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# Reef fish biodiversity and occurrence of endangered sharks within a small marine protected area off Sint Maarten, Dutch Caribbean

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**Abstract** Marine protected areas (MPAs) are common conservation tools supporting the protection of threatened marine fishes, such as sharks. However, the creation of shark MPAs has been less common in the Greater Caribbean region despite a growing need and opportunity. In this study, we evaluated the occurrence of shark and reef fish biodiversity off Sint Maarten, Dutch Caribbean, with a particular emphasis on endangered shark presence within the Man of War Shoal Marine Protected Area (MPA). We utilized baited remote underwater video systems (BRUVs) to gather non-invasive data on the abundance and diversity of reef fish and shark species inside and outside the local MPA. Generalized linear models (GLMs) revealed no significant effect of protection status on the presence of the endangered Caribbean reef shark (*Carcharhinus perezi*). However, we found a significant influence of depth on shark occurrence, as well as an effect of habitat type on shark and reef fish biodiversity, with reef habitats showing the greatest significance. These results suggest that the effect of small coastal MPAs on bolstering local endangered species conservation in the Dutch Caribbean is likely to vary according to habitat features and how those species utilize those habitats across various life stages. These findings have implications for adaptive MPA management, which should be informed by the ecology and habitat preferences of target species to achieve maximum benefits for biodiversity conservation.

**Keywords** Biodiversity · Baited remote underwater video · Tropical Atlantic · Marine park · Shark

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## Introduction

Overfishing and climate change continue to impact the health and vitality of coral reef ecosystems in the Greater Caribbean (Keller et al. 2009; Clementi et al. 2021; Lawman et al. 2022). These effects are particularly evident from declines in the biodiversity of reef fishes and high trophic predators such as sharks (Dwyer et al. 2020). Compared to other subtropical

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regions, sharks in the Greater Caribbean are relatively uncommon (MacNeil et al. 2020), locally absent, or even seemingly extirpated at the national level (Ward-Paige et al. 2018). The loss of apex predators from Caribbean waters, where they were once historically abundant, has resulted in calls for expansive marine protected areas (MPAs) in the region, such that they may overlap with the relatively larger home ranges of threatened mobile species (Gallagher et al. 2020; Perera-Valderrama et al. 2020; Gallagher et al. 2021; Pacoureau et al. 2021). Given the socioeconomic and ecological implications of healthy reef biodiversity in the Caribbean and the benefits of mobile sharks in promoting nutrient flow and resilience across seascapes (Shipley et al. 2023), evaluations of the efficacy of existing marine protected areas in the region for conserving threatened species is both timely and critical.

Monitoring how mobile fishes use habitat within MPAs poses a series of logistical and operational challenges. Classic reef survey techniques, such as underwater visual census (UVC), typically use scuba divers to assess diversity and abundance. UVC relies heavily on a diver's ability to count the number of fish correctly, which can introduce errors (Harvey et al. 2004). A second limitation of UVC includes the behavioral response of mobile fish species to divers, as smaller and rarer fish species often vacate the study area upon hearing scuba equipment, thereby impacting survey accuracy and increasing species misidentification (Kulbicki 1998; Harvey et al. 2004; Watson and Harvey 2007). Baited remote underwater video systems (BRUVs) offer a non-invasive, cost-effective alternative to more traditional monitoring (Brooks et al. 2011). Despite their limitations, such as visibility constraints, BRUVs, for at least 40 years, have proven instrumental in providing a reliable measure of relative abundance for marine biodiversity (Miller 1975; Cappo et al. 2003; Colton and Swearer 2010; Brooks et al. 2011; Langlois et al. 2012; Santana-Garcon et al. 2014a). BRUVs are considered a valuable tool in measuring shark abundance and diversity (Brooks et al. 2011; Goetze and Fullwood 2013; White et al. 2013) and complement traditional survey methods, such as longlines. This is because they provide an abundance of information on additional species that cannot be surveyed due to gear selectivity (Santana-Garcon et al. 2014b).

The Dutch Caribbean comprises a network of six territories spanning two regions in the Lesser Antilles region of the Greater Caribbean, the northeastern Caribbean Sea (Sint Maarten, Sint Eustatius, Saba), and the southern Caribbean Sea (Aruba, Bonaire, Curacao). These territories have embraced MPAs as a tool for managing their marine resources, such as Bonaire, whose reefs are considered among the healthiest in the Caribbean (MacRae and De Meyer 2020). The primary goals of these protected areas include protecting biodiversity and providing societal benefits such as increased inclusivity, accountability, and transparency among stakeholders (Grorud-Colvert et al. 2021). The island of Sint Maarten established its first marine protected area in 2010, the Man of War Shoal Marine Park, featuring a reduced-wake zone and a no-take area (Nature Foundation of Sint Maarten 2022). The MPA covers a diversity of benthic habitats and was established as a potential refuge for an assortment of threatened species, including the endangered Caribbean reef shark *Carcharhinus perezi* (Poey 1876) (CITES 2022; Nature Foundation of Sint Maarten 2022). To date, however, the effectiveness of the MPA has yet to be evaluated, particularly for highly migratory sharks. Addressing this knowledge gap is critical for understanding how MPAs can be optimized for the conservation of these species.

