Diversity, occurrence and conservation of sharks in the southern South China Sea

Takaomi Arai*, Azie Azri

Environmental and Life Sciences Programme, Faculty of Science, Universiti Brunei Darussalam, Jalan Tungku Link, Gadong, BE, Brunei Darussalam

* takaomi.arai@ubd.edu.bn

Abstract

Sharks constitute a vital sector of marine and estuarine nekton and are of great commercial importance all over the world. International concern over the fate of shark fisheries has grown recently. However, information concerning the species diversity, geographic distribution and life histories of sharks in the Indo-Pacific region is highly limited. Comprehensive research on the species composition, distribution and seasonal occurrence of sharks in the southern South China Sea (SSCS) was conducted for four years. A total of 4742 sharks belonging to 10 families and 28 species were recorded from 6 fishing ports in SSCS. The families recorded included Squalidae, Heterodontidae, Orectolobidae, Hemiscylliidae, Alopiidae, Scyliorhinidae, Triakidae, Hemigaleidae, Carcharhinidae and Sphyrnidae. Seventeen of 28 shark species were landed at various developmental stages from newborn juveniles to fully-mature. The results suggest that these sharks were born just before fishing and landing, and reproductive-stage sharks were also fished and landed. In total, 15 species, four species and one species in 28 shark species were categorized as Near Threatened, Vulnerable and Endangered species, respectively, on the IUCN Red List. Sharks are not targeted by fisheries practices in the SSCS, but are caught as bycatch throughout the year in various developmental stages. Thus, current fisheries practices in the SSCS area might lead to further decline to critical levels and lead to extinction of some of species in the future. These results suggest that the need for gear selectivity of the commercial fishing gears in order to reduce mortality and to conserve shark stocks.

Introduction

Sharks are an evolutionarily conservative group, comprising approximately 250 species, ranging in size from 30 cm tiny pygmy shark, Euprotomicrus bispinatus, to 12 m plankton-feeding whale shark, Rhincodon typus, that have functioned successfully in diverse ecosystems for 400 million years [1]. Sharks constitute an important predator group in marine ecosystems and consequently play an essential role in energy exchange within the highest trophic levels [2]. Despite their evolutionary success, a number of sharks are threatened with extinction as a result of overfishing over recent decades in all oceans [3–5]. The main issues include the high
demand for shark fins and gill plates in Asia, unregulated fisheries, bycatch, and increased shark fishing due to the collapse of other fisheries [5, 6–9]. Therefore, sharks are recognized as highly vulnerable to overexploitation leading to population depletion due to their life history strategies [10]. Sharks are predominantly characterized as long-lived and slow growing and they produce few offspring. These characteristics are associated with low productivity, close stock recruitment relationships, and long recovery times in response to overfishing. Other threats such as habitat degradation and environmental contamination through bioaccumulation and biomagnification processes through the food web [11, 12] are serious issues for sharks [13–15].

Shark landings that constitute a part of the demersal fishery occur throughout the southern South China Sea (SSCS) area, especially in Malaysian waters, from the coasts to the edges of its Exclusive Economic Zone [16]. Fisheries in Malaysia and other Southeast Asian countries are expanding rapidly, new fisheries are being actively developed, and the trade in and value of shark products are increasing [17]. In many Southeast Asian countries, drastic increases in fishing effort and shark landings have been followed by marked declines in shark catch rates in fisheries, and a fall in the numbers and biodiversity of sharks entering markets from coastal waters has been detected [17]. Some historically common species no longer appear to be present in some areas. Multispecies fisheries could potentially result in the local extinction of rare sharks taken as bycatch and even the complete extinction of rare regional endemics [17]. The lack of management of shark fisheries is therefore cause for concern. Sharks are not targeted by fishers but are caught together with other commercially important species in SSCS areas [16].

In Southeast Asia, scientific information on sharks is sporadically documented. A large knowledge gap exists regarding the shark population trends within Southeast Asia, the major global consumers of sharks [18]. A major obstacle to the conservation and management of shark populations in the world is the lack of information on the diversity, seasonal occurrence, life history and fisheries of sharks in many areas. A few studies and publications addressing the diversity, species composition and life history of shark are available for the SSCS areas. Of the 109 species present historically in the South China Sea (SCS) [18], 48, 63 and 53 shark species have been reported in 1999 [19], 2004 [20] and 2005 [21], respectively in SSCS areas. This information suggests that approximately half of the SCS’s shark species occur in Malaysian waters. Although few fisheries reports and taxonomical information of sharks from SSCS waters are available [16, 19–21], biological and ecological studies are at a rudimentary level. Therefore, studies on the diversity, seasonal occurrence and landing patterns of sharks in SSCS are urgently needed to provide information not only for fundamental biology and ecology of sharks but also for conservation and fisheries management and assessment of sharks.

In the present study, the species diversity and seasonal occurrence of sharks has been comprehensively researched at six landing ports in SSCS areas of the eastern coast of the Peninsular Malaysia (West Malaysia) and the western coast of Borneo Island (East Malaysia) over four years. We also discuss the current status of the impacts of fisheries on sharks in SSCS areas. The results are relevant for shark conservation and protection of shark diversity.

**Results**

A total of 4742 shark specimens composed of 28 species from ten families—Squalidae, Heterodontidae, Orectolobidae, Hemiscylliidae, Alopidae, Scyliorhinidae, Triakidae, Hemigaleidae, Carcharhinidae and Sphyrnidae—were found in the SSCS (Fig 1, Table 1). Carcharhinidae dominated with 14 species, followed by Hemiscylliidae with 5 species, and the other families were represented by one to two species (Table 2). Among the 28 species found in this study,
the brownbanded bamboo shark *Chiloscyllium punctatum*, had the highest number of landings with a total of 1355 specimens (29%). The second most dominant species was the Indonesian bamboo shark *Chiloscyllium hasseltii* (871 specimens, 18%), followed by the spot-tail shark *Carcharhinus sorrah* (604 specimens, 13%), the whitespotted bamboo shark *Chiloscyllium plagiosum* (367 specimens, 8%), and the sliteye shark *Loxodon macrorhinus*, which registered 364 specimens (8%) (Table 2). The scalloped hammerhead shark, *Sphyrna lewini*, which is listed as an Endangered species on the IUCN Red List [22] (Table 1), was also abundant (184 specimens, 4%). Furthermore, *Alopias pelagicus*, *Hemigaleus microstoma*, *Hemipristis elongata* and *Carcharhinus plumbeus* are listed as Vulnerable species, while 15 of the 28 shark species are listed as Near Threatened on the IUCN Red List [22] (Table 1).

Seventeen of the 28 species commonly occurred in both West and East Malaysia, while 2 species (*Carcharhinus leucas* and *Galeocerdo cuvier*) occurred in West Malaysia and 9 species (*Squalus alitpinis*, *Heterodontus zebra*, *Orectolobus leptolineatus*, *Alopias pelagicus*, *Halaelurus buergeri*, *Mustelus widodoi*, *Carcharhinus plumbeus*, *Scoliodon macrorhynchos* and *Triacodon obesus*) occurred in East Malaysia (Fig 2, Table 3). The brownbanded bamboo shark *Chiloscyllium punctatum* or the Indonesian bamboo shark *Chiloscyllium hasseltii* were the most dominant species in all sites except Sarawak State (Fig 2). The scalloped hammerhead shark *Sphyrna lewini* was the most dominant species in Sarawak state (Fig 2). Although we conducted much more intensive landing port surveys in West Malaysia (4 sites and 43 times (months)) than in East Malaysia (2 sites and 7 times (months)), more shark species were observed in East Malaysia (26 species) than in West Malaysia (19 species) (Table 3). The results suggest that shark diversity is higher in the eastern areas than the western areas of the SSCS.

