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Citizen science highlights rare behaviours by the spotted eagle ray *Aetobatus ocellatus* Kuhl 1823

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Introduction

The Spotted Eagle Ray *Aetobatus ocellatus* (Kuhl 1823) is the largest member of the Aetobatidae family reaching 300 cm disc width (DW) (Last et al., 2016), but little is known about the ecology of this species. *Aetobatus ocellatus* is distributed throughout the Indo-West Pacific and possess k-selected life history traits, such as slow growth and late maturity (Schluessel et al., 2010), which render this species susceptible to overexploitation. In parts of its range, for example in Borneo, *A. ocellatus* is commonly caught in coastal fisheries including trawlers and demersal longlines (Last et al., 2010). Such threats have led to inferred population declines of 50-79% over the last three generations (39 years) across much of its range, resulting in *A. ocellatus* being uplisted to Endangered in the recent IUCN Red List of Threatened Species assessment (Finucci et al., 2024). Given the magnitude of these threats to the species, it is necessary to identify critical habitats essential for management and conservation.

Due to their evasive nature, behavioural observations of *A. ocellatus* can be logistically challenging to obtain. To date, ten distinct behaviours of *A. ocellatus* have been described, with the predominant behaviours being swimming, foraging, chafing, cruising and escaping threats (Berthe et al., 2018). Chafing in *A. ocellatus* has been reported in French Polynesia and inferred as a behaviour to rid itself of parasites (Berthe et al., 2017), likely analogous to cleaning behaviour associated with cleaning stations that has been observed in other elasmobranch species, such as the Oceanic Manta Ray *Mobula birostris* and the Reef Manta Ray *M. alfredi* (Jaine et al., 2012; O'Shea et al., 2010; Barr and Abelson, 2019). Escaping is

an avoidance behaviour in response to swimmers or close vessel approaches or loud boat engine noise (Berthe and Lecchini, 2016). In response to disturbance or a predator, eagle rays speed-up and swim away from the threat (Berthe and Lecchini, 2016), which is likely to incur an energetic cost. Recovery from these excursions may take the form of resting behaviour, as documented in *A. narinari* in Belize (Flowers and Kelley, 2020) and the Bahamas (Silliman and Gruber, 1999) where rays were recorded as being completely stationary on the substrate for prolonged periods of time. Although the drivers of this resting behaviour remains unknown, this behaviour does suggest that pelagic eagle rays utilise benthic environments for purposes beyond foraging.

Understanding the behaviour of wide-ranging and evasive elasmobranchs is not trivial and tends to be both resource and time intensive. Citizen science can complement dedicated research efforts by increasing the amount of in-water survey effort and thus data produced (Chin and Pecl, 2018; Bateman et al., 2024). For batoid species, citizen science has been used to understand the connectivity of reef manta rays *Mobula alfredi* across the Indonesian archipelago (Germanov and Marshall, 2014), to discern the range and occurrence of the rare ornate eagle ray *Aetomylaeus vesperilio* (Araujo et al., 2020a), and to understand the occurrence and abundance of 11 species in the Canary Islands (Tuya et al., 2021), amongst others. Behavioural studies have also made use of citizen science, for example, in the Philippines to

understand the philopatric behaviour of whale sharks *Rhincodon typus* (McCoy et al., 2018), and in Fiji to measure the effects of provisioning on the occurrence and abundance of sharks (Ward-Paige et al., 2020). Citizen science can therefore play a key role in our understanding of threatened and rare species, including shedding light on their elusive behaviours.

Here, we present eight examples of previously unreported resting behaviour by *A. ocellatus*, six of which are from Australia, in Ningaloo Reef, Western Australia, and at Lady Elliot Island (LEI) and Mooloolaba in Queensland (Figure 1), with additional observations from both the Maldives and Japan (Table 1). Additionally, we report resting individuals also engaging in cleaning behaviour in association with the blue-streak cleaner wrasse *Labroides dimidiatus* Valenciennes 1839, the moon wrasse *Thalassoma lunare* Linnaeus 1758 and the schooling bannerfish *Heniochus diphreutes* Jordan 1903.

