Mapping Principe's fish biodiversity using Baited Remote Underwater Video

A. INTRODUCTION

Baited Remote Underwater Video (BRUV) is a non-invasive technique for studying fish fauna (for example, their presence, relative abundance and behaviour), consisting on attracting fish species towards an underwater camera using a bait (Kelaher *et al.*, 2014). In addition, BRUV systems can also be used for estimation of biomass (using stereo-BRUVs) or used in different environments (both demersal and pelagic, Whitmarsh *et al.* 2017).

When compared to other methods, benefits include being a non-invasive technique (for example, scientific fishing requires harvesting) and fieldwork and data collection that does not require intensive training or previous fish identification skills (for example, underwater visual census require experienced SCUBA divers and accurate identification of fish species underwater) (Brooks *et al.*, 2011). In addition, it creates a permanent record of the sampling and the video material from BRUVs can be used for training students, technicians and researchers on fish identification, as well as being useful for outreach and environmental awareness activities.

The method was used to understand differences in fish composition associated to the different habitats, and to create baseline information on Principe's marine environment for selected key species.

B. METHODS

B.1. Data collection

Five BRUV devices were used for this study. Each device consists on a weighed PVC frame holding a front-facing camera 35 cm over the sea floor, with a bait cage located 120 cm in front of the camera. For each deployment, 600 g of chopped "Fulu fulu" (*Euthynnus alletteratus*) were used, a small species of tuna caught in high numbers by Principe's artisanal fishers during the whole year. Fish was kept frozen in a cooling box until taken to the sea, and only unfrozen immediately deploying the camera. Each BRUV device was deployed for 90 minutes at each sampling point (due to battery life restrictions), tied to a buoy in the surface with a long rope marking the position of the camera. An 8-10 kg weight was tied to the middle of the rope, separated 10 metres to the camera, to prevent waves or very strong surface currents from moving the device.

The study was limited to a maximum depth of 28 metres, due to low visibility below that. The area between 2 and 25-metre deep around the island was divided in six sectors (NE, E, SE, SW, W and NW) of equal size. Ten sampling points were randomly allocated in each of them, setting a minimum distance between them of 400 metres, totalling 60 sampling points (10 per sector) (Hill *et al.*, 2014).

This sampling was conducted twice: one period in July-August 2018 and another one in December 2018-January 2019. For July and August 2018, only five points were sampled per day, deploying 5 BRUV devices simultaneously from 9AM to 11AM. For December 2018 and January 2019, 15 sampling points were deployed per sampling day due to time constrains, deploying 5 BRUV devices in the morning (around 09:00), noon (around 12:00) and afternoon (around 15:00).

B.2. Video analysis

BRUV videos were analysed by three observers, one of them being the lead researcher. All observers were trained for at least 20 hours using previously collected video material from Principe (previous scoping study, September 2017). Comparability of the video analysis will be assessed by June 2019 by the lead researcher, analysing 15 videos analysed by the other two observers and comparing the results. Maximum number of individuals of each species per frame (MaxN) were recorded (Whitmarsh *et al.* 2017), identifying species to the lowest taxonomical level possible. All species were recorded, including sea turtles and invertebrates such as octopuses and other molluscs, crabs and polichaetes, although only finfish was considered for statistical analysis. For each species, MaxN was recorded, alongside the time in the video. The species was only registered again in a new entry if the number of individuals was higher than in the last data entry. Time and position of the species not identified was recorded and will be re-analysed using input of experts. To date, 78 of the videos have been analysed, remaining 32 to be analysed. Twelve videos were lost due to failure of the hard-drives and back-ups.

B.3. Data analysis

Habitat was classified after Abreu et al (2016), distinguishing between three main habitats: *rocky reefs*, *sandy grounds* and *maerl beds* (see Figure 3). Species recorded in the videos were classified by family, trophic group and maximum size of the species (*small*, <30 cm; *medium*, between 30 and 90 cm; and *large*, over 90 cm; average maximum species size 45 cm) using information from FishBase.org. Catch Per Unit Effort (CPUE) was defined as MaxN per hour. Occurrence was defined as presence of a species or functional group per sampling site. MaxN of the small-sized, schooling species *Prionurus biafraensis* and *Paranthias furcifer*, was divided by 10 to make it comparable to other less numerous species (1 school unit = 10 fish).

