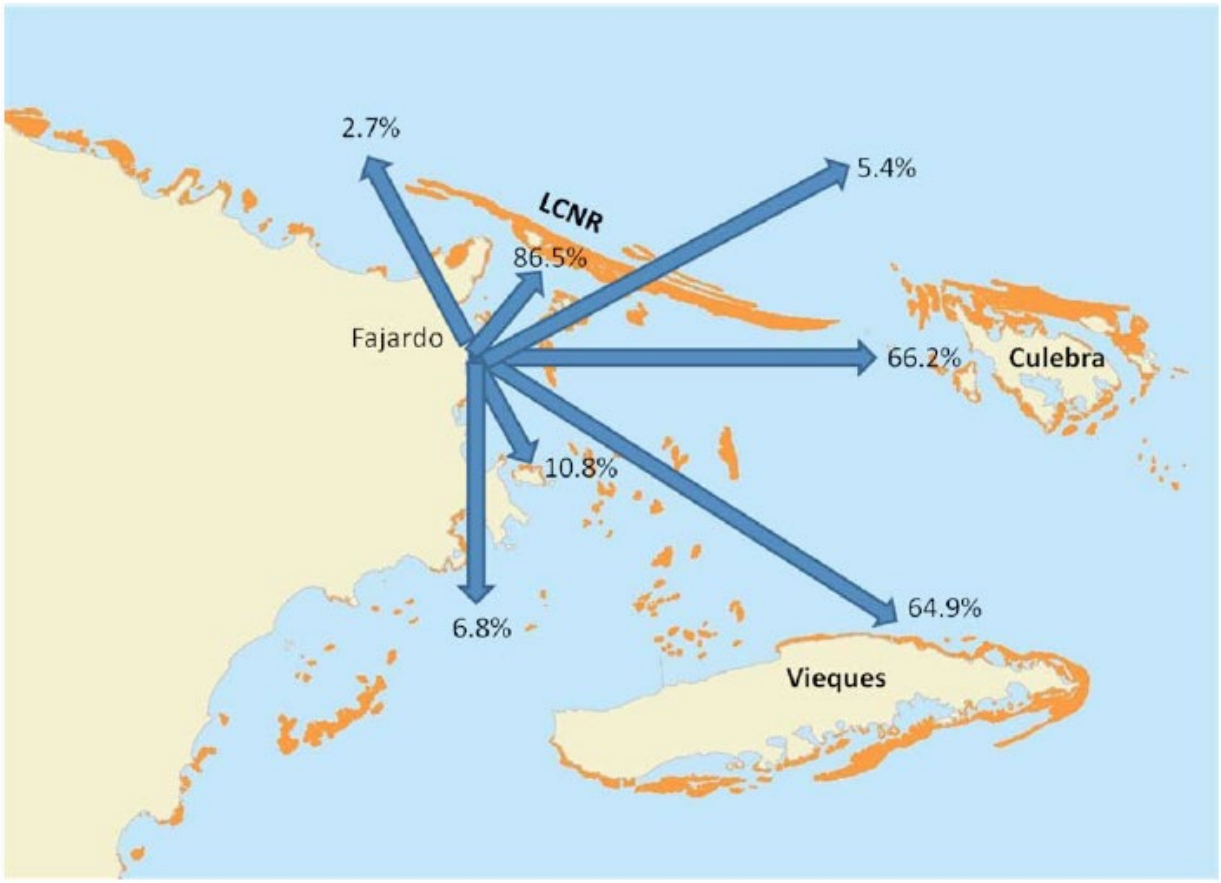

Figure 7: Recreational vessel use patterns in the eastern NMC, Culebra, and Vieques

Conclusions

A full characterization of the NMC and Culebra following Hurricanes Irma and Maria has to consider the possibility that even as the Commonwealth's habitat and fauna and tourism and fisheries recover, the stakeholders, their communities, and the socio-ecological relationships that emerge and mature will be very different than those existed before the storm. This is because the storm in many ways accelerated an underlying shift in uses and use patterns that had been occurring at least a decade preceding the hurricane; this shift includes changing

preferences in gear types in the commercial fishery, reduced participation in recreational angling, and diversification in the water operator industry.

How changes in the human dimensions will be influenced by the rate and extent of ecological recovery and the ways in which the human and ecological dimensions will affect each other's state; it is thus important that future research consider the post-Hurricane Maria stakeholders, industries, and communities as a new baseline, which can be compared in future years as per the evolving relationship between the social and biophysical systems.

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Authority: The collection of this information is authorized under the Coral Reef Conservation Act (P.L. 106-562).

Purpose: Stakeholder use information, as related to frequency and areas of use, views on area conditions, and perceptions concerning congestion are needed to determine limits of acceptable change (LAC) in Puerto Rico's Northeastern Marine Corridor (Northeast Reserves and Culebra Island), which can be used to strengthen conservation of the area's coral reef and related ecosystems.

NOAA Routine Uses: NOAA will use this information to gather information from main stakeholders in the Northeast Marine Corridor of Puerto Rico. Disclosure of this information is permitted under the Privacy Act of 1974 (5 U.S.C. Section 552a**)** to be shared among NOAA staff for work-related purposes. Disclosure of this information is also subject to all of the published routine uses as identified in the Privacy Act System of Records Notices COMMERCE/NOAA-6, Fishermen's Statistical Data and COMMERCE/NOAA-11, Contact Information for Members of the Public Requesting or Providing Information Related to NOAA's Mission.

Disclosure: Furnishing this information is voluntary; however, failure to participate in the survey will result in less information to support the conservation and management goals of the Coral Reef Conservation Program.

