Diversity, Spatial Distribution, and Relative Abundance of Reef Sharks Using Stereo Baited Remote Underwater Video Around the Windward Islands of the Caribbean Netherlands

Diversidad, Distribución Espacial y Abundancia Relativa de Tiburones de Arrecife Usando Estéreo Ceban Remoto Video Submarino alrededor de las Islas de Barlovento de Los Países Bajos del Caribe

Diversité, Distribution Spatiale et l'Abondance Relative des Requins De Rédif à l'Aide de Stéréo Appatés Distant Vidéo Sous-Marine Autour des Îles du Vent des Pays-Bas des Caraïbes

MARTIN DE GRAAF[1,*], TWAN STOFFERS[1,2] ,INGRID J.M. VAN BEEK[1], WOUTER VAN LOOIJENGOED[1,2], TIEDO VAN KUIJK[1,2], and LEO A.J. NAGELKERKE[2]
[1]*Institute of Marine Resources and Ecosystem Studies (IMARES), P.O. Box 68, 1970 AB IJmuiden, The Netherlands.*
[2]*Wageningen University, Aquaculture & Fisheries Group, P.O. Box 338, 6700 AH Wageningen, The Netherlands.*
[*]*martin.degraaf@wur.nl*

EXTENDED ABSTRACT

A key ambition of the Dutch Caribbean Nature Policy Plan 2013 - 2017, is the effective implementation of shark protection. The first step towards effective protection is to conduct a base-line survey and to develop robust, quantifiable objectives and reference points for conservation (and fisheries) in order to be able to evaluate the performance of management actions. Baited Remote Underwater Video (BRUV) is a method to study species richness, relative abundance, and accurate length frequency of large mobile fish species such as sharks that are difficult to sample using traditional fish survey techniques such as underwater visual survey (UVC) using scuba. More importantly, compared to conventional longline survey, baited video surveys are a non-invasive method to study shark assemblages across broad spatial scales. The use of BRUV systems to study species richness and abundance of elasmobranchs is spreading rapidly (Bond et al. 2012, Brooks et al. 2011, White et al. 2013, Espinoza et al. 2014). During this study, we used a stereo set-up (sBRUV) to collect accurate length data of observed shark specimens. The objectives of the current study were to examine the utility of sBRUV surveys to determine reef shark abundance and distribution, and to determine the factors that define the spatial distribution of reef sharks.