In Terengganu State, 11 species were found in monthly observations for approximately four years (Fig 3). Three species, the brownbanded bamboo shark *Chiloscyllium punctatum*, the spot-tail shark *Carcharhinus sorrah* and the Indonesian bamboo shark *Chiloscyllium hasseltii*, were the most dominant species comprising 90% of the shark species in the Terengganu State (Fig 3). The seasonal occurrences in the three dominant species of *C. punctatum*, *C.
Table 1. Sharks landed in the southern South China Sea and their depth preference, habitat and distribution [24, 43–44, 46–59] and IUCN status [22].

| Species                      | Depth preference (m) | Habitat                                    | Distribution                                      | Reference | IUCN status     |
|------------------------------|----------------------|--------------------------------------------|---------------------------------------------------|-----------|-----------------|
| *Squalus altipinnis*         | 50 to 732            | continental shelves and upper slopes       | temperate and tropical seas                       | 44        | Data Deficient  |
|                             |                      | on or near the bottom                      | Eastern Atlantic, western Indian Ocean, western Pacific and Australia |
| *Heterodontus zebra*         | 50 to 200            | bottom of continental                      | Western Pacific,                                     | 46, 47, 48 | Least Concern   |
|                             |                      | and insular shelves                        |                                                   |
| *Orectolobus leptolineatus*  | 20 to at least 110   | inshore to offshore bottom of continental shelves, | tropical and warm temperate waters, | 44        | Not Evaluated   |
|                             |                      | and juveniles occurs in low reefs, seagrass beds | Western Pacific |
| *Chiloscyllium hasseltii*    | 0 to 12              | inshore bottom dweller, rock and coral reefs, | Indo-west Pacific, Eastern Indian Ocean | 46, 49, 50 | Near Threatened |
|                             |                      | sandy and muddy bottom                      | and western central Pacific |
| *Chiloscyllium indicum*      | 0 to 90              | demersal inshore, possibly enter brackish water | Indo-west Pacific region | 47, 51, 52 | Near Threatened |
|                             |                      | and freshwater                             |                                                   |
| *Chiloscyllium plagiosum*    | 0 to 50              | inshore reef dwelling, rocks and coral reefs | Indo-west Pacific region | 46, 50, 51 | Near Threatened |
| *Chiloscyllium punctatum*    | limit to 85          | nearshore intertidal and subtidal habitat, coral reef, | Indo-west Pacific region, | 53        | Near Threatened |
|                             |                      | seagrass beds and rocky, sandy and muddy substrates | tropical and warm-temperate waters |
| *Alopias pelagicus*          | surface to at least 152 | oceanic and nearshore, highly migratory and is epipelagic | Oceanic and wide-ranging, | 44, 46   | Vulnerable      |
|                             |                      | at least 152                               | tropical Indo-Pacific                             |
| *Mustelus widodoi*           | 20 to 250            | demersal on mid continental shelf to upper slopes | Indian Ocean | 45, 46, 54 | Data Deficient  |
|                             |                      | in deep water, inshore and offshore and sometimes | on coral reef |
| *Hemigaleus microstoma*      | surface to at least 170 | continental and insular shelves | Indo-west Pacific region | 44, 55   | Vulnerable      |
| *Hemipristis elongata*       | 1 to 130             | continental and insular shelves            | Indo-west Pacific region                           | 53, 54, 56 | Vulnerable      |
| *Carcharhinus amblyrhynchoides* | 10 to 50          | coastal pelagic on continental and insular shelves | tropical Indo-West Pacific | 46, 56, 57 | Near Threatened |
| *Carcharhinus brevipinna*    | surface to at least 75 | continental and insular shelves from close inshore | warm temperate, subtropical, and tropical Atlantic, Indian |
|                             |                      | to offshore, nearshore waters off beaches, in bays and off river mouths, pelagically offshore | and Westerns Pacific Oceans |
| *Carcharhinus tjujot*        | surface to 170       | demersal inshore                           | tropical Indo-West Pacific | 43, 57   | Near Threatened |
| *Carcharhinus leucas*        | 1 to 150             | coastal, estuarine and freshwater          | tropical and warm temperate areas | 43, 47, 57 | Near Threatened |

(Continued)
hasseltii and C. sorrah were similar among the years (Fig 3). Eight of the 11 shark species were sporadically found among months and years (Fig 3). There were significant monthly fluctuations in the abundance of C. sorrah (one-way ANOVA, $F_{11, 31} = 3.198$, $p < 0.05$). However, C. punctatum and C. hasseltii did not show significant monthly fluctuations (one-way ANOVA, $F_{11, 31} = 1.701–1.984$, $p > 0.05$). C. punctatum dominated throughout the years with the highest abundances from January to May and October and November (Fig 3). C. sorrah and C. hasseltii were the second and third dominant species, respectively, occurring throughout the years (Fig 3). C. sorrah was the most abundant in June and July for three years between 2015 and 2017 (Fig 3).

The TL distribution of the three most dominant species (C. punctatum, C. hasseltii and C. sorrah) in Terengganu State were significantly different among months and years (Kruskal-Wallis test, $H_3 = 2.712$, $p < 0.005$). For C. sorrah, most of the specimens found in June and July were in the newborn stage, that is less than 60 cm, while the sharks in the other months were mostly at the adult stage (> 70 cm) (Fig 4). The total lengths in June and July in 2015 and
2016 were significantly smaller than other months in both sexes (Mann-Whitney- \( U \) test, \( U = 706.5, df = 43, p < 0.005 \)), while no significant difference was found between June and July and other months in 2015 for female (Mann-Whitney- \( U \) test, \( U = 141, df = 8, p > 0.05 \)). Significant differences in TL were found between four years in each sex in \( C. punctatum \) (Kruskal-Wallis test, \( H = 2.652, p < 0.005 \)) with the exception between 2014 and 2015 for males and between 2014 and 2015 and between 2016 and 2017 for females (Mann-Whitney- \( U \) test, \( U = 1193, df = 43, p > 0.05 \)). However, there were no

Table 2. Number of sharks and species composition landed in the southern South China Sea.

