*Journal of the Marine Biological Association of the United Kingdom*, 2014, 94(3), 599–606. 
doi:10.1017/S0025315413001781

# Evaluation of a low-cost, non-invasive survey technique to assess the relative abundance, diversity and behaviour of sharks on Sudanese reefs (Southern Red Sea)

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*A low-cost and non-invasive survey technique focused on pelagic sharks was evaluated during an ecotourism cruise on two Sudanese reefs, Angarosh and Sha'ab Rumi, in the Southern Red Sea. The research technology was based on a set of small, underwater video recording cameras and a pair of laser pointers. Video footage provided insight into shark biodiversity on the two reefs, detecting five species,* Alopias vulpinus, Sphyrna lewini, Triaenodon obesus, Carcharhinus amblyrhynchos *and* Galeocerdo cuvier, *during 15.8 h of video recording. These recordings also provided preliminary information on aggregations of* S. lewini. *The laser pointers were used to measure the size of sharks, providing seven total length (TL) measurements for* S. lewini *(N = 2) and* C. amblyrhynchos *(N = 5), confirming the possibility of easily obtaining size parameters using this tool. These low-cost and user-friendly instruments provide ecotourism divers with an opportunity to become involved in marine research projects.*

**Keywords:** survey technique, *Sphyrna lewini*, *Carcharhinus amblyrhynchos*, sharks, Sudanese reefs, ecotourism divers

Submitted 29 June 2013; accepted 26 November 2013; first published online 16 January 2014

## INTRODUCTION

The high costs of field research on pelagic sharks and the depth–duration relationship limits in underwater visual census (UVC) methods, emphasize the importance of developing low-cost techniques for *in situ* visual assessments, which can be used to produce large quantities of information within a limited time (Bortone & Mille, 1999). This is especially important under particular operating conditions, such as poor visibility, presence of strong currents, deep and cold water and in remote environments. In this context, recreational SCUBA diving, which is a growing component of the international tourism market, could be a very important vehicle to monitor the distribution and population abundance of elasmobranchs (Ward-Paige & Lotze, 2011). Worldwide studies of various taxa, such as whale sharks, *Rhincodon typus* (Smith, 1828) (Quiros, 2005; Rowat & Engelhardt, 2007; Rezzolla & Storai, 2010), grey nurse sharks, *Carcharias taurus,* Rafinesque, 1810 (Barker *et al.*, 2011) and others, such as grey reef sharks, *Carcharhinus amblyrhynchos* (Bleeker, 1856), and whitetip reef sharks, *Triaenodon obesus* (Rüppel, 1837), both extensively studied using underwater visual censuses, baited and unbaited remote underwater video (Robbins *et al.*, 2006; Hussey *et al.*, 2011; Clarke *et al.*, 2012; McCauley *et al.*, 2012), have already demonstrated this. Shark-based tourism can benefit research and conservation, with significant economic profits for local communities, and it can also help engender a conservation ethic through highlighting the value of live sharks (Dobson *et al.*, 2005; Topelko & Dearden, 2005).

In 2012 a low-cost and non-invasive technique, using inexpensive underwater video cameras and laser pointers, was evaluated as a shark survey tool during an ecotourism cruise on two Sudanese reefs, Angarosh and Sha'ab Rumi (Southern Red Sea).

This study not only provides preliminary data on site-attached and reef-associated species, such as grey reef shark and whitetip reef shark, but also on semi-oceanic species such as the scalloped hammerhead shark *Sphyrna lewini* (Griffith & Smith, 1834) (Hazin *et al.*, 2001). Adult scalloped hammerhead sharks are pelagic predators (Holland *et al.*, 1993) that remain during the day in large polarized schools along drop-offs in deep water (Klimley & Nelson, 1984). In the East Pacific Ocean it has been suggested that female scalloped hammerheads form large schools in which individuals compete for males (Klimley, 1985). Within these groups dominance hierarchies exist whereby female sharks will display subordinate behaviour to individuals of a larger size which aggressively compete for central positions within the school (Klimley, 1985). This study presents the first observations of schooling structure, behaviour and size composition of scalloped hammerhead sharks on Sudanese reefs which contrasts, as previously reported by Martin (2003), with the behaviour described in other areas, such as the Sea of Cortez (Klimley, 1983) and Malpelo Island (Bessudo *et al.*, 2011).

