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Using individual-specific conditioning to reduce stereotypic behaviours: A study on smooth dogfish *Mustelus canis* in captivity

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Abstract

Despite how frequently stereotypic behaviours are discussed in the field of animal behaviour and welfare, research on stereotypies in captive elasmobranchs is far less represented in the literature compared to studies on mammalian species. This is particularly unfortunate as aquatic species exhibited in aquariums may be just as likely to perform stereotypic behaviours as other taxa. This study focused on documenting the stereotypic behaviours exhibited by a female smooth dogfish *Mustelus canis* housed in an aquarium, and the resulting effects of two specific interventions on the performance of those behaviours. The behaviour of the smooth dogfish and her location within the exhibit was monitored for approximately 11 months (5 months of baseline, and 6 months following interventions) using focal scan sampling. Following initial observations, two individual-specific interventions were implemented: 1) the smooth dogfish was removed from her normal exhibit and relocated into a less dynamic medical pool ('modified social-isolation'); and 2) a more individualised feeding and conditioning method was established to reinforce performance of species-specific behaviours ('food-based conditioning'). Results indicate that the smooth dogfish not only performed stereotypic behaviours far less frequently following the interventions, but also began performing increased species-specific behaviours (namely resting), and utilised her exhibit space more ubiquitously, suggesting that the interventions had a positive impact. The specific interventions discussed may not be a 'one-size-fits-all' solution for stereotypic behaviours displayed in other captive smooth dogfish. However, this study highlights the importance of taking action when stereotypic behaviours are noted, provides initial suggestions for possible interventions, and demonstrates the efficacy of utilising individual-specific approaches for addressing animal care and welfare concerns in captive aquatic species.

Background

Animal welfare can be an ambiguous term, defined in many different ways. In general, the welfare of an animal consists of its physical health, as well as its mental health (Broom 1991). The importance of monitoring animal welfare has become increasingly emphasised in zoos and aquariums (Wolfensohn et al. 2018), but recent research has also highlighted the importance of incorporating animal welfare into wildlife conservation as well (Dubois and Fraser 2013; Beausoleil et al. 2018). Welfare state can be equated with the propensity to perform species-specific behaviours that are similar to those exhibited in their wild habitat (Bracke and Hopster 2006). Therefore, performance of stereotypic behaviours (repetitive behaviours with no obvious goal or function; Mason 1991) may be an indicator of poor welfare (Bracke and Hopster 2006). These behaviours can include pacing, over-grooming and swaying movements (Broom 1983; Mason 1991). Although the performance of stereotypic behaviours has been noted in wild elasmobranchs (Miller et al. 2011), stereotypic behaviours are almost exclusively seen in animals in captivity (Mason 1991; Swaisgood and Shepherdson 2005). Therefore, mitigating stereotypies is often a top priority for captive animal welfare (Mason et al. 2007).

It has been hypothesised that individuals in captivity may perform stereotypies due to a lack of stimulation (Mason 1991; Mason and Latham 2004), as individuals in captivity are not performing time-intensive behaviours such as foraging, defending territories and courting that they would perform in the wild (Shepherdson 1989; Morgan and Tromborg 2007). To increase stimulation in captivity, studies have shown that integrating enrichment into an individual's habitat, and variability into an individual's schedule, can decrease the frequency of stereotypic behaviours, as the individual's time is being filled with a stimulating task (for a review, see Mason et al. 2007). Aside from behaviour, another indicator of poor welfare in captive animals can be an inappropriate use of habitat space. This can include actively avoiding parts of an individual's exhibit or spending an inordinate amount of time in a particular area (Ross et al. 2009). Inappropriate habitat use can also result from other individuals in the exhibit, novel or adverse items placed in the exhibit, or ingrained patterns of habitat use in the individual (Morgan and Tromborg 2007).