Methods and results

Observations of resting and cleaning behaviours by *A. ocellatus* were sourced and collated from social media posts, outreach and existing citizen science initiatives, including Fin Focus Research that invites photo submissions of elasmobranchs from recreational ocean users and ecotourism industry crew while

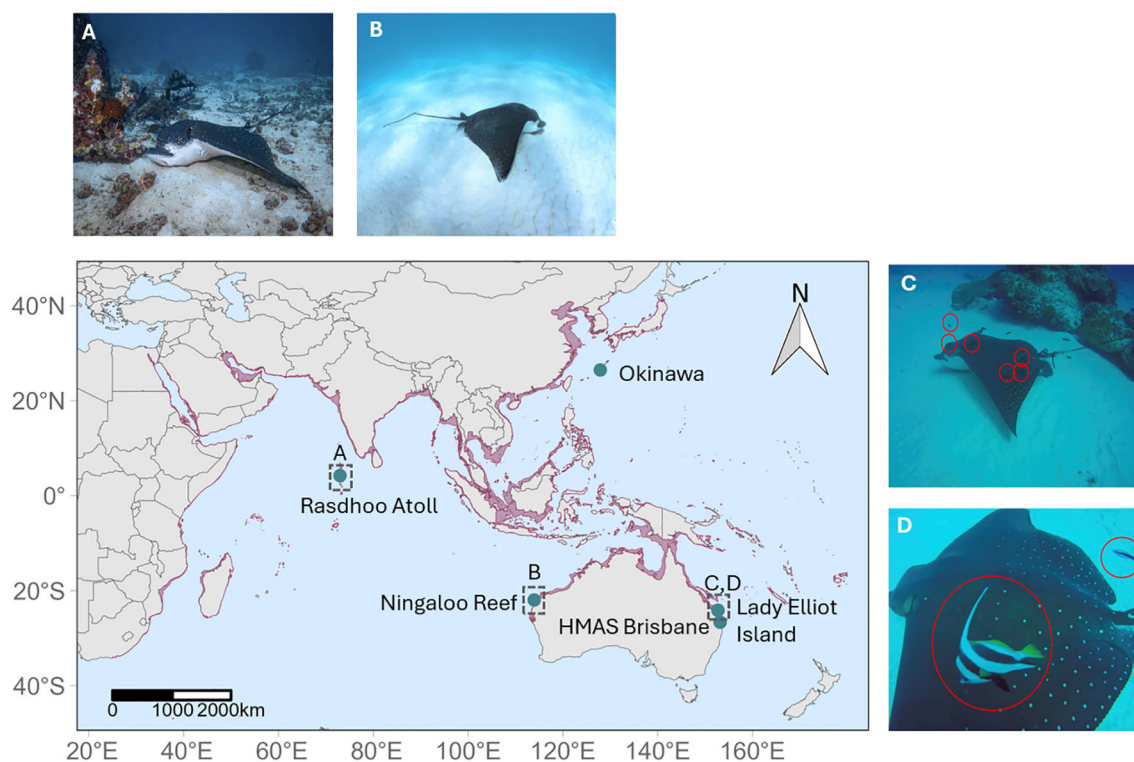


FIGURE 1
Map and examples of resting and cleaning behaviour of the Spotted Eagle Ray *Aetobatus ocellatus*. The highlighted areas indicate the known range of the species (IUCN Red List of Threatened Species, Finucci et al., 2024) and points indicate recorded observations of resting behaviour. Example photographs of resting behaviour are from (A) Rasdhoo Atoll, Maldives, (B) Ningaloo Reef, Australia, (C, D), Lady Elliot Island, Australia. Note the red circles in (C, D) highlight the cleaner fish species identified in association with *A. ocellatus*: the blue-streak cleaner wrasse *Labroides dimidiatus*, the moon wrasse *Thalassoma lunare* and the schooling bannerfish *Heniochus diphreutes*.