Here, we investigate the role of a small MPA in enhancing the local biodiversity of threatened mobile species in the Dutch Caribbean and evaluate the role of benthic habitat in influencing patterns of shark and fish biodiversity. Specifically, we deployed BRUVs throughout the Man of War Shoal Marine Park in Sint Maarten to describe abundance patterns of reef fish and sharks within and outside park boundaries. We discuss our results as they relate to the role of Caribbean MPAs in supporting fish biodiversity conservation, the communities that depend on healthy reefs, and the potential scalability of these tools for conserving threatened sharks in the region.

## Materials and methods

All research efforts adhered to Dutch and Sint Maarten animal welfare laws, guidelines, and policies. The research permit was approved by Nature Foundation Sint Maarten.

## Sampling locations and BRUV deployment

From September 13, 2022, to October 14, 2022, we deployed 62 BRUVs throughout the Dutch territorial waters off Sint Maarten (18.0425° N, 63.0548° W). We randomly selected 24 sites within the boundaries of the Man of War Shoal Marine Park, on the southeast Sint Maarten coast, as well as another 38 sites outside the marine park boundaries, between the western and eastern borders of the Dutch territorial waters (Fig. 1). Weather-influenced oceanographic conditions during Caribbean hurricane season limited access to the eastern waters of Sint Maarten (Winter and de Graff 2019). Between three and six BRUVs were deployed daily. Sample sites comprised four main habitat types: sand, seagrass, algal turf, and reef substrates. Sand habitats were characterized by predominantly sandy substrates with minimal structural complexity. Seagrass habitats were regions dominated by seagrass beds. Algal turf habitats consisted of short, dense mats of algae covering rocky surfaces. Reef habitats were located within coral reef structures with high structural complexity. Depth and sea surface temperature were recorded using onboard tools, with sea surface temperature data supplemented from seatemperature.org.

Each BRUV consisted of a 48-cm-tall metal pyramid frame with sides converging on a flat, square platform, similar to Phenix et al. (2019). Units had a baited arm extending 1 m, which contained a bait