Every animal in captivity has the capacity to perform stereotypic behaviours (Mason 1991), including aquatic animals (Cooke 2017). However, available literature on stereotypic behaviour still tends to be heavily biased toward captive mammals and birds (Rose et al. 2017), despite evidence that suggests that elasmobranchs (i.e., sharks and rays) can and do exhibit stereotypies as well (Scott et al. 1998b; Miller et al. 2011; Näslund and Johnsson 2016). Previously described stereotypies in captive elasmobranchs include obvious/conspicuous behaviours, such as swimming in spiral patterns in smoothhound sharks *Mustelus* sp. (Casamitjana 2004) and bobbing and surface breaking behaviours in *Raja* sp. rays (Scott et al. 1998a; Greenway et al. 2016). However, findings have also suggested that aquarium-raised elasmobranchs may display more subtle behavioural differences (i.e., reduced movement/more sedentary behaviour) compared to their wild counterparts, even when re-released back into their natural environment (Buckley et al. 2020). Given the range of possibilities, stereotypies of captive elasmobranchs are likely occurring in many captive aquatic environments but may go unreported due to lack of recognition that a stereotypy has developed.

This study focuses on the stereotypies displayed by a smooth dogfish *Mustelus canis* housed at the SEA LIFE Michigan Aquarium. The individual was noted to swim in a stereotypic fashion, with performance of behaviours including inverted swimming, spiralling and surface breaking, as well as uneven habitat use. The individual had a long history of performing these behaviours prior to arriving at the SEA LIFE Michigan Aquarium, suggesting the behaviours had likely become an ingrained pattern. The goal of this study was to therefore investigate the effects of various interventions on performance of stereotypic behaviour, particularly the rate of stereotypic swimming, of the smooth dogfish at the SEA LIFE Michigan Aquarium.

To establish what constitutes normal and stereotypic behaviour in smooth dogfish, it is important to note the natural behaviours and distribution of the species in the wild. Smooth dogfish are often found along eastern coastlines of the US, as well as in the Gulf of Mexico and parts of the eastern coastlines of South America (Heemstra 1997). Smooth dogfish are primarily nocturnal (Casterlin and Reynolds 1979), and typically consume benthic prey (Gelsleichter et al. 1999). Due to this, smooth dogfish often inhabit mostly shallow and estuarine coastal waters and are often found along the seafloor (Gelsleichter et al. 1999). Many species of sharks are obligate-ram ventilators, meaning they must keep in constant motion in order to respirate (Wegner et al. 2012). Smooth dogfish, however, possess buccal pumps (Hughes 1960; Vapuel 2010). Buccal pumps, which are organs that allow oxygen uptake regulation by passing water over the gills (Saunders 1961; 1962; Wegner 2015), allow individuals to continue respirating while remaining motionless (Randall 1970; Wegner and Graham 2010). With these aspects of smooth dogfish natural history in mind, it was assumed that a captive smooth dogfish in a good welfare state should regularly swim lower in the water column, rest frequently, and make use of the majority of the habitat space provided.

Action

Subject

The focal individual for this study was a female smooth dogfish housed at the SEA LIFE Michigan Aquarium in Auburn Hills, Michigan. She arrived at this location in the summer of 2017 after having lived in another aquarium for most of her life. In the animal's previous institution, the individual was typically housed with other smooth dogfish and smaller elasmobranchs including cownose rays *Rhinoptera bonasus* in a mixed-species exhibit. Documentation showed that she was likely wild caught in 2005, but her exact age is unknown. Records also indicated that she arrived at the SEA LIFE Michigan Aquarium with a pre-existing history of performing stereotypic behaviours. Specifically, animal husbandry staff at the animal's original institution had stated that individuals of the smooth dogfish population, including the female who came to reside at the SEA LIFE Michigan Aquarium, had displayed atypical swimming patterns, such as surface breaking, and unusual orientation like swimming sideways in the exhibit.

Exhibit

At the SEA LIFE Michigan Aquarium, the main exhibit where the studied smooth dogfish resided (known as the 'Ocean Exhibit') had a volume of 473,000 l and a depth of 4.3 m. The exhibit aimed to mimic tropical ocean conditions, with temperature held at 24–25°C, dissolved oxygen concentration held at 98%, salinity held at 29–30 ppt, and photoperiod held at 14:10. The smooth dogfish shared the exhibit with about 250 teleost fish as well as two dozen other elasmobranchs. Of the elasmobranchs that shared this exhibit, none are considered to be natural predators of smooth dogfish, and aggression towards the focal individual was not noted by animal husbandry staff. While other sharks shared the same space as the smooth dogfish, it is important to note that she was the only individual of her species present in the aquarium.

