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Evidence of hawksbill turtle (*Eretmochelys imbricata*) depredation on fish caught in gillnets

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Bycatch is a major global threat to marine megafauna and occurs in nearly all fishing fleets, including small-scale fisheries that use gillnets. Gillnets represent a threat to endangered air-breathing megafauna, who incidentally entangle in bottom-set gillnets and suffocate after being attracted by bait that is secured on fishing gear. We here provide the first evidence that hawksbill turtles feed on trapped fish in gillnets, suggesting that potential prey items trapped in gillnets may act as additional bait, attracting carnivorous sea turtles towards this threat. This overlooked depredating behaviour potentially explains and increases the likelihood of critically endangered hawksbill turtle bycatch in gillnet fisheries, calling for technological and management solutions.

KEYWORDS
incidental bycatch, food source, small-scale fishery, depredation, sea turtle, marine megafauna bycatch, marine megafauna

Main body

Incidental take, i.e., the bycatch of marine megafauna, occurs in nearly all fishing fleets and is of growing global concern (Baum et al., 2003; Lewison et al., 2004; Lewison and Crowder, 2007; Peckham et al., 2007; Rees et al., 2016). Recent research reveals that marine migratory megafauna, including cetaceans (Brownell et al., 2019), elasmobranchs (Temple et al., 2018) and sea turtles (Wallace et al., 2013a), frequent coastal areas within the range of small-scale fisheries, potentially increasing the likelihood of producing high levels of bycatch (Block et al., 2005; James et al., 2005) and/or depredation, i.e., the predation of fish trapped by fishing gear while the gear is still in the water (Fader et al., 2021). The deployment of gillnets is a typical technique used in small-scale fisheries, yet this technique poses lethal threats to marine mammals (Muir and Kiszka, 2012; Temple et al., 2019), elasmobranchs and batoids (Temple et al., 2018), and sea turtles (Lewison and Crowder, 2007; Peckham et al., 2007). The magnitude of these threats can be seen in the International Union for Conservation of Nature (IUCN) Red List status for sea turtles, listing 6 out of 7 as vulnerable [Olive Ridley Turtle (Abreu-Grobois et al., 2008), Leatherback Turtle (Wallace et al., 2013b), Loggerhead Turtle (Casale and Tucker, 2017)], endangered [Green Turtle, (Seminoff et al., 2004)], or critically endangered [Kemp's Ridley (Wibbels and Bevan, 2019), Hawksbill Turtle (Mortimer and Donnelly, 2008)]. Despite having historically been hunted for trading purposes, hawksbill sea turtles worldwide are now particularly susceptible to being entangled within marine debris (including fishing gear), as well as mistakenly ingesting it (Mortimer and Donnelly, 2008).

The importance of hawksbill sea turtles as keystone species for reef and seagrass ecosystems has been highlighted before (Jackson, 1997), and reductions to their population have been hypothesised to cause pivotal effects on these ecosystems, due to their role as marine grazers (León and Bjorndal, 2002). *E. imbricata* is considered an