| Order                  | Family/Species | Common name                  | Total landing (number) | Composition (%) |
|------------------------|----------------|------------------------------|------------------------|-----------------|
| Squaliformes           | Squalidae      | Piked spurdog                | 39                     | 1               |
|                        | \( Squalus altipinnis \) |                              |                        |                 |
| Heterodontiformes      | Heterodontidae | Zebra horn shark             | 3                      | 0.06            |
|                        | \( Heterodontus zebra \) |                              |                        |                 |
| Orectolobiformes       | Orectolobidae  | Indonesian wobbegong        | 1                      | 0.02            |
|                        | \( Orectolobus leptolineatus \) | Indonesian bamboo shark     | 871                    | 18              |
|                        | Hemiscyllidae  | Slender bamboo shark         | 10                     | 0.21            |
|                        | \( Chiloscyllium hasseltii \) | Whitespotted bamboo shark   | 367                    | 8               |
|                        | \( Chiloscyllium indicum \) | Brownbanded bamboo shark    | 1355                   | 29              |
| Lamniformes            | Alopiidae      | Pelagic thresher             | 5                      | 0.11            |
|                        | \( Alopias pelagicus \) |                              |                        |                 |
| Carcharhiniformes      | Scyllorhinidae | Coral catshark               | 122                    | 2               |
|                        | \( Halaelurus buergeri \) | Blackspotted catshark       | 3                      | 0.06            |
|                        | Triakidae      | Arabian smooth-hound         | 3                      | 0.06            |
|                        | \( Mustelus widodoi \) |                              |                        |                 |
|                        | Hemigaleidae   | Weasel shark                 | 119                    | 2               |
| Hemigaleus microstoma  |                              |                              |                        |                 |
| Hemipristis elongata   | Fossil shark   |                              | 5                      | 0.11            |
|                        | Carcharhinidae | Graceful shark               | 7                      | 0.15            |
|                        | \( Carcharhinus amblyrhynechoides \) |                              |                        |                 |
|                        | Blacktip shark |                              | 121                    | 2               |
|                        | \( Carcharhinus tjaeto \) | Whitecheek shark             | 12                     | 0.25            |
|                        | Bull shark     |                              | 7                      | 0.15            |
|                        | \( Carcharhinus limbatus \) | Blacktip shark              | 12                     | 0.25            |
|                        | Blacktip reef shark |                              | 5                      | 0.11            |
|                        | Sandbar shark  |                              | 4                      | 0.08            |
|                        | Blackspot shark |                              | 185                    | 4               |
|                        | Spot-tail shark |                              | 604                    | 13              |
|                        | Tiger shark    |                              | 7                      | 0.15            |
|                        | Sliete eye shark |                              | 364                    | 8               |
|                        | Milk shark     |                              | 287                    | 6               |
|                        | Pacific spadenose shark |                              | 39                     | 1               |
|                        | Whitetip reef shark |                              | 1                      | 0.02            |
| Sphyrnidae             | \( Sphyrna lewini \) | Scalloped hammerhead shark   | 184                    | 4               |

https://doi.org/10.1371/journal.pone.0213864.t002
significant differences in TL between four years in both sexes in *C. hassettii* (Kruskal-Wallis test, \(H_3 \leq 2.712, p > 0.05\)) except for males during 2014 and 2015 (Mann-Whitney-\(U\) test, \(U = 148, \text{df} = 10, p < 0.05\)). In *C. sorrah*, four out of six TL combinations were significantly different between years for males (Mann-Whitney-\(U\) test, \(36 \leq U \leq 646.5, 7 \leq \text{df} \leq 79, p < 0.05\)) and significant differences were found in three out of six TL combinations for females (Mann-Whitney-\(U\) test, \(4 \leq U \leq 919.5, 28 \leq \text{df} \leq 99, p < 0.05\)).
The size ranges varied among species, ranging from 20 to 309 cm TL (Figs 5 and 6) and from 0.03 to 26.9 kg body weight (Table 4). The TL at birth varied among species [22–26] (Table 4). Various growth stages from newborn to the mature adults were landed (Figs 5 and 6). Ten of the 28 captured shark species, *Squalus altipinnis*, *Carcharhinus brevipinna*, *C. tjutjot*, *C. limbatus*, *C. plumbeus*, *C. sealei*, *C. sorrah*, *Loxodon macrorhinus*, *Rhizoprionodon acutus* and *Sphyrna lewini* were in or less than the length at birth (Figs 5, 6 and 7A, Table 4). Although the TL of seven of the shark species, *Chiloscyllium hasseltii*, *C. plagiosum*, *C. punctatum*, *C. melanopterus*, *Hemigaleus microstoma* and *Scoliodon macrorhynchos*, were greater than the TL at birth, various growth stages from newborn juveniles to mature adults were landed (Figs 5 and 6).

**Discussion**

The spatial and temporal variations in diversity and occurrence of sharks were examined in SSCS for four years. Known habitats of the 28-shark species ranged widely from coral reefs, seagrass beds, and pelagic, oceanic and demersal habitats with various depths from epipelagic to mesopelagic zones (Table 1). The sharks were caught from various fishing grounds. In Malaysian waters, at least 63 freshwater and marine water shark species have been reported [20], thus ranking this area fourth in the Southeast Asian region, after Indonesia (111 species), the Philippines (94 species), and Thailand (64 species) [26]. In the present study, *Carcharhinus* was the most diverse group with 14 species, followed by Hemiscylliidae (5 species) (Table 2). Of the 28 species found, *Chiloscyllium hasseltii*, *C. plagiosum*, *C. punctatum*, *Carcharhinus sorrah*, *Loxodon macrorhinus* and *Sphyrna lewini* occurred frequently in the SSCS (Table 2), although the dominant species differed among six landing ports (Fig 2). This occurrence pattern was consistent with a previous study in the same region [16].

Higher diversity was found in the eastern part of the SSCS (East Malaysia) even though we conducted much more intensive surveys and more landing sites in the western part of the

---

**Table 3. Sharks landed on the eastern coast of the Peninsular Malaysia (West Malaysia) and the western coast of Borneo Island (East Malaysia) and their overlapping species.**

| Peninsular Malaysia (West Malaysia) | Borneo Island (East Malaysia) | Peninsular Malaysia and Borneo Island |
|------------------------------------|-----------------------------|-------------------------------------|
| *Carcharhinus leucas*              | *Squalus altipinnis*        | *Chiloscyllium hasseltii*            |
| *Galeocerdo cuvier*                | *Heterodontus zebra*        | *Chiloscyllium indicum*              |
| *Orectolobus leptolepis*           | *Chiloscyllium plagiosum*   |                                     |
| *Alopias pelagicus*                | *Chiloscyllium punctatum*   |                                     |
| *Halscarus buergeri*               | *Atelomycterus marmoratus*  |                                     |
| *Mustelus widodoi*                 | *Hemigaleus microstoma*     |                                     |
| *Carcharhinus plumbeus*            | *Hemipristis elongata*      |                                     |
| *Scoliodon macrorhynchos*          | *Carcharhinus amblyrhynchoideos* |                     |
| *Triamondon obesus*                | *Carcharhinus brevipinna*   |                                     |
|                                     | *Carcharhinus tjutjot*      |                                     |
|                                     | *Carcharhinus limbatus*     |                                     |
|                                     | *Carcharhinus melanopterus* |                                     |
|                                     | *Carcharhinus sealei*       |                                     |
|                                     | *Carcharhinus sorrah*       |                                     |
|                                     | *Loxodon macrorhinus*       |                                     |
|                                     | *Rhizoprionodon acutus*     |                                     |
|                                     | *Sphyrna lewini*            |                                     |

https://doi.org/10.1371/journal.pone.0213864.t003
SSCS (West Malaysia), which can be explained by the differences in shelf topography and habitat diversity between the western and eastern parts of the SSCS. The broad and shallow Sunda Shelf lies off the east coast of the Peninsular Malaysia (West Malaysia), and the depth in the fishing grounds is shallower than 50 m [27]. The physical features of the seabed vary from the
Fig 4. Monthly size distributions of three dominant species, the brownbanded bamboo shark *Chiloscyllium punctatum*, the Indonesian bamboo shark *Chiloscyllium hasseltii* and the spot-tail shark *Carcharhinus sorrah*, landed in Terengganu State in the southern South China Sea. Monthly size distributions were recorded for approximately four years from 2014 to 2017.