TABLE 1 Location of resting Spotted Eagle Rays *Aetobatus ocellatus* and further information collected where available.

| Date | Location | Time | Depth (m) | DW (cm) | Sex | Cleaning behaviour |
|------------|---------------------------------------|-------|-----------|---------|-----|--|
| 07/06/2018 | Lady Elliot Island, Qld, Australia | 7:30 | 17 | 150 | F | Y |
| 17/06/2020 | Northern Ningaloo Reef, WA, Australia | 13:30 | 5 | 150 | F | N |
| 27/12/2020 | Lady Elliot Island, Qld, Australia | 11:30 | 7 | 130 | M | Y |
| 21/10/2021 | North of Coral Bay, WA, Australia | N/A | 4 | N/A | M | N |
| 17/12/2021 | Mooloolaba, Qld, Australia | N/A | 27 | 150 | F | Y – no current present during this encounter |
| 11/07/2022 | Northern Ningaloo Reef, WA, Australia | 14:20 | 6 | <100 | M | N |
| 15/06/2022 | Rasdho, Maldives | N/A | 17 | N/A | N/A | Cleaner wrasse present in photo. |
| 29/06/2022 | Okinawa, Japan | N/A | 9 | 130 | M | Y |

DW, estimated disc width reported by observers. N/A, not available.

on tour (see <https://www.facebook.com/finfocusresearch>). Where possible, observers recorded estimate disc width (in m), behaviour and sex. From the collected footage, cleaner fish species were visually identified using Allen et al. (2003) and validated through FishBase (www.fishbase.org).

Here we describe six of the eight reported examples of resting *A. ocellatus* for which further information was available (Table 1). On 07 June 2018 at 7:30 am (moon irradiance 40%, low tide c. 9:10 am) a female *A. ocellatus* was observed resting at ‘Lighthouse Bommies’ in LEI (24.11 S, 152.71 E) albeit no depth information was provided. While resting, this individual was also being cleaned by three species of fish: blue-streak cleaner wrasse *Labroides dimidiatus*, the moon wrasse *Thalassoma lunare* Linnaeus 1758 and the schooling bannerfish *Heniochus diphreutes* Jordan 1903 (Figure 1C). This individual was visually estimated at 150 cm DW and 230 cm total length. The ray departed following collection of photo-ID footage. Similarly, on 17 June 2020, at 1:30 pm (moon irradiance 14%, low tide c. 2:30 pm) at ‘Ranger Bommies’ on the Ningaloo Reef (21.93 S, 113.94 E; Figure 1B), an *A. ocellatus* female individual was observed resting on the substrate at c. 5 m depth, visually estimated at 150 cm disc width (DW) and total length of 230 cm (Figures 1A, B). There was no predator (i.e., shark or cetacean) noted within the vicinity of the resting eagle ray.

On 27 December 2020 at 11:30 am (moon irradiance 94%, low tide c. 12:50 pm) at ‘Lighthouse Bommies’ on LEI (Figures 1C, D) a male *A. ocellatus* was observed resting on the substrate at c. 7 m depth, visually estimated at 130 cm DW. Upon close inspection, this individual ray was being cleaned by a blue-streak cleaner wrasse *L. dimidiatus* Valenciennes 1839. A fourth observation was filmed and reported on 21 October 2021 at c. 9:30 am (moon irradiance 99.9%, low tide c. 4:45 am) from ‘Mooch Patch’ in approximately 4 m depth north of Coral Bay (22.91 S, 113.77 E) on the Ningaloo Reef. The male *A. ocellatus* was observed resting (with a remora on the substrate behind the ray) for a few minutes, and when the observer dived down adjacent to the ray it slowly rose and swam away. No other information was recorded for this encounter.