Data collection and analysis

Prior to data collection, an ethogram was created (Table 1), which included typical behaviours expected to be seen in a smooth dogfish (Bres 1993), such as swimming, resting and eating. The ethogram also contained the stereotypic behaviours this individual was previously observed performing, such as swimming upside down or vertically, swimming strictly against the perimeter of the exhibit, spiralling swimming patterns and surface breaking. No stereotypic behaviours had been observed in any of the other animals that lived in the Ocean Exhibit. Swimming patterns and other behaviours displayed by all other elasmobranchs in the exhibit were considered normal and consistent with wild populations of conspecifics.

Data collection took place from 7 January to 24 November 2019. In order to ensure data were well represented, data collection was randomised by day of the week as well as time of day via a random number generator. Data collection was done on a tablet with the ZooMonitor programme (Ross et al. 2016). Each session of data collection lasted 10 min, with focal scan sampling (Altmann 1974) occurring at 1-min intervals to record the behaviour and location of the smooth dogfish.

In addition to collecting behavioural data, the ZooMonitor programme also allowed for tracking the location and water column position of the dogfish during each scan. The generated

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Table 1. Ethogram of expected behaviours for a smooth dogfish in its wild habitat, as well as stereotypic behaviours observed in captivity for this individual.

Normal behaviours	Definitions
Swimming	Moving through the water from one part of the exhibit to another
Darting	Quickly moving through the water from one part of the exhibit to another in response to a stimulus
Eating	Consuming food items, either from a target or from being thrown into the exhibit
Resting	Lying motionless along the exhibit floor while continuing to respire
Swimming in place	Moving against a water current, resulting in no change in location
Stereotypic behaviours	Definitions
Surface breaking	Using any part of the body to breach the waterline
Swimming inverted	Moving through the water while dorsal fin is facing the exhibit floor
Swimming sideways	Moving through the water while pectoral fin is facing the exhibit floor
Spiraling	Moving through the water column of the exhibit in a circular fashion

'heat maps' consisted of a map of the exhibit, which displayed the location of the individual as dots. The dots were coloured based on the density of data points at that location; blues and greens represented one to two data points, whereas yellows and reds represented three or more data points (Wark et al. 2019). A 60 × 60 cm grid was then placed over the heat maps in order to divide the exhibit into three equal sections of 245 cm^2: the front of the exhibit, the back of the exhibit and the perimeter (Figure 1). The total number of data points within each section of the map were then calculated both before and after the interventions to show how the distribution of the smooth dogfish in the exhibit changed over time.

Baseline behavioural data were collected on the smooth dogfish from 7 January to 1 May 2019. The smooth dogfish had performed stereotypic behaviours since she arrived at the SEA LIFE Michigan Aquarium, but the behaviours were often limited to occasionally swimming sideways and surface breaking. However, after several concerning episodes of extreme spiralling swimming behaviours and unbalanced habitat use were noted during observations throughout April 2019, specific interventions were devised to tackle the increased frequency of stereotypic behaviours performed by the smooth dogfish. After the interventions had been introduced, data collection continued until 24 November 2019 to monitor the effects they had on the individual's welfare.