https://doi.org/10.1371/journal.pone.0213864.g004
inshore to the deep sea in the Sabah and Sarawak states (East Malaysia). The continental shelf slopes to 200 m depth, while the continental slope dips from 200 m to 800 m depth in the fishing ground of Sarawak State [25]. A deep-sea trench stretches towards Sabah State with depth ranging from 2000 m to 2500 m [28]. In landing ports of the Sabah and Sarawak states, *Squalus*...
Fig 6. Size distributions of sharks landed in the southern South China Sea. Sixteen shark species with less than 5 specimens were landed at various growth stages from the newborn juveniles and/or to mature adults. LB (black arrow), LMM (green arrow) and LMF (red arrow) indicate the length at birth, length at maturation of male and length at maturation of female, respectively.

https://doi.org/10.1371/journal.pone.0213864.g006
Table 4. Total length and body weight of sharks in this study and total length at birth, hatch and maturity of sharks [22–26].

| Species                        | Sex          | Number of specimens examined | Total length (cm) | Total length at birth/hatch (cm) | Total length at maturity (cm) |
|--------------------------------|--------------|-----------------------------|-------------------|---------------------------------|-------------------------------|
|                                |              |                             | Range            | Mean ± SD | Range            | Mean ± SD | Range            | Mean ± SD | Range            | Mean ± SD |
| Squalus altipinnis             | Female       | 1                           | 54.5 ± 0.37      | 0.37     | 20–25            | 34–41     |
|                                | Male         | 4                           | 39–73            | 0.25–1.75| 10 ± 0.7         | 53–57     |
| Heterodontus zebra             | Female       | 1                           | 73.5 ± 1.95      | 1.95     | 15               | 64        |
|                                | Male         | 2                           | 71–78.5          | 2.59–4.63| 3.6 ± 1.4        | no data   |
| Orectolobus leptocephalus      | Female       | 0                           |                  |          | 21               | 60        |
|                                | Male         | 1                           | 95 ± 6.85        |          | 94               |           |
| Chiloscyllium hasseltii        | Male         | 145                         | 27.5–90.5        | 66.5 ± 12.2| 145             | 0.18–3.4 | 1.4 ± 0.7       | 9–12     | 44–54           |
|                                | Female       | 155                         | 37.5–77          | 61.7 ± 7.9| 155             | 0.2–2.44 | 1.1 ± 0.4       | 9–12     |
| Chiloscyllium indicum          | Male         | 0                           |                  |          | no data          | 39–42     |
|                                | Female       | 10                          | 54–63            | 58.6 ± 3.0| 10               | 0.42–0.76| 0.6 ± 0.1       | 43       |
| Chiloscyllium plagiosum        | Male         | 104                         | 41–89            | 70.2 ± 9.9| 104             | 0.18–3.6 | 1.0 ± 0.5       | 10–13    | 50–63           |
|                                | Female       | 81                          | 46–93            | 71.3 ± 10.6| 81               | 0.34–2.12| 1.2 ± 0.5       | 65       |
| Chiloscyllium punctatum        | Male         | 452                         | 20.7–105         | 72.7 ± 17.9| 452             | 0.03–4.6 | 1.7 ± 1.1       | 13–17    | 68–76           |
|                                | Female       | 367                         | 20–101           | 70.2 ± 15.2| 367             | 0.08–4.04| 1.5 ± 0.9       | 63       |
| Alopias pelagicus              | Male         | 4                           | 182–308.5        | 226.1 ± 58.3| 3               | 11.4–25  | 16.7 ± 7.3      | 130–160  | 245–270         |
|                                | Female       | 1                           | 178 ± 11         |          | 265–290         |           |
| Aetomycterus marmoratus        | Male         | 52                          | 31–70            | 53.2 ± 7.6| 52               | 0.08–1.12| 0.5 ± 0.2       | 10–13    | 45–47           |
|                                | Female       | 43                          | 37–68            | 53.0 ± 6.3| 43               | 0.15–0.95| 0.5 ± 0.2       | 49       |
| Halaelurus buergeri            | Female       | 0                           |                  |          | no data          | 36–43     |
|                                | Male         | 3                           | 39.5–44.4        | 42.3 ± 2.5| 3                | 0.19–0.31| 0.3 ± 0.1       | 40       |
| Mustelus vidiodoi              | Female       | 3                           | 55–67            | 61.3 ± 6.0| 3                | 0.47–0.89| 0.7 ± 0.2       | 26–28    | 63–67           |
|                                | Male         | 0                           |                  |          | 82               |           |
| Hemigaleus microstoma          | Female       | 52                          | 40.4–99          | 69.3 ± 15.3| 52               | 0.22–2.84| 1.4 ± 0.8       | 26–28    | 60              |
|                                | Male         | 27                          | 41.5–95          | 68.4 ± 16.3| 27               | 0.21–4.18| 1.4 ± 1.1       | 65       |
| Hemipristis elongata           | Female       | 4                           | 62.5–155         | 101.3 ± 43.1| 3               | 0.77–19  | 7.1 ± 10.3      | 45–52    | 110             |
|                                | Male         | 1                           | 69 ± 1.18        | 1         | 120              |           |
| Carcharhinus amblyrhynchoides  | Male         | 2                           | 62.5–169         | 115.8 ± 75.3| 1               | 1.77     | 52–55           | 104–115  |
|                                | Female       | 5                           | 61–162           | 96.3 ± 39.1| 4               | 1.62–5.88| 3.9 ± 2.1       | 104–115  |
| Carcharhinus brevipinna        | Male         | 41                          | 69–165           | 87.4 ± 15.4| 40               | 1.3–7.15 | 3.3 ± 1.4        | 60–81    | 159–203         |
|                                | Female       | 50                          | 69.5–180         | 89.2 ± 18.4| 48               | 1.9–16.38| 3.5 ± 2.3        | 170–220  |
| Carcharhinus ttaioj           | Male         | 4                           | 38.4–86.0        | 58.1 ± 23.7| 4                | 0.28–3.68| 1.5 ± 1.6        | 28–40    | 65–75           |
|                                | Female       | 4                           | 40.5–88.5        | 56.9 ± 21.5| 2                | 0.46–4.18| 2.3 ± 2.6       | 70–75    |
| Carcharhinus leucas            | Male         | 2                           | 200–225          | 212.5 ± 17.7| 0               |          | 55–81           | 197–226  |
|                                | Female       | 5                           | 210–278.5        | 248.7 ± 34.0| 0               |          | 180–230         |           |
| Carcharhinus limbatus          | Male         | 6                           | 57–82.5          | 72.7 ± 9.4| 6                | 1.1–3.1  | 2.1 ± 0.8        | 38–72    | 135–180         |
|                                | Female       | 5                           | 65.5–150         | 87.9 ± 35.1| 4                | 1.85–2.94| 2.3 ± 0.5        | 120–190  |
| Carcharhinus melanopterus      | Male         | 2                           | 55.5–122         | 88.8 ± 47.0| 2                | 0.93–12.3| 6.6 ± 8.0        | 33–52    | 91–113          |
|                                | Female       | 3                           | 56–61.3          | 57.9 ± 3.0| 3                | 0.76–1.18| 0.9 ± 0.2        | 96–120   |
| Carcharhinus plumbeus          | Male         | 1                           | 65.5 ± 1.4       | 1         | 52–75            | 130–180  |
|                                | Female       | 3                           | 66.0–70.0        | 68.0 ± 2.0| 3                | 1.39–19  | 1.6 ± 0.3        | 145–185  |
| Carcharhinus sealei            | Male         | 59                          | 37–132.5         | 60.3 ± 21.1| 57               | 0.21–11.82| 1.3 ± 1.6        | 33–45    | 70–80           |
|                                | Female       | 54                          | 29.5–148.5       | 57.7 ± 20.3| 52               | 0.12–3.74| 1.2 ± 1.1        | 68–75    |