ANOVA was used to detect differences in CPUE between habitat types. As the video analysis has not concluded yet and the six sectors (NE, E, SE, SW, W, NW) were not equally represented in the videos analysed to date, differences between sector have not been analysed yet and results will be provided by the end of June 2016. In addition, once the video analysis is complete, extra analysis will be done to detect potential differences in the fish species depending at the different deployment times.

C. RESULTS

To date, 78 videos (112 hours) have been analysed, resulting in the identification of 92 different species (Table 1); we were not able to assign 12.5% of the data entries to any taxa for now. The most common family in terms of occurrence (number of species per sampling site) was Carangidae (pelagic; jacks and pompanos), comprising 16% of all the observed species, with a total CPUE of 3.16 fish per hour. CPUE of carangids did not show significant differences between habitats ($p>0.1$).

Snappers were most common in rocky habitats, showing significantly higher CPUE and occurrence than sandy and maerl habitats ($p<0.001$). However, they were also occasionally found in sandy and maerl habitats and strongly interacting with the bait cage (Figure 3).

CPUE for elasmobranchs was 0.04 sharks per hour and 0.06 rays per hour. Three different species of sharks were identified: nurse shark (*Ginglymostoma cirratum*), lemon shark (*Negaprion brevirostris*) and an unidentified hammerhead shark. Two different species of rays were identified, both belonging to Myliobatiformes: *Taeniura grabata* and *Daysatis pastinaca*. All sharks recorded were found in December/January and 3 out of 4 of them from 15:00 onwards.

CPUE was largely dominated by predatory fish for all the habitat types (Figure 2). Herbivore fish are almost absent from sandy grounds and maerl beds, with small, medium and large tertiary consumers comprising 57% of the total MaxN in maerl and 61% in sand. CPUE of rocky habitats is significatively higher than sandy grounds and maerl beds, for all the trophic and size categories ($p<0.001$). Total MaxN for rocky habitats is comprised by medium and small herbivores (10%); by small, shoal-forming, medium and large secondary consumers (50%) and small, medium and large tertiary consumers (40%).

Figure 1: CPUE by habitat of lutjanid snappers and carangids.

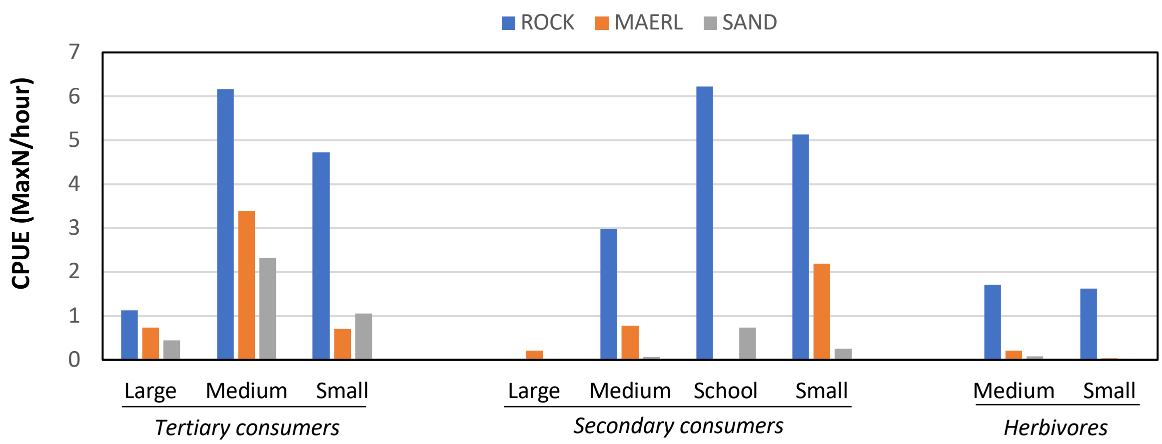

Figure 2: CPUE of the different trophic groups of finfish registered in the BRUVs: Large (max length =<90cm); Medium (max length between 30 and 89 cm); Small (max length <30cm); School (schooling species *Prionurus biafraensis* and *Paranthias furcifer*, below 30cm). For all the categories, CPUE was expressed in MaxN per hour, except for "School" (the unit for schooling species was considered to be 10 fish, so as to reduce the contrast).