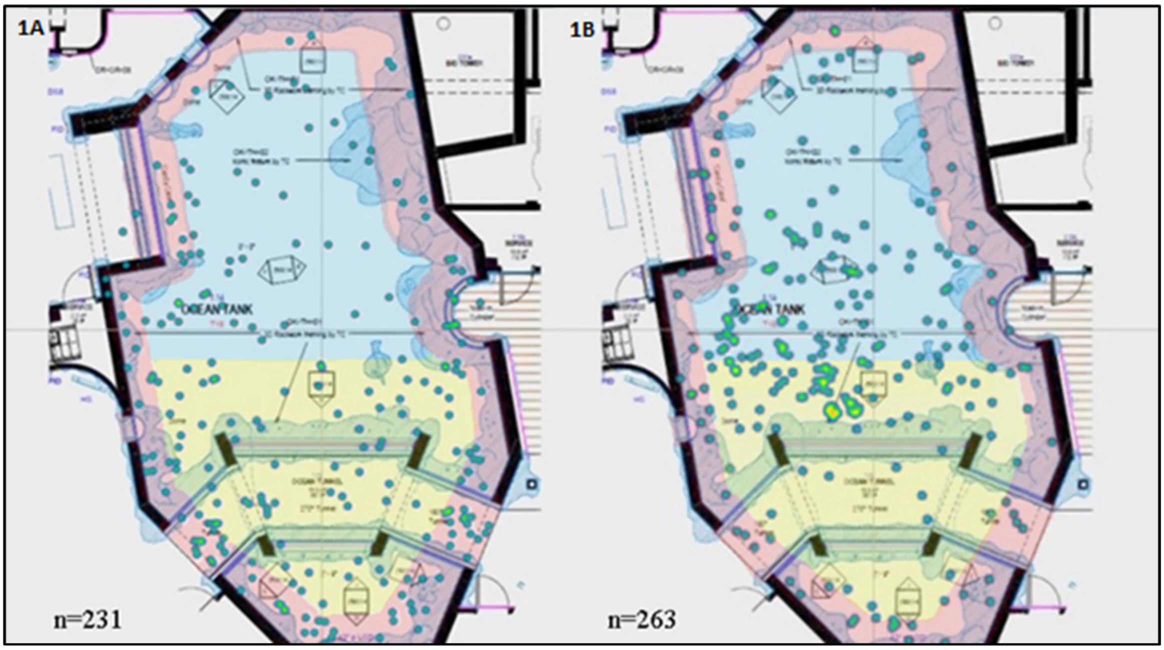

Figure 1. Baseline and post-intervention heat maps. Heat maps showing the location of the smooth dogfish in the Ocean Exhibit during the Baseline Phase (A; n=231) and following the interventions (B; n=263). Using a 60 × 60 cm grid, the exhibit was split into three equal parts of area 245 cm^2: the front (yellow), the back (blue) and the perimeter (red). Blues and greens represent low frequency of distribution, whereas yellows and reds represent higher frequency. A) Distribution frequencies for the Baseline Phase were 31.3% for the front, 14.3% for the back and 54.4% for the perimeter. B) Distribution frequencies post-intervention were 35.5% for the front, 37.1% for the back and 27.4% for the perimeter.

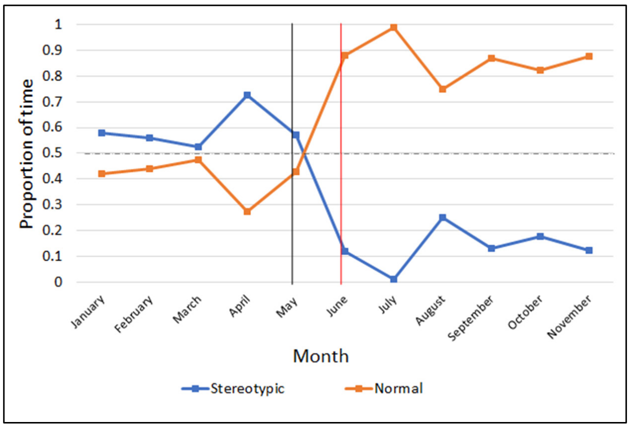

Figure 2. Behaviour proportions over time. Scatterplot displaying the proportion of time the smooth dogfish spent performing stereotypic (blue) behaviours and normal (orange) behaviours by month. The black vertical line indicates when Intervention 1 (modified social isolation) began (3 May 2019). The red vertical line indicates when Intervention 2 (food-based conditioning) began (3 June 2019). The dashed horizontal line represents 50%. Baseline (7 January–2 May 2019) n=231; post-interventions (29 May–24 November 2019) n=263.