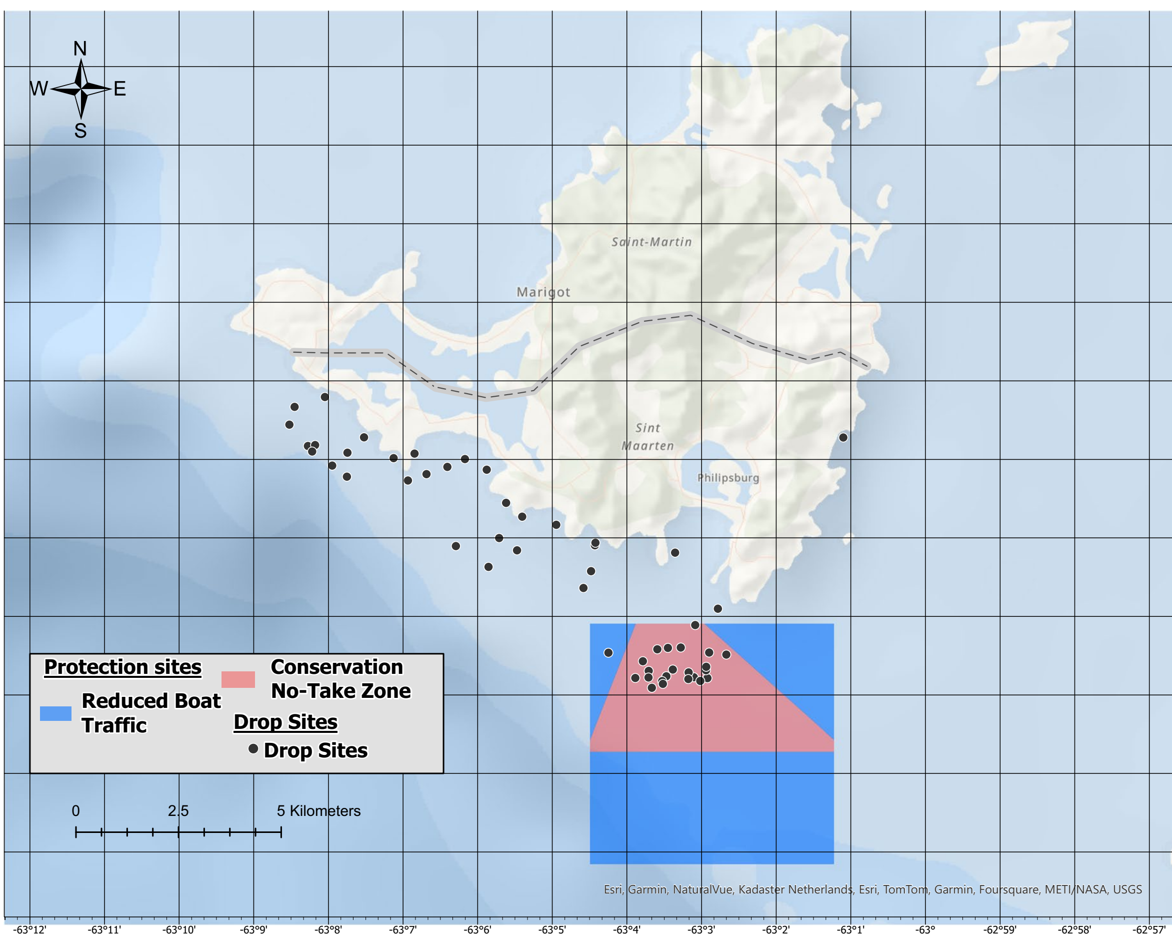


**Fig. 1** Map of Sint Maarten, with dots representing individual BRUV deployment locations. Marine park boundaries (red indicating the MPA's conservation no-take zone, and blue representing reduced boat traffic zones) are highlighted. Esri, Garmin, NaturalVue | Kadaster, Netherlands, Esri, HERE, Garmin, Foursquare, GeoTechnologies, Inc., METI/NASA, USGS

canister filled with ~500 g of Atlantic bonito (*Sarda sarda* Boch, 1793). For consistency, the same bait type was used for every BRUV deployment (Ghazilou et al. 2016; Walsh et al. 2016; MacNeil et al. 2020). High-definition cameras (GoPro Hero 7, 8, and 10) were attached in a roughly 8-in. round camera housing frame, with an estimated 160° field of view (Parton et al. 2023). Each GoPro camera (GoPro Hero 7, 8, and 10) was set to record at 1080 p at 30 frames per second for up to 90 min. BRUVs were deployed during daylight hours off an 8-m center console vessel. Each BRUV was attached to a 30-m rope and float for surface identification and simplified retrieval (Harvey et al. 2021). BRUVs were lowered by a free diver or scuba diver on reef substrate to avoid damaging coral until they were firmly situated on the seafloor. All three BRUVs were deployed at least 500 m away from each other, per the recommendations of Harvey et al. (2021). For each deployment, we logged the GPS location and habitat type.

### Video and statistical analyses

Any BRUV deployments shorter than 45 min were excluded from the analysis in addition to those displaced by strong currents of surge (Harvey et al. 2021). A total of 54 BRUV deployments were statistically analyzed—32 outside and 22 inside the MPA. Recordings from individual BRUVs were analyzed by a single observer (Wong et al. 2019), who provided continuous estimates of species Max*N* (e.g., the maximum number of individuals per species in one frame, Whitmarsh et al. 2017). To account for the high variance of Caribbean reef shark Max*N* values, we created a presence/absence variable indicating whether individuals were observed in each BRUV deployment (Shea et al. 2020).

We quantified biodiversity by integrating Max*N* values into a Shannon-Wiener diversity index ($H'$) (La Manna et al. 2021) for each BRUV deployment: $H\prime = -\sum_{i=1}^{K} pi(\log pi)$, where $pi$ represents the proportion of total individuals from the $i$th species for each BRUV deployment and $K$ represents the total number of species for each BRUV deployment. We used generalized linear models to investigate the potential effects of benthic habitat type, protection, depth, video length, and temperature on the occurrence of endangered Caribbean reef sharks (family = binomial) and biodiversity indices (family = Gaussian). Given their role as apex predators and endangered status, Caribbean reef sharks serve as a critical indicator species for evaluating the effectiveness of the MPA (Heupel et al. 2014; Graham et al. 2015). To assess the potential impacts of variable video length on biodiversity estimates, we included this as a fixed effect in our models. Model residuals were tested for normality and equal variances using the check_model() function from the *performance* package in R (v2022.07.2), and the fit was examined through visual inspection of QQ plots. We used stepwise elimination of non-significant effects to retain the most important factors influencing biodiversity using the Akaike information criteria (AIC). All statistical analyses were performed using R (v2022.07.2) (R Core Team 2021) with the RStudio interface (RStudio Team 2022). Due to the low variation in temperature (<1.5 °C), we removed temperature from the analysis. To validate that 54 BRUV deployments over a month were enough to acquire an estimate of general marine biodiversity in Sint Maarten and to ensure we conducted an effective number of deployments to estimate biodiversity, we generated species accumulation curves with the *vegan* package in R (v2022.07.2). Finally, a heatmap overlaying MPA boundaries with observed Shannon-Wiener indices from each BRUV deployment was generated using ArcGIS Online (version 9.3; Esri, Redlands, CA, USA).