Figure 3: Three main habitat types. **A)** Rocky reef, with corals (marked with an arrow); **B)** Sandy ground, with a Brown African Snapper (*Lutjanus dentatus*) attacking the bait cage; **C)** Maerl bed with a nurse shark (*Ginglymostoma cirratum*) approaching the BRUV device.

D. DISCUSSION

The results obtained for carangids suggest that carangids are highly motile species without a preferential habitat. This means that any spatial management measure -such as no-take zones-designed to protect these species would probably not have a strong positive impact on its populations, given that the geographical range of these species would probably surpass the boundaries of the managed areas. However, the ubiquity of these species and especially *Caranx crysos* and *Carangoides bartholomaei* makes these two species a robust indicator species to detect long-term changes in the fishery using BRUVs.

The significantly higher presence and MaxN of snappers in rocky habitats indicate that snappers are probably found in these grounds for most of the time. However, the presence of snappers in sandy grounds and maerl beds, and especially the fact that some snappers attacked the bait cage, indicates that snappers might leave the rocky reefs and go to sandy habitats to hunt. This means that management or protection of rocky habitats is a priority in order to protect snappers, but it would also be necessary to create a buffer zone around the rocky reefs, in order to protect them when they adventure out to hunt. To estimate the appropriate size of the buffer zone, information from published studies should be collected to estimate the geographical range for these species or close relatives.

CPUE of elasmobranchs was markedly lower when compared to other parts of the world (Jabado *et al.*, 2018), and this value could be amongst the lowest CPUE recorded in the world. Given that sharks are more active at dawn, this low abundance of sharks might be related to the sampling strategy, and the fact that 3 out of 4 of the sharks recorded were found from 15:00 onward might be a consequence of this. The strong dominance of predators over herbivorous fish does not necessarily reflects the actual trophic structure of the system, but it might be due to the lack of other taxa different than finfish and the fact that herbivorous fish might not be attracted to the bait at all.

Future improvements of the study include increasing sampling the same points in the morning (09:00) and in the evening (15:00), to account for potential differences in fish behaviour at different times of the day.

E. SPECIES LIST

Table 1: Preliminary species list based on XX videos analysed so far. Information on family, trophic level, trophic group and size (*Large*, max length =<90cm; *Medium*, max length between 30 and 89 cm; *Small*: max length <30cm) from FishBase.org

species	**Occurrences (nº points)**	**Family**	**Trophic level**	**Size**	**Trophic group**
Abudefduf hoefleri	3	Pomacentridae (damselfishes)	2.7	Small	Herbivores
Abudefduf saxatilis	2	Pomacentridae (damselfishes)	2.7	Small	Herbivores
Abudefduf taurus	1	Pomacentridae (damselfishes)	2.1	Small	Herbivores
Acanthocybium solandri	1	Scombridae (wahoo)	4.3	Large	Tertiary consumers
Acanthostracion guineensis	2	Ostraciidae (cowfishes)	2.4	Medium	Herbivores
Acanthostracion notacanthus	3	Ostraciidae (cowfishes)	2.4	Medium	Herbivores