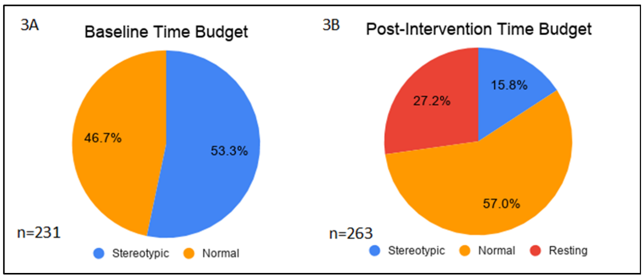

Figure 3. Behavioural time budgets. Time budgets displaying the frequency of stereotypic, normal and resting behaviours for the smooth dogfish for both the baseline and post-intervention phases of the study. Intervention 1. A) Baseline (7 January–2 May 2019) n=231; B) post-interventions (29 May–24 November 2019) n=263.

Interventions

Intervention 1: Modified social isolation (3–28 May 2019): For the first intervention, the smooth dogfish was relocated into a medical pool that was connected adjacently to the Ocean Exhibit in order to reduce stimuli that may have been negatively affecting her welfare. The ovular shaped medical pool was a smaller, shallower and overall less dynamic environment than the primary exhibit. It had a volume of about 11,400 l and a level depth of about 1.2 m. The medical pool was accessible from the Ocean Exhibit through a submerged gate that could be left open or closed to move and isolate an animal without removing it from the water. The same system water from the Ocean Exhibit flowed into the medical pool whether the gate was opened or closed. Due to this design, water parameters of the medical pool were consistent with those of the Ocean Exhibit, with temperature at 24–25°C, a salinity of 29–30 ppt and photoperiod held at 14:10. Water parameters including temperature, salinity and dissolved oxygen concentration were the same as the Ocean Exhibit as the medical pool is connected to the exhibit, allowing water to flow in.

The smooth dogfish was moved into the medical pool on 3 May 2019 and remained there until 28 May 2019. Having the smooth dogfish isolated to this space allowed husbandry staff to monitor her more closely and consistently, and also allowed for more individualised care. During this time, no observations were conducted, as the observer did not have access to the medical pool. Observations resumed upon the return of the smooth dogfish to the Ocean Exhibit on 28 May. Following the intervention, the smooth dogfish continued to have free access to the medical pool but was not required to enter by staff.

Intervention 2: Food-based conditioning (3 June–24 November 2019): Following the return of the smooth dogfish to the Ocean Exhibit after Intervention 1, an additional, conditioning-based intervention was devised to target her unbalanced use of the exhibit. Baseline observations of the smooth dogfish in the Ocean Exhibit showed that she spent almost all of her time swimming in the upper water column (generally within the top 1 m of the 4.3-m-deep exhibit), occasionally breaching the water's surface. Given that smooth dogfish are benthic elasmobranchs (Gelsleichter et al. 1999), this observed behaviour was determined to be inconsistent with how the species behaves in the wild. Additionally, she often strictly swam along the perimeter of the exhibit in an anti-clockwise direction and was rarely observed entering the back half of the exhibit. She also regularly displayed a very conspicuous pattern of repetitive swimming throughout the exhibit: she would orient herself 'sideways', with her left pectoral fin parallel to the wall of the exhibit, her dorsal fin parallel with the substrate, and her right pectoral fin often cutting through the water's surface. This irregular swimming pattern was consistently displayed along the perimeter of one half of the exhibit. As previous studies suggested that conditioning is an effective way to decrease the frequency of stereotypic behaviours and increase welfare in captive animals (Swaisgood and Shepherdson 2005; Mason et al. 2007; Greenway et al. 2016), an intervention was devised to attempt to encourage more typical species-specific swimming patterns through positive reinforcement of swimming in a more typical orientation.

