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Research article

How does crowd size impact behaviour of elasmobranchs in a touch pool exhibit?

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Abstract
Touch tanks are a feature in a number of zoos and aquariums, but the usage of these interaction-based exhibits may create concerns for animal welfare. It is unclear whether or not touch tanks have a negative impact on shark and ray wellbeing. The purpose of this study is to examine the behaviour of animals based on crowd size in the Shark and Ray Bay touch pool exhibit at the Aquarium of Niagara. Data were collected from November 2022 until January 2024 via the exhibit's security camera to observe exhibit use by whitespotted bamboo sharks *Chiloscyllium plagiosum*, Atlantic stingrays *Hypanus sabinus* and yellow stingrays *Urobatis jamaicensis*. We collected data for 5 minutes per hour throughout the Aquarium's open hours multiple times per week. All three species spent significantly less time on the ledge, where visitors could touch them, when crowd sizes were high. The results were particularly strong for both ray species. These patterns should be taken into consideration when structuring touch tank activities to enhance welfare of the animals involved. We provide suggestions for zoological facilities that still house animals in touch pools to ensure that their welfare needs are being achieved to the highest standard.

Introduction

Conservation education has become an integral component of modern zoos and aquariums. This type of outreach facilitates individual changes in behaviour by creating a connection between the public and the natural world (Ardoin et al. 2020). Zoological facilities have the unique ability to spread conservation messaging, as zoos and aquariums attract over 700 million visitors a year globally (Gusset and Dick 2011). Various strategies for conservation education are utilised across facilities, including community outreach, zookeeper talks and animal encounters (Schilbert and Scheersoi 2023). One of the most popular means of education across zoological facilities is the use of ambassador animals, which create a direct experience with visitors from a wide array of backgrounds. Ambassador animals can be defined as animals that directly interact with the public through education and conservation messaging, allowing for visitors to personally connect with and appreciate species they will most likely never see in a wild setting (Rank et al. 2021). Species such as cheetahs *Acinonyx jubatus* are trained to participate in educational demonstrations to inspire pro-conservation attitudes in visitors (Whitehouse-Tedd et al. 2022). Smaller species may participate in direct contact sessions with visitors, as seen with guinea pigs *Cavia porcellus* (Powell et al. 2020). However, recent studies suggest that the presence of ambassador animals is not effective when it comes to changing visitor attitudes towards conservation, which may have implications for the use and welfare of ambassador animals in education programs (Kirsch et al. 2024).

Ambassador animal welfare has begun to receive considerable attention, as these animals are frequently on display and interacting with visitors. Animal welfare, specifically in zoological facilities accredited by the Association of Zoos and Aquariums (AZA), has been described as the physical, emotional

and mental states of an animal over a period of time (Veasey 2022). Species across taxa are considered ambassador animals, each with their own welfare and husbandry needs (Martin et al. 2024). In order to assess animal welfare, zoos have created species-specific approaches to indicate positive or negative welfare (Tallo-Parra et al. 2023).

Most animal welfare assessments follow the consistently updated Five Domains model, which focuses on an animal's nutrition, environment, health, behaviour and mental domain (Mellor et al. 2020) as welfare indicators. Guidelines from various zoo accrediting organisations broadly support use of the Five Domains model, though they differ in specific recommendations. The World Association of Zoos and Aquariums (WAZA) provides some over-arching guidelines and recommendations for animal-visitor-interaction (AVI) which focus on the Five Domains model (WAZA 2020). AVI should always include careful monitoring of animal welfare, provide for the safety of visitors, staff, and volunteers, and include clear and appropriate education messaging. WAZA offers recommendations, and while there are no universal regulations governing touch tank interactions, each country has specific laws, and each zoo organisation offers guidelines to facilitate appropriate interactions.

BIAZA (2025), the British and Irish Association of Zoos and Aquariums, notes that all contact activities must ensure animal welfare, be guided by trained staff or volunteers, and focus on ethical and appropriate messaging. In May of 2025, the UK passed legislation prohibiting use of vertebrates, crabs, and cephalopods in touch tanks (Pinkstone 2025). The UK has long been a leader in animal welfare, and such legislation aims to enhance welfare of these specific taxa. While other nations may develop similar guidelines, as of this writing, the UK is the only country to enact such legislation.