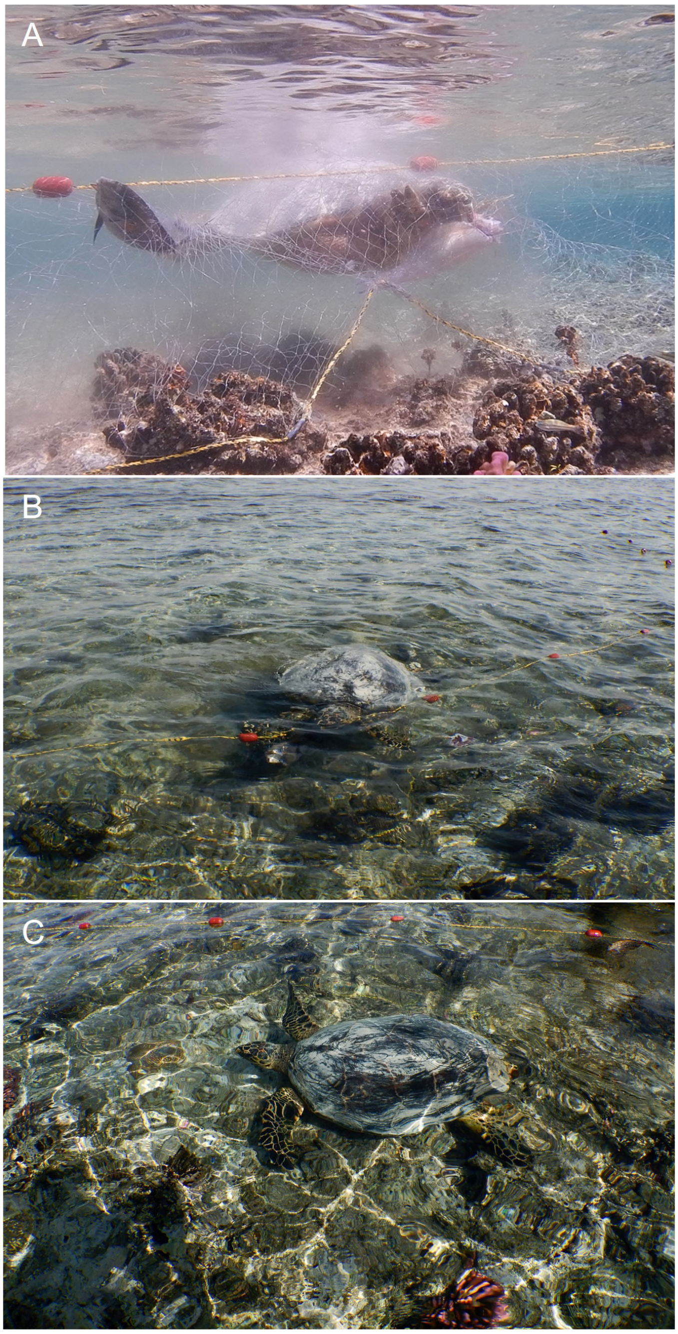

FIGURE 1
(A) Hawksbill sea turtle (*Eretmochelys imbricata*) depredating sohal surgeonfish (*Acanthurus suhal*) trapped in gillnet; **(B)** *E. imbricata* disentangling from gillnet; **(C)** *E. imbricata* swimming along gillnet to the next caught fish. Photos were taken by Yusuf C. El-Khaled.

omnivorous species (Bjorndal, 2017), with behavioural observations (Blumenthal et al., 2009), stomach content analyses (Carr and Stancyk, 1975), oesophageal lavage (Forbes, 1999), and stable isotope analyses from blood plasma and skin tissue (Clyde-Brockway et al., 2022) all showing that hawksbill sea turtles feed on benthic (e.g., sponges, tunicates, ascidians; León and Bjorndal, 2002; Blumenthal et al., 2009; Carríon-Cortez et al., 2013) or pelagic (jellyfish; Blumenthal et al., 2009) invertebrates and macroalgae (Carr and Stancyk, 1975; León and Bjorndal, 2002). Only anecdotal reports exist that document hawksbill sea turtle hatchlings or captive adults, where they were found to feed on fish fillet pieces provided in an experimental setup (Witzell, 1983; Mellgren et al., 1994).