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## MATERIALS AND METHODS

### Study area

The reefs examined in the present study are located in a wide, protected area (Persga/GEF, 2004), in the Southern Red Sea, off the Sudanese coast (Figure 1). Of the nine reefs (Sha'ab Rumi, Angarosh, Quita el Banna, Pinnacolo, Sha'ab Ambar, Sanganeb, Habington, Jumna and Merlo), where the authors conducted ecotourism expeditions between 2004 and 2011, Angarosh and Sha'ab Rumi showed the highest occurrence of scalloped hammerhead sharks. For this reason these reefs were chosen as study sites.

Angarosh is a sandy islet, 1.5 m high, that lies on a reef (20°54′N 37°12′E) about 4 km south–south-west of Abington Reef, which is located 22 km south-east of Ras Abu Shajarh (Buckles, 1999; National Geospatial-Intelligence Agency, 2011). The reef belongs to a small chain of reefs far from the coast, which rise up over 500 m from the deep sea. This is a flat-topped 'cake' reef, with sheer drop-offs on the three sides of a small cay and a sloping plateau on the fourth side. For this study, observations were restricted to the two plateaus located at 25 m and 45 m depths on the southern side of Angarosh.

Sha'ab Rumi is a spindle-shaped coral lagoon lying outside the two main reef chains in the western Red Sea (National Geospatial-Intelligence Agency, 2011). It is situated 15 km

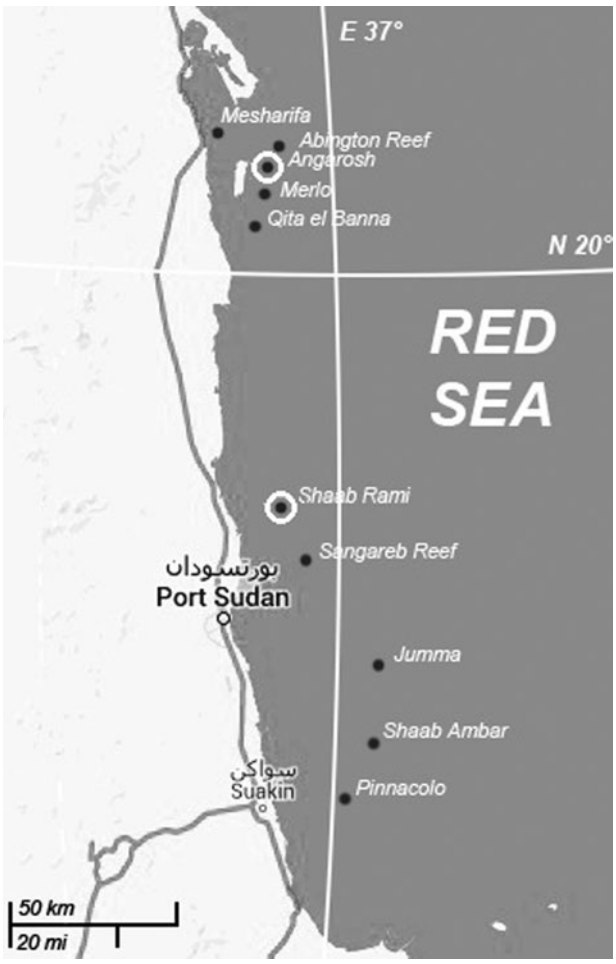


**Fig. 1.** Map of the study area, the Sudanese reefs, Southern Red Sea.

north-east of Port Sudan (19°56.3′N 37°24.2′E) and is approximately 3.8 km long by 1 km wide and orientated north-east–south-west (Hussey *et al.*, 2011). The south of Sha'ab Rumi is a plateau that extends from the base of the reef slope, which descends near vertically to a depth of 20 m. The plateau itself is 50 m long (north–south) by 25 m wide (east–west). The maximum depth at the southern edge of the plateau is 40 m. The southern, eastern and western edges of the plateau drop almost vertically to a depth of 600 m (Hussey *et al.*, 2011).

The waters surrounding the reefs are influenced by the monsoon winds which govern the overall circulation pattern of the Red Sea (Patzert, 1974). From November to April, surface currents flow northward and for the rest of the year southward. Near-shore surface currents, however, generally follow the local wind pattern. The surface water temperature in the Port Sudan area ranges from 26.2°C to 30.5°C (Robinson, 1973), but may be higher in shallow and/or enclosed coastal waters (Schroeder, 1982) while at 150 m depth the range is still 23.9–25.9°C. Surface salinity ranges from 38 to 41‰ in the Sudanese Red Sea (Schroeder, 1982), which is known for the clarity of its waters (Schroeder, 1982), with visibility generally ranging between 20–30 m. In coastal waters, however, it may be less than 1 m (Schroeder, 1982).

### Technical tools

The vessel used for research was the 29 m MSY 'Elegante', a motorized Iveco with two 400 hp motors. Two 5 m Zodiacs with 40 hp engines were used to support the divers during their research dives.