## Results

A total of 54 BRUV deployments were analyzed inside and outside the marine park boundary, encompassing all habitat types (Table 1). Depths ranged from 6 to 26 m, with a mean depth of 14.2 ± 5.7 m. Elasmobranch species observed were Caribbean reef sharks (*C. perezi*) ($n$ = 21, Max*N* = 3), southern stingrays [*Hypanus americanus* (Hildebrand & Schroeder, 1928)] ($n$ = 18, Max*N* = 1), nurse sharks [*Ginglymostoma cirratum* (Bonnaterre, 1788)] ($n$ = 5, Max*N* = 1), and juvenile tiger sharks [*Galeocerdo cuvier* (Péron & Lesueur, 1822)] ($n$ = 2, Max*N* = 1) (Fig. 2). Caribbean reef sharks were observed over every recorded habitat type (Fig. 3). We observed a total of 99 fish species, with the species accumulation curve suggesting sampling newer species began to asymptote after 45 deployments (Fig. 4). The three reef fish species spotted most frequently were bar

**Table 1** Depth of the BRUV (depth), benthic habitat type (habitat type), whether the BRUV was placed inside or outside of the MPA (protection status), video length, and the Shannon-Wiener biodiversity index (biodiversity index) were included in the models. The two best models are shown. Predictor variables with significant ($p < 0.05$) effects on endangered Caribbean reef shark presence are indicated with an asterisk

| Model | Variables included in the model | AIC | ΔAIC | Significant variables |
|---|---|---|---|---|
| 1 | Depth, habitat type | 64.53 | 0 | Depth** |
| 2 | Depth, habitat type, protection status | 65.85 | 1.32 | Depth** |
| 3 | Depth, habitat type, protection status, biodiversity index | 67.49 | 2.96 | Depth** |
| 4 | Depth, habitat type, protection status, biodiversity index, video length | 69.34 | 4.81 | Depth* |

*$p < 0.05$, **$p < 0.01$

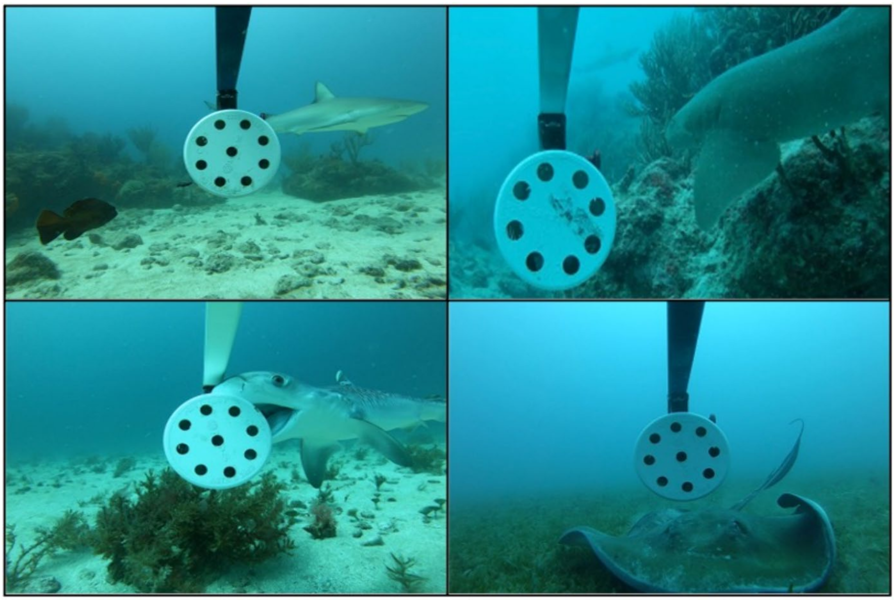

**Fig. 2** Elasmobranch sightings over different habitat types during BRUV deployments. From top left going to the right: Caribbean reef shark (*Carcharhinus perezi*), nurse shark (*Ginglymostoma cirratum*), tiger shark (*Galeocerdo cuvier*), southern sting ray (*Hypanus americanus*)

jacks [*Caranx ruber* (Bloch, 1793)] ($n$ = 34, Max$N$ = 40), barracuda [*Sphyraena barracuda* (Edwards, 1771)] ($n$ = 29, Max$N$ = 2), and yellowtail snapper [Ocyurus chrysurus (Bloch, 1791)] ($n$ = 23, Max$N$ = 8) (Tables 2 and 3).

We did not detect an effect of protection (inside versus outside the marine park) on Caribbean reef shark occurrence (Table 1) or reef fish biodiversity (Table 2). Depth significantly influenced the occurrence of Caribbean reef sharks (Table 1; family = binomial; df = 1, 51; AIC = 64.53). Specifically, depth was a significant predictor with an estimate of 0.19320 (SE = 0.06506, $z$ = 2.970, $p$ = 0.00298).

While protection did not significantly impact the Shannon-Wiener biodiversity index of reef fish species, habitat type did (Table 2; family = Gaussian; df = 3, 47; p = 0.01; AIC = 105.23), with higher biodiversity indices observed over reef habitat. Specifically, reef habitat was a significant predictor with an estimate of 0.57045 (SE = 0.22396, $t$ = 2.547, $p$ = 0.014), while sand and seagrass habitats were not significant predictors (sand—estimate = −0.06014, SE = 0.24129, $t$ = −0.249, $p$ = 0.804; seagrass—estimate = 0.06300, SE = 0.27995, t = 0.225, $p$ = 0.823). Seagrass habitats were not observed inside the MPA (Fig. 5). High biodiversity indices were observed within the bounds of the MPA relative to areas outside, with the exception of the reef system ante Mullet Bay (18.046° N,63.126° W) (Fig. 6).