Acanthurus monroviae	15	Acanthuridae (doctorfishes)	2.5	Small	Herbivores
Aluterus scriptus	6	Monacanthidae (filefishes)	2.91	Large	Herbivores
Aulostomus strigosus	1	Syngnathiformes (trumpetfishes)	4.2	Medium	Tertiary consumers
Balistes carolinensis	7	Balistidae (triggerfishes)	4.1	Medium	Tertiary consumers
Balistes punctatus	7	Balistidae (triggerfishes)	3.4	Medium	Secondary consumers
Bodianus pulcellus	3	Labridae (wrasses)	3.6	Small	Secondary consumers
Bodianus speciosus	13	Labridae (wrasses)	3.6	Medium	Secondary consumers
Bothus guibei	16	Pleuronectiformes (flatfishes)	3.7	Small	Secondary consumers
Cantherhines pullus	10	Monacanthidae (filefishes)	2.6	Small	Herbivores
Canthidermes sufflamen	1	Balistidae (triggerfishes)	3.5	Medium	Secondary consumers
Canthigaster supramacula	7	Tetraodontidae (puffers)	3	Small	Secondary consumers
Carangoides bartholomaei	36	Carangidae (jacks and pompanos)	4.5	Medium	Tertiary consumers
Caranx crysos	37	Carangidae (jacks and pompanos)	4.1	Medium	Tertiary consumers
Caranx hippos	2	Carangidae (jacks and pompanos)	4.1	Medium	Tertiary consumers
Caranx latus	1	Carangidae (jacks and pompanos)	4.2	Medium	Tertiary consumers
Caranx lugubris	2	Carangidae (jacks and pompanos)	4.5	Large	Tertiary consumers
Cephalopholis nigri	11	Serranidae, epinephelinae (groupers)	4.1	Small	Tertiary consumers
Cephalopholis taeniops	9	Serranidae, epinephelinae (groupers)	4.1	Small	Tertiary consumers
Chaetodon hoefleri	1	Chaetodontidae (butterflyfishes)	3.5	Small	Secondary consumers
Chaetodon robustus	1	Chaetodontidae (butterflyfishes)	3.3	Small	Secondary consumers
Chilomycterus reticulatus	1	Diodontidae (porcupinefishes)	3.5	Medium	Secondary consumers
Cirrhitus atlanticus	6	Cirrhitidae (hawkfishes)	3.6	Small	Secondary consumers
Clepticus africanus	2	Labridae (wrasses)	3.5	Small	Secondary consumers
Coris atlantica	13	Labridae (wrasses)	3.5	Small	Secondary consumers
Dactylopterus volitans	15	Dactylopteridae (flying gurnard)	3.65	Medium	Secondary consumers
Dasyatis pastinaca	3	Myliobatiformes (stingrays)	4.1	Rays	Tertiary consumers

Decapterus punctatus	1	Carangidae (jacks and pompanos)	4.4	Small	Tertiary consumers
Diodon sp	3	Diodontidae (porcupinefishes)	3.9	Medium	Secondary consumers
Echeneis naucrates	3	Echenidae (remoras)	3.7	Medium	Secondary consumers
Elagatis bipinnulata	7	Carangidae (jacks and pompanos)	4.27	Large	Tertiary consumers
Enchelycore nigricans	11	Anguiliformes (eels and morays)	4.5	Medium	Tertiary consumers
Epinephelinae	1	Serranidae, epinephelinae (groupers)	4.1	Medium	Tertiary consumers
Epinephelus adscensionis	3	Serranidae, epinephelinae (groupers)	4.1	Medium	Tertiary consumers
Epinephelus aeneus	1	Serranidae, epinephelinae (groupers)	4.02	Large	Tertiary consumers
Fistularia tabacaria	1	Syngnathiformes (trumpetfishes)	3.7	Medium	Secondary consumers
Ginglymostoma cirratum	2	Sharks	4.15	Large	Tertiary consumers
Grammonus longhursti	1	Bythitidae (viviparous brotulas)	3.4	Small	Secondary consumers
Hemiramphus balao	1	Beloniformes (needlefishes)	3.9	Small	Secondary consumers
Holocantus africanus	9	Pomacanthidae (angelfishes)	2.86	Small	Herbivores
Holocentrus adscensionis	10	Holocentridae (squirrelfishes, soldierfishes)	3.11	Medium	Secondary consumers
Kyphosus incisor	5	Kyphosidae (sea chubs)	2	Medium	Herbivores
Labrisomus nuchipinnis	1	Labrisomidae (labrisomids)	3.6	Small	Secondary consumers
Lagocephalus laevigatus	2	Tetraodontidae (puffers)	4	Medium	Tertiary consumers
Lethrinus atlanticus	15	Lethrinids (emperor)	3.54	Medium	Secondary consumers
Lutjanus agennes	8	Lutjanidae (snappers)	4	Large	Tertiary consumers
Lutjanus dentatus	10	Lutjanidae (snappers)	4	Large	Tertiary consumers
Lutjanus fulgens	2	Lutjanidae (snappers)	4	Medium	Tertiary consumers
Lutjanus goreensis	4	Lutjanidae (snappers)	4	Medium	Tertiary consumers
Melichthys niger	1	Balistidae (triggerfishes)	2.4	Medium	Herbivores
Microphis aculeatus	1	Syngnathiformes (trumpetfishes)	3.4	Small	Secondary consumers
Microspathodon frontatus	2	Pomacentridae (damselfishes)	2.3	Small	Herbivores