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Commercial fishing operator survey Survey number_____ Date_____

Name of operation_____

Name of person interviewed_____

Position of person in operation_____

Address_____
_____
_____

Tel_____

Email of operation_____

1. What is the principal port of the operation? Please identify the port/marina and city, where applicable.
   _____
2. Does the operation have a secondary port? YES NO
   a. If YES, what is the secondary port?
      _____
   b. If YES, then how many months/year does the operation use this port? _____months
   c. If YES, then which areas are targeted when using the secondary port? _____
3. How many years has the operation been in existence? _____yrs
4. How many years have you worked with this operation?_____yrs
5. How many years have you worked in this profession?_____yrs
6. Which of the following includes your age?
7. What percentage of your household income is derived from commercial fishing?_____%
8. What percentage of what you catch is consumed at home?_____%
9. Who else in your family fishes with you in your operation or vessel?_____
10. How do you pay your crew members?
    a. Shares (types of shares) _____%
    b. Fixed pay (per trip/day) $_____
11. Vessel characteristics
    a. Number of vessels_____
    b. Length of vessels _____ft _____ft
    c. Vessel hull type _____
    d. Number of engines_____ hp_____
    e. Replacement actual value of vessels $_____
    f. Replacement actual value of engines $_____
    g. Replacement actual value of electronic equipment $_____
    h. Replacement actual value of safety equipment $_____
12. Fishery equipment (number and replacement actual cost)
    a. Fish traps_____; $_____
    b. Lobster traps_____; $_____
    c. Nets_____; $_____
    d. Vertical longline (cala/fuete)_____; $_____
    e. Handlines_____; $_____
    f. Dive gear and spearguns; $_____

13. Gear maintenance (annual)
    a. Vessels and engines $_____
    b. Fishing gear $_____
    c. Other costs $_____

14. What are your main fishing gears?
    a. Gear 1_____
    b. Gear 2_____
    c. Gear 3_____

15. Please provide your best estimate for the trips to fishing areas trip costs, and catches/landings for last year (2018). Also, please refer to the following map for the zones (areas) to provide percentages of trips taken to each area per year.

Area 1 – Aguadilla to Rio Grande
Area 2 – Rio Grande to the northeast, north of Fajardo to Culebra
Area 3 – Rio Grande to the east, including all shallow platform/shelf waters east and south of Culebra
Area 4 – south of Fajardo to Maunabo, including Vieques and other points east
Area 5 – Manuabo to the west to Ponce
Area 6 – Ponce to the west to Cabo Rojo
Area 7 – Cabo Rojo to the north to Aguadilla

Commercial fishing operator survey Survey number_____ Date_____

In the table below, please identify the **total number of trips** you took in 2018. If you took trips in which you used more than one gear type, please list those separately from trips that you took using only one gear or another combination of gear types. Also, please list the top three species you caught with each gear type.

Table 1

Gear 1	**Gear 2**	**Gear 3**	**Total trips (2018)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Gear:	Gear:	Gear:								
Species: 1. 2. 3.	Species: 1. 2. 3.	Species: 1. 2. 3.								
Gear:	Gear:	Gear:								
Species: 1. 2. 3.	Species: 1. 2. 3.	Species: 1. 2. 3.								
Gear:	Gear:	Gear:								
Species: 1. 2. 3.	Species: 1. 2. 3.	Species: 1. 2. 3.								

In the table below, please list your **typical trip costs**. If you took trips in which you used more than one gear type, please list those separately from trips that you took using only one gear or another combination of gear types.

Table 2

Gear 1	**Gear 2**	**Gear 3**	**Fuel and oil**	**Ice**	**Bait**	**Food and supplies**	**Air for tanks**	**Crew**
Gear:	Gear:	Gear:						
Gear:	Gear:	Gear:						
Gear:	Gear:	Gear:						

In the table below, please list up to the **top five species** you harvested in 2018, including the total pounds for each species.

Table 3

Species	Total pounds (2018)
Species 1:	
Species 2:	
Species 3:	
Species 4:	
Species 5:	

16. How do you decide whether and where to take a fishing trip? Please rank the following factors from 1-5, where is the most important and 5 is the least important factor.

Factor	Rank (1-5)
a. Weather	_____
b. Fuel price	_____
c. Species market price	_____
d. Crowding in an area	_____
e. Preferred habitat/area	_____

17. Number of vessels in the fishing area
    a. What is the maximum number of vessels that you can tolerate around your vessel in your fishing area before you change your fishing location?

       Number of vessels _____

    b. What is the average/usual number of vessels that fish around your vessel in your fishing area?

       Number of vessels_____

18. Please rate the following in terms of how crowding affects your fishing activities, where 1 is least effect and 5 is most effect.

a. Lower catch	1	2	3	4	5
b. Lower catch rates	1	2	3	4	5
c. Use conflicts	1	2	3	4	5
d. Lack of space/hazards	1	2	3	4	5
e. Habitat damage	1	2	3	4	5

19. What is the optimal number of vessels that should operate around you in your fishing area? _____number of vessels

20. Please rate the following types of users/vessels that may affect your fishing activities, where 1 is the least impact and 5 is the most impact.

a. Recreational fishers	1	2	3	4	5
b. Commercial fishers	1	2	3	4	5
c. Recreational divers	1	2	3	4	5
d. Commercial divers	1	2	3	4	5
e. Large party boats/cats	1	2	3	4	5
f. Charter boats (6-pack)	1	2	3	4	5
g. Private vessels	1	2	3	4	5

21. Please rate the condition of the following coastal and marine resources, where 1 is excellent and 5 is poor.

a. Fish and fisheries	1	2	3	4	5
b. Lobster	1	2	3	4	5
c. Conch	1	2	3	4	5
d. Coral reefs	1	2	3	4	5
e. Sea grasses	1	2	3	4	5
f. Mangroves	1	2	3	4	5
g. Other rocky bottom	1	2	3	4	5
h. Water quality	1	2	3	4	5

22. Please rate the trends in the following coastal and marine resources compared to how these were when you first started fishing in the area, where 1` is much better and 5 is much worse.

a. Fish and fisheries	1	2	3	4	5
b. Lobster	1	2	3	4	5
c. Conch	1	2	3	4	5
d. Coral reefs	1	2	3	4	5
e. Sea grasses	1	2	3	4	5
f. Mangroves	1	2	3	4	5
g. Other rocky bottom	1	2	3	4	5
h. Water quality	1	2	3	4	5

23. Which coastal and marine resources have most declined the most in your area of use and why? What are the reasons for the decline?

    _____
    _____
    _____
    _____

24. In terms of use total, please state whether the following users/vessels should be decreased, remain the same, or be increased in the areas where you fish.