The European Association of Zoos and Aquariums (EAZA) similarly supports the Five Domains model and states, "Any direct physical contact between animals and the visiting public only to be under the control of zoo staff or trained volunteers and for periods of time and under conditions consistent with the animal's welfare and not leading to their discomfort." (EAZA 2024). The AZA (the zoo accrediting body under which the current study takes place) recommendations focus on the risk of zoonotic disease transmission, and advise hand-washing following contact (AZA 1997), and further require member institutions to establish their own policies for ambassador animals (which includes animals in touch tanks). Conservation education recommendations emphasize the importance of clear messaging in any programs involving contact (AZA 2022).

These guidelines and recommendations, however, have historically been focused on charismatic mammals and less towards other non-mammal ambassador species such as fish and invertebrates (Oldfield and Bonano 2024). Recent research suggests that most fish have the ability to recognize positive or negative welfare experiences (Smith 2023). Koi *Cyprinus rubrofuscus* have been observed to seek out physical human interaction and will display individual levels of interaction, which indicate positive welfare (Fife-Cook and Franks 2021).

Traditional approaches to researching animal welfare and behaviour have relied on in person observations. With the growth of webcam use in zoos for education and outreach, some researchers have begun to capitalize on this technology for research purposes. While zoological facilities may have installed webcams in specific exhibits for increased public engagement, this technology can also be utilized for remote data collection. Webcam observations have the potential to reduce disturbance as well as provide data over longer observation periods than would be possible via live observations (Wood et al. 2025).

Across aquatic species, there are relatively few studies focused on animal welfare in touch pools. Touch pools are a popular interactive exhibit found in some zoos and aquariums, in which visitors can directly touch aquatic ambassador species. These exhibits are typically monitored by staff or volunteers and accessible to all visitors, allowing for educational messaging about marine life to be wide-reaching (Ogle 2016). Common animals found within touch pools include a variety of elasmobranchs (Ito et al. 2017). Many elasmobranchs such as sharks and stingrays are often portrayed negatively in popular media - their presence in touch pools allows visitors to have a personal interaction with these animals, which in turn can influence conservation attitudes (Hancock et al. 2024). Limited research available on elasmobranchs found in touch pools suggests that these animals may be impacted by human interaction, either positively or negatively, which has implications for welfare. Larger ray species have been observed to seek out interactions with visitors, either for the purpose of food or physical contact (Smith 2023). However, increased levels of human interaction may lead to increased stress responses such as avoidance, as seen in cownose stingrays *Rhinoptera bonasus* (Hope 2023). More research is required to understand if daily human interaction is an enriching or aversive experience for smaller elasmobranch species that are commonly housed in these exhibits.

Little is known about the effects of crowd on small elasmobranch welfare in touch pools. Here, we explore the impact of crowd size on the behaviour of animals in the M&T Bank Shark and Ray Bay Exhibit at the Aquarium of Niagara in Niagara Falls, USA. We hypothesize that if contact with visitors is stressful, then sharks and rays in a touch pool will spend less time in areas of the exhibit where they could interact with visitors (defined here as "the ledge") when crowd size is high. We predicted that both sharks and rays would spend more time on the ledge when crowds were low. If sharks and rays in the touch pool keep their distance from the ledge when crowds are high, this may serve as an indicator that the animals find high levels of human interaction aversive and could help inform future management decisions for aquatic ambassador species.

Materials and methods

Study site and subjects

Data were collected at the Aquarium of Niagara's M&T Bank Shark and Ray Bay touch pool exhibit. The 15,000 litre exhibit opened in 2020. The Aquarium gave access to their exhibit webcam, which allowed data to be collected up to about 36 hours after occurrence. Observations were conducted on four bamboo sharks *Chiloscyllium punctatum*, three Atlantic stingrays *Hypanus sabinus* and five yellow stingrays *Urobatis jamaicensis*. Bamboo sharks are nocturnal animals which are commonly found close to shore in shallow water (Soura 2022). Both yellow and Atlantic stingrays are generally nocturnal, however, Atlantic stingrays are more likely to behave in an opportunistic fashion when hunting (Weinheimer 2021). Yellow stingrays and Atlantic stingrays will both bury themselves in the sand or mud of the seafloor during the day (Weinheimer 2021). The touch pool is a mixed species exhibit, which houses all of these species together as well as horseshoe crabs *Limulus polyphemus*, which were not included in the observations. The touch pool includes a shallow water ledge where individual animals can interact with visitors, a deep water area in the middle of the exhibit and an artificial mangrove tree in the deep water to provide an area to allow animals to take a break from interactions (Figure 1). The exhibit was always staffed by aquarium staff, volunteers, or docents who were specifically trained. Water quality was assessed daily during the course of data collection. Formal animal welfare assessments were conducted by aquarium staff monthly, and daily keeper observations noted

