Effects of food-based enrichment on the behaviour of juvenile green turtles (*Chelonia mydas*) in a rehabilitation facility in Florida

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Introduction

Marine turtles suffering from a range of injuries and illnesses (Foley et al. 2007; Chaloupka et al. 2008; Duffy & Burkhalter 2020) are rehabilitated at centres around the globe. Many of these ailments are due to anthropogenic interactions such as boat strikes, fishing line/hook entanglements, and ingestion of large quantities of plastic (Bjorndal et al. 1994; Chaloupka et al. 2008; Barreiros 2015; Eastman et al. 2020). Marine turtles, particularly green sea turtles (*Chelonia mydas*), also strand afflicted by virulent tumours, fibropapillomatosis (FP) (Foley et al. 2007; Chaloupka et al. 2008; Page-Karjian et al. 2014; Duffy et al. 2018; Farrell et al. 2018; Whilde et al. 2019; Yetsko et al. 2021), the incidence of which correlated to human-induced alterations to inshore habitats (Van Houtan et al. 2010; Hargrove et al. 2016; Jones et al. 2016). Currently, surgery is the primary treatment for turtles with FP, but post-surgical tumour regrowth is common, prolonging rehabilitation (Page-Karjian et al. 2012; Duffy et al. 2018; Farrell et al. 2018; Whilde et al. 2019). As captive environments are more restrictive and simplistic than natural ones, longer rehabilitation periods further curtail turtles' abilities to exhibit their full range of natural behaviours. It is therefore important that the process of treating and rehabilitating wild turtles is as effective and rapid as possible. While advances are being made from a medical perspective (Manire et al. 2017; Whilde et al. 2017; Duffy et al. 2018; Duffy & Martindale 2019), there has been considerably less research on improving the wellbeing of captive sea turtles by encouraging positive behaviours.

There are still many gaps in our understanding of sea turtle behaviour. Research on the behaviour of turtles in the wild tends to focus more broadly on foraging and migration habits (Godley et al. 2002; Heithaus et al. 2002; Dodge et al. 2014; Hochscheid 2014). Behavioural enrichment is an animal husbandry principle that seeks to enhance captive animal care by providing the environmental stimuli necessary for optimal psychological and physiological well-being (Shepherdson 1998). Although a growing field (Burghardt 2013), the research literature on behaviour and environmental enrichment in reptiles (de Azevedo et al. 2007; Mohan-Gibbons & Norton 2010) lags well behind that of mammals, where enrichment has been shown to produce numerous beneficial effects (Shyne 2006). Studies specifically on marine turtle behaviour are very scant, despite many sea turtles being housed at rehabilitation and aquarium facilities globally. However, it is highly likely that rehabilitating marine turtles would benefit from enrichment as much as their mammalian counterparts.

It has been shown that the provision of enrichment on the behaviour of healthy permanently captive (aquarium-housed) sea turtles resulted in significant decreases in undesirable behaviour such as repetitive swimming, and significant increases in desirable behaviour such as random (i.e. non-repetitive) swimming and focussed (investigating and grooming) behaviour (Therrien et al. 2007). Stereotypical or repetitive behaviours (e.g. repetitive swimming) are useful indicators of animal welfare in captivity and can be indicative of stress (Dantzer 1991; Langkilde & Shine 2006). To our knowledge, the behavioural response to enrichment of wild sea turtles that are held in rehabilitation facilities with the ultimate goal of being released back into the wild has not been documented in the scientific literature. It is particularly important that such turtles' mental wellbeing is considered and stimulated through environmental enrichment, to promote successful reintroduction to their natural habitat. Environmental enrichment has been demonstrated to produce beneficial effects in numerous other species (Burghardt 2013). Ideally, stereotypical behaviours should be minimised and as many natural behaviours as possible within the confines of a rehabilitation setting should be promoted. In addition to improving the rehabilitation experience, enrichment can be useful for conditioning adaptive behaviour for animals reintroduced from captivity, or at least ensuring it degrades as little as possible while in captivity.

Here we present behavioural observations of six juvenile green sea turtles held at the University of Florida's Whitney Laboratory Sea Turtle Hospital, with food-based enrichment, to determine how the provision of such enrichment directly affects turtle activity budgets. We hypothesised that provision of enrichment decreases stereotypical behaviours and increases species-typical behaviours for rehabilitated sea turtles, and we predicted that turtles would decrease undesirable behaviour such as stereotypical repetitive swimming patterns, and increase desirable behaviours such as random swimming and investigating when provisioned with enrichment.