GROUP	Decrease	Same	Increase	Desired % change
Commercial fishers				
Recreational fishers				
Private boaters				
Large party boats/cats				
Charter boats				
Commercial divers				
Recreational divers				
Water taxis				

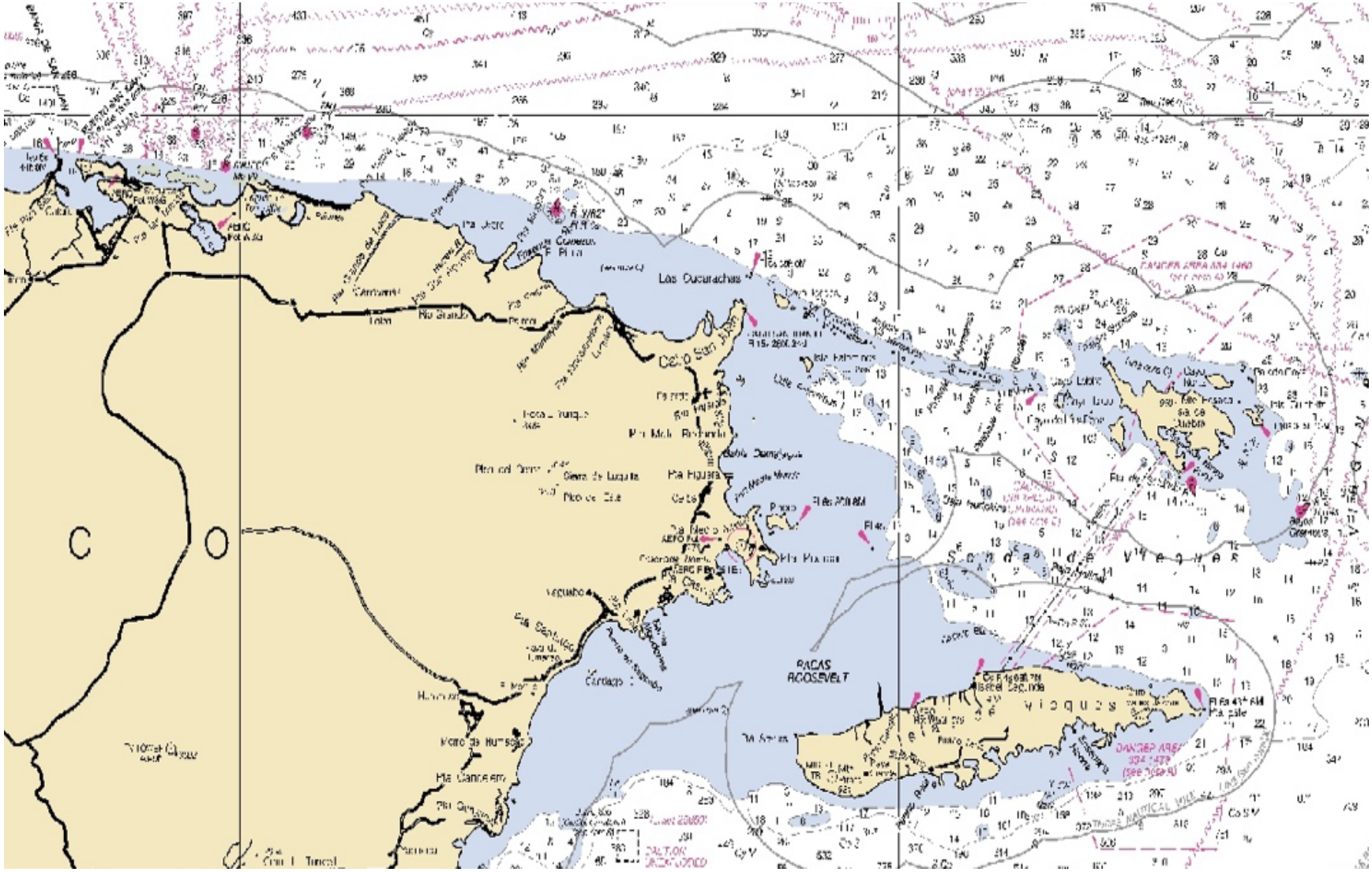
25. What coastal or marine resources would you identify as indicators that can be tracked such that if changes were to occur to these indicators, changes in management should take place?
    a. _____
    b. _____
    c. _____

26. What type of management measures would you prefer to address ongoing resource impacts or to maintain present conditions? Please rate the measures on a scale from 1-5, where is 1 is least preferred, and 5 is most preferred.

    a. No use areas 1 2 3 4 5
    b. No take areas 1 2 3 4 5
    c. Zoned areas, by use 1 2 3 4 5
    d. Education and awareness 1 2 3 4 5
    e. Enforcement 1 2 3 4 5
    f. Limits on total vessel use 1 2 3 4 5
    g. Fishing quotas 1 2 3 4 5

27. Please use the following map to identify the following:
    a. Current areas of use, by species
    b. Historical areas of use, by species
    c. Areas of high use, congestion
    d. Areas of conflict with other fishers and stakeholder groups

Commercial fishing operator survey Survey number_____ Date_____



Privacy Act Statement

Authority: The collection of this information is authorized under the Coral Reef Conservation Act (P.L. 106-562).

Purpose: Stakeholder use information, as related to frequency and areas of use, views on area conditions, and perceptions concerning congestion are needed to determine limits of acceptable change (LAC) in Puerto Rico's Northeastern Marine Corridor (Northeast Reserves and Culebra Island), which can be used to strengthen conservation of the area's coral reef and related ecosystems.

NOAA Routine Uses: NOAA will use this information to gather information from main stakeholders in the Northeast Marine Corridor of Puerto Rico. Disclosure of this information is permitted under the Privacy Act of 1974 (5 U.S.C. Section 552a**)** to be shared among NOAA staff for work-related purposes. Disclosure of this information is also subject to all of the published routine uses as identified in the Privacy Act System of Records Notices COMMERCE/NOAA-6, Fishermen's Statistical Data and COMMERCE/NOAA-11, Contact Information for Members of the Public Requesting or Providing Information Related to NOAA's Mission.

Disclosure: Furnishing this information is voluntary; however, failure to participate in the survey will result in less information to support the conservation and management goals of the Coral Reef Conservation Program.

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Public reporting burden for this collection of information is estimated to average 30 minutes/hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other suggestions for reducing this burden to CHRISTOPHER JEFFREY, NOAA NOS, 1305 East West Highway, Rm #9213, N/SCI-1, Silver Spring, MD 20910 USA.

Everything we discuss will be protected. When we complete our interviews and other work, we will write a report that summarizes everything we have learned. We will not use people's names in our reports, or write about anything that is sensitive.

Notwithstanding any other provisions of the law, no person is required to respond to, nor shall any person be subjected to a penalty for failure to comply with, a collection of information subject to the requirements of the Paperwork Reduction Act, unless that collection of information displays a currently valid OMB Control Number.