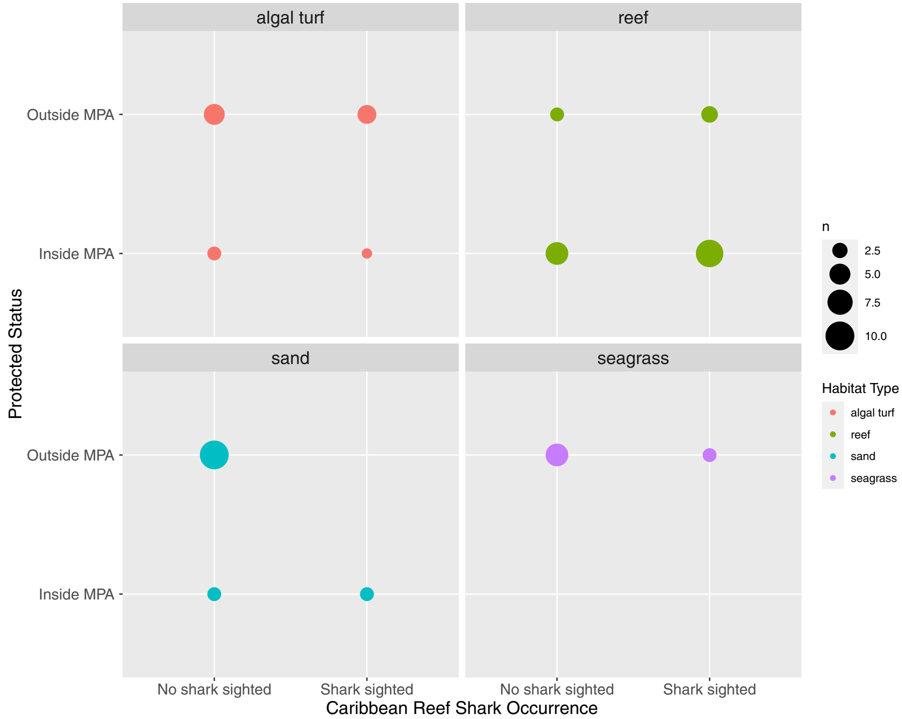


**Fig. 3** Count plot indicating the number of BRUV deployments Caribbean reef sharks were present inside and outside of the MPA by habitat type, with replication for a given category and treatment displayed by circle size

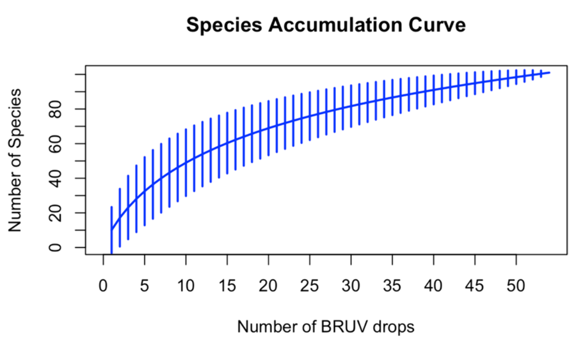


**Fig. 4** Species accumulation curve showing the number of species observed (99) over the total number of BRUV deployments (54)

## Discussion

### Shark occurrences and depth

Within the confines of the Man of War Shoal Marine Park, our observations did not indicate a significant influence of the protection offered by the MPA on the occurrence of Caribbean reef sharks. This lack of significant influence could be due to several factors, including the possibility of a lack of fisheries targeting Caribbean reef sharks in these sites outside the MPA. The absence of targeted fishing pressure in areas outside the MPA might reduce the relative difference in shark occurrence between protected and unprotected

**Table 2** Depth of the BRUV (depth), sea surface temperature of the water (temperature), benthic habitat type (habitat type), whether the BRUV was placed inside or outside of the MPA (protection status), video length, and the occurrence of an endangered Caribbean reef shark (shark occurrence) were included in the models. The 4 best models are shown. Predictor variables with significant ($p < 0.05$) effects on the Shannon-Wiener biodiversity index are indicated with an asterisk

| Model | Variables included in the model | AIC | ΔAIC | Significant variables |
|---|---|---|---|---|
| 1 | Depth, habitat type | 105.23 | 0 | Habitat type reef** |
| 2 | Depth, habitat type, protection status | 106.6 | 1.37 | Habitat type reef** |
| 3 | Depth, habitat type, protection status, video length | 107.13 | 1.9 | Habitat type reef* |
| 4 | Depth, habitat type, protection status, shark occurrence, video length | 108.72 | 3.49 | N/A |