Such detailed behavioural observation of marine turtles and their response to enrichment can be used to generate individually tailored husbandry regimes for each patient, to increase the levels of physical and mental activity, thus improving patient wellbeing and their ability to reintegrate into the wild.

Methods

Turtles

Turtle study subjects were patients at the University of Florida's Whitney Laboratory for Marine Bioscience and Sea Turtle Hospital, on the northeastern coast of Florida, USA. Sea turtles that were stranded or injured and afflicted with FP were held at the hospital to regain strength until they were fit enough to have FP tumours surgically removed, and after surgery were held at the hospital until they had fully recovered and were fit to be released (Fig. 1). Five juvenile turtles and one sub-adult were included in this study (Table 1), and had been at the Sea Turtle Hospital for at least one month prior to behavioural observations. This increases the likelihood that they will have become habituated to the surroundings prior to observations being carried out, and that they had recovered from the immediate acute stress of being stranded and transported to the hospital (Gregory et al. 1996). Turtles were held in 240cm diameter circular tanks, holding 2,270 litres of continuously filtered sea water, which were partitioned in the middle with one turtle on each side of the partition, except for Patient 1, which was a sub-adult and was held in an unpartitioned tank. Note that although turtles were assigned identifying names, their sexes were not known due to the difficulty of sexing juvenile sea turtles.

Behaviour

Turtle behaviour was categorised (Table 2) based on preliminary observations of the turtles and on previously described captive turtle behaviour (Therrien et al. 2007).

Table 1. Carapace length, weight, origin, condition on arrival and outcome of green sea turtles observed during this study at the University of Florida Whitney Laboratory for Marine Bioscience Sea Turtle Hospital. Patient 1 was a sub-adult and all other patients were juveniles.

Patient No.	Hospital's ID	Straight carapace length	Weight	Origin	Condition on arrival	Days in care (outcome)
1	Banana (1-2016-Cm)	64.7cm	36.3kg	Banana River, FL	FP, boat strike	218 days (released)
2	Emma (13-2016-Cm)	37.8cm	5.8kg	Daytona Beach, FL	FP, floating	148 days (released)
3	Major (6-2015-Cm)	40.0cm	7.6kg	Daytona Beach, FL	FP, emaciated	302 days (released)
4	Mean Joe Green (5-2016-Cm)	33.7cm	6.6kg	Crescent Beach, FL	FP, cold stunned	523 days (released)
5	Pons (46-2016-Cm)	42.8cm	7.5kg	Ponce Inlet, FL	FP, floating, fishing line entanglement, emaciated	173 days (released)
6	Mars (24-2019-Cm)	37.3cm	5.4kg	St. Augustine, FL	FP, debilitated	305 days (released)

Table 2. Behaviour categories of captive green sea turtles.

Behaviour	Definition
Feeding	Manipulating, investigating or eating food.
Focussed	Investigating; moving directly towards and observing or touching object (with the exception of food items) or observing a person, and grooming; rubbing carapace or body against flipper or tank.
Random swimming	Swimming in a non-repetitive way.
Repetitive swimming	Swimming in repetitive patterns around/back and forth across tank.
Resting	Any period of inactivity.

Fig. 1. Green sea turtles undergoing rehabilitation at the Whitney Laboratory Sea Turtle Hospital. Top: In the absence of enrichment, turtles have minimal environmental stimulation. Bottom: Green turtle interacting with food ice block.

Enrichment

Turtles were provided with large ice blocks made up of approximately 2 litres of water with part of their daily allocated food frozen in the block (Fig. 1). The food included was either fish or greens (e.g. cucumber and lettuce), depending on the dietary requirements of each individual turtle as assessed by the clinical care manager ('fish ice' or 'green ice', as appropriate). Food used in the ice block was part of the daily allowance of each turtle, and did not represent additional food over the daily amount prescribed by the clinical care manager. Two patients also received large ice blocks made up of approximately 2 litres of freshwater in a cube shape ('plain ice'). Ice blocks were randomly placed at the surface of the water within arms' reach of the edge of the tank, but not directly over or next to the turtles. As part of a focussed case study one turtle was also provided with a sea lettuce (*Ulva* sp.) gate and a floating or submerged whiffle ball containing greens.