(Continued)
altipinnis, Heterodontus zebra, Alopias pelagicus, Halaclurus buergeri and Mustelus widodoi were landed with known habitats on continental and insular shelves and bottom-dwelling habitats (Table 1), while shark habitats in the western coast of the Peninsular Malaysia were mainly on coral reefs, seagrass beds and inshore reefs (Table 1). Furthermore, the fishing grounds in West Malaysia are rather limited (22 km (12 nautical miles)), while fishing grounds are rather wide in the Sabah and Sarawak states, where most are more than 22 km [16]. These results suggest that the greater geographic variations and wider fishing grounds in the eastern SSCS might lead to more shark diversity than that in the western SSCS.

Among 11 sharks observed in Terengganu State, three species—C. punctatum, C. sorrah and C. hasseltii—were the dominant species, constituting 90% of the sharks. The seasonal occurrences of sharks were similar among years, although the dominant species were slightly different in different seasons (see Fig 3). These results suggest that migratory patterns and habitat use of sharks in the western coast of the SSCS might be common among species throughout the year with a few seasonal migratory species in the area. Migration of both adult and juvenile sharks is strongly influenced by temperature [29]. However, there is less seasonal seawater temperature fluctuation in tropical waters such as Terengganu State in the SSCS (26.7°C on average, ranging from 25.9°C to 27.6°C) [30]. Therefore, species composition might be similar temporally and spatially in the area. As small-bodied sharks tend to have productive life-history strategies such as early maturity and annual reproduction, moving widely and using additional habitats may benefit these species by increasing foraging success and promoting fast growth [31, 32]. Long-term use of nearshore regions, however, has been reported in some small-bodied species. For example, adult female Triakis semifasciata remained in a California estuary for up to 229 days, which was thought to be due to high productivity, with individuals remaining in the region to forage [33]. Long-term presence and high residency of adult C. sorrah in Cleveland Bay suggests that this nearshore region provides individuals with sufficient prey resources, and perhaps other benefits such as shelter from larger predators [32]. The nearshore region of Terengganu State in the SSCS might also provide sharks with suitable habitat

---

**Table 4.** (Continued)

| Species            | Sex | Number of specimens examined | Total length (cm) | Body weight (kg) | Total length at birth/hatch (cm) | Total length at maturity (cm) |
|--------------------|-----|------------------------------|-------------------|-----------------|---------------------------------|-----------------------------|
|                    |     |                              | Range            | Mean ± SD       | Range                          | Mean ± SD                  |
| Carcharhinus sorrah| Male| 210                          | 47.5–131.3       | 71.8 ± 17.8     | 207                            | 0.32–12.52                 | 45–60                      | 103–128                    |
|                    | Female| 208                         | 51–165           | 76.5 ± 25.9     | 192                            | 0.56–18.6                  | 2.1 ± 2.3                 | 110–118                    |
| Galeocerdo cuvier  | Male| 4                            | 110–200          | 163 ± 43.8      | 2                              | 5.34–15.9                  | 10.6 ± 7.5                | 50–76                      | 300–305                    |
|                    | Female| 3                            | 96–168           | 138.7 ± 37.8    | 2                              | 2.75–26.9                  | 14.8 ± 7.1                | 250–350                    |
| Loxodon macrochirus| Male| 55                           | 41–89.5          | 64.6 ± 15.0     | 51                             | 0.22–2.15                  | 0.9 ± 0.6                 | 40–55                      | 62–83                      |
|                    | Female| 60                           | 38–92            | 64.2 ± 16.8     | 55                             | 0.12–2.78                  | 1.0 ± 0.8                 | 79–90                      |
| Rhizoprionodon acutus| Male| 80                          | 31.3–200         | 63.0 ± 33.5     | 77                             | 0.11–19                    | 1.3 ± 2.3                 | 29–40                      | 68–72                      |
|                    | Female| 93                           | 31.1–144         | 59.5 ± 21.5     | 93                             | 0.11–12.78                 | 1.3 ± 1.7                 | 70–81                      |
| Scoliodon macrorhynchos| Male| 17                         | 26.8–55.6        | 37.7 ± 9.2      | 17                             | 0.06–0.71                  | 0.3 ± 0.2                 | 12–15                      | 24–36                      |
|                    | Male| 22                          | 28.5–61.9        | 39.2 ± 6.9      | 22                             | 0.06–0.97                  | 0.3 ± 0.2                 | 33–35                      |
| Triaenodon obesus   | Male| 0                           |                  |                 |                                |                            |                           |                            |                            |
|                    | Female| 1                            | 120              |                 |                                |                            |                           |                            |                            |
| Sphyrna lewini      | Female| 73                           | 47–245.3         | 68.8 ± 26.6     | 63                             | 0.43–25                    | 1.8 ± 3.1                 | 40–55                      | 140–180                    |
|                    | Male| 60                          | 47.1–123         | 68.0 ± 18.3     | 49                             | 0.44–3.19                  | 1.3 ± 0.8                 | 200–230                    |

https://doi.org/10.1371/journal.pone.0213864.t004
Fig 7. Sharks landed in the southern South China Sea. Piked spurdog *Squalus altipinnis* at various growth stages from the newborn to mature adults were landed (a). Sharks with fins cut off at landing ports in southern South China Sea (b). Shark finning practice at landing ports in southern South China Sea (c).

https://doi.org/10.1371/journal.pone.0213864.g007
for reproduction and prey resources and the suitable nursery throughout their lives. No similar work in the SSCS or Southeast Asian region is available to compare with the present findings. Further studies regarding baseline biological information such as breeding behaviour, feeding habit, age of maturity, fecundity, growth, habitat and migration are needed to understand the seasonal occurrence patterns of sharks.

Little else is known about the movement and habitat use patterns of sharks in the SSCS, and in the Indo-Pacific waters other than the information on the species composition and diversity. The two bamboo sharks *C. hasseltii* and *C. punctatum* are bottom dwellers, living in tidal pools on coral reefs, on muddy banks, and amongst mangroves and seagrasses [25]. The spot-tail shark *C. sorrah* occurs over continental and insular shelves [28], including around coral reefs, and moves relatively short distances of \( \leq 50 \text{ km} \) in nearshore waters, but some have been reported to move distances \( > 1000 \text{ km} \) [34]. The bamboo sharks might be more sedentary compared to the spottail shark. Interestingly, however, the size ranges differed between *C. punctatum* and *C. hasseltii* and *C. sorrah* (Fig 4). All the bamboo shark specimens found throughout the studied years were from juvenile to adult stages with no newborn stage (Table 4). The newborn stage less than 20 cm in the bamboo sharks might not be caught by the current fishing methods and gears in SSCS. However, for the spottail shark, 99% specimens found in June and July consecutively for three years were in the newborn juvenile stage (TL \(< 60 \text{ cm})\), while there were more adult specimens in other months (Fig 4). These results suggest that *C. sorrah* might pup in June and July in the western SSCS, and the spawning and/or nursery ground of *C. sorrah* might overlap with the fishing ground in Terengganu State. Therefore, a number of newborn juveniles might be fished especially in June and July; however, adult *C. sorrah* might migrate widely in the region, and thus, a few adult *C. sorrah* occurred throughout the studied years. Differences in life history and habitat use among species and developmental stages might change the seasonal occurrence and species composition in the region.