Prior to implementing the food-based intervention on 3 June 2019, the smooth dogfish was fed from a target that she was conditioned to approach. Research performed by Scott et al. (1998b) on four species of captive benthic rays *Raja* sp. discovered that providing food lower in the water column (as opposed to surface-level feeding) was beneficial in decreasing the frequency of stereotypic behaviours such as surface breaking. It was therefore predicted that implementing similar food-based conditioning for the smooth dogfish would yield comparable results. Similar to the methods of Scott et al. (1998b), the food-based conditioning intervention involved husbandry staff encouraging the smooth dogfish into deeper parts of the exhibit, as well as away from the perimeter where her unusual swimming patterns were displayed, using a long feeding pole. The goal was to capture the behaviour of swimming normally and reinforce that behaviour by offering food whenever and wherever that she displayed swimming patterns that were consistent with wild populations of conspecifics. Specifically, there was a focus to offer food when

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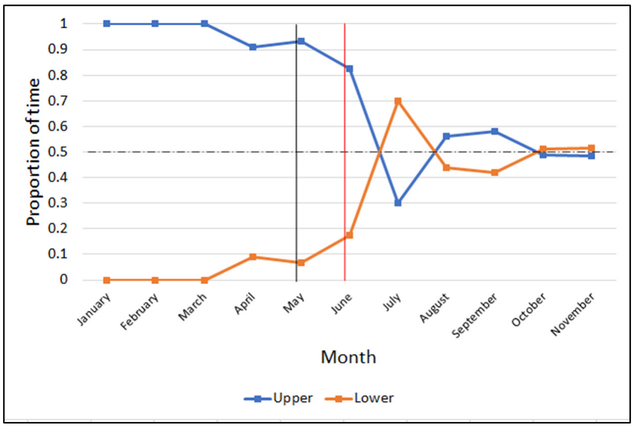

Figure 4. Water column inhabitancy over time. Scatterplot displaying the proportion of time the smooth dogfish spent in the upper (blue) and lower (orange) water columns of the exhibit by month. The black vertical line represents the date when Intervention 1 began (3 May 2019). The red vertical line represents the date when Intervention 2 began (3 June 2019). The dashed horizontal line represents 50%. Baseline (7 January–2 May 2019) n=231; post-interventions (29 May–24 November 2019) n=263.

her dorsal fin was oriented upward with her ventral side parallel with the substrate, and no indication that she was going to surface break by moving her head above the waterline or spin irregularly. Use of this novel feeding method continued until the end of the study (24 November 2019).

Consequences

In total, nearly 8.25 hr of data collection were amassed over 55 10-min observation sessions that occurred from 7 January to 24 November 2019. A total of 26 observation sessions (231 total data points) occurred in the baseline phase of the study, and 29 sessions (263 total data points) in the post-intervention phase. After data collection had completed, any entry marked 'not visible' was removed for the purpose of analysis. The proportion of time the smooth dogfish spent performing normal and stereotypic behaviours, and the proportion of time spent in the upper and lower water column, were then calculated for each session based on time spent visible.

Intervention 1: Modified social isolation

The smooth dogfish was first introduced into the medical pool on 3 May 2019 and continued to reside there until 28 May 2019. From January through May (prior to Intervention 1), the smooth dogfish performed stereotypic behaviours an average of 53.3% (95% CI [45.8%, 60.7%]) of the time, with a peak of abnormal behaviour (75.0% of her time) occurring immediately before the intervention began (Figure 3A). However, from June through November (post-intervention), the proportion of time she spent performing stereotypic behaviours was only 15.8% on average (95% CI [10.8%, 20.8%]; Figure 3B).

Interestingly, the smooth dogfish was also observed resting for the first time by staff while in the medical pool. She continued performing this resting behaviour following the intervention when released back into the Ocean Exhibit (Figure 3B), and by the end of data collection, she had been observed spending an average of 27.2% of her time resting (95% CI [15.4%, 39.0%]).

Intervention 2: Food-based conditioning

Prior to introducing the new feeding method on 3 June 2019, the smooth dogfish spent nearly all of her time (98.8%; 95% CI [97.3%, 100.5%]) in the upper 1 m of the water column while in the main Ocean Exhibit during the baseline phase (Figure 4). Following initiation of this intervention, the smooth dogfish was observed spending an average of 47.2% (95% CI [35.1%, 59.4%]) of the time in the lower water column (compared to the baseline value of 1.1%; 95% CI [-0.05%, 2.7%]).