Observations

Turtles were observed for sampling periods of 20 min at intervals. As turtles were held in tanks continuous focal sampling was performed (Altmann, 1974). We recorded the total time spent performing each type of behaviour (Table 2) during each 20 min sampling period. Five observation samples were obtained for each of the five turtles without enrichment provided, and five samples were obtained for each turtle with each enrichment.

The five observations of each turtle under each condition (i.e. no enrichment, plain ice or food ice) were made as close as possible to each other, over the course of a few days. In total sixty-three 20 min observations (1,260 min) were carried out by a total of four individuals, who were trained by the first author to ensure consistency between observers in behaviour recording (observers and the first author carried out trial observations of the same turtle at the same time until consistency was achieved). Observations were conducted in the following time periods: patients 1 to 4 April/May 2016, patient 5 March 2017 and patient 6 June/July 2019.

Analysis

Data were analysed using SPSS 24.0 for Windows. Distributions and variances of data for all behaviours for each individual during each period were checked, and any dataset not displaying normal distribution were log transformed. Paired t-tests were used to assess changes in individual turtle behaviour, between no enrichment and enrichment observations, and also between enrichment types. P values lower than 0.05 were considered to be statistically significant. Additionally, the proportion of time per observation session ($N = 5$) that all turtles spent exhibiting each behaviour with no enrichment was compared (Wilcoxon signed-rank test) with their behaviour when enrichment was provided. The total amount of time per observation session that the turtles spent carrying out each behaviour without enrichment and with enrichment was compared.

Results

When patients 1-5 were analysed as a single cohort, resting significantly decreased ($p = 0.03$) and focussed behaviour and feeding significantly increased ($p = 0.0002$ and 0.0001 respectively) when frozen food ice block enrichment was provided, compared with no enrichment (Fig. 2A). This

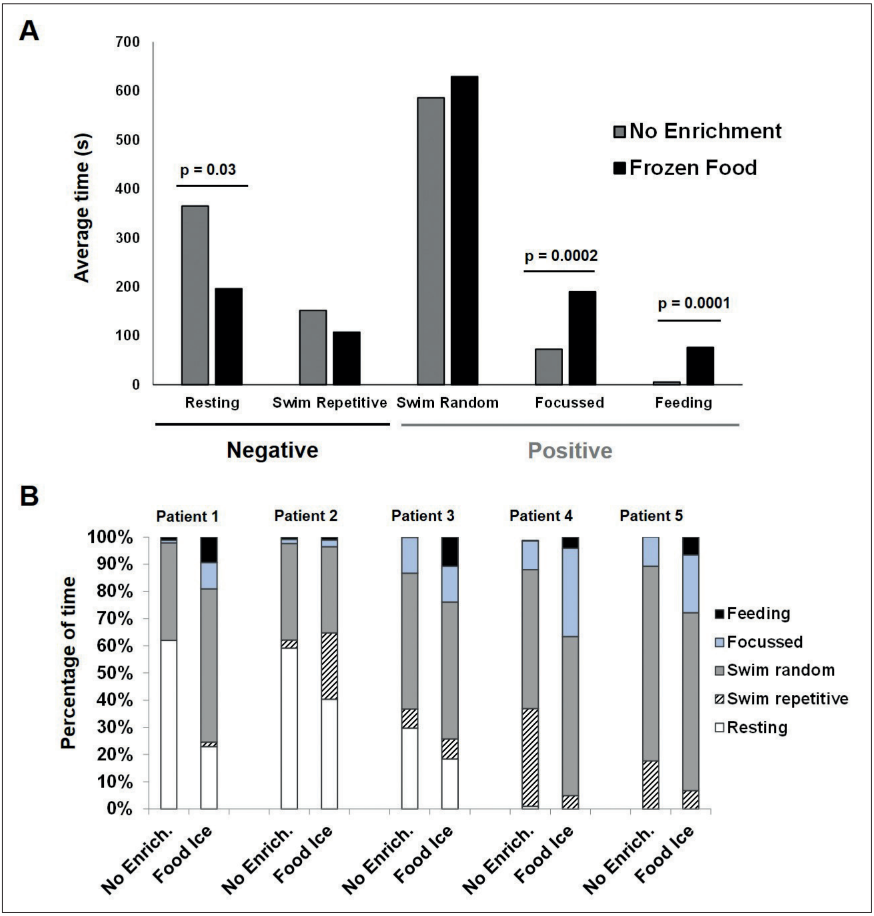

Fig. 2. Behavioural responses to food-based enrichment. A) Average time (seconds) spent by all turtles exhibiting each behaviour with no enrichment or frozen food enrichments (five turtles). Behaviours have been categorised as 'positive' or 'negative'. (Five turtles; per turtle observation N = 5; each observation = 20 min). All statistically significant changes have been indicated with the p-value above (Wilcoxon signed-rank test). B) Activity budget of five green turtles (*C. mydas*) when observed without enrichment or with food ice blocks.