The submerged Saba Bank and the islands of Saba and St. Eustatius are located in the north-eastern Caribbean and are part of the inner arc of the Lesser Antilles. The Saba Bank is a large (roughly 2200 km^2), shallow (< 50 m) submerged bank located roughly 5 km to the south-west of the island of Saba between 17°14' and 17°36' N latitude and 63°10' and 63°46' W longitude. While the edges of the Saba Bank are steep and drop off to a depth of a 1000 m, the more or less rectangular (40 x 60 km) top of the bank is remarkably flat with its long axis oriented northeast to southwest. The average depth of the Saba Bank is around 25 m with a shallower ridge along the eastern and south-eastern edges of 15 to 18 m depth while sloping gradually deeper towards the west (30 - 50 m depth). This shallower ridge corresponds to the limited coral reef area on the Saba Bank. Saba is a small island (13 km^2) located between 17°36' and 17°39' N latitude and 63°12' and 63°15' W longitude. The Saba Marine Park extends from the high tide level out to a depth of 60 m all around the island. The total surface area of the Saba Marine Park is 1300 ha (13 km^2). The Marine Park was established in 1987 and includes a marine reserves (429 ha) where no fishing or anchoring is allowed. St. Eustatius is a small island (21 km^2) located between 17°28' and 17°32' N latitude and 62°56' and 63°0' W longitude. The Statia National Marine Park extends from the high tide level out to a depth of 30 m all around the island. The total surface area of the Statia National Marine Park is 2700 ha (27.5 km^2). The Marine Park, which includes two marine reserves, the Northern Reserve (163 ha) and the Southern Reserve (364 ha), was established in 1996. In these two reserves no fishing or anchoring is allowed. Shark abundance was surveyed on the Saba Bank, Saba and St. Eustatius using three baited remote underwater stereo-video (stereo-BRUV) units. Each unit consisted of two Canon Legria HFG10 digital camcorders within waterproof housings mounted 0.7 m apart on a base bar inwardly converged at 8° to gain an optimized field of view. A synchronising diode and plastic coated wire mesh bait bag were positioned in front of the cameras. Prior to field use, the stereo-BRUV units were calibrated using SeaGIS CAL V2.01 software (www.seagis.com.au). Stereo-BRUVs were deployed during daylight hours between 10:00 and 17:00 and were retrieved after 50 - 70 minutes. A distance of 500 m was maintained between simultaneous deployments. For each deployment 0.8 - 1 kg of 'Japanese bait' (pilchards, *Sardinops sp.*) was placed in the bait bag. The stereo-BRUV deployments were conducted between March 2013 and February 2014 on the Saba Bank (n = 164), between July and December 2012 on Saba (n = 108) and between March and June 2013 on St Eustatius (n = 104). On the large Saba Bank, stereo-BRUVs were only deployed on the top of the bank between 15 - 50m depth. Sites were selected along each side and in the centre of the rectangular bank to ensure a broad geographical coverage. In the coastal waters of the smallest island, Saba, stereo-BRUVs were deployed roughly every 500 m at 15, 50 and 100 m around the island. On St. Eustatius, the survey was limited to the 30m depth boundary of the Statia National Marine Park but covered both Marine Reserves and the fishing zone on the leeward and windward side of the island. The first 45 - 60 minuntes after the stereo-BRUV settled on the bottom was analysed using Seagis EventMeasure software (www.seagis.com.au). The species and size of each shark was recorded and for each deployment an estimate of the maximum number of individuals observed per species was made based on differ-

ences in size or markings. Sharks within 8 m distance from the cameras were recorded and used in the analysis.

Six species of shark (Caribbean reef shark, nurse shark, blacktip shark, silky shark, tiger shark, and scalloped hammerhead) were observed, with nurse shark and Caribbean reef shark the most common on all three locations. Shark assemblages were structured by habitat complexity, depth and to a lesser extend management zone (Figure 1). Overall, the relative abundance (nr sharks/hr) of the Caribbean reef shark and nurse shark decreased with depth on the Saba Bank and Saba. On St. Eustatius, all sBRUV were deployed at teh same depth. On the Saba Bank, the relative abundance of Caribbean reef shark increased with habitat complexity, while this pattern was not observed for this species at Saba and St. Eustatius. No clear pattern of nurse shark abundance in relation to habitat complexity was found on the Saba Bank, Saba or St. Eustatius. Caribbean reef shark, nurse shark and tiger shark mature around 150 - 200, 230, 320 cm, respectively (Compagno 1984, Bonfil 1997 and references therein). The vast majority of recorded sharks were juveniles indicating that the shallow (< 25 m depth) coastal waters are mainly used as nursery areas. Average size of Caribbean reef shark increased with depth. On both Saba and St. Eustatius, the abundance of Caribbean reef sharks were higher inside Marine Reserve (no-fishing zone), however, the differences were not significant. Zoning had little impact on the abundance of nurse sharks on Saba. On St. Eustatius the relative abundance of nurse sharks was even significantly higher outside the Marine Reserves. The most likely cause for the decline of many elasmobranchs in the Caribbean is the combination of increased human pressure (fishing) and slow reproductive life-history characteristics (Ward-Paige et al. 2010). Overall, the shark populations of the Saba Bank, Saba and St. Eustatius appeared to be in reasonably healthy state. Nurse shark are presently the most commonly encountered shark species on reefs in the Caribbean most likely because of their limited value for reef fisheries (Ward-Paige et al. 2010). The relative abundance of nurse sharks in this study was similar to densities found by Brooks et al. (2011) in the Bahamas. However, the relative abundance of the Caribbean reef shark (*C. perezii*) was higher than reported for similar studies in the Bahamas (Brooks et al. 2011) and Belize (Bonds et al. 2012). A possible explanation for the current status of the reef shark populations in the Caribbean Netherlands is the lack of destructive industrial-scale fishery practices (directed shark fisheries, shark finning, long-lining, or gillnetting). The establishment of a formal shark sanctuary in the Caribbean Netherlands would prevent the future development of such destructive fishery practises without completely restricting the occasional landing of sharks as by-catch in the existing artisanal, small-scale fishery. sBRUV is a suitable, efficient, and non-invasive method to study shark diversity and abundance in a standardized way. Disadvantages of sBRUV compared to scientific longline surveys are lower percentage of successful determination of a shark's sex and a lower percentage of accurate species identification (Brooks et al. 2011). If funding of the DCNA special project *Save our Sharks* is approved by the Postcode Lottery similar sBRUV surveys will be conducted on the remaining island within the Dutch Caribbean (St Maarten, Bonaire, Curacao and Aruba) and reference point based on standardized sBRUV surveys will be developed to evaluate the impact of management actions such as a shark sanctuary on shark abundance and diversity. Recently, the University of Western Australia initiated a project entitled *A Global Assessment of the Abundance of Reef Sharks Relative to Fishing Pressure*, combining the majority of baited video surveys from different regions of the world.