Experimental collection of visual observation data was conducted over 2 days, 25 March 2012 and 30 March 2012. The first set of observations was conducted at Angarosh reef and the second set at Sha'ab Rumi reef. Three GoPro Hero 2 high-resolution video cameras (8 × 5.5 × 8 cm), each equipped with a wide-angle (170°) lens, a 32 GB memory card and a resolution set on 720 p, were mounted in GoPro video housings. The cameras were attached to acrylic platforms, anchored with aluminum weights at a depth of 43 m at both sites, and allowed to record continuously for an average of 4 h each. The cameras, facing opposite of the reef and downward at an inclination of 10°, captured an image of the coral patch and water column. The underwater video survey (UVS) field resulted in a spherical sector, having an approximate volume ($V$) of 51.600 m$^3$, calculated:

$$\mathrm{UVS}V = 2/3\pi \mathrm{VL}^2 h$$

where the visibility line (VL), estimated around 30 m in both sites, represents the radius of the sphere and $h$ is the height of the spherical cap (Figure 2).

On the reef plateau, where the video cameras were anchored, the current was weak at both sites, though diver-operated video monitoring revealed that it was much stronger beyond the edge of the reef. The two GoPro video cameras were programmed to switch on every 4 h, leaving the third as a spare, allowing the possibility of recording up to 8 h of video footage. Filming was restricted to daylight conditions between 09:00 and 17:30 hours on Angarosh reef, while in Sha'ab Rumi it ended at 16:23 hours because of poor light conditions due to overcast skies. Videotapes were downloaded to

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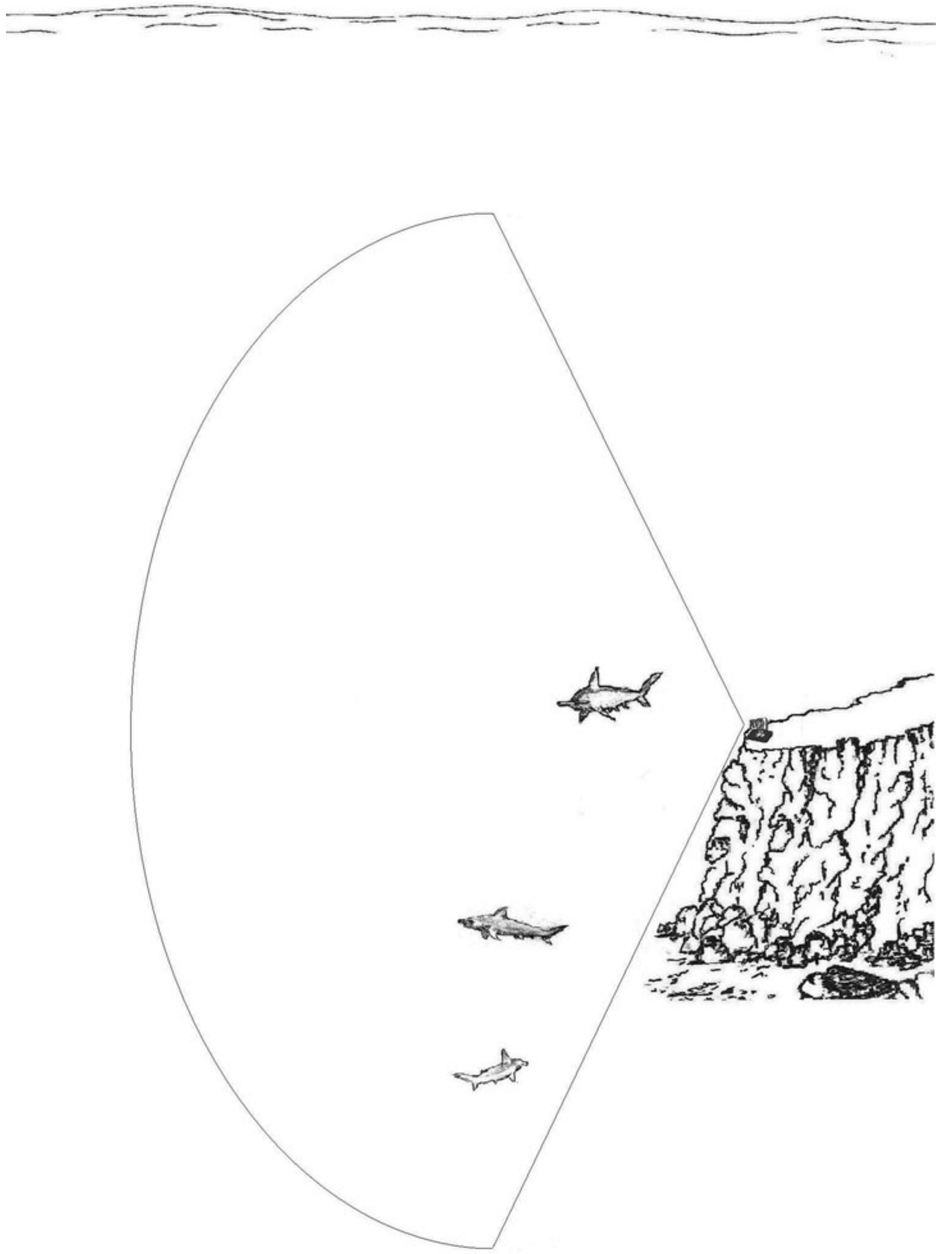