demonstrates that food ice enrichments can induce desirable behaviours, encouraging active movement in marine turtles while they are being housed in rehabilitation centres. Note that patient 6 was not included in this analysis as the dramatic increase in repetitive swimming (a behaviour associated with stress) meant that more than one replicate with food ice could not be conducted (as per our FWC permit).

Next, we investigated the behavioural changes of each turtle individually, to assess whether general enrichment plans or individually tailored plans would be more suitable. Figure 2B shows the activity budgets of the five green turtles without enrichment and with ice blocks with frozen food. Patient 1 significantly increased the time spent exhibiting focussed behaviour when fish ice blocks were provided (t = 5.3436, p = 0.006). Patient 1's feeding time also increased significantly when the fish ice block was present (t = 3.8031, p = 0.02). Patient 1 also spent increased time investigating when plain ice was provided (t = -5.142, p = 0.01). The amount of time Patient 3 spent feeding increased significantly when an ice block with frozen green food was provided, compared with no enrichment (t = 4.1565, p = 0.01). Patient 3 spent significantly less time resting when plain ice blocks were provided than when there was no enrichment provided (t = 3.9726, p = 0.02). Patient 4 spent significantly less time swimming repetitively when provided with a fish ice block (t = 3.1665, p = 0.03), while there was a corresponding increase in feeding (t = 3.8796, p = 0.02) (Fig. 2A). Conversely, Patient 2 significantly increased the amount of time spent swimming repetitively when provided with a food ice block (t = 1.986, p = 0.01). Patient 6 also adversely reacted to food ice block enrichment, increasing the time spent swimming repetitively (see case study below). Unfortunately, as Patient 6 reacted so strongly, additional food ice block replicates could not be performed. Finally, Patient 5 increased the time spent feeding whilst enrichment was provided (food ice block), but this change was not statistically significant (t = 2.6355, p = 0.06). Behaviours that increased and decreased significantly for each of the five turtles when food ice block enrichment was provided are summarised in Table 3. The observed variation in individuals' responses to the same enrichment type suggest that it would be beneficial to develop individually tailored enrichment plans. Given Patient 6's adverse reaction to the food ice block, we conducted further observation on this individual to identify a more appropriate food-based enrichment, and provide a case study of how an individualised enrichment plan can be optimised.

Table 3. Statistically significant changes in behaviour observed when turtles were provided with food ice blocks, compared with turtle behaviour without enrichment.

ID	Food ice block
Patient 1	Increased focussed (p = 0.006). Increased feeding (p = 0.02).
Patient 2	Increased repetitive swimming (p = 0.014).
Patient 3	Increased feeding (p = 0.01).
Patient 4	Decreased repetitive swimming (p = 0.03). Increased feeding (p = 0.02).
Patient 5	No change.

Patient 6 individual case study: to demonstrate the potential benefits of monitored and tailored enrichment to individual turtles to achieve positive results, we next employed enrichment coupled with behavioural observation to overcome problematic behaviour. Patient 6, a juvenile green sea turtle (*C. mydas*), did not feed well during rehabilitation, refusing all food items provided. Therefore, enrichment was used to help encourage Patient 6 to feed. When no enrichment was provided, Patient 6 only exhibited potentially negative behaviours: prolonged resting and repetitive swimming (Fig. 3A). When presented with a greens ice block Patient 6 decreased resting but increased repetitive swimming (Fig. 3A), and still did not feed. When given a sea lettuce gate (a feeding device used successfully with other *C. mydas* patients at the hospital) patient 6 swam repetitively with no resting or feeding (Fig. 3A). Next, a whiffle ball with greens was given to Patient 6, and again the patient did not feed and increased repetitive swimming (Fig. 3A). As all of these enrichments strongly elicited negative and potentially stress-related behaviours in this patient, the devices were only given to Patient 6 once (as per our FWC permit requirements), and replicates could not be performed. It was observed that Patient 6 increased repetitive swimming whenever an item was floating at the surface of the tank. Therefore, the whiffle ball was modified (Fig. 3B) by attachment to PVC piping which would sink to the bottom of the tank, allowing the whiffle ball to float a short distance above the bottom. When presented with the sunken whiffle ball with greens enrichment, Patient 6 spent less time resting and swimming repetitively (Fig. 3A). Crucially, the patient fed from the sunken enrichment, which she had refused to do with all other feeding mechanisms, and feeding increased significantly ($t = 3.3363$, $p = 0.03$) compared with when there was no enrichment (Fig. 3A). Random swimming and focussed behaviour (grooming and investigating) also occurred in the presence of the enrichment, but were absent when there was no enrichment. Repetitive swimming decreased significantly (Fig. 3A, $t = 6.5135$, $p = 0.02$) when the sunken whiffle ball enrichment was provided compared with the other three enrichments (as single replicates, statistical analysis of these enrichments individually was not possible, and therefore they were pooled for analysis).