KEY WORDS*:* Elasmobranchs, conservation, fisheries, Saba, St. Eustatius

LITERATURE CITED

Bond, M.E., E. Babcock, E.K. Pikitch, D.L. Abercrombie, and N.F. Lamb. 2012. Reef sharks exhibit site-fidelity and higher relative abundance in marine reserves on the Mesoamerican Barrier Reef. *PLoS One* **7**: e32983. doi:10.1371/journal.pone.0032983.

Bonfil, R. 1997. Status of shark resources in the Southern Gulf of Mexico and Caribbean: implications for management. *Fisheries Research* **29**:101-117.

Compagno, L.J.V. 1984. *FAO Species Catalogue, vol. 4. Sharks of the World. An Annotated and Illustrated Catalogue of Shark Species Known to Date. Part 2. Carcharhiniformes*. FAO Fish Synopsis 125. 655 pp.

Brooks, E.J., K.A. Sloman, D.W. Sims, and A.J. Danylchuk. 2011. Validating the use of baited remote underwater video surveys for assessing the diversity, distribution and abundance of sharks in the Bahamas. *Endangered Species Research* **13**:231-243.

Espinoza, M., M. Cappo, M.R. Heupel, A.J. Tobin, and C.A. Simpfendorfer. 2014. Quantifying shark distribution patterns and species-habitat associations: Implications of Marine Park zoning. *PLoS ONE* **9**(9): e106885. doi:10.1371/journal.pone.0106885.

Ward-Paige, C.A., C. Mora, H.K. Lotze, C. Pattengill-Semmens, and L. McClenachan. 2010. Large-scale absence of sharks on reefs in the Greater-Caribbean: A footprint of human pressures. *PLoS ONE* **5**(8): e11968. doi:10.1371/journal.pone.0011968.

White, J., C.A. Simpfendorfer, A.J. Tobin, and M.R. Heupel. 2013. Application of baited remote underwater video surveys to quantifying spatial distribution of elasmobranchs at an ecosystem scale. *Journal of Experimental Marine Biology and Ecology* **448**: 281-288.

