Preliminary observations on behaviour and prey items of the whale shark *Rhincodon typus* in a juvenile aggregation site (Nosy Be, Madagascar)

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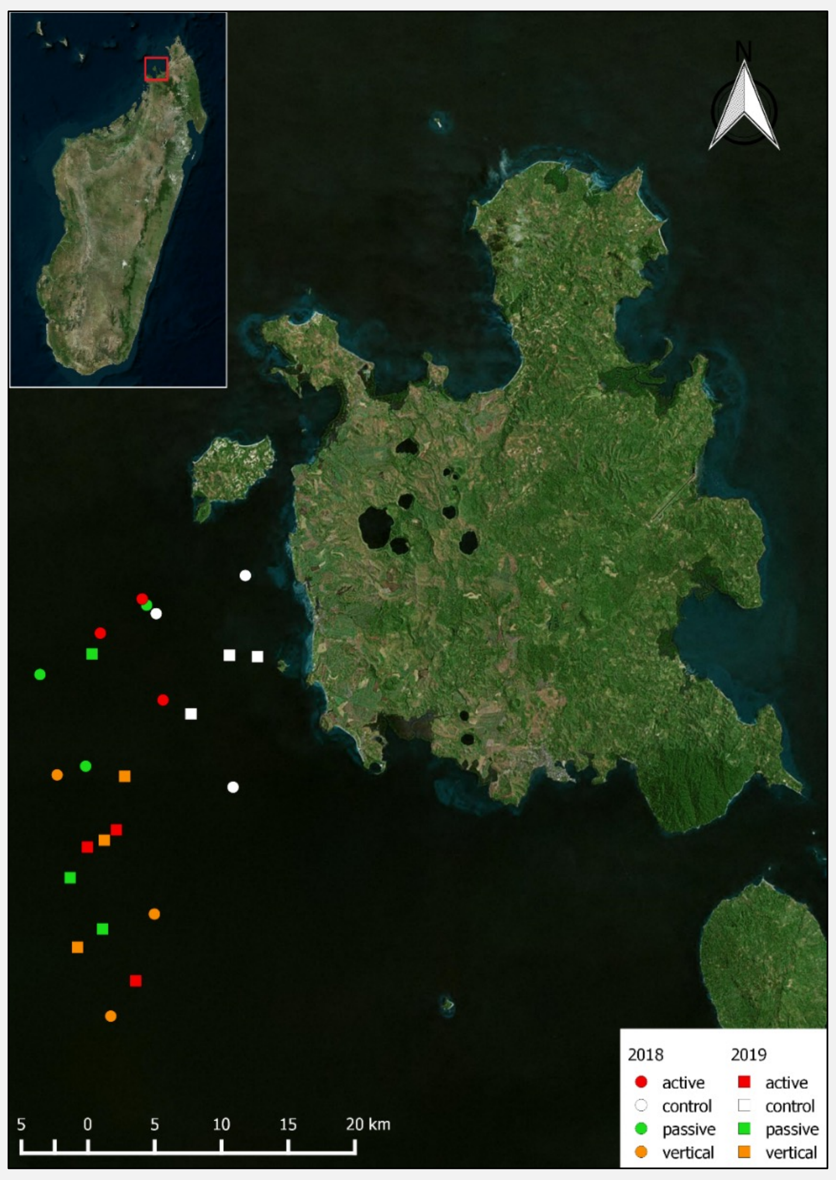
Introduction

Rhincodon typus, commonly known as whale shark, is currently listed by the IUCN in the "Endangered" category; it's believed to feed primarily on meso- and macrozooplankton and has been reported to gather seasonally at a few, well known, coastal regions where has been fuelling a growing tourism industry (Rowat & Brooks, 2012). However, legislation to regulate the interaction between tourists and the foraging sharks is lacking. Well known threats affect the survival of this species, but many aspects of its ecology are still unknown: a deeper knowledge of *R. typus* feeding ecology is required to better manage interactions at these sites and guarantee a sustainable exploitation of the species.