**Fig. 2.** Diagram of the underwater video camera installation and of the resulting underwater video survey field.

a laptop computer and viewed using Pinnacle Studio HD v.15.0.

A shark sighting event is defined as the moment the shark (single individuals or aggregations) is first captured by the video camera until it exits from the video footage.

Total length (TL) of scalloped hammerhead sharks and grey reef sharks was estimated using paired-laser photogrammetry, in which two parallel laser pointers mounted onto a single camera project two points of light, a known distance apart, onto a target (Figures 3A, B, 4A, B), from which the size of the target can be calculated (Deakos, 2010). Measurements were conducted over 2 days, on 24 March 2012 at Angarosh reef and on 29 March 2012 at Sha'ab Rumi reef, using two underwater green laser pointers (BALP-LG05-B150; output power $<5$ mW, wavelength $=$ 532 nm, 190 mm in length, 25 mm in diameter) mounted parallel, with their centres 240 mm apart from a Camcorder Panasonic NV-GS 250s, 3CCD model with NIMAR underwater covering and a Panasonic AG-HSC1 HD, model, with Isotta SPJ-7 underwater covering. Digital images were uploaded on graphics software. Shark lengths were measured from the digital images using PhotoShop software and the known separation distance of the lasers (240 mm). A Sharp PH Temp. WP digital thermometer has been used to record the temperature of the water.

## RESULTS

During the video recording on Angarosh reef (25 March 2012), the water temperature was 25.0°C and the thermocline was at a depth of 38 m. The weather conditions reported a

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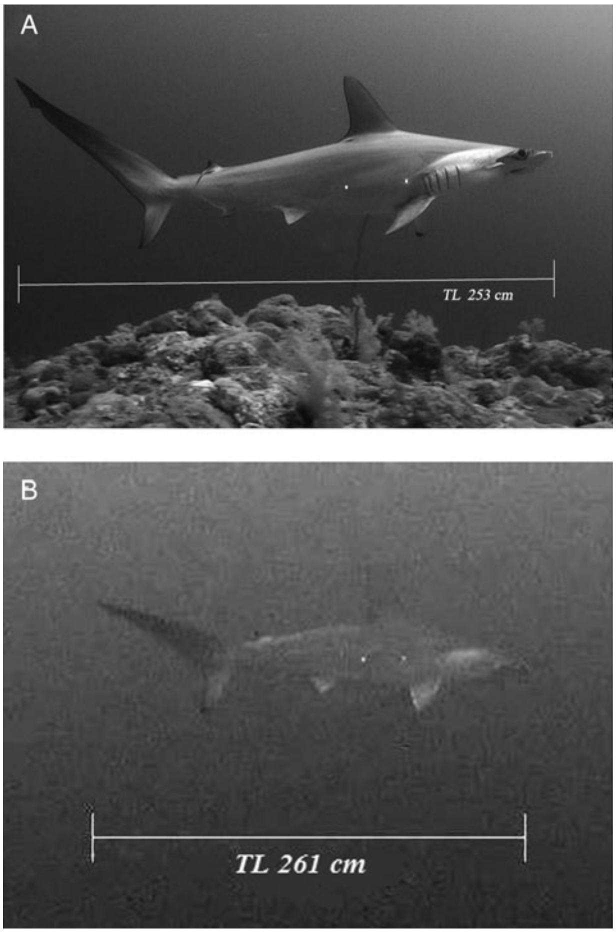


**Fig. 3.** Individuals of *Sphyrna lewini* (Griffith & Smith, 1834) measured using the pair of laser pointers: male from Angarosh (A) and female from Sha'ab Rumi (B).

weak wind from north-west and a sea state 1. During the second day of survey in Sha'ab Rumi (30 March 2012), the water temperature was 25.4°C and the thermocline was at 36 m depth. The weather conditions reported no wind and sea state 1.