*$p < 0.05$, **$p < 0.01$

**Table 3** Reef fish species observed in 5 or more BRUV deployments. The species name, common name, and the highest relative abundance value recorded (MaxN) are listed in order of most BRUV deployments they appeared in

| Species | Common name | MaxN |
|---|---|---|
| *Caranx ruber* | Bar jack | 40 |
| *Sphyraena barracuda* | Barracuda | 2 |
| *Ocyurus chrysurus* | Yellowtail snapper | 8 |
| *Halichoeres bivittatus* | Slippery dick wrasse | 23 |
| *Carcharhinus perezi* | Caribbean reef shark | 2 |
| *Hypanus americanus* | Southern stingray | 1 |
| *Thalassoma bifasciatum* | Bluehead wrasse | 18 |
| *Acanthurus bahianus* | Ocean surgeonfish | 6 |
| *Pseudupeneus maculatus* | Spotted goatfish | 13 |
| *Cephalopholis fulva* | Coney grouper | 8 |
| *Selar crumenophthalmus* | Big eye scad | 360 |
| *Balistes vetula* | Queen triggerfish | 6 |
| *Caranx crysos* | Blue runner | 40 |
| *Lactophrys bicaudalis* | Spotted trunkfish | 3 |
| *Scomberomorus regalis* | Cero | 70 |
| *Stegastes partitus* | Bicolor damselfish | 8 |
| *Sparisoma viride* | Stoplight parrotfish | 4 |
| *Holacanthus ciliaris* | Queen angelfish | 2 |
| *Xyrichtys martinicensis* | Rosy razorfish | 23 |
| *Chaetodon capistratus* | Foureye butterflyfish | 2 |
| *Calamus pennatula* | Pluma porgy | 4 |
| *Chaetodon striatus* | Banded butterflyfish | 2 |
| *Xyrichtys novacula* | Pearly razorfish | 11 |
| *Holocentrus adscensionis* | Squirrelfish | 3 |
| *Haemulon flavolineatum* | French grunt | 3 |
| *Trachinotus falcatus* | Permit | 3 |
| *Remora remora* | Remora | 3 |
| *Ginglymostoma cirratum* | Nurse shark | 1 |
| *Malacanthus plumieri* | Sand tile fish | 2 |
| *Halichoeres pictus* | Rainbow wrasse | 24 |
| *Lutjanus synagris* | Lane snapper | 20 |
| *Haemulon scudderii* | Grey grunt | 4 |
| *Seriola rivoliana* | Almaco jack | 2 |
| *Sphoeroides spengleri* | Bandtail puffer | 3 |

areas, thereby diminishing the apparent impact of the MPA's protection. A recent study by Gallagher et al. (2021) found that Caribbean reef sharks demonstrated higher residency and comparatively diminished habitat connectivity relative to shark species with more migratory tendencies but that environmental factors can lead to differences in their detection. Notwithstanding, Caribbean reef sharks occasionally undertake extensive movements between disparate reef systems (Baremore et al. 2021). Dwyer et al. (2020) posited that for MPAs to benefit reef sharks, they should span a minimum of 10 km and a more expansive 50 km for species with greater mobility. While the Man of War Shoal Marine Park (32 km$^2$ in size) aligns with the spatial parameters delineated by Dwyer et al. (2020), our observations of reef sharks in deeper waters off Sint Maarten (Fig. 3) suggest that their conservation may be further enhanced by extending the spatial zones of the MPA to overlap with their life history needs, as advocated by Gallagher et al. (2020). Sharks can benefit significantly from expansions of MPAs, as evidenced by the recent study in the Alcatrazes Archipelago, which observed increased shark sightings and a healthier ecosystem following the enlargement of the no-take zone and enhanced enforcement (Motta et al. 2024).

Numerous empirical studies, including those by Bond et al. (2012) and MacNeil et al. (2020), have consistently reported elevated shark densities within marine protected areas. The temporal context of our investigation might have contributed to the observed non-significance of the MPA on reef shark occurrence. Our research was undertaken during the hurricane season, during which Udyawer et al. (2013) observed that sharks in the Caribbean exhibit a proclivity for deeper aquatic strata during meteorological disturbances. Depth emerged as the most salient variable influencing the occurrence of Caribbean reef sharks in our study (Table 1) conducted in Sint Maarten. This suggests a potential transient alteration in Caribbean reef shark habitat utilization during the hurricane season or the presence of a copious habitat in Sint Maarten conducive for this endangered species. Future studies should extend sampling across seasons to encompass a broader range of behavioral patterns of Caribbean reef sharks off Sint Maarten. Given the relative longevity characteristic of reef sharks, extended time series spanning a minimum of a decade are indispensable for effective marine management, as underscored by Flowers et al. (2022).