Seventeen of the 28 observed shark species were landed at various developmental stages from newborn to mature adults (Figs 5 and 6). These results suggest that these sharks hatched around the fishing grounds just before fishing, and the fishing grounds in the SSCS overlap with their spawning, nursery and feeding grounds. Furthermore, *Sphyrna lewini, Carcharhinus plumbeus, C. brevipinna, C. tjutjot, C. limbatus, C. sealei* and *C. sorrah* are listed as Endangered, Vulnerable or Near Threatened species [22] (Table 1). Newborn scalloped hammerhead shark individuals were commonly found in 4 of the 6 landing ports in the SSCS (Fig 2). Thus, the current fishing practices may lead declines in shark abundance to critical levels, which may lead to extinction of some species in the future. Furthermore, a number of newborn shark species were fished, suggesting that the populations of those sharks might also be threatened in the future.

Sharks are not targeted by fishers but are caught together with other commercially important species, such as mackerel, scad, sardine and tuna mainly by means of drift gill nets, bottom trawl nets and hook and line in the SSCS region [16, 28]. However, we found at least 28 shark species caught in the SSCS region and many of these sharks were represented by various developmental stages from newborn juveniles to adults at all landing ports. The observed catch suggests that young-of-the-year and fully mature sharks might be captured frequently in the SSCS area. Sharks are predominantly characterized as long-lived and slow-growing, and they produce few offspring. The International Union for Conservation of Nature and Natural Resources [22] reported that over half of the evaluated pelagic shark species are believed to be under threat from extinction [22]. These characteristics are associated with low productivity, close stock recruitment relationships, and long recovery times in response to overfishing.
Thus, an improvement in the species selectiveness of the fishing gears and strong enforcement for shark fishing are needed to protect and conserve sharks.

A number of incidents of shark finning and shark specimens without fins were found in the present study (Fig 7B and 7C), although sharks are not officially considered to be targeted by fisheries in the SSCS region. In the SSCS region, all parts of sharks such as meat, liver and fins are fully utilized as food and the inedible parts such as skin and teeth are used for ornamental products and souvenirs [35]. Information on world shark catches and usages is often inadequate and regionally incomplete, despite questions and arguments for sustainability and protection of shark fisheries globally [18, 36, 37]. Bycatch leads to high incidental shark catches, either from general multispecies fisheries or from large-scale to long-range fisheries that target high-value species [38]. Shark fisheries around the world are typically unmanaged and the details of their operations are often not well known. An increasing number of studies reveal shark populations are collapsing in different parts of the world such as the Atlantic Ocean [37–40], the Gulf of Mexico [41], and the Mediterranean Sea [42]. In Southeast Asia, however, most shark fisheries are scarcely documented although sharks are the most significant bycatch species in the region. A large knowledge gap exists regarding shark population trends within Southeast Asia, which is a region of intense human pressure, particularly through unregulated and unmanaged fisheries for sharks. Elasmobranches are not considered to be a highly-priced fishery product globally. Therefore, information related to their biology, fishery and landings is scarce or non-existent.

We observed that 28 shark species at various developmental stages (newborn, juveniles, to fully mature and almost delivering adults) were fished and landed as bycatch products in the SSCS region. The results suggest that the current disorderly fisheries practice might not be regulated and managed in the region for all shark species. Therefore, further fishing pressure can affect shark stock structure, diversity, and biological parameters and, in the worst of cases, could cause a species to become extinct in the future.

Materials and methods

We observed the sharks at the landing ports in the southern South China Sea (SSCS) between October 2014 and July 2017 (Fig 1). This study was conducted in six sites (states) in the Malaysian South China Sea areas of the eastern coast of the Peninsular Malaysia (West Malaysia) and the western coast of Borneo Island (East Malaysia) for four years (Fig 1). All study sites face the SSCS in Malaysia territorial waters, covering the four states, of Kelantan (5˚52´34" N, 102˚27´29" E), Terengganu (5˚19´20" N, 103˚7´43" E), Pahang (3˚47´13" N, 103˚19´1" E) and Johor (2˚38´29" N, 103˚39´41" E) in West Malaysia and two states, Sabah (5˚58´58" N, 116˚4´19" E) and Sarawak (5˚58´58" N, 116˚4´19" E) in East Malaysia (Fig 1). Specific permissions were granted from the Fisheries Department of Malaysia for the landing ports survey. Shark specimen collection at landing ports did not require permits in Malaysia. Our protocol was in accordance with the guide for animal experimentation of the Universiti Malaysia Terengganu (UMT) and Universiti Brunei Darussalam (UBD), and fish-handling approvals were granted by the animal experiment committees of UMT and UBD. In six sites, monthly surveys were conducted in Terengganu State for approximately four years between October 2014 and July 2017 to understand the spatial and temporal occurrence and diversity of sharks, and other states were sampled one-to-five times (months) during the four years. Overall, we conducted landing port surveys in four sites for 43 times (months) in West Malaysia and seven times at two sites in East Malaysia. All specimens were donated or purchased in the landing ports and were examined on-site at each landing port or were transported to a laboratory for observation. Sharks from SSCS were captured by commercial trawlers, purse seiners, and hook
and line fishing as part of the demersal fishery from the coasts to the edge of Malaysia’s Exclusive Economic Zone (EEZ) (Fig 1).

After the sharks were landed, biological parameters, such as total length (TL), body weight (BW) and sex, were measured and observed. We could measure TL for all specimens with fins in caudal and/or tail parts, while BW could not be measured for 74 specimens because the specimens were too heavy and/or their fins had been cut. Twenty external morphometric and meristic characteristics such as colour patterns, shapes, sizes and positions in each shark were measured and observed, and then species identification for each shark specimen was conducted according to Last et al. [25], Ahmad and Lim [43] and Ahmad et al. [44, 45]. During the four years, however we found a number of sharks without fins in caudal and/or tail parts in the East Malaysia (Sabah and Sarawak states); the specimens could not be identified to species level, and we excluded such specimens from the analysis (Fig 7B and 7C).

In Terengganu State, three species, the brownbanded bamboo shark *Chiloscyllium punctatum*, the spot-tail shark *Carcharhinus sorrah* and the Indonesian bamboo shark *Chiloscyllium hasseltii*, were the most dominant species. Their monthly fluctuation of abundance was examined using One-way ANOVA using SPSS (ver. 20.0; SPSS Inc., Armonk, New York, USA). For each variable, a Shapiro–Wilk test was performed to check the normality, and a Bartlett test to check the homoscedasticity. Data that fulfilled the normality and homoscedasticity assumptions were analysed through One-way ANOVA. The differences in the TL across months or years for each month in each sex were examined through a Kruskal-Wallis test in Terengganu State. Consequently, post hoc Mann-Whitney- *U* tests were employed for comparisons.

**Supporting information**

S1 Table. Shark species studied in this study.

(XLSX)

S2 Table. Numbers of size distributions of sharks landed in the southern South China Sea.