As shown in Table 1, the total video footage of 15.8 h (8.5 h at Angarosh and 7.3 h at Sha'ab Rumi) revealed five species of sharks: scalloped hammerheads *Sphyrna lewini (*Fam. SPHYRNIDAE*)*, common thresher sharks *Alopias vulpinus* (Bonnaterre, 1788), (family Alopiidae), grey reef sharks *Carcharhinus amblyrhynchos*, whitetip reef sharks *Triaenodon obesus* and tiger sharks *Galeocerdo cuvier* (Péron & Lesueur, 1822) (family Carcharhinidae). On Angarosh reef, scalloped hammerhead sharks accounted for 69.6% (N = 57) of the observed sharks, followed by grey reef sharks, 20.7% (N = 17). On Sha'ab Rumi reef, grey reef sharks were the most common, 58.5% (N = 259), followed by scalloped hammerhead sharks, 40.2% (N = 178). Whitetip reef sharks were observed just three times (two males and one female estimated from videoframe between 100 cm and 150 cm), common thresher sharks twice (large individuals over 300 cm but too far away to determine their sex) and tiger sharks just once (a female of approximately 300 cm length). All five species were recorded in Angarosh, while in Sha'ab Rumi only scalloped hammerheads, grey reef and whitetip reef sharks were detected. At both sites it was impossible to identify eight individuals due to the distance from the video camera. A total of 276 grey reef sharks and 235 scalloped hammerhead sharks were recorded in the UVS field of both sites, but the number should only be considered as an indicator of maximum abundance during the study period because of possible repeated sightings of the same individuals.

In order to reduce interference with the sharks' behaviour which could compromise the remote underwater video recording, the green laser pointers were tested the day before the filming in both sites. The lengths of one scalloped hammerhead shark and three grey reef sharks in Angarosh and one scalloped hammerhead shark and two grey reef sharks in Sha'ab Rumi were determined. The hammerhead shark sexed in Angarosh was a male of 253 cm (Figure 3A) while in Sha'ab Rumi it was a female of 261 cm (Figure 3B). In Angarosh there were two female grey reef sharks of 159 cm and 163 cm (Figure 4A) and a male of 153 cm; in Sha'ab Rumi the specimens were a female and a male of 157 cm and 144 cm (Figure 4B), respectively. We were unable to test the paired laser pointers with individuals of other species because their presence was recorded during UVS activities and not during the test of the laser pointers.

In Angarosh the average number of sharks sighted per hour was 9.1 ± 9 (SD) and the maximum number of specimens recorded in a single hour was 27, between 1300 and 1400 hours. In Sha'ab Rumi, the average was 55.4 ± 63.1 sharks per hour and the maximum number of sharks encountered was 191, recorded between 1300 and 1400 hours, and 103 recorded between 1100 and 1200 hours. Between 1700 and 1800 hours no sharks were recorded in Angarosh and just three in Sha'ab Rumi. Regarding the grey reef shark sightings, in Angarosh reef the mean number per hour was 1.9 ± 2.5 and the maximum number was eight (1300–1400 hours). In Sha'ab Rumi the average number per hour was 32.4 ± 41.6 and the maximum numbers sighted were between 1100 and 1200 hours and 1300 and 1400 hours, with 40 and 131 individuals, respectively.

**Table 1.** Number of sharks recorded during the two days of survey on Angarosh and Sha'ab Rumi reefs.

| | | | Percentage of occurrence | |
|---|---|---|---|---|
| **Common name** | **Scientific name** | **Number of sharks** | **Angarosh** | **Sha'ab Rumi** |
| Grey reef shark | *Carcharhinus amblyrhynchos* | 276 | 20.7 | 58.5 |
| Scalloped hammerhead shark | *Sphyrna lewini* | 235 | 69.6 | 40.2 |
| Whitetip reef shark | *Triaenodon obesus* | 3 | 2.4 | 0.2 |
| Common thresher shark | *Alopias vulpinus* | 2 | 2.4 | 0 |
| Tiger shark | *Galeocerdo cuvier* | 1 | 1.2 | 0 |
| Unknown species | | 8 | 3.7 | 1.1 |