Materials and Methods

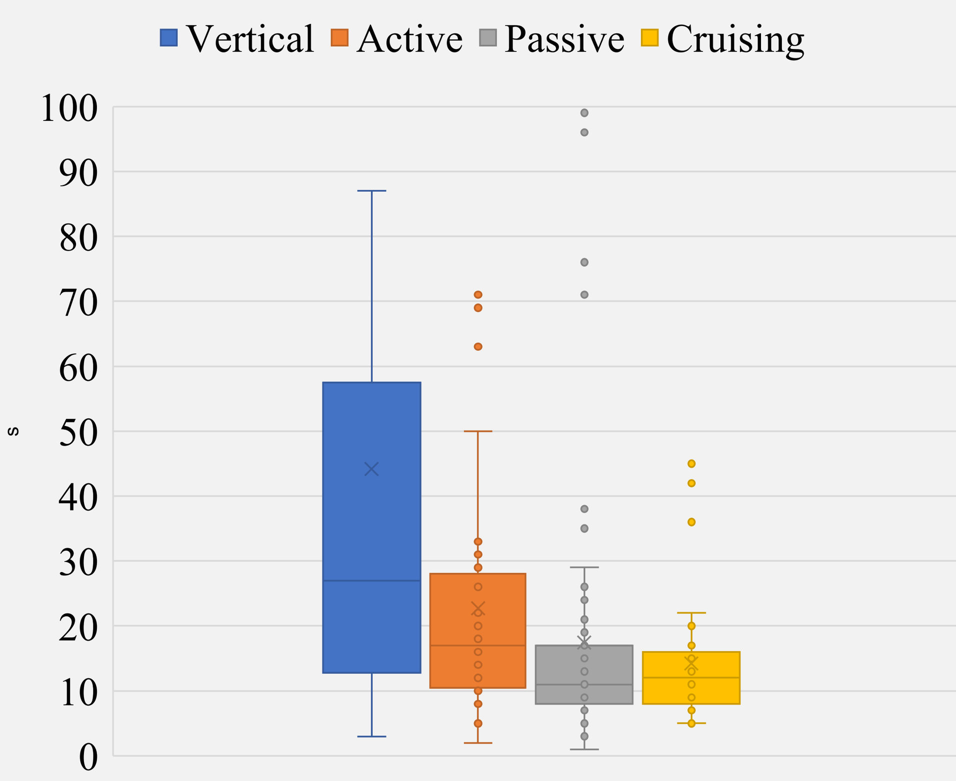
To investigate the feeding behaviour and prey item selection of *R. typus,* two scientific expeditions, coordinated by the Sharks Studies Center-Scientific Institute with the logistical support of Manta Diving, were carried out in November and December 2018 and 2019 in Nosy Be (Madagascar), where juvenile whale sharks aggregate. Each encounter was video recorded and photo-identification was performed using the program I³S *Classic* while zooplankton assemblages were sampled when sharks displayed a clear Feeding Behaviour. Feeding behaviours were categorized as Active (A), Passive (P) and Vertical (V), while non-feeding behaviour was labeled as Cruising (C) (Nelson & Eckert, 2007). In total, 32 zooplankton samples were collected during foraging activity while 13 samples were collected near the coast, in an area where sharks are never encountered. Zooplankton was collected using a plankton net (50 cm mouth-diameter, 200 µm mesh net size), from 10 m depth to the surface. Samples were immediately concentrated with a 50 µm mesh net filter and fixed in 100 ml Lugol (1% v:v) (Carlo Erba, Milan, Italy).



Results

In total, 69 different individuals were photo-identified: the majority (>90%) was males and the estimated length was, on average, around 4 m. The four behavioural modules were recorded 195 times in total: 93 P, 35 C, 34 V, and 33 A; in 41 instances more than one behaviour was displayed consecutively by the same shark and on average the behaviour displayed for more consecutive seconds at a time was V (44.15 ± 63.71 s), followed by A (22.70 ± 17.59 s), P (17.43 ± 22.26 s), and C (14.20 ± 9.53 s). Totally, 14 mesozooplanktonic phyla were identified, with the overwhelming majority being ≤ 2mm. Overall abundance was on average 555.46 ± 37.58 individuals/m³ (mean ± standard error S.E.), while total dry biomass was to 2.63 ± 0.28 mg/m³, and wet biomass 41.67 ± 3.66 mg/m³. The total number of individuals per m³ was significantly lower (26%) in 2019 and comparing data in the two sampling areas, Foraging and Control, no significant difference was evidenced in mesozooplankton composition, while both wet and dry weight biomass were higher in the Control area where the contribution to total of biomass from organisms >2mm was also higher. Among behaviours, both the abundance and biomass were slightly higher for A (closely followed by V) and lower for P; however the number of Copepoda was higher in V.