Commercial water operator survey Survey number_____ Date_____

Name of operation_____

Name of person interviewed_____

Position of person in operation_____

Address_____
_____
_____

Tel_____

Email of operation_____

Background information

1. What is the principal port of the operation? Please identify the port/marina and city, where applicable.
   _____

2. Does the operation have a secondary port? YES NO
   a. If YES, what is the secondary port?
      _____
   b. If YES, then how many months/year does the operation use this port? _____months
   c. If YES, then which areas are targeted when using the secondary port? _____

3. How many years has the operation been in existence? _____yrs

4. How many years have you worked with this operation?_____yrs

5. How many years have you worked in this profession?_____yrs

6. Which of the following includes your age?
   a. Less than 18
   b. 18-30
   c. 31-40
   d. 41-50
   e. 51-60
   f. More than 60

Trip information

7. Vessel information

Please list the information for each vessel type in the table below to identify if it is a powerboat, yacht, catamaran, or other. If you have more than one vessel, then please list the information for each vessel type under 1, 2, and 3.

Table 1

Vessel type	Length	Capacity	Divers	Snorkelers	Crew	Present value of vessel
1						
2						
3						
Kayak/SUP						
Jetski						

8. Fixed costs and annual expenses
    a. Boat slip(s)/marina fees: $_____
    b. Insurance: $_____
    c. Dive equipment (fins, masks, tanks, regulators, compressors, other): $_____
    d. Fishing equipment (rods and reels, fishing line, weights, hooks, spearguns, other): $_____

9. Trip information

In the following table, please again list the vessel types (powerboat, yacht, catamaran, other) to consider the trips taken by each vessel.

Table 2

Vessel type	Work year round (Y/N)	Trips per day	Average passengers per trip	Average divers per trip	Average snorkelers per trip
1					
2					
3					
Kayaks/SUP					
Jetski					

10. What are the approximate percentage of trips taken by number of clients/passengers in your operation?
    a. Snorkeling _____%
    b. Diving_____%
    c. Spearfishing _____%
    d. Hook and line fishing_____%
    e. Cruising_____%
    f. Kayak/SUP _____%
    g. Jetski_____%
    h. Water taxi_____%

11. Does your operation give a talk before or on the way to a trip?
    a. NO
    b. YES
        i. IF YES, then please describe what the talk entails

_____
_____

12. Please refer to the following map for the zones (areas) used by vessel type to provide percentages of trips taken to each area per year in the table below. Again, please list the vessel types (powerboat, yacht, catamaran, other) for each vessel.

Area 1 – Aguadilla to Rio Grande
Area 2 – Rio Grande to the northeast, north of Fajardo to Culebra
Area 3 – Rio Grande to the east, including all shallow platform/shelf waters east and south of Culebra
Area 4 – south of Fajardo to Maunabo, including Vieques and other points east
Area 5 – Manuabo to the west to Ponce
Area 6 – Ponce to the west to Cabo Rojo
Area 7 – Cabo Rojo to the north to Aguadilla

Commercial water operator survey

Survey number_____ Date_____

Area 1: _____% Area 2: _____%
Area 3: _____% Area 4: _____%
Area 5: _____% Area 6: _____%
Area : _____%

Table 3

Vessel type	Main activities	1	2	3	4	5	6	7
1								
2								
3								
Kayaks/SUP								
Jetski								

13. In the accompanying map, please indicate the following:
    a. Use areas including routes taken if more than one site is visited (ex., Icacos to Palomino)
    b. Areas of use by activities offered
    c. Alternate use areas, based on weather, congestion, or resource conditions
    d. Areas of high use, congestion, and conflict
    e. Areas used in the past, historically

14. In the following table, please consider the number of vessels that you encounter in the activity area. In the following table, Specifically, please address the following questions. Again, please list the vessel types (powerboat, yacht, catamaran, other) for each vessel.

    a. What is the maximum number of vessels that you can tolerate around your vessel in activity area before you change your location?
    b. What is the average/usual number of vessels that participate in recreational activities around your vessel in your activity area?
    c. What has been the change in the number of vessels in your activity area since when you first started taking trips, in terms of percentage change?
    d. What is the optimal number of vessels in your activity area?

Table 4

Vessel type	Maximum of number of vessels	Average number of vessels	Change in average number of vessels over time (%)	Optimal number of vessels
1				
2				
3				
Kayaks/SUP				
Jetski				

15. Please rate the following in terms of how each affects your willingness to visit a particular site, where 1 is the least important and 5 is the most important factor, in the table below. Please rank each factor for each type of vessel you operate. Again, please list the vessel types (powerboat, yacht, catamaran, other) for each vessel.

Table 5

Vessel type	Weather	Time to site	Site congestion	Sonic or music pollution	Site resource conditions
1					
2					
3					
Kayaks/SUP					
Jetski					

16. Please estimate the changes in the following types of users/vessels over the time when you have been operating in the region, where 1 is much less use than in the past, 3 is the same as in the past, and 5 is much more use than in the past.
    a. Recreational fishers 1 2 3 4 5
    b. Commercial fishers 1 2 3 4 5
    c. Recreational divers 1 2 3 4 5
    d. Commercial divers 1 2 3 4 5
    e. Large party boats/cats 1 2 3 4 5
    f. Charter boats (6-pack) 1 2 3 4 5
    g. Private vessels 1 2 3 4 5
    h. Others (_____) 1 2 3 4 5

17. Please rate the following types of users/vessels that may affect your activities, where 1 is the least impact and 5 is the most impact.
    a. Recreational fishers 1 2 3 4 5
    b. Commercial fishers 1 2 3 4 5
    c. Recreational divers 1 2 3 4 5
    d. Commercial divers 1 2 3 4 5
    e. Large party boats/cats 1 2 3 4 5
    f. Charter boats (6-pack) 1 2 3 4 5
    g. Private vessels 1 2 3 4 5
    h. Others (_____) 1 2 3 4 5

18. Please rate the condition of the following coastal and marine resources, where 1 is excellent and 5 is poor.
    a. Fish and fisheries 1 2 3 4 5
    b. Lobster 1 2 3 4 5
    c. Conch 1 2 3 4 5
    d. Coral reefs 1 2 3 4 5
    e. Sea grasses 1 2 3 4 5
    f. Mangroves 1 2 3 4 5
    g. Other rocky bottom 1 2 3 4 5
    h. Water quality 1 2 3 4 5

19. Please rate the trends in the following coastal and marine resources compared to how these were when you first started fishing in the area, where 1` is much better and 5 is much worse.
    a. Fish and fisheries 1 2 3 4 5
    b. Lobster 1 2 3 4 5
    c. Conch 1 2 3 4 5
    d. Coral reefs 1 2 3 4 5
    e. Sea grasses 1 2 3 4 5
    f. Mangroves 1 2 3 4 5
    g. Other rocky bottom 1 2 3 4 5
    h. Water quality 1 2 3 4 5

20. Please rate the following types of users/vessels in terms of their impacts on coastal and marine resources, where 1 is the least impact and 5 is the most impact.
    a. Recreational fishers 1 2 3 4 5
    b. Commercial fishers 1 2 3 4 5
    c. Recreational divers 1 2 3 4 5
    d. Commercial divers 1 2 3 4 5
    e. Large party boats/cats 1 2 3 4 5
    f. Charter boats (6-pack) 1 2 3 4 5
    g. Private vessels 1 2 3 4 5
    h. Others (_____) 1 2 3 4 5

21. Which coastal and marine resources have most declined the most in your area of use and why? What are the reasons for the decline?
    _____
    _____
    _____
    _____

22. In terms of use total, please state whether the following users/vessels should be decreased, remain the same, or be increased in the areas where you operate.