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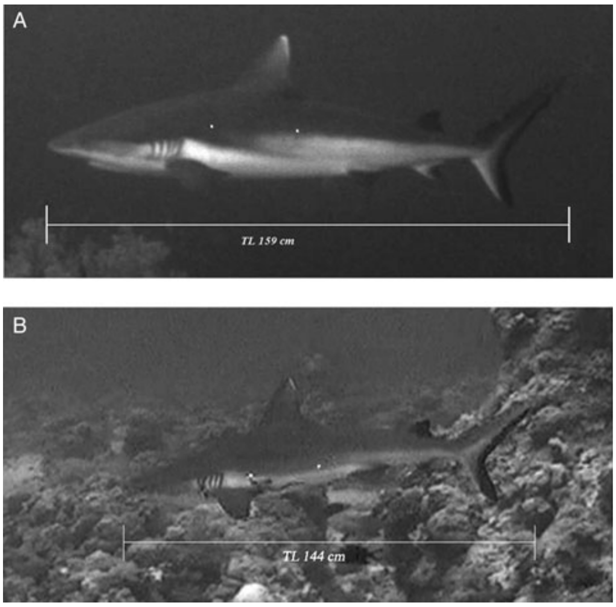


**Fig. 4.** Individuals of *Carcharhinus amblyrhynchos*, Bleeker, 1856 measured using the pair of laser pointers: female from Angarosh (A) and male from Sha'ab Rumi (B).

In Angarosh the average number of scalloped hammerhead sharks sighted per hour of observation was 6.3 ± 7 and the maximum number of specimens observed per hour was 17, between 1300 and 1400 and 1600 and 1700 hours. In Sha'ab Rumi, the average number per hour was 22.3 ± 25.7 and the maximum number of sharks encountered was 60, recorded between 1300 and 1400 hours, and 59 recorded between 1100 and 1200 hours. No specimens were recorded between 1400 and 1600 and 1700 and 1800 hours in Angarosh or between 1500 and 1700 hours in Sha'ab Rumi.

The total video footage of 15.8 h comprises 100 events showing both scalloped hammerhead aggregations and solitary individuals, always swimming below the thermocline. In Angarosh reef 70.4% of the events (N = 19) revealed solitary individuals swimming in the UVS field, while in the remaining 29.6% (N = 8) sharks exhibited polarized swimming behaviour, forming groups of 2–17 individuals, with an average of 4.8 (SD = 5.1; mode = 2; median = 3). In Sha'ab Rumi reef 35.6% of the sightings (N = 26) were aggregations ranging from 2 to 20, and an average of 5 (SD = 5; mode = 2; median = 3). The other 64.4% (N = 47) were solitary sharks. Overall, the mean aggregation size was 5 ± 4.8 specimens and the most frequently sighted groups, comprised two (41%) and three (24%) individuals each (Figure 5). The schools never broke up during the video recording, therefore the duration of the aggregation behaviour was measured as the period of time starting with the appearance, in the video footage, of the first shark and ended when the last one exited the frame. On Angarosh reef, the duration of the schooling behaviour ranged from 16 to 114 s with a mean of 45 ± 31 s, while on Sha'ab Rumi reef it ranged from 10 to 191 s with a mean of 62 ± 39 s. Regarding the solitary shark events, on Angarosh reef the duration ranged from 6 to 70 s with a mean value of 25 ± 21 s, and on Sha'ab Rumi reef, ranged from 3 to 119 s with an average of 27 ± 27 s. Overall 66% of the encounters were single sharks, while the remaining 34% were schools of hammerheads.

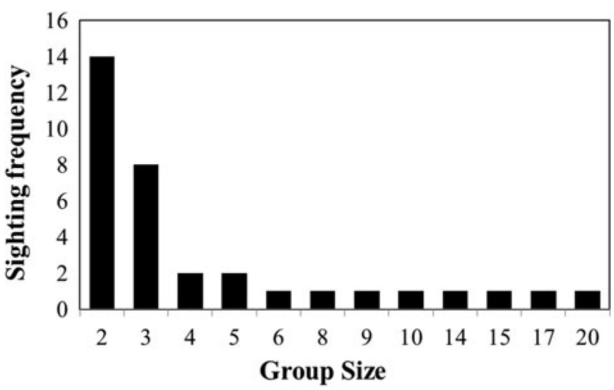


**Fig. 5.** Sighting frequencies of scalloped hammerhead sharks in relation to their group size.

Since the grey reef sharks swam closer to the video cameras than the hammerheads, a higher percentage of the grey reef sharks was sexed. In Angarosh 94.1% of these sharks were sexed, with 11 males and 5 females recorded. In Sha'ab Rumi 78% were sexed, with 114 males and 88 females. No aggregations were observed for this species. Because of the greater distance from the video cameras, only 74 individuals (31.5%, 56 females and 18 males) of the 235 scalloped hammerhead sharks recorded were sexed. On Angarosh 5 of 8 groups were partially sexed, leading to the identification of 18.4% of total sharks aggregated, while 18 of 19 solitary sharks were sexed, with 14 females and 4 males. On Sha'ab Rumi reef, 8 of 26 groups were partially sexed, 13.7% of the total number of grouped sharks, while 31 of 47 solitary individuals were sexed (24 females and 7 males).