## Influence of protection status on reef biodiversity

Habitat type emerged as a salient determinant of biodiversity (Fig. 3). The observation is supported by Cornell and Karlson (2000), who highlighted habitat fragmentation's potential implications on species richness. The support is further underscored by theories surrounding fragmented resource aggregation (Shorrocks 1990; Ives 1991). The pronounced biodiversity of reef habitats, as elucidated by Knowlton et al. (2010), was

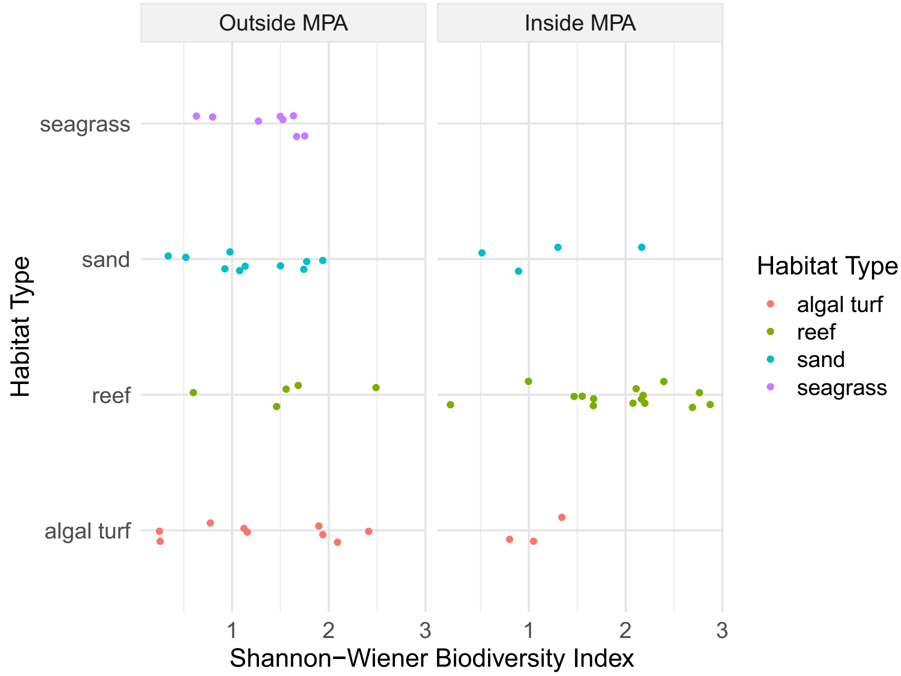


**Fig. 5** Scattered jitter plot of the Shannon-Wiener biodiversity index and observed benthic habitat type split by protection status

consistent with the data from this study (Fig. 3). This emphasizes the pressing need for conservation strategies to prioritize these habitats in Sint Maarten to foster local biodiversity. The lack of significance of protection status on reef fish biodiversity may result from the high biodiversity observed relatively far away from the MPA in the reef system to the west of Sint Maarten ante Mullet Bay (18.046° N,63.126° W) (Fig. 6). Additional research is advised to determine whether endangered species are encompassed among the varied array of species present in that location. To protect biodiversity, an essential part of establishing MPAs per Grorud-Colvert et al. (2021), the reef systems ante Mullet Bay may be important for future conservation efforts.

Reef fish species observations

We recorded 99 species of reef fish across all BRUV deployments (Fig. 4), with the most frequently observed species being *Caranx ruber*, *Sphyraena barracuda*, and *Ocyurus chrysurus* (Fig. 3). The high occurrence of these species in both protected and unprotected areas suggests that certain fish populations are thriving across different habitats. *Caranx ruber* was particularly abundant, observed in 34 BRUV deployments with a maximum number recorded (Max*N*) of 40 individuals. *S. barracuda* was noted in 29 BRUV deployments, while *O. chrysurus* appeared in 23 deployments with a Max*N* of 8 individuals (Fig. 3). These observations indicate robust populations that may benefit from the available habitats and the protections provided by the MPA. Additionally, observations of *Hypanus americanus* and *Ginglymostoma cirratum* in multiple deployments (Fig. 3) highlight the diversity and abundance of elasmobranch species in Sint Maarten.

Indicator species such as *Caranx ruber* and *Sphyraena barracuda* can be used to gauge the health of the ecosystem, per McClanahan et al. (2000). According to Pinna et al. (2023), the presence and abundance of these species often indicate good water quality and a well-structured habitat. Furthermore, large fish and apex predators such as barracudas and reef sharks are strong indicators of a healthy reef ecosystem (Heupel et al. 2014; Graham et al. 2015). Additionally, Chabanet et al. (1997) emphasize that the abundance and diversity of reef fish are closely linked to the quality of the reef substratum. Healthy populations of indicator species reflect a balanced ecosystem (Brooks et al. 2011; Grorud-Colvert et al. 2021). The high occurrence of these indicator species we found suggests that the reef fish populations around Sint Maarten are likely to be healthy and resilient, supporting the ecological integrity of the region's reefs.