Mulloidichthys martinicus	10	Mullidae (goatfishes)	3.2	Medium	Secondary consumers
Muraena melanotis	3	Anguiliformes (eels and morays)	3.5	Medium	Secondary consumers
Myrichthys pardalis	1	Anguiliformes (eels and morays)	3.5	Medium	Secondary consumers
Myripristis jacobus	5	Holocentridae (squirrelfishes, soldierfishes)	3.39	Small	Secondary consumers
Negaprion brevirostris	1	Sharks	4.3	Large	Tertiary consumers
Ophichthus ophis	2	Anguiliformes (eels and morays)	4.5	Medium	Tertiary consumers
Pagrus caeruleostictus	1	Sparidae (porgies)	3.7	Medium	Secondary consumers
Pagrus pagrus	1	Sparidae (porgies)	3.9	Large	Secondary consumers
Paranthias furcifer	15	Serranidae (seabasses)	3.2	Small	Secondary consumers
Pomadasys rogeri	5	Haemulidae (grunts)	3.6	Medium	Secondary consumers
Prionurus biafraensis	7	Acanthuridae (doctorfishes)	2.5	Small	Herbivores
Pseudupeneus prayensis	1	Mullidae (goatfishes)	3.2	Medium	Secondary consumers
Rypticus saponaceus	12	Serranidae (seabasses)	4.1	Medium	Tertiary consumers
Scarus hoefleri	4	Scaridae (parrotfishes)	2	Medium	Herbivores
Selar crumenopthalmus	1	Carangidae (jacks and pompanos)	3.8	Medium	Secondary consumers
Seriola rivoliana	3	Carangidae (jacks and pompanos)	4.45	Large	Tertiary consumers
Serranus cabrilla	2	Serranidae (seabasses)	3.4	Medium	Secondary consumers
Serranus pulcher	14	Serranidae (seabasses)	3.4	Small	Secondary consumers
Sparisoma choati	13	Scaridae (parrotfishes)	2	Small	Herbivores
Sparisoma rubripinne	6	Scaridae (parrotfishes)	2	Medium	Herbivores
Sphoeroides marmoratus	16	Tetraodontidae (puffers)	3.4	Small	Secondary consumers
Sphyraena barracuda	15	Sphyraenidae (barracudas)	4.49	Large	Tertiary consumers
Sphyrnidae	1	Sharks	4.2	Large	Tertiary consumers
Stephanolepis hispidus	1	Monacanthidae (filefishes)	2.6	Small	Herbivores
Synodus synodus	2	Synodontidae (lizardfishes)	4.2	Small	Tertiary consumers
Taeniura grabata	3	Myliobatiformes (stingrays)	4	Rays	Tertiary consumers

Thalassoma newtoni	8	Labridae (wrasses)	3.5	Small	Secondary consumers
Trachinotus ovatus	2	Carangidae (jacks and pompanos)	3.7	Medium	Secondary consumers
Xyrichthys novacula	13	Labridae (wrasses)	3.51	Small	Secondary consumers
NA	72	NA	NA	NA	NA

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