A fifth observation was made at the HMAS Brisbane dive site in Mooloolaba, Queensland, on 17 December 2021 at 9:30 am (moon irradiance 97.5%, low tide c. 1:30 am). The ray was resting at 27 m whilst getting cleaned by at least four blue-streak cleaner wrasse *L. dimidiatus* (Supplementary Figure 1). A sixth observation was made at 2:20 pm on 11 July 2022 (moon irradiance 92.8%, low tide c. 2:39 pm), again at ‘Ranger Bommies’ on the Ningaloo Reef during a snorkel ecotour. A male *A. ocellatus* was observed resting on the substrate at c. 6 m depth, visually estimated at >100 cm DW, with a large Bottlenose Wedgefish *Rhynchobatus australiae* also seen resting approximately 5 m away. The photographer making the observation dived down very close to the *A. ocellatus* for photographs, and no cleaner fish were observed. As the diver ascended and broke the surface, the ray began to move away. A female zebra shark *Stegostoma tigrinum* was also observed resting at the same site during the snorkel.

On 15 June 2022, a seventh observation was reported in Rasdho atoll, Maldives (moon irradiance 99.8%), of a resting *A. ocellatus*. Although at least two blue-streak cleaner wrasses can be observed in the photo, we cannot assume active cleaning was taking place. An eighth observation was reported from Diamond Beach, Okinawa, Japan, on 29 June 2022, of a resting *A. ocellatus* at 9 m depth. The ray was also getting cleaned by at least two blue-streak cleaner wrasse *L. dimidiatus* (see Supplementary Video 1).

Discussion

The resting behaviour of benthopelagic rays is not fully understood, nor well documented. For which size was estimated herein were adult-sized (100–150 cm DW; Last et al., 2016; Schluessel et al., 2010). There are several plausible hypotheses for the observed resting behaviour. The first, is that resting behaviour is a result of post-copulatory or post-courtship behaviour. This explanation seems unlikely, however, given the lack of mating scars on the three confirmed female *A. ocellatus* reported here, and that courtship/copulation usually involves the male grasping or biting the female (Berthe, 2017; McCallister et al., 2020). A second theory, is that eagle

rays might rest for short periods of time before foraging in the sand (Smith and Merriner, 1985) or potentially after feeding. Matern et al. (2000) suggest that feeding on deeply burrowed prey items may be energetically demanding, and that Bat Rays *Myliobatis californicus* feed in shallow, warm waters and subsequently move to rest in cooler water, potentially acquiring metabolic or reproductive benefits. Furthermore, Flowers and Kelley (2020) noted that the resting *A. narinari* had sand streaks on its dorsum, which they generate during foraging with sediment jetting through their spiracles, further highlighting the likelihood of this as post-foraging behaviour. Finally, resting behaviour may be a form of predator avoidance, as reported in French Polynesia (C. Berthe, pers. comm.). A decrease in activity can lower the probability of an animal being predated upon (Werner and Anholt, 1993; Gerritsen and Strickler, 1977), by reducing the probability of being detected or encountered (Lima, 1998); by remaining stationary, the ray may be able to exercise vigilance against potential predators by scanning its environment for the presence of predators. This may allow the animal to avoid or delay a flight response, therefore reducing the energetic costs associated with fleeing a predator (Møller and Erritzøe, 2014), albeit *A. ocellatus* have a dark dorsal colouration and tend to forage in sandy substrates. Given the high costs of escape behaviour, an alternative theory is that these observations may represent resting behaviour following an escape from a predator (Heithaus and Vaudo, 2012). Further research is needed, however, to elucidate the energetics of predator-prey interactions involving *A. ocellatus*, as suggested by Ajemian et al. (2012). Although no predators (e.g. large sharks such as hammerhead sharks) were observed in the cases presented here, their presence in these locations is not uncommon (MacNeil et al., 2020). It should be noted that humans were in-water in the vicinity of the rays during the behaviours reported herein, and short-term behavioural responses of elasmobranchs to humans have been documented (e.g. whale sharks, Araujo et al., 2017; reef sharks, Bradley et al., 2017; manta rays, Murray et al., 2020), as it has for *A. ocellatus* (e.g. Berthe and Lecchini, 2016).