Here, we report the first visual evidence of hawksbill turtles engaging in the natural depredation of fish trapped in gillnets (Figure 1A, Supplementary Video 1). Our observation was made at Rabigh beach, Saudi Arabia, in the Central Red Sea on the 20th of January 2023 at 12:20 pm, where a gillnet was deployed by local fishermen on a reef flat (30 to 80 cm water depth covering an area of approx. 30 x 30 m, water temperature: 26°C). The turtle, which was approximately 50 to 70 cm long, was observed an hour after low tide [low tide: 11.12 am (GASGI, 2023)]. This observation is of particular importance for two reasons: firstly, we were able to document that hawksbill turtles have a broader dietary range that exceeds herbivory, spongivory or jellyfish carnivory (Naro-Maciel et al., 2008), with piscivory being part of it. Thus far, only a few anecdotal observations have indicated that *E. imbricata* may consider fish a food source when provided as size-chopped pieces to captive individuals (Witzell, 1983) or as hatchlings (Mellgren et al., 1994), with no prior knowledge or direct evidence of piscivory of wild individuals. Secondly, we observed that an individual *E. imbricata* was able to disentangle itself from the gillnet after having fed on a trapped fish (Figure 1B) before swimming along the deployed gillnet to continue its depredation of fish trapped in the net (Figure 1C). Personal communication with the fishermen who deployed the gillnets confirmed that both the feeding on trapped fish and the ability to disentangle itself are well-known for this sea turtle species among local fishermen in the Central Red Sea (El-Khaled 2023, personal communication). Therefore, we suggest that trapped fish are a previously overlooked food source for hawksbill turtles, which is outside of their regular diet, presumably due to the Hawksbill's limited capacity to hunt them in the wild. We hypothesize that our observations provide a mechanism to explain the active attraction of hawksbill sea turtles to gillnets through depredation opportunities, with its catch acting as additional bait to attract the turtles. Ultimately, this may contribute to hawksbill sea turtle mortality as bycatch, although the significance of fish depredation from gillnets to the diet of hawksbill sea turtles regionally remains unknown and warrants future investigation.

Hence, the (regular) deployment of gillnets may have unintended consequences. Several studies indicate that multiple sea turtles species, such as hawksbill (Wood et al., 2017), loggerhead (Hawkes et al., 2011) and green turtles (Christiansen et al., 2017), can navigate within familiar reaches of their home range where their prey distribution is well-known. As such, hawksbill sea turtles could regularly engage in this depredation behaviour by collecting fish from bottom-set gillnets, despite the high risk of entanglement and ending up as bycatch. Deploying gillnets outside of regular hawksbill habitats could minimise the risk of sea turtle bycatch.

In conclusion, the disentanglement behaviour observed here represents a first observation, adding to recent evidence of limb use by hawksbill turtles when feeding (Fujii et al., 2018), in this case, to catch the entangled prey while disentangling themselves from the gillnet. The extent to which these patterns could apply to further sea turtle species remains to be determined. Ultimately, the observed behaviour contributes to the urgent need for i) practical and affordable solutions (i.e., bycatch reduction technologies, BRTs; Lucas and Berggren, 2023) and ii) management approaches to reduce the risk of bycatch in gillnet fisheries. Bycatch reduction may be achieved using selective deterrent devices (reviewed in Lucas and Berggren, 2023). For instance, BRTs that have been evaluated and discussed recently involve the deployment of illuminated gillnets with light-emitting diodes (LEDs), chemical lightsticks, or ultraviolet light (Wang et al., 2010; Wang et al., 2013), which may selectively deter unwanted bycatch, such as sea turtles. Recent studies demonstrate that gillnets equipped with green or ultraviolet LEDs can significantly reduce loggerhead and green turtle bycatch (Wang et al., 2010; Wang et al., 2013; Ortiz et al., 2016; Virgili et al., 2018) and seem to be particularly promising for future investigations and management implementations (Lucas and Berggren, 2023). However, knowledge about the potential benefitting effect of LED-equipped gillnets for hawksbill sea turtles is particularly scarce. The extent to which illuminated gillnets are beneficial, or having the undesired effect of attracting hawksbill sea turtles is not known, despite their overall successes in a few studies (Cox et al., 2007; Lucas and Berggren, 2023).

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Materials. Further inquiries can be directed to the corresponding author.

Ethics statement

Ethical approval was not required for the study involving animals with the local legislation and institutional requirements as the individuals were observed in their natural environment with fishing devices being used by local fishermen without intentional preparation or placement by the authors.

Author contributions

YE-K wrote the manuscript with significant contributions of CD and RP. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2023.1180219/full#supplementary-material

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