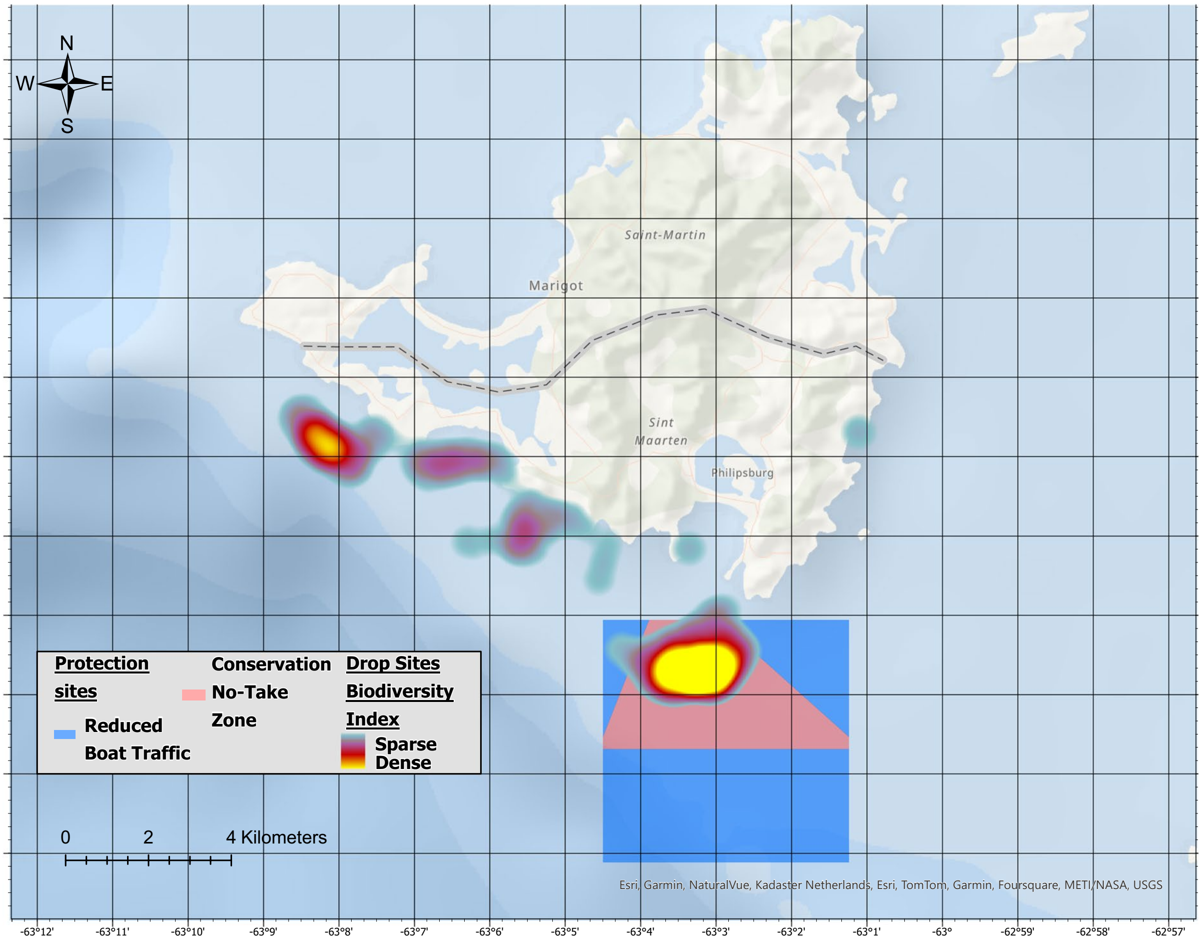


**Fig. 6** Biodiversity index (Shannon-Wiener) heatmap of Sint Maarten. Marine park boundaries (red indicating the MPA's Conservation no-take zone, and blue representing reduced boat traffic zones), provided by the Nature Foundation of Sint Maarten, were overlayed with Shannon-Wiener biodiversity indices calculated from relative abundance counts (Max*N*) of individual BRUV deployments ($n = 54$). Esri, Garmin, NaturalVue | Kadaster, Netherlands, Esri, HERE, Garmin, Foursquare, GeoTechnologies, Inc, METI/NASA, USGS

## Recommendations for future research

It was noted that the MPA does not cover seagrass habitats off Sint Maarten (Fig. 5). The ecosystem services provided by blue carbon habitats such as seagrass meadows include their ability to sequester and store large amounts of atmospheric carbon in the wider Caribbean (Gallagher et al. 2022; Lucero and Herrera-Silveira 2021); they also serve as a network hub for supporting shark biodiversity (Dixon and Gallagher 2023). Therefore, these habitats should be considered for future adaptive management of the MPA. This is especially the case as we observed young-of-year tiger sharks on BRUVs deployed in dense *Syringodium filiforme* (Kützing 1860) seagrass meadows, underscoring their potential to act as a local nursery for the species.

In conclusion, our study indicates that while the current spatial configuration of the Man of War Shoal Marine Park aligns with established guidelines for protecting site-attached reef sharks, the lack of significant impact on Caribbean reef shark occurrence highlights the need for broader protection measures that consider their varying residency patterns and environmental influences. Conservation strategies should be adaptive, prioritizing a diversity of habitats, including seagrass meadows, to address the dynamic life history needs of marine species and support the function of these critical blue carbon habitats.

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**Data availability** Data sets generated during the current study are available from the corresponding author upon reasonable request.

**Declarations**

**Competing interests** The authors declare no competing interests.



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