Figure 1. Camera view of M&T Bank Shark and Ray Bay exhibit, Aquarium of Niagara. The "ledge" is clearly visible around the circumference of the exhibit

any more immediate changes in behaviour or health. Guests were required to wash their hands at designated washing stations both before and after touch pool interactions. The exhibit was open to visitors during regular aquarium hours and was closed at least twice daily during scheduled animal training demonstrations at other exhibits throughout the aquarium and during touch tank feedings.

Procedures

A total of 458 observations were collected between November 2022 and January 2024. Behaviour was observed for five minutes per hour between 0900-1700 on both weekends and weekdays as well as holidays to account for anticipated differences in crowd size. Data were collected at one-minute intervals during these five minutes. Previous studies have suggested that infrequent, sporadic observations collected over an extended period of time can still provide an accurate measure of behaviour (Margulis and Pruett-Jones 2008; Margulis and Westhus 2008). During each scan, the following data were recorded: number of individuals of each species in each location (ledge, water, mangrove, or out of view); the date; day of the week; time; and crowd size. Crowd levels were defined as "none" (zero guests), "low" (one to five guests), "medium" (six to fourteen guests), and "high" (more than fourteen guests). Individual animals were not identified or tracked - the data therefore represent average behaviour by species.

Analysis

Data were analysed in R version 4.3.3 using readxl to import raw data from excel (Wickham and Bryan 2023). Data were organised for analyses using dplyr (Wickham et al. 2023), tidyr (Wickham et al. 2024) and knitr (Xie 2024). The percentage time spent on the ledge by each species (averaged across individuals of that species) compared to crowd size was analysed using FSA (Ogle et al. 2023). Data were visualised using ggplot2 (Wickham 2016), ggsignif (Ahlmann-Eltze and Patil 2021) and ggpubr (Kassambara 2023). a Kruskal Wallis test was conducted to investigate the species differences in the proportion of time each species of elasmobranch spent on the ledge based on crowd size. To quantify the amount of time spent on the ledge across different crowd size categories a proportional generalised linear mixed model (GLMM) was constructed using nnet (Veneables and Ripley 2002) with crowd size and time of day as predictor variables, and species as a random effect. The model was fitted using lme4 (Bates et al. 2015) and lmerTest (Kuznetsova et al. 2017).

Ethics

As an observational study the Canisius University IACUC Chair considered this study to be low-risk and therefore it did not need to go through a full ethical review. The study was also reviewed and approved by the Aquarium of Niagara, as it was non-invasive.