In the Galápagos, Pacific eagle rays (*Aetobatus laticeps*) have also been observed resting with no obvious indication of the drivers (D. Pazmiño, pers. comm.). Our observations corroborate that observed for *A. narinari* in Belize (Flowers and Kelley, 2020) and indicate a possible association with cleaning behaviour. To confirm the drivers of these behaviours, future research needs to move beyond opportunistic observations. One tractable avenue could be to combine the use of accelerometer tags with animal-borne cameras (e.g. Huvneers et al., 2018) to help elucidate the drivers of eagle ray behaviour. For example, a complete decline in overall dynamic body acceleration (ODBA) following a rapid increase could indicate a predator avoidance, or a routine ODBA followed by a complete stop could indicate a resting period following an extended period of foraging. The camera footage could then ground truth the drivers of these behaviours for *A. ocellatus*, as has been performed on manta rays (Stewart et al., 2019).

Our observations of resting *A. ocellatus* also show cleaning behaviour on four occasions – likely five if counting the Maldives

report – both from LEI, Mooloolaba and Japan. It remains unclear whether the cleaning was opportunistic, or whether the resting in association with cleaning is common behaviour. Cleaner-client associations have been documented for various species elasmobranchs, like the reef manta ray *Mobula alfredi* Krefft 1868 (Kashiwagi et al., 2011) and the pelagic thresher shark *Alopias pelagicus* (Nakamura, 1935; Oliver et al., 2011). In the Indo-West Pacific the moon wrasse *T. lunare* and blue-streaked cleaner wrasse *L. dimidiatus* are often the main cleaner species (e.g. Araujo et al., 2020b), though other species like the schooling bannerfish *H. diphreutes* are also common. Their ecological role is important for healthy communities as they remove ectoparasites, dead tissue or mucus (Côté, 2000). The relationship between *A. ocellatus* and cleaning stations has not been thoroughly assessed, yet our results herein highlight the species' association with healthy reef communities, and habitat use of reef ecosystems beyond the simple need to forage. Further research is necessary to determine their fidelity to specific cleaning stations, like that observed in reef manta rays for example (Venables et al., 2020), and whether resting behaviour is indeed closely associated with cleaning. The cleaning and resting behaviour reported from Mooloolaba, Australia, noted no current present during the encounter, which raises the question whether resting behaviour during cleaning interactions could be attributable to a lack of current (NM, pers. obs.).

The observations reported here highlight the value of citizen science for documenting elasmobranch behaviour in the wild. Although further research is required to fully understand the drivers of resting behaviour in *A. ocellatus*, we can continue to engage members of the general public to contribute rare and interesting observations that shed light on the behavioural ecology of elusive elasmobranchs.

Data availability statement

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

Ethics statement

Ethical approval was not required for this study involving animals in accordance with the local legislation and institutional requirements. No animal was restrained for this study and observations were non-invasive and opportunistic in nature, made by citizen scientists.

Author contributions

GA: Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing, Conceptualization, Data curation,

Formal analysis, Funding acquisition, Investigation. RB: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. JS: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. CG: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. NM: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. DW: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. JR: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. AJ: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. KS: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. EL: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

Author NM is the owner of Nigel Marsh Photography. Author DW was employed by company Ningaloo Discovery. Author JR was employed by company Sail Ningaloo. Author AJ is the owner of OceanAimee Photography. Author KS was employed by the company Heppoko Taylor Inc.

The remaining 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.2024.1406803/full#supplementary-material>

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