Additionally, the smooth dogfish also started to use her habitat space more evenly after the intervention was initiated. During the baseline phase, she spent a disproportionate amount of time along the perimeter of the exhibit (54.4%; 95% CI 45.2%, 63.7%]) and was only observed in the back of the exhibit 14.3% of the time (95% CI [9.8%, 18.8%]; Figure 1A). Following the intervention, her habitat use was almost perfectly even for both the front and the back of the exhibit (37.1%; 95% CI [26.7%, 44.3%] and 36.7%; 95% CI [29.2%, 45.0%], respectively), and she only spent 27.4% of her time along the perimeter (95% CI [18.9%, 36.0%]), compared to 54.8% prior; Figure 1B.

Overall, the combination of both interventions appeared to produce a dramatic change in the behaviour of the smooth dogfish. In addition to a significant reduction in the performance of stereotypic behaviours, the smooth dogfish also began utilising her exhibit more thoroughly, in a manner that mirrors wild counterparts, after the interventions were applied. Taken together, these results suggest that the interventions produced the desired goal of encouraging more 'natural' behaviours in this individual.

Aside from a dramatic reduction in performance of stereotypic behaviours, it is also important to note that the smooth dogfish began to exhibit resting behaviour following the interventions. Although resting is a natural behaviour for smooth dogfish (Vaupel 2010), prior to Intervention 1, care staff had never previously noticed the smooth dogfish resting during the day, let alone performing the behaviour with such consistency. As smooth dogfish are primarily nocturnal (Casterlin and Reynolds 1979), increased performance of resting behaviour during the day following the interventions may additionally indicate an enhanced welfare state for the smooth dogfish.

The proportion of time the smooth dogfish spent in the lower water column of the Ocean Exhibit also increased dramatically compared to baseline observations. As wild smooth dogfish are primarily benthic (Gelsleichter et al. 1999), this important behavioural change was extremely encouraging. These results mirror those of Scott et al. (1998a), who suggested that surface breaking behaviour in captive benthic rays may be linked to appetitive motivation, and that feeding the rays lower in the water column may reduce surface breaking behaviour. Given that the smooth dogfish was initially target-fed at the surface of the Ocean Exhibit prior to the interventions, her stereotypic behaviours and water column distribution could likewise be linked to appetitive anticipation/need. Providing the smooth dogfish new foraging opportunities lower in the water column, which is more representative of the natural history of her species (Gelsleichter et al. 1999), appears to have been behaviourally beneficial. Previous studies have suggested the importance of taking natural history into account when managing captive mammalian species (Troxell-Smith and Miller 2016; Miller et al. 2019), but these factors should also be considered for captive elasmobranchs as well (Scott et al. 1998b).

While not directly documented in this study due to visibility constraints, the impact of environmental complexity should also be considered. Following her release into the main exhibit after Intervention 1, the smooth dogfish was still able to access the medical pool at any time she chose. Interestingly, there were several instances where animal care staff reported seeing her enter the medical pool on her own without encouragement following the initial intervention. Providing captive animals with increased environmental choice has previously been shown to reduce the performance of stereotypic behaviours in a variety of taxa (Young 2003; Owen et al. 2005; Ross 2006; Kurtycz et al. 2014). It is therefore possible that providing the smooth dogfish with additional environmental complexity allowed for increased control and choice, thus resulting in a reduction in stereotypic behaviours.

Indeed, it is difficult to say with certainty which of the behaviours were impacted by each intervention, as both interventions began at nearly the same time. It is also possible that the combination of interventions had the greatest impact, as each was designed to target a specific aspect of the animal's behaviour. It is important to note that conditioning techniques are never 'one-size-fits-all' (Swaisgood and Shepherdson 2005), meaning that the interventions that were successful for this individual smooth dogfish may not result in the same success when applied to a different smooth dogfish. While we hope the interventions outlined here will provide caretakers with some inspiration for planning purposes, every animal would likely benefit from an individualised conditioning plan based on their specific needs. The emphasis should therefore be placed on the fact that the interventions did lead to a drastic behavioural change and an overall increase in welfare for this individual, and that natural history and behaviour should be taken into account for welfare-based decisions.