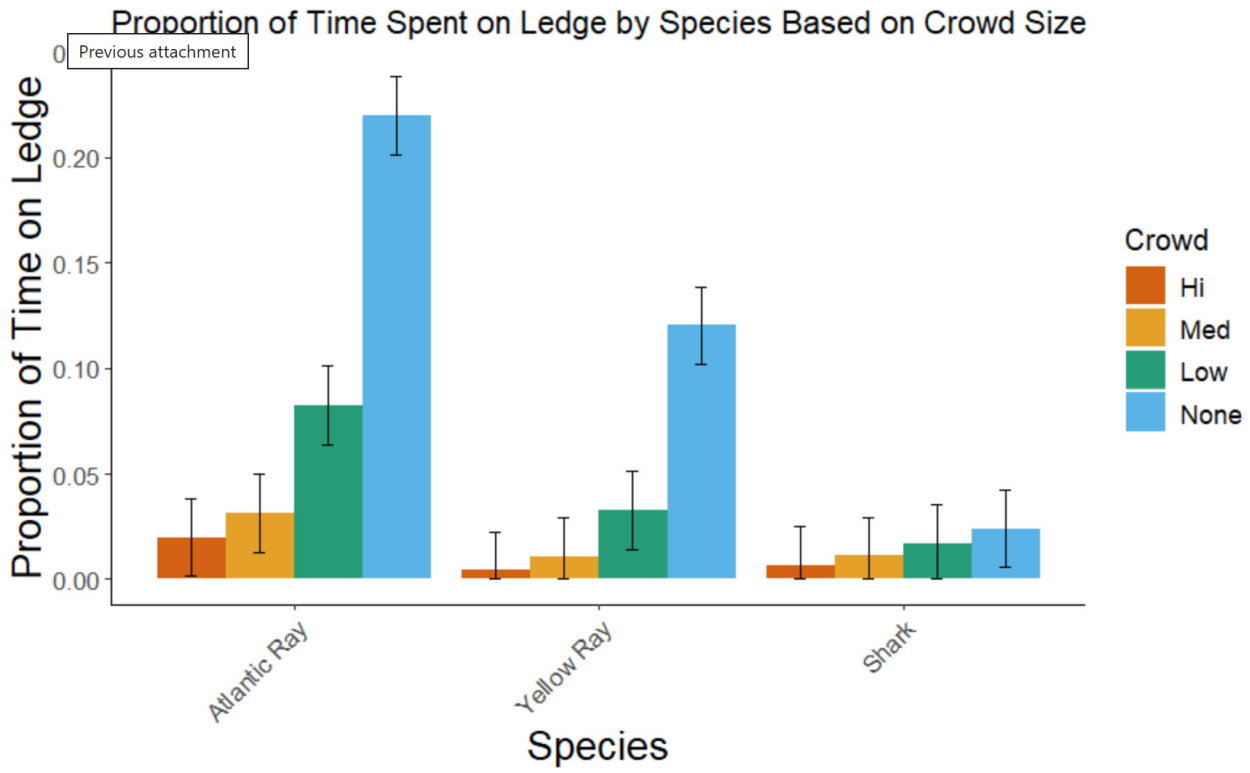

Figure 2. Proportion of time spent on the exhibit ledge based on crowd size. All three species spent significantly more time on the ledge when crowds were low and avoided the ledge at high crowd sizes.

Results

Time spent on ledge:

All three species spent less time on the ledge in crowded conditions (Kruskal Wallis test, P<0.001, H=55.887 for Atlantic rays, P<0.001, H=154.67 for yellow rays and P<0.001, H=10.861 for bamboo shark) (Figure 2).

Time of day

In a GLMM including the crowd and time of day as predictors of time spent on ledge, elasmobranchs were significantly more likely to use the ledge in lower crowd conditions or when no visitors were present compared to high crowd conditions (estimate=+0.45, P<0.001 for medium crowd level, estimate=+1.36, P<0.001 for low crowd level, estimate=+1.68, P<0.001 for no crowd present). There was a weak negative relationship between time of day and ledge use (estimate=-0.12, P<0.001). Elasmobranchs spent significantly less time on the ledge in later hours of the day. Crowds were highest from approximately 1100 until 1400 hrs, as would be expected based on general zoo/aquarium visitation patterns.

Discussion

This study showed strong evidence that all three species spend less time on the ledge, where they are able to physically interact with visitors, in high crowd conditions. Bamboo sharks spent the least amount of time on the ledge regardless of crowd size. Sharks were most frequently found resting in the deepest area of the pool underneath an artificial mangrove tree. The sharks' preferred location within the touch pool correlates with their natural behaviour as a nocturnal, bottom-dwelling species (Maia and Wilga 2013). Both stingray species spent more of their time on the ledge when crowd size was lower. When they were not on the ledge, they were typically found buried in the sand. Rays will bury themselves in the sand as camouflage to lower the risk of predation and hide from potential prey items (Newton and Kajiura 2017). More research is necessary to understand if stingrays are avoiding detection by burying themselves more often in periods of high crowd conditions. While time of day did have an impact on the behaviour of elasmobranchs, the relationship between crowd size and ledge use was stronger. The relationship between time of day and crowd size likely influenced these patterns.