Discussion

There is evidence to suggest that Chelonians benefit from behavioural enrichments. In freshwater river turtles (*Carettochelys insculpta*), the provision of numerous forms of environmental enrichment to captive individuals has been demonstrated to increase time spent foraging for food (Bryant & Kother 2014). Similarly, a significant increase in time spent feeding was observed in four of the six green sea turtles in the current study. Stereotypical behaviours, which can be indicative of stress (Dantzer 1991; Langkilde & Shine 2006),

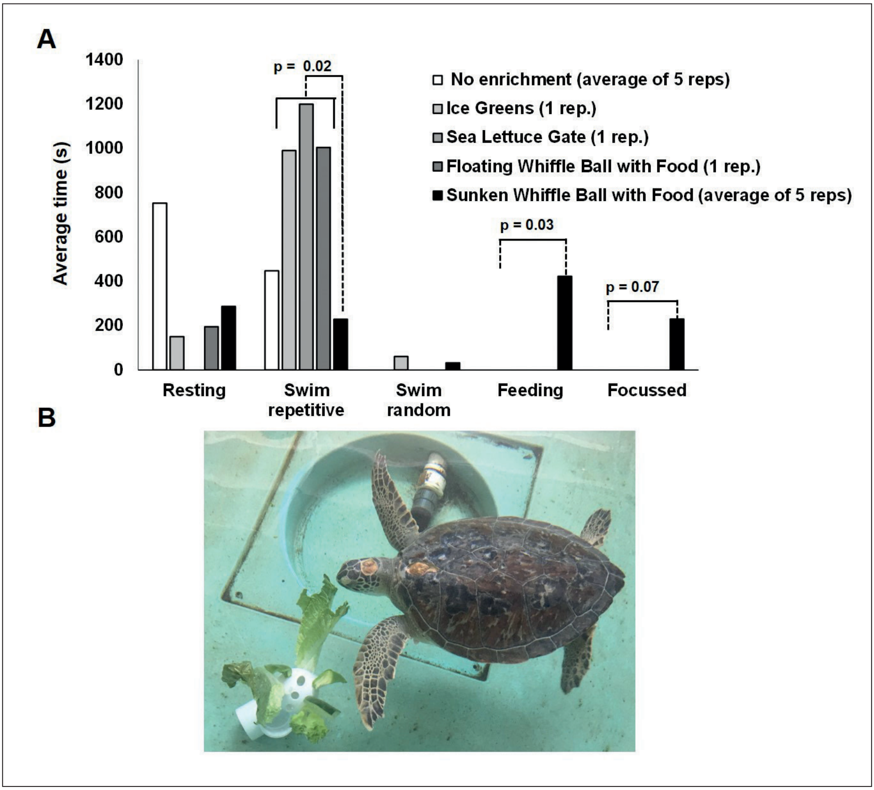

Fig. 3. Patient 6 case study. A) Average time (seconds) spent by Patient 6 exhibiting each behaviour across five conditions (no enrichment, frozen food [ice greens], sea lettuce gate, floating whiffle ball with food and sunken whiffle ball with food). Behaviours have been categorised as 'positive' or 'negative'. N = 5 for no enrichment and sunken whiffle ball, N = 1 for all other enrichments; each observation = 20 min). All statistically significant (and near significant) changes have been indicated with the p-value above the comparisons (paired t-test). B) Image of Patient 6 feeding from sunken whiffle ball enrichment.