While the interventions provided were effective in alleviating stereotypic behaviours for this smooth dogfish, the cause of her stereotypic behaviour remains unknown. Previous literature has suggested that spinal deformities in captive sand tiger sharks *Carcharias taurus* could lead to repetitive/stereotypic swimming patterns (Preziosi et al. 2006; Tate et al. 2013). However, no obvious spinal deformity was noted in the smooth dogfish. Interestingly, wild elasmobranchs are one of the few taxa that have been previously observed displaying stereotypic behaviours in the wild, potentially due to becoming accidentally conditioned to scheduled events, such as diving excursions (Miller et al. 2011). Since observation of stereotypic behaviour is extremely rare in wild individuals, it is important to consider just how strongly elasmobranchs may be impacted by accidental conditioning. Given the necessary consistency of daily aquarium life, it is plausible that becoming conditioned to a feeding/caretaker schedule could have impacted the maintenance of stereotypic behaviours in this individual. It may also be important to consider the possible impact of any previous housing conditions. It has been suggested that certain stereotypic behaviours in elasmobranchs, like spiralling, may be influenced by captive environmental conditions (i.e., living in a touch tank) (Cooke 2017). Given that the smooth dogfish had been noted to already perform stereotypic behaviours while residing at her previous institution, it is possible that previous environments may have played a role in the development of those behaviours. While we likely will never know with certainty why her stereotypic behaviours developed in the first place, it is important to note that, at least in the case of this smooth dogfish, the behaviours appear to be highly modifiable with specific, directed behavioural interventions.

Future studies on monitoring stereotypic behaviour in captive elasmobranchs could also consider a different method of behavioural tracking. In the current study, the ZooMonitor programme was used to document general behaviour and swimming patterns. While this programme was extremely useful, results were admittedly limited, as they only reflected behaviours documented when the animal was visible to the observer, and those that were performed during the hours the facility was open to the public. As an alternative, there have been promising studies which have instead utilised acoustic accelerometry (Whitney et al. 2007; Kadar et al. 2019) to successfully monitor shark behaviour and swimming patterns. Such technology allows for more rigorous tracking of swimming patterns and water column location, and allows for consistent, 24-hour monitoring. For example, use of acoustic accelerometry in another benthic species, Port Jackson sharks *Heterodontus portusjacksoni,* revealed that captive individuals displayed increased activity at night during migration season, suggesting that captive individuals displayed similar 'migratory restlessness' behaviours compared to their wild counterparts (Kardar et al. 2019). As wild smooth dogfish are also nocturnal and migratory (Casterlin and Reynolds 1979), future studies could benefit greatly from utilising accelerometry to determine if these same nocturnal swimming patterns occur in the smooth dogfish seasonally in captivity, and if frequency of stereotypic behaviour is impacted by such factors.

Conclusion

Implementing individual-specific interventions directly targeted to the unique stereotypies of the smooth dogfish led to a substantial reduction of performed stereotypic behaviours, increased species-specific behaviours, and increased use of exhibit space. Despite not being able to extrapolate these results to the entire captive smooth dogfish population, recognising and addressing stereotypic behaviour in individuals is no less important to the goal of improving animal care and welfare of captive species (Troxell-Smith and Miller 2016; Michaels et al. 2020). Therefore, the results of this study not only highlight the importance of acknowledging stereotypic behaviours performed in an aquarium setting, but also add to a growing body of literature on stereotypic behaviour performance in elasmobranchs (Scott et al. 1998a; b; Miller et al. 2010; Tate et al. 2013; Greenway et al. 2016; Naslund and Johnsson 2016). It is hoped that these results will inspire continued investigation into the topic of performance of stereotypic behaviours in aquariums, highlight the importance of implementing individual-specific intervention approaches for aquatic species, and provide caretakers with some initial suggestions for addressing and mitigating such behaviours in their own populations.

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