GROUP	Decrease	Same	Increase	Desired % change
Commercial fishers				
Recreational fishers				
Private boaters				
Large party boats/cats				
Charter boats				
Commercial divers				
Recreational divers				
Water taxis				
Kayaks/SUPs				
Jet skis				
Other _____				

23. What coastal or marine resources would you identify as indicators that can be tracked such that if changes were to occur to these indicators, changes in management should take place?
    a. _____
    b. _____
    c. _____

24. What type of management measures would you prefer to address ongoing resource impacts or to maintain present conditions? Please rate the measures on a scale from 1-5, where is 1 is least preferred, and 5 is most preferred.

    a. No use areas 1 2 3 4 5
    b. No take areas 1 2 3 4 5
    c. Zoned areas, by use 1 2 3 4 5
    d. Education and awareness 1 2 3 4 5
    e. Enforcement 1 2 3 4 5

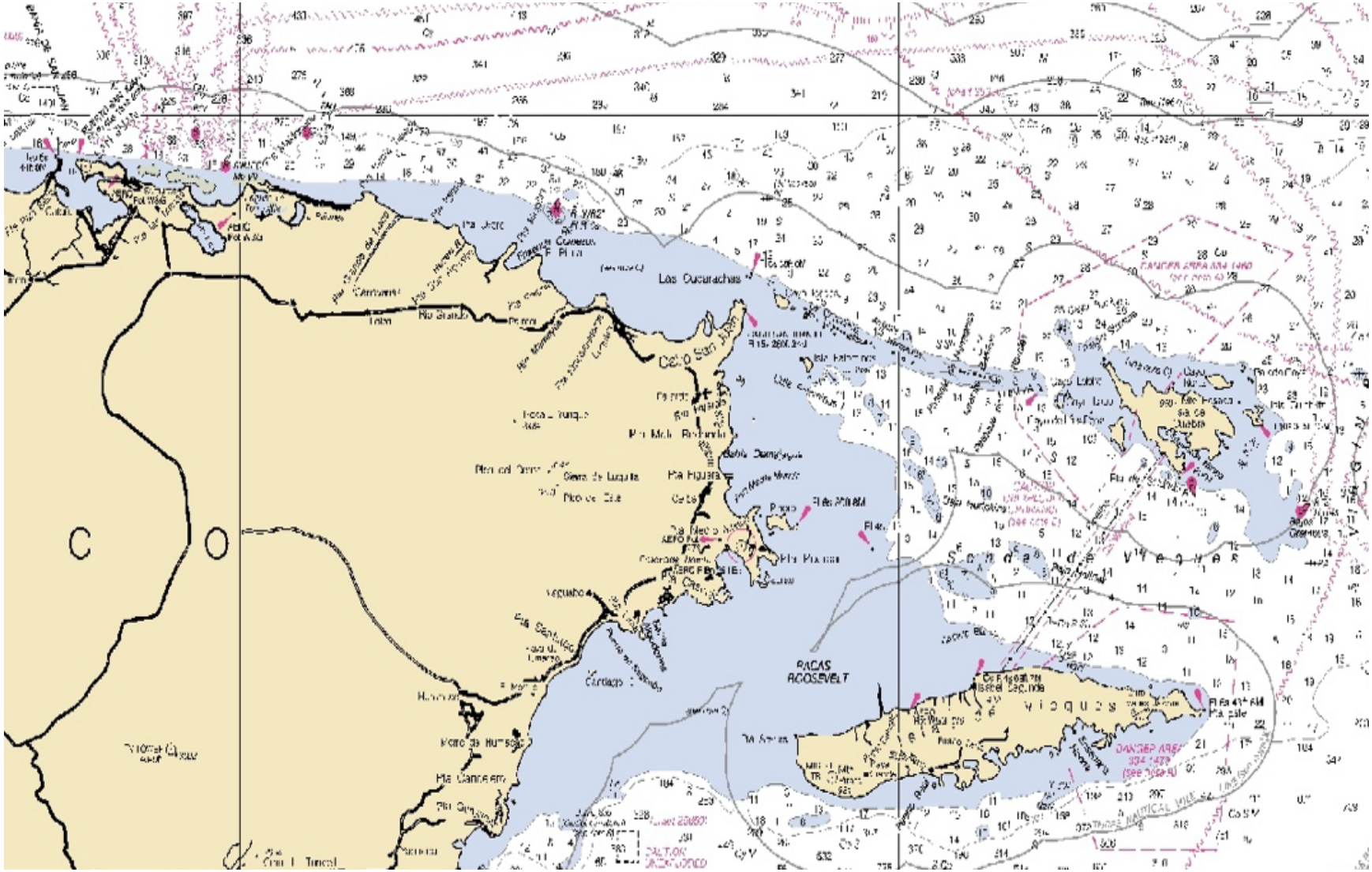
25. In the accompanying map, please identify areas that could be zoned as:
    a. No use/activity (sensitive areas with fragile and vulnerable habitats)
    b. No take (no fishing or other extractive activities)
    c. Use separation (areas where different uses are allowed)

26. Would you favor having some type of limit on the total number of users in your activity area? YES NO

27. If there were to be limits on total numbers of users, please rate your preference for the following limits options, where 1 is most preferred and 5 is least preferred.

    a. Daily limits on vessels by area 1 2 3 4 5
    b. Daily limits on visitors by area 1 2 3 4 5
    c. Mandatory operator licensing 1 2 3 4 5
    d. Mandatory mooring buoy use 1 2 3 4 5
    e. Limited entry for operators 1 2 3 4 5
    f. Rotation of areas for use 1 2 3 4 5

Commercial water operator survey Survey number_____ Date_____



Map showing NMC and environs for questions 13 and 25.