(XLSX)

**Acknowledgments**

We thank Dr. Ahmad Ali (The Southeast Asian Fisheries Development Center/Marine Fishery Research Development and Management Department) and Ms. Annie Lim Pek Khiok (Regional Fisheries Bio-security Centre, Sarawak) for their kind guidance in identifying sharks. We also express gratitude to Dr. Shuhadah Mustapha, Ms. Ainun Jariah Jeropakal and Mr. Jasper Mazlan Shadat (Department of Fisheries Sabah) and Messrs. Buniamin Kiprawi, Zaidi Abdullah and Yunus Hamid (Department of Fisheries Miri, Sarawak) for their kind support for conducting landing port surveys. Thanks are also due to Mss. Shi Ling Gan, Siti Raudah Abdul Kadir, Inn Ju Chai, Wan Yin Chai, Nik Hani Shahira Nik Shirajuddin and Sakinah Abdul Razak (Universiti Malaysia Terengganu) and Mss. Noorlela Md Yassin and Iy-Vonne Tan (Universiti Brunei Darussalam) for the assistance with the landing port survey. We also thank the two anonymous reviewers for their constructive comments, which helped us to improve the manuscript. This work was supported by the Higher Institution Centre of Excellence (HICoE) Research Grant (Grant No. 66928), under the Institute of Oceanography and Environment, Universiti Malaysia Terengganu and by Universiti Brunei Darussalam under the Competitive Research Grant Scheme (Grant No. UBD/OVACRI/CRGWG(003)).

**Author Contributions**

Conceptualization: Takaomi Arai.
Data curation: Takaomi Arai, Azie Azri.
Formal analysis: Takaomi Arai, Azie Azri.
Funding acquisition: Takaomi Arai.
Investigation: Takaomi Arai, Azie Azri.
Methodology: Takaomi Arai, Azie Azri.
Project administration: Takaomi Arai.
Resources: Takaomi Arai, Azie Azri.
Software: Takaomi Arai, Azie Azri.
Supervision: Takaomi Arai.
Validation: Takaomi Arai, Azie Azri.
Visualization: Takaomi Arai, Azie Azri.
Writing – original draft: Takaomi Arai.
Writing – review & editing: Takaomi Arai, Azie Azri.

References
1. Compagno L, Dando M, Fowler S. Sharks of the World. New Jersey: Princeton University Press; 2005. 496 pp.
2. Wetherbee BM, Cortés E. Food consumption and feeding habits. In Carrier JC, Musick JA, Heithaus MR, editors. Biology of Sharks and their Relatives. Florida: CRC Press; 2004. pp. 225–246.
3. Ferretti F, Worm B, Britten GL, Heithaus MR, Lotze HK. Patterns and ecosystem consequences of shark declines in the ocean. Ecol. Lett. 2010; 13: 1055–1071. https://doi.org/10.1111/j.1461-0248.2010.01489.x PMID: 20528897
4. Worm B, Davis B, Kettemer L, Ward-Paige CA, Chapman D, Heithaus MR. et al. Global catches, exploitation rates, and rebuilding options for sharks. Mar Policy 2013; 40: 194–204.
5. Dulvy NK, Fowler SL, Musick JA, Cavanagh RD, Kyne PM, Harrison LR. et al. Extinction risk and conservation of the world’s sharks and rays. Elife 2014; 3: e00590. https://doi.org/10.7554/eLife.00590 PMID: 24448405
6. Musick JA, Burgess G, Cailliet G, Camhi M, Fordham S. Management of Sharks and Their Relatives (Elasmobranchii). Fisheries 2000; 25: 9–11.
7. Clarke SC, McAllister MK, Milner-Gulland EJ, Kirkwood GP, Michiezens CG, Agnew D. et al. Global estimates of shark catches using trade records from commercial markets. Ecol. Lett. 2006; 9: 1115–1126. https://doi.org/10.1111/j.1461-0248.2006.00968.x PMID: 16972875
8. Herndon A, Gallucci VF, Demaster D, Burke W. The case for an international commission for the conservation and management of sharks (ICCMS). Mar Policy 2010; 34: 1239–1248.
9. McClanathan L, Cooper AB, Dulvy NK, Rethinking. Trade-Driven Extinction Risk in Marine and Terrestrial Megafauna. Curr Biol 2016; 26: 1640–1646. https://doi.org/10.1016/j.cub.2016.05.026 PMID: 27291051
10. IUCN. Intervention at General Fisheries Council for the Mediterranean-Tangiers. 2003.
11. Serrano R, Fernández M, Rabanal R, Hernández M, Gonzales MJ. Congener-specific determination of polychlorinated biphenyls I shark and grouper livers from the Northwest African Atlantic Ocean. Arch Environ Contam Toxicol 2000; 38: 217–224. PMID: 10629285
12. Strid A, Jóurundsdóttir H, Pápke O, Svavarsson J, Bergman Å. Dioxins and PCBs in Greenland shark (Somniosus microcephalus) from the North-East Atlantic. Mar Pollut Bull 2007; 54: 1514–1522. https://doi.org/10.1016/j.marpolbul.2007.04.018 PMID: 17570442
13. Hutchings JA. Collapse and recovery of marine fishes. Nature 2000; 406: 882–885. https://doi.org/10.1038/35022565 PMID: 10972288
14. Lotze HK, Lenihan HS, Bourque BJ, Bradbury RH, Cooke RG, Kay MC. et al. Depletion, degradation, and recovery potential of estuaries and coastal seas. Science 2006; 312: 1806–1809. https://doi.org/10.1126/science.1120351 PMID: 16794081

15. Polidoro BA, Brooks T, Carpenter KE, Edgar GJ, Henderson S, Sanciangco J. et al. Patterns of extinction risk and threat for marine vertebrates and habitat-forming species in the Tropical Eastern Pacific. Mar Ecol Prog Ser 2012; 448: 93–104.

16. Department of Fisheries Malaysia. Malaysia National Plan of Action for the Conservation and Management of Shark, Ministry of Agriculture and Agro-based Industry Malaysia, Putrajaya. 66 pp. IUCN, Gland, Switzerland and Cambridge, UK. iv + 39 pp (2006).

17. White WT, Kyne PM, Harris M (2019) Lost before found: A new species of whaler shark Carcharhinus obsolerus from the Western Central Pacific known only from historic records. PloS ONE 14(1): e0209387. https://doi.org/10.1371/journal.pone.0209387 PMID: 30601867

18. Lam VYY, Sadovy de Mitcheson Y. The sharks of South East Asia–unknown, unmonitored and unmanaged. Fish Fisher. 2011; 12: 51–74.

19. Ahmad A, Rosidi A, Solahuddin AR. Elasmobranch fishery, research and conservation in Malaysia. J Ocean 1999; 16: 92–101.

20. Ahmad A, Abdul Haris Hilmi AA, Gambang AC, Ahmad S, Solahuddin AR. Elasmobranch resources, utilization, and management in Malaysia. SEAFDEC/MFRDM/SP/8 2004.

21. Yano K, Ali A, Gambang AC, Hamid IA, Razak SA, Zainal A. Sharks and Rays of Malaysia and Brunei Darussalam. SEAFDEC-MFRDM/SP/12. 2005.

22. IUCN The IUCN Red List of Threatened Species. Version 2017.3. <http://www.iucnredlist.org>. Downloaded on 19 March 2018.