It was not uncommon to record scalloped hammerhead sharks and grey reef sharks in the same video frame. In fact, on 26 of the 27 occasions scalloped hammerhead shark appeared in the footage video on Angarosh reef, grey reef sharks were also present. On Sha'ab Rumi, there were 73 recordings of hammerhead sharks and 43.8% of them (N = 32) showed the two species together in the same video frame. In one of these events, grey reef sharks were swimming with the scalloped hammerhead shark aggregation. In particular, one shark was in front of the group and other two were swimming in the back. In another event, two grey reef sharks were swimming close to and in the same direction as a solitary hammerhead shark, and in the other four a solitary hammerhead and grey reef shark were recorded swimming together.

## DISCUSSION

The observations reported here demonstrate that low cost, continuous, non-invasive equipment, such as GoPro video cameras and underwater green laser pointers, can be used to monitor the ecology not only of reef-specific species, but also of pelagic sharks and, consequently, elasmobranch biodiversity. During a survey of just 2 days, which provided 15.8 h of video footage, it was possible to provide preliminary information about the relative abundance, sex-ratio, length measurements, ecology and behaviour of sharks occurring in Sudanese reefs, and their aggregations. Furthermore, the results prove that this technology is very suitable for challenging sites, such as in the Sudanese reefs, where the open sea, swimming depth of the sharks and potentially strong currents make diving very difficult (Rezzolla *et al.*, unpublished data). Direct observations of marine animal behaviour, in fact, are restricted to varying degrees by the harsh operating environment. Physiological limits to dive duration and physical limits of water visibility complicate such studies underwater (Rutecki *et al.*, 1983). Another important issue to consider is that diver-based underwater surveys have a potential bias created by the very presence of human observers in the water (Watson & Harvey, 2007). Some sharks may be attracted to divers, while others may actively avoid them, and these reactions can change with context and over time (McCauley *et al.*, 2012).

The technique based on laser pointers and digital elaboration of the relative images also provides data concerning size of the head (HDL), the preoral (POR), the eye (EYL), the first dorsal fin (D1H), the anterior margin of the first dorsal fin (D1A), the dorsal margin of the caudal fin (CDM), the preventral caudal margin (CPV), the caudal peduncle height (CPH) and the pectoral fin anterior margin (P1A) of sharks, in addition to the TL data; all useful for morphometric studies. While stereo-photogrammetry is inherently more accurate than single camera systems, and 3D measurements are possible, this type of system is cumbersome both in the field and during analysis (Webster *et al.*, 2010). Laser photogrammetry is a simple method and a particularly useful non-invasive field technique as it does not require the animal's capture. Furthermore, this system is inexpensive, simple and easy to set up and use (Webster *et al.*, 2010). Overall, the use of remote video recording and laser pointers overcomes many of the problems and biases associated with diver observations. Finally, but not less importantly, this low-cost technique can be used not only by academic researchers, but also by students, nature guides or just shark enthusiasts, who could collect data independently during increasingly popular and frequent ecotourism trips.

Schooling behaviour of scalloped hammerhead sharks has been most extensively studied in the Sea of Cortez (Klimley, 1983, 1985; Klimley & Brown, 1983; Klimley & Nelson, 1984; Klimley *et al.*, 1988) and in the Pacific Ocean (Hearn *et al.*, 2010; Bessudo *et al.*, 2011), where adults remain in large polarized schools along drop-offs into deep water during the day and at dusk move away from their core area (Klimley & Nelson, 1984). These authors observed that group size varied greatly, reporting aggregations of 3–225 with a mean of 19 in the Gulf of California. On the Sudanese reefs the group size did not vary as much, and the aggregations were composed of a maximum of 20 individuals with a mean of 5 (Figure 5). In Sudan, single sharks were more common (66%) than schools of hammerheads (34%), the opposite of what was reported by Klimley & Nelson (1981).