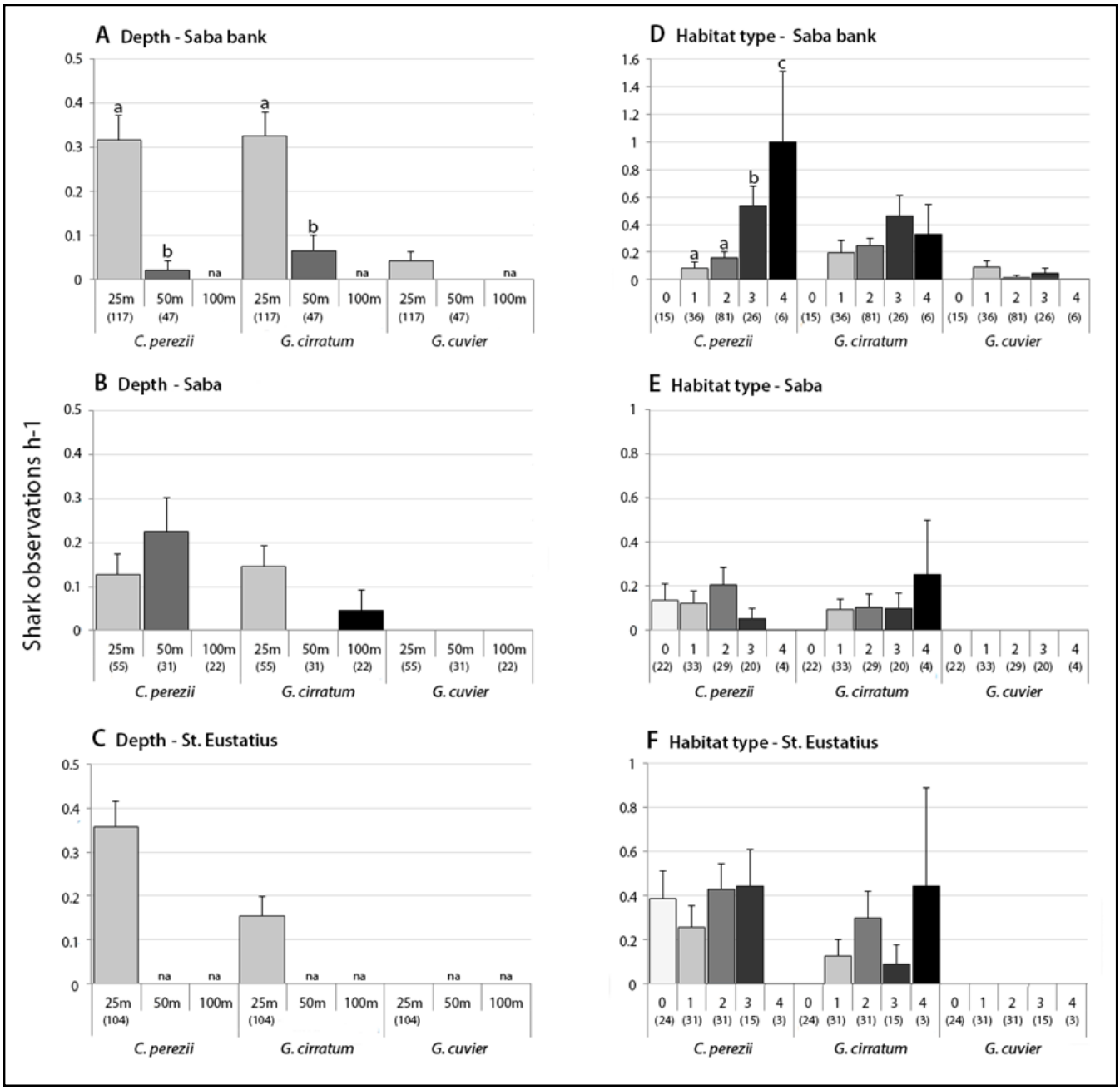

Figure 1. Effect of depth and habitat complexity on the relative abundance of Caribbean reef shark, nurse shark and tiger shark on the Saba Bank, Saba and St. Eustatius. Error bars indicate standard errors. (ANOVA with Bonferoni correction; different letters indicate signifcant difference)