23. Bass AJ, Heemstra PC, Compagno LJV, Carcharhinidae. In: Smith MM, Heemstra PC, editors. Smiths’ Sea Fishes. Berlin Heidelberg Springer-Verlag; 1986. pp. 67–87.

24. Hövel A, Ommen S, Ziegler T. Keeping and breeding of the coral catshark (Atelomycterus marmoratus) at the Aquarium of the Cologne Zoo. Zool Garten 2010; 79: 243–253.

25. Last PR, White WT, Pongonski JJ. Sharks and Rays of BORNEO. Melbourne CSIRO Publishing; 2010. 304 pp.

26. Ahmad A, Annie LPK. Field guide to sharks of the Southeast Asian region. SEAFDEC-MFRDM/SP/18. 2012.

27. Lipa BJ, Barrick DE, Bourg J, Nyden BB. HF radar detection of tsunamis. J Oceanogr 2006; 62: 705–716.

28. Gambang AC. Bottom Longline Fishing in Sarawak Water by Commercial Bottom Longline Boats 26-9-95 to 15-10-95. Fisheries Research Institute, Sarawak 1994.

29. Bass AJ, D’auvrey JD, Kistnasamy N. Sharks of the east coast of Southern Africa. I. The genus Carcharhinus (Carcharhinidae). Investigational Report Oceanographic Research Institute 1973; 33: 1–168.

30. World Sea Temperature (2018) https://www.seatemperature.org/ (accessed 11 April 2018).

31. Knip DM, Heupel MR. Simpfendorfer CA. Sharks in nearshore environments: models, importance, and consequences. Mar Ecol Prog Ser 2010; 402: 1–11.

32. Knip DM, Heupel MR, Simpfendorfer CA. Habitat use and spatial segregation of adult spottail sharks Carcharhinus sorrah in tropical nearshore waters. J Fish Biol 2012; 80: 767–784. https://doi.org/10.1111/j.1095-8649.2012.03223.x PMID: 22471798

33. Carlisle AB, Starr RM. Habitat use, residency, and seasonal distribution of female leopard sharks Triakis semifasciata in Elkhorn Slough, California. Mar Ecol Prog Ser 2009; 380: 213–228.

34. Stevens JD, West GJ, McLoughlin KJ. Movements, recapture patterns, and factors affecting the return rate of Carcharhinid and other sharks tagged off Northern Australia. Mar Freshw Res 2000; 51: 127–141.

35. Department of Fisheries Malaysia. Malaysia National Plan of Action for the Conservation and Management of Shark (plan 2), Ministry of Agriculture and Agro-based Industry Malaysia 2014.

36. Rose DA. An Overview of World Trade in Sharks and Other Cartilaginous Fishes. TRAFFIC International 1996.

37. Baum JK, Myers RA, Kehler DG, Worm B, Harley SJ, Doherty PA. et al. Collapse and conservation of shark populations in the Northwest Atlantic. Science 2003; 299, 389–392. https://doi.org/10.1126/science.1079777 PMID: 12532016

38. Bonfil R. Overview of World Elasmobranch Fisheries. FAO Fisheries Technical Paper 1994.

39. Myers RA, Worm B. Rapid worldwide depletion of predatory fish communities. Nature 2003; 423: 280–283. https://doi.org/10.1038/nature01610 PMID: 12748640
40. Hutchings JA, Baum JK. Measuring marine fish diversity: temporal changes in abundance, life history and demography. Philos. Trans. Roy. Soc. 2005; 360: 315–338.

41. Baum JK, Myers RA. Shifting baselines and decline of pelagic sharks in the Gulf of Mexico. Ecol Lett. 2004; 7: 135–145.

42. Ferretti F, Myers RA, Serena F, Lotze HK. Loss of large predatory sharks from the Mediterranean Sea. Conserv. Biol. 2008; 22: 952–964. https://doi.org/10.1111/j.1523-1739.2008.00938.x PMID: 18544092

43. Ahmad A, Lim APK, Fahmi, Dharmadi. Field Guide to Sharks of the Southeast Asian Region. SEAFDEC/MFRDMD/SP/18 2012.

44. Ahmad A, Lim APK, Fahmi, Dharmadi, Krajangdara T. Field Guide to Look-alike Sharks and Rays Species of the Southeast Asian Region. SEAFDEC/MFRDMD/SP/22 2013.

45. Ahmad A, Lim APK, Fahmi, Dharmadi, Krajangdara T. Identification Guide to Sharks, Rays and Skates of the Southeast Asian Region. SEAFDEC/MFRDMD/SP/31 2017.

46. Compagno LJV. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Volume 2. Bullhead, Mackerel and Carpet Sharks (Heterodontiformes, Lamniformes and Orectolobiformes). FAO, 2001.

47. Compagno LJV. FAO Species Catalogue. Vol. 4. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Part 1—Hexanchiformes to Lamniformes. FAO Fish. Synop. 125, 1–249 (1984).

48. Compagno LJV, Last PR, Stevens JD, Alava MNR. Checklist of Philippine Chondrichthyes. Marine Laboratories Report 243 CSIRO, 2005.

49. Compagno LJV, Niem VH. Hemiscylliidae. Longtail carpetsharks. p. 1249–1259. In Carpenter K.E. and Niem V.H. eds. FAO identification guide for fishery purposes. The Living Marine Resources of the Western Central Pacific. FAO, 1998.

50. Allen GR, Erdmann MV. Reef fishes of the East Indies. Perth, Australia: University of Hawai’i Press, Volumes I-III. Tropical Reef Research 2012.

51. Weigmann S. Annotated checklist of the living sharks, batoids and chimaeras (Chondrichthyes) of the world, with a focus on biogeographical diversity. J Fish Biol. 2016; 88: 837–1037. https://doi.org/10.1111/jfb.12874 PMID: 26860638

52. Riede K. Global register of migratory species—from global to regional scales. Final Report of the R&D-Projekt 808 05 081. Federal Agency for Nature Conservation, Germany, 2004.

53. Last PR, Stevens JD. Sharks and Rays of Australia. Second Edition. CSIRO Publishing, 2009.

54. Ferretti F, Myers RA, Serena F, Lotze HK. Loss of large predatory sharks from the Mediterranean Sea. Conserv. Biol. 2008; 22: 952–964. https://doi.org/10.1111/j.1523-1739.2008.00938.x PMID: 18544092

55. White WT, Last PR, Stevens JD, Yearsley GK, Fahmi, Dharmadi. Economically important sharks and rays of Indonesia. Australian Centre for International Agricultural Research Australia, 2006.

56. Compagno LJV, Niem VH. Family Carcharhinidae. Requiem sharks. In Carpenter KE, Niem VH eds. The Living Marine Resources of the Western Central Pacific. Volume 2: Cephalopods, crustaceans, holothurians and sharks. FAO Species Identification Guide for Fishery Purposes. FAO, 1998.

57. Last PR, Stevens JD. Sharks and rays of Australia. (CSIRO, 1994).

58. Florida Museum of Natural History. Biological profiles: blacktip shark. Retrieved on 26 August 2005, from www.fmmh.ufl.edu/fish/Gallery/Description/BlacktipBlacktipshark.html. Ichthyology at the Florida Museum of Natural History: Education-Biological Profiles University of Florida, 2005.

59. Myers RF. Micronesian reef fishes: a comprehensive guide to the coral reef fishes of Micronesia, 3rd revised and expanded edition. Coral Graphics Guam, 1999.