Duration of each behavioural module **(a)**

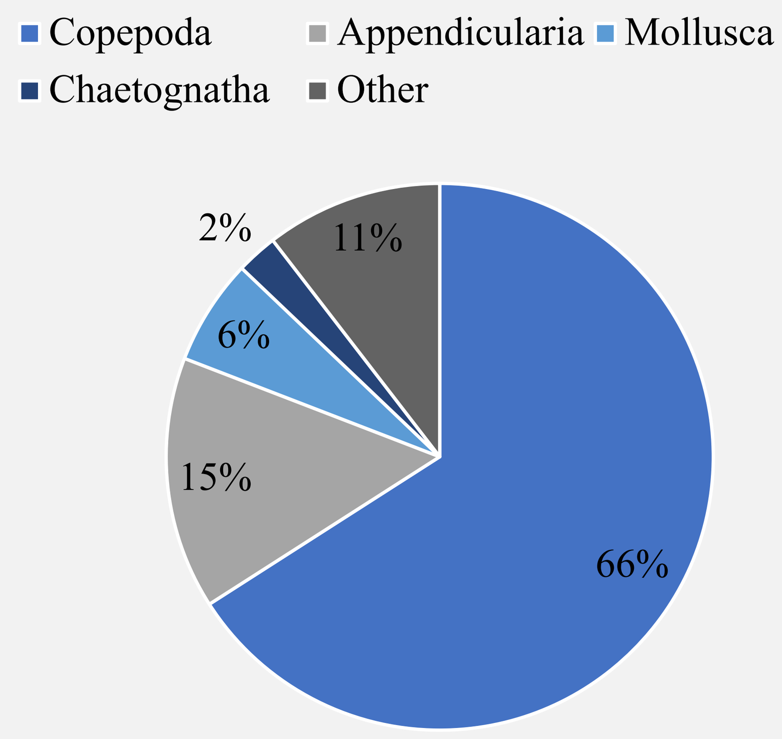


Discussions

Data from this study suggest for the seasonal aggregation of Nosy Be a composition of mainly young males of around 4 m in length on average and the recording of a few re-sightings indicates some degree of site fidelity, both during the season and across different years. This is in accordance with the findings of Diamant et al. (2021), while the encounter rate per day of survey was 4 times higher, which is to be expected as our survey was conducted only during the peak of the season. Passive was the most employed behaviour despite the Vertical being singularly displayed for longer periods of times. Duration of single modules lasted for more than 300 s on some occasion but, overall, the values were quite low (22.40 ± 0.17s).

Zooplankton samples were dominated by holoplanktonic taxa, particularly calanoid copepods and Appendicularia, with a small contribution from meroplanktonic ones. Biomass per cubic meter values were unexpectedly low in Nosy Be, reflecting the low numbers of individuals per cubic meter and the considerably larger component of animals smaller than 2 mm in length. If we were to apply the estimation of filtered volumes of water proposed by Motta et al. (2010) considering the biomass values measured in this study, a shark in Nosy Be could only reach one hundredth of the food ingested by the sharks of similar size encountered by Motta et al. (2010) at Cabo Catoche, Mexico. Biomass values seem incompatible with the metabolic needs of a whale shark estimated in previous works (Motta et al., 2010), indicating other contributing items in the diet of the sharks of Nosy Be. Accordingly, the comparison between zooplankton collected in Feeding and Control areas in Nosy Be showed no significant difference in abundance and composition while the slightly higher biomass in Control samples could be due to the bigger dimension of these organisms. The lack of significant differences between mesozooplankton collected in Control and Feeding areas and among the Feeding behaviours, indicates that the assemblages sampled in this study may not be the main discriminatory variable in whale shark occurrence, which also implies the presence of other food sources that could be in the form of different food items, such as small fish, or zooplankton hunted at different times or depths from those of this study.

Mean composition of samples **(a)**



References

-Diamant, S., Pierce, S.J., Rohner, C.A., Graham, R.T., Guillemain d'Echon, A., Guillemain d'Echon, T. et al. (2021). Population structure, residency, and abundance of whale sharks in the coastal waters off Nosy Be, north-western Madagascar. Aquatic Conservation: Marine and Freshwater Ecosystems, 31(12), 3492– 3506. https://doi.org/10.1002/aqc.3743

-Motta, P. J., Maslanka, M., Hueter, R. E., Davis, R. L., Parra, R. d. l., Mulvany, S. L., Habegger, M. L., Strothere, J. A., Mara, K. R., Gardiner, J. M., Tyminski, J. P. & Zeigler, L. D. (2010). Feeding anatomy, filter-feeding rate, and diet of whale sharks *Rhincodon typus* during surface ram-filter feeding off the Yucatan Peninsula, Mexico. Zoology, 113, 199–212. doi:10.1016/j.zool.2009.12.001

-Nelson, J.D., Eckert, S.A. (2007). Foraging ecology of whale sharks (*Rhincodon typus*) within Bahia de Los Angeles, Baja California Norte. Mexico. Fish. Res, 84, 47–64.

-Rowat, D., Brooks, K.S. (2012). A review of the biology, fisheries and conservation of the whale shark *Rhincodon typus* [published correction appears in J Fish Biol. 2013 May;82(5):1769]. J Fish Biol., 80(5),1019-1056. doi:10.1111/j.1095-8649.2012.03252.x