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.

Registered vessel operator survey. Survey number_____ Date_____

1. What is your home zip code? _____

2. What is your primary port from where you take out your vessel?_____

   a. Do you have secondary port? _____

3. Which of the following includes your age?

   [ ] Less than 18 [ ] 18-30 [ ] 31-40 [ ] 41-50 [ ] 51-60
   [ ] More than 60

4. For how many years have you had a vessel in Puerto Rico?

   [ ] Less than a year [ ] 1- 5 [ ] 6-10 [ ] 11-15 [ ] 16-20
   [ ] More than 20 years

5. What type of vessel do you use (primary vessel)?

   Sailboat Motorboat Catamaran Other_____

6. How long is your primary vessel? _____ feet

7. How many horsepower does your primary vessel have? _____hp

8. How many times per month do you use your vessel?

   a. Weekdays per month (0-22 days) _____
   b. Weekend days per month (between 0-8 days) _____

9. How long is a typical trip (from port to back to port)?
   _____hours

10. How many persons usually go on a typical trip (including yourself)?

    [ ] Me alone [ ] 2 [ ] 3 [ ] 4 [ ] 5 [ ] 6 [ ] 7 [ ] more than 7

11. Please refer to the following map for the zones (areas) used by vessel type to provide percentages of trips taken to each area per year.

Area 1 – Aguadilla to Rio Grande
Area 2 – Rio Grande to the northeast, north of Fajardo to Culebra
Area 3 – Rio Grande to the east, including all shallow platform/shelf waters east and south of Culebra
Area 4 – south of Fajardo to Maunabo, including Vieques and other points east
Area 5 – Manuabo to the west to Ponce
Area 6 – Ponce to the west to Cabo Rojo
Area 7 – Cabo Rojo to the north to Aguadilla

Area 1: _____% Area 2: _____%
Area 3: _____% Area 4: _____%
Area 5: _____% Area 6: _____%
Area 7: _____%

Registered vessel operator survey. Survey number_____ Date_____

12. What are the crowding/space conditions in the area where you take a majority of your trip?

    [ ] Very crowded – Little to no space for my activities
    [ ] Moderately crowded – Little space for my activities
    [ ] Normal
    [ ] Minimally crowded – lots of space for my activities
    [ ] Not crowded at all – all the space needed for my activities

13. Please estimate how often you participate in the following activities per trip.

Activity	Always, every trip	Most trips	Half of the trips	Few trips	Never
Line fishing					
Spearfishing					
Diving					
Snorkeling					
Swimming					
Waterskiing					
Cruising					
Visiting beaches					
Other _____					

14. In those activities in which you participate, how many other vessels do you see around you/next to you on a typical trip?

Activity	1-5	6-10	11-15	16-20	21-30	26-30	Mas que 30
Line fishing							
Spearfishing							
Diving							
Snorkeling							
Swimming							
Waterskiing							
Cruising							
Visiting beaches							
Other _____							

15. What is the MAXIMUM number of other vessels/users that you tolerate around you when participating in the following activities before leaving to find another location?

Activity	Number of vessels	Number of users
Line fishing		
Spearfishing		
Diving		
Snorkeling		
Swimming		
Waterskiing		
Cruising		
Visiting beaches		
Other _____		

Registered vessel operator survey. Survey number_____ Date_____

16. What is the condition of the following resources/experiences in the areas that you visit for a majority of your trips? Please rate all resources that apply.

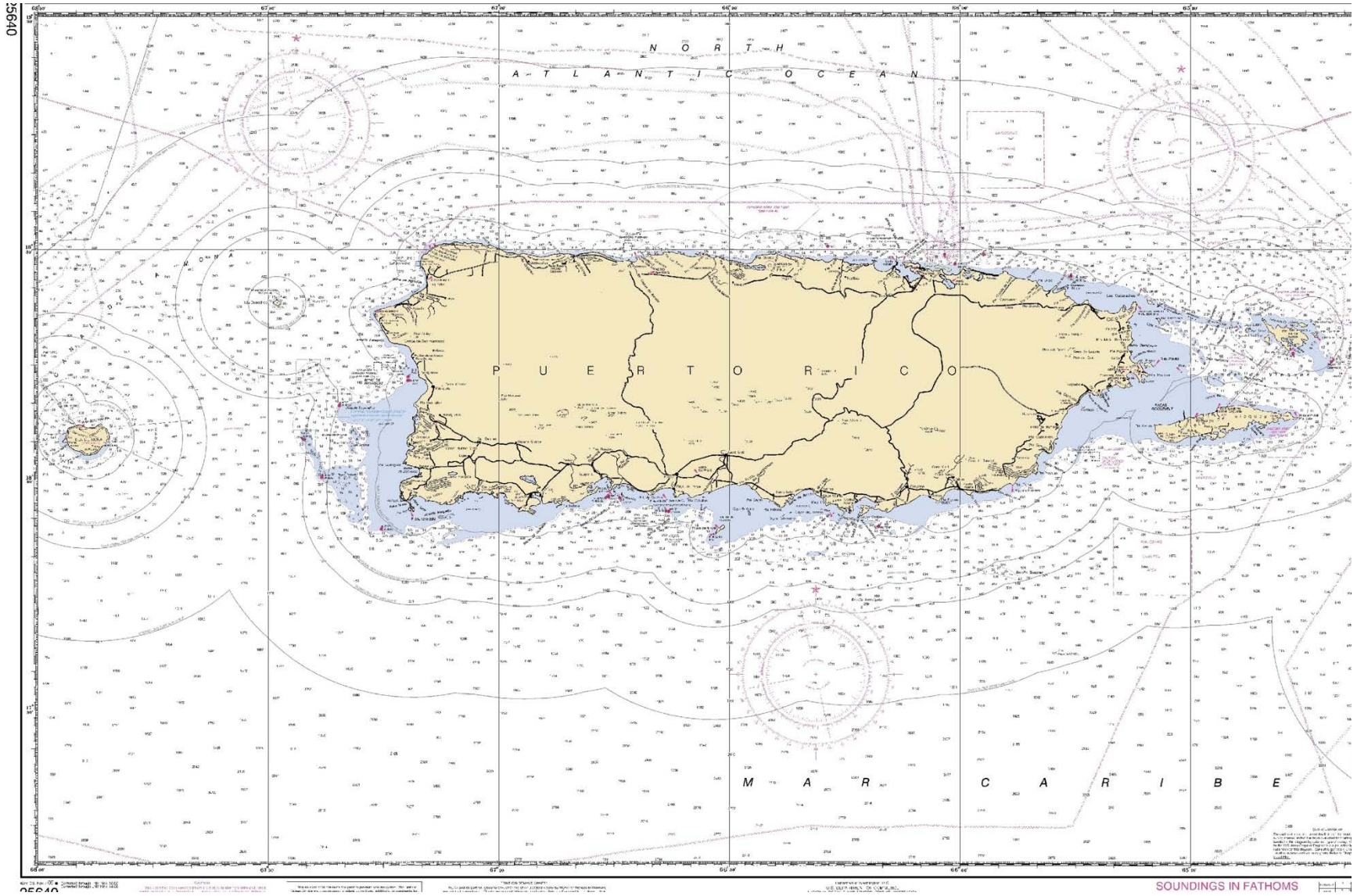
Factor	High impact	Moderate impact	Some impact	Low impact	No impact at all
Number of other vessels in the area					
Number of other users/persons in the area					
Behavior/etiquette of other vessels					
Music, sound from other vessels					
Waste/garbage from other vessels					