To understand if this pattern is to avoid human interaction, future research needs to consider the natural activity pattern of these species. Bamboo sharks, Atlantic stingrays and yellow stingrays are naturally nocturnal and, in a natural setting, would not be active during the hours in which the aquarium is open to the public (Morris et al. 2010). While these elasmobranch species are commonly found in touch pools due to their docile nature, their natural hours of activity may not correlate with the objective of touch pools, which is to facilitate human-animal interactions throughout the day. When zoos and aquariums house nocturnal species, it is common practice to have exhibits with reversed light cycles, which typically have red lights on during the day to mimic nighttime hours (French et al. 2024). This practice allows for nocturnal species to be active during peak visitor hours but is somewhat impractical for touch-tank exhibits. At the Aquarium of Niagara, the touch pool exhibit is not on a reverse light cycle, so

it is uncertain whether or not elasmobranch nocturnality plays a role in where they choose to spend their time when visitors are present.

To better assess the reason for the animals spending less time on the ledge in high crowd conditions, attempts were made to measure stress hormones in the water on high and low crowd days. However, the logistics of detecting small quantities of stress hormones in a circulating 15,000 litre exhibit proved insurmountable. We hope to continue to explore methods to non-invasively detect hormones, and encourage others to pursue this as well, to provide corroborating physiological support for our behavioural findings.

Interactive exhibits such as touch pools facilitate public understanding of conservation by creating direct connections between visitors and animals. However, when the animals in these exhibits are inactive or are potentially avoiding interactions with humans, it is important to consider other options to create an experience that is not only engaging for guests, but also enriching or neutral for animals that serve as ambassadors for their species. New zoological regulations in the United Kingdom no longer allow visitors to touch fish and cephalopods. However, touch pools still exist globally; zoos and aquariums that still manage these exhibits must understand the moral and ethical demands of touch pools to promote welfare (Biasetti et al. 2020). We suggest incorporating a crowd control mechanism at touch tank exhibits. We used a number of more than 14 visitors as an indicator of large crowd size. While what constitutes a large crowd size will vary based on the size of the exhibit, for a small touch tank such as this one, fifteen people likely represents a high crowd size, especially if there is no empty space surrounding the exhibit. It may be beneficial to limit the touch pool occupancy to a smaller number at any one time to maintain a relatively steady flow of visitors while also preventing large waves of human interactions that may be overwhelming for the animals. We also suggest that aquariums take into account the activity cycles of elasmobranchs before housing them in touch pools. It may be beneficial to select diurnal elasmobranchs over nocturnal species to better facilitate the opportunity for visitor-animal interactions. If an aquarium decides to house nocturnal species in a touch pool setting, they may want to consider adding reversed light cycles to the exhibit. However, this may come with a challenge, as it may be more difficult for visitors to see the animals. Comparing the levels of human-animal interaction between diurnal and nocturnal elasmobranch species should be incorporated into future research. To ensure that interactions are purposeful for both visitors and animals, we suggest that aquarium volunteers and staff always provide meaningful messaging to visitors regarding individual species behaviour and the importance of their conservation.

Our understanding of elasmobranch welfare in touch pools is still limited, as it is difficult to assess what behaviours may indicate positive or negative welfare, especially in captivity. Natural elasmobranch behaviour must be considered when deciding upon what species should be placed into touch pools. While Truax et al. (2023) found higher levels of activity during high-crowd conditions in their study of rays in a touch tank, they note that they could not confirm whether this was a positive or negative welfare indicator. Finding a balanced system that is sustainable for elasmobranchs and inspires visitors through the lens of conservation education is imperative for zoos and aquariums.

In this study, small elasmobranch species spent less time in areas meant for human-animal interaction when crowds were higher. Differences in ledge use between shark and ray species may be due to their natural activity cycles, which must be considered when housing animals in touch pools. Care should be taken in choice of species for touch tanks, particularly if nocturnal species are used in a diurnal manner. In existing touch pool exhibits, protocols that prioritize animal welfare must be implemented and followed. It is important to remember that every animal is an individual and has their own tolerance for human interaction. Future studies may focus on how specific individuals in touch pools respond to human contact, which has potential for both welfare and cognitive research. Continuing research in this field is essential to ascertaining the best husbandry practices for ambassador elasmobranchs and to improve the way touch pools operate.

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