may be alleviated by the judicious provision of environmental enrichment (Mason et al. 2007). Nile soft-shelled turtles (*Trionyx triunguis*) provided with environmental enrichment show a large decrease in self-mutilation behaviour, high levels of interaction with the enrichment devices, and increased overall activity (Burghardt et al. 1996). Physiological indicators, including blood counts, faecal corticosterone and body weights, have been used to show that box turtles (*Terrapene carolina carolina*) prefer enriched housing environments over unenriched ones (Case et al. 2005). Even captive-reared box turtles innately preferred naturalistic habitat, and such innate behaviour would hopefully aid successful reintroduction of captive-reared box turtles to the wild (Tetzlaff et al. 2018). Such Chelonian studies demonstrate the ability of enrichment to reduce stress and stereotypical behaviours for this group. Our study suggests that the same may be true for *C. mydas*, although we recommend investigating such responses in a larger number of individuals. Furthermore, as enrichment provides important opportunities for rehabilitated animals to continue to exhibit appropriate behaviours that will be necessary when they are returned to the wild (Reading et al. 2013), it is important that the effects of enrichment are scientifically tested in rehabilitating sea turtles. Promoting natural behaviours also helps the rehabilitation process by stimulating appetite, building strength, and encouraging alertness (Bluvias & Eckert 2010). However, the type of enrichment provided does need to be evaluated, as not all enrichment is guaranteed to be effective in promoting activity (Rosier & Langkilde 2011; Januszczak et al. 2016), a point further highlighted by our *C. mydas* study.

The behavioural responses of *C. mydas* observed in this study indicate that enrichment can have a positive effect, but that the effectiveness of a given enrichment may depend on the individual turtle. Across our patient cohort food-based enrichment significantly reduced the amount of time the turtles were inactive (resting) while significantly increasing active behaviours such as focussed and feeding (Fig. 2B). Five turtles (Patients 1, 3, 4, 5 and 6) showed significant increases in feeding, while Patients 1 and 3 spent significantly more time engaged in focussed behaviour (primarily investigating). Enrichment-induced behavioural changes were also observed with non-food-based enrichment, i.e. plain ice (Patients 1 and 3). For Patient 6, sunken enrichments compared with floating enrichments resulted in the turtle spending significantly less time swimming repetitively (a stress related activity). Similarly, Patient 4 significantly decreased the amount of time spent swimming in a repetitive pattern when ice blocks with food were provided. Conversely, Patient 2 significantly increased the amount of time spent swimming repetitively in the presence of enrichment, as did Patient 6 in the presence of floating enrichments, suggesting that enrichments should be tailored to individual turtle's preferences/responses. Most crucially Patient 6 only ate from a specific enrichment device, refusing all other feeding methods. Therefore, enrichment devices played a major role in the successful rehabilitation of this turtle.

As also seen in this *C. mydas* study, repetitive or stereotypic behaviour can be indicative of stress (Mason 1991), and while the provision of enrichment devices can be effective in alleviating stress by relieving boredom and allowing more natural behaviours to be exhibited, it can in some cases increase stress levels (see enrichment responses of Patient 2 and 6), perhaps owing to an object being unfamiliar or otherwise distressing. This study demonstrates that *C. mydas* can exhibit inter-individual response differences to the same enrichment, ranging from positive engagement, to dramatically increased repetitive swimming. One potential cause of these heterogeneous responses may be that the individuals were wild-born captive animals, therefore each having unique experiences prior to stranding. Differing responses may also arise due to inherent personality differences between the patients (i.e. temperament, behavioural types, conservative or promiscuous prey/grazing choice), a subject that warrants further investigation. Importantly, this study further highlights the established fact that the response of each individual animal to enrichment should be evaluated carefully before being made a regular feature of the husbandry routine (Rosier & Langkilde 2011; Januszczak et al. 2016). Additionally, individuals receiving enrichment should be evaluated on a regular basis to ensure continual value of the enrichment (Tarou & Bashaw 2007).

For marine turtles being held temporarily in a rehabilitation setting prior to being released back into the wild, it is vital that they are allowed and encouraged as much as possible to maintain physical activity and natural behaviours that will contribute to their survival once they return to their natural habitat. Therefore, we recommend further research with a wider range of enrichment devices, such as those described in previous studies of turtles (Therrien et al. 2007). We recommend specifically for marine turtles (Bluvias & Eckert, 2010), as well as for other reptiles (Mohan-Gibbons & Norton 2010; Bashaw et al. 2016), that various enrichments including but not limited to visual (e.g. mirrors, images), olfactory (