17. How do the following factors affect the quality of a typical trip?

Resource/experience	Excellent	Good	Fair/neutral	Poor	Very poor
Water clarity					
Marine life diversity					
Marine life size					
Marine life abundance					
Coral reef abundance and diversity					
Coral health					
Beach quality					

Registered vessel operator survey. Survey number_____ Date_____

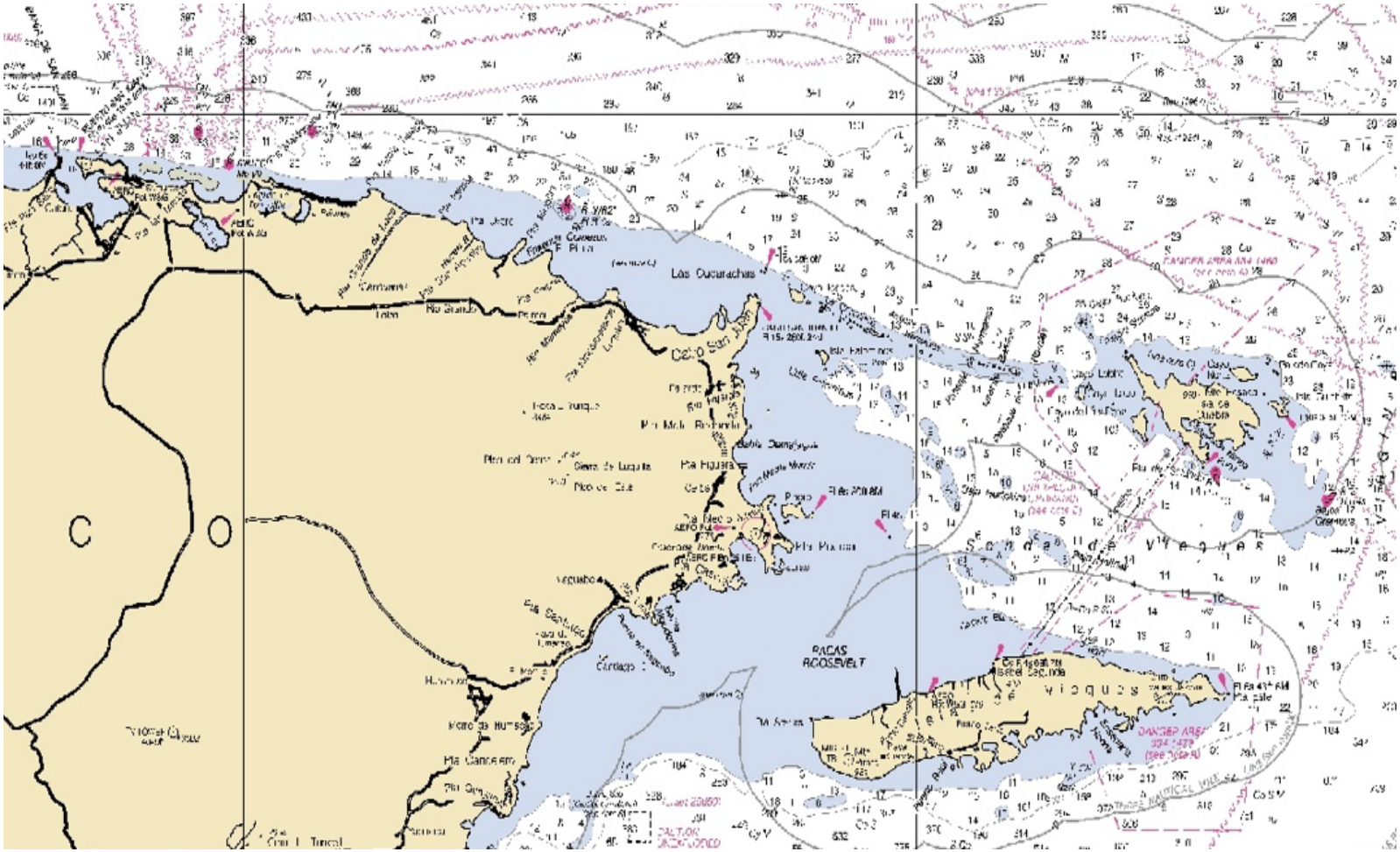
18. Using the map below, please identify the areas related to a typical trip, marking O for your primary port and X for the areas visited.



Registered vessel operator survey. Survey number_____ Date_____

19. If you use the areas shown below (northeastern Puerto Rico), please identify the areas that you use for the following activities:

Cruising Snorkeling Diving Visiting beaches Line fishing Spearfishing



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NOAA Routine Uses: NOAA will use this information to gather information from main stakeholders in the Northeast Marine Corridor of Puerto Rico. Disclosure of this information is permitted under the Privacy Act of 1974 (5 U.S.C. Section 552a**)** to be shared among NOAA staff for work-related purposes. Disclosure of this information is also subject to all of the published routine uses as identified in the Privacy Act System of Records Notices COMMERCE/NOAA-6, Fishermen's Statistical Data and COMMERCE/NOAA-11, Contact Information for Members of the Public Requesting or Providing Information Related to NOAA's Mission.

Disclosure: Furnishing this information is voluntary; however, failure to participate in the survey will result in less information to support the conservation and management goals of the Coral Reef Conservation Program.

Public reporting burden for this collection of information is estimated to average 10 minutes/hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other suggestions for reducing this burden to CHRISTOPHER JEFFREY, NOAA NOS, 1305 East West Highway, Rm #9213, N/SCI-1, Silver Spring, MD 20910 USA.