Scalloped hammerheads, photographed using laser pointers, measured 253 cm and 261 cm respectively. Comparing these measurements with those from the north eastern Brazil (Hazin *et al.*, 2001) and the western Pacific Ocean (Chen *et al.*, 1988; Stevens & Lyle, 1989), it is evident that these individuals were adults. Despite the fact that just two sharks were measured, in the 34 recorded schools, there was marked uniformity in the size of these sharks, indicating that the groups comprised mainly adults. In addition, the length variation within schools appeared to be smaller than in the Pacific groups (Klimley & Brown, 1983). Although it was not possible to sex all the hammerhead sharks in this study, adults of both sexes were observed. The majority of solitary sharks which were sexed on both Angarosh and Sha'ab Rumi reefs were females, with percentages of 77.8% and 77.4%, respectively. Further studies are needed to test for statistical significance among the sexes of this species. As in other areas (Klimley & Nelson, 1981, 1984; Holland *et al.*, 1993), hammerhead sharks were never observed foraging during the day on the two Sudanese reefs, suggesting that they were unlikely to aggregate for feeding reasons. Furthermore it has been possible to observe in some aggregations a sort of 'scout behaviour' from one or two individuals. This hypothetical phenomenon appeared evident in a video sequence recorded during an ecotourism cruise in 2011, where a sharksucker, *Echeneis* spp., attached to a solitary shark, made the specimen distinguishable from other members of the aggregation. Unfortunately, the survey on 2012 was too short to add other elements to confirm or reject this hypothesis.

Overall school structure in the Sudanese Red Sea appears to be quite different from that studied in the Sea of Cortez, as already reported by Martin (2003). Groups are characterized by an average of five individuals, composed of adults of similar size which do not appear to compete with each other for a position at the centre of the schools, as described by Klimley (1985), and do not have any evident scars or wounds.

Grey reef sharks were the second most common species, with 276 individuals recorded. While in Sha'ab Rumi, grey reef sharks were the most common elasmobranch species observed, in Angarosh reef just 17 individuals were recorded. At both sites the majority of sexed sharks were males, in contrast with the findings of Hussey *et al.* (2011) that females dominated in water of 22–32 m at Sha'ab Rumi reef. Wetherbee *et al.* (1997) suggested that the grey reef sharks in Hawaii may segregate by sex, with males in deeper water (mean of 36 m) than females (mean of 22 m). This could explain the different results obtained from the two studies at Sha'ab Rumi. Using laser photogrammetry, the length of five grey reef sharks was 157–163 cm for females and 144–153 cm for males. All individuals measured were adults, as were most of the animals recorded in the video footage. This is based on estimated length at maturity of 120–140 cm and ~125 cm, for males and females, respectively (Wetherbee *et al.*, 1997). This suggests that sub-adults are not common on the outer reefs of Sha'ab Rumi and likely reside in nursery habitats within the protected lagoonal areas, as described by Wetherbee *et al.* (1997). Sharks recorded did not show any aggregating behaviour. Hussey *et al.* (2011), using SCUBA diver observations, reported that the mean number of grey reef sharks observed per diving day was $5.9 \pm 0.3$ with a maximum of 16 sharks sighted in one day. Using the remote video cameras and switching them every 4 h, the mean number of sharks per hour was $32.4 \pm 41.6$, with a maximum number of 131 individuals. In Angarosh fewer sharks of either species were observed.

The overall difference in shark sightings, recorded between the two sites, could be explained by the proximity of Sha'ab Rumi to Port Sudan, which may have deterred illegal fishing activities (Hussey *et al.*, 2011). The shark resources, in fact, are heavily fished, especially in Sudan, where there is evidence of depletion. This is attributed to a lack of control over national shark fisheries and also an increase in illegal fishing by fishermen working outside their normal territorial boundaries for the south-east Asian shark-fin market (Hariri *et al.*, 2000). As already reported by Hussey *et al.* (2011), data on elasmobranch biodiversity, abundance or expected number of sharks on offshore reefs are limited on the Sudanese reefs. Without a historical dataset with which to compare the data from this study, it is difficult to draw a definitive conclusion. However, ecotourism expeditions utilizing this low-cost technology could be of particular importance for monitoring sharks at remote locations, such as the Sudanese reefs, where there are no reliable data on shark numbers, fishing effort or current population status. Similarly, such data collection could contribute to global research on marine species in many other parts of the world.

## ACKNOWLEDGEMENTS

Many people made important contributions to this study. We are grateful to Claudio Scarpellini for providing the MSY 'Elegante' (www.sealandadventures.com) as a base for all the ecotourism expeditions, Nosytour for logistics in Sudan (www.nosytour.it), Mares (www.mares.com), PADI (www.padi.com) and AcquaSport Lecco (www.acquasportlecco.com) for technical support. We are particularly grateful to Dr Alexia Morgan and Dr Geremy Cliff for their assistance, and to the unknown referees who contributed greatly to improve this study with their observations. We also want to thank all volunteers and supporters of the Danishark Elasmobranch Research Association who have assisted this research by reporting sightings of hammerhead sharks.

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https://doi.org/10.1017/S0025315413001781 Published online by Cambridge University Press