Everything we discuss will be protected. When we complete our interviews and other work, we will write a report that summarizes everything we have learned. We will not use people's names in our reports, or write about anything that is sensitive.

Notwithstanding any other provisions of the law, no person is required to respond to, nor shall any person be subjected to a penalty for failure to comply with, a collection of information subject to the requirements of the Paperwork Reduction Act, unless that collection of information displays a currently valid OMB Control Number.

Visitor survey

Date_____ Ferry time: AM PM Ferry dock: Culebra Vieques

1. What is your zip code? _____ Country?_____

2. Gender: M F

3. Which of the following includes your age group?
    a. Less than 18
    b. 18-30
    c. 31-40
    d. 41-50
    e. 51-60
    f. Over 60

4. Number of persons in your group: _____

5. Are you a day visitor or overnight visitor in this area? DAY OVERNIGHT

    - If overnight, then how many days were you in this location? _____
    - If overnight, then how many days were/will you be in Puerto Rico?_____

6. Is this your first trip to the area in Puerto Rico?
    a. Yes
    b. No
        i. If No, then when was your last trip (year)?_____
    c. I am a resident of Puerto Rico

7. Which of the locations/areas have you visited on this trip apart from this area?

    Culebra_____

    Vieques_____

    Fajardo, including Icacos, Palomino_____

    Luquillo_____

    Other areas, please list: _____

8. In which of the following activities did you participate over your trip? Mark all those that apply.

Relaxation	Beaches	Snorkeling from shore
Snorkeling from a boat	Diving from shore	Diving from a boat
Kayaking	Culture	Bio Bays
Fishing from shore	Fishing from a boat	Spearfishing
Hiking	Surfing	Cruising
Waterskiing	Jetskiing	Other

9. What was the TOP reason for your visit? Please only select one.

Relaxation	Beaches	Snorkeling from shore
Snorkeling from a boat	Diving from shore	Diving from a boat
Kayaking	Culture	Bio Bays
Fishing from shore	Fishing from a boat	Spearfishing
Hiking	Surfing	Cruising
Waterskiing	Jetskiing	Other

10. What is the number of visitors/users you would consider as being a reasonable number (in your immediate area) for the following activities?

Activity	Number of other visitors						
Visiting a beach	1-5	6-10	11-15	16-20	21-25	26-30	Over 30
Snorkeling	1-5	6-10	11-15	16-20	21-25	26-30	Over 30
Diving	1-5	6-10	11-15	16-20	21-25	26-30	Over 30
Kayaking	1-5	6-10	11-15	16-20	21-25	26-30	Over 30
Surfing	1-5	6-10	11-15	16-20	21-25	26-30	Over 30
Hiking	1-5	6-10	11-15	16-20	21-25	26-30	Over 30
Fishing	1-5	6-10	11-15	16-20	21-25	26-30	Over 30
Spearfishing	1-5	6-10	11-15	16-20	21-25	26-30	Over 30
Visiting the bio bay	1-5	6-10	11-15	16-20	21-25	26-30	Over 30

11. Top 3 beaches visited, in terms of total use
    a. Beach 1 _____
    b. Beach 2 _____
    c. Beach 3 _____

12. Please list the condition of each resource, **from 1 to 5**, where is excellent and 5 is very poor.

Location	Please list the number of visitors seen	Amenities	Cleanliness	Space	Crowding	Condition of natural resources	Lower visitor totals? (YES OR NO)
Beach 1							
Beach 2							
Beach 3							

13. Snorkeling

If you snorkel, would you consider yourself:

a. Beginner – just started and have limited ability
b. Intermediate – have snorkeled several times before and feel comfortable using gear
c. Advanced – have snorkeled many times and are very comfortable using gear

14. Please list the condition of each resource, **from 1 to 5**, where is excellent and 5 is very poor.

Location	Please list the number of snorkelers seen	Water clarity	Number of fish	Types of fish	Size of fish	Coral condition	Crowding	Lower visitor totals? (YES OR NO)
Shoreline (in NMC area)								
Luis Pena								
La Cordillera								

15. Diving

If you dive, would you consider yourself:

a. Beginner – just got certified for open water and made 1-2 dives
b. Intermediate – have dived several times but only so often each year
c. Advanced – have dived often and recently

16. Please list the condition of each resource, **from 1 to 5**, where is excellent and 5 is very poor.

Location	Please list the number of divers seen	Water clarity	Number of fish	Types of fish	Size of fish	Coral condition	Crowding	Lower visitor totals? (YES OR

								NO)
Shoreline								
Luis Pena								
La Cordillera								

17. Fishing

If you fish would you consider yourself:

d. Beginner – just go out and throw a hook in the water
e. Intermediate – know how to fish but do so on occasion
f. Advanced – avid fisher who fishes frequently and is well versed with gear and bait

18. Please list the condition of each fishing resource, **from 1 to 5**, where is excellent and 5 is very poor.

Location	Please list the number of fishers seen	Number of fish caught	Size of fish caught	Target species caught	Crowding	Lower visitor totals? (YES OR NO)
Shoreline fishing						
Fishing from a boat						
Spearfishing						

19. Please rate your views on the following resources/conditions as these apply.

Resources	Excellent condition	Good condition	Fair condition	Poor condition	Very poor condition
Beaches					
Mangroves					
Sea grasses					
Water clarity					
Plastics on the coast and in the water					
Other trash, such as bottles and cans on beaches and water					
Coral reefs					

Fishes and invertebrates					
Overall resource conditions					

20. Compared to your expectations, how would rate the number of other users/visitors you saw over your trip?
    a. Much more than I expected
    b. More than I expected
    c. About what I expected
    d. Less than I expected
    e. Much less than I expected

21. How likely are you willing to return to this area for another trip in the next 1-5 years?
    a. Very likely
    b. Likely
    c. Not likely
    d. Not likely at all

22. How would the following factors affect your expected likeliness to return for another trip?

Location	Very important	Important	Somewhat important	Not very important	Not important at all
Beach quality					
Condition of marine resources, such as corals, mangroves					
Amount of coastal pollution, such as plastics and garbage					
Crowding conditions, space					
Amount of noise, especially from music					
Cost of trip, in terms of lodging, activities					

23. Which of the factors is the single most important that would influence your willingness to return for another trip?
    a. Beach quality
    b. Marine resources conditions
    c. Coastal pollution, such as plastics, garbage, and other solid waste
    d. Crowding conditions
    e. Amount of noise
    f. Cost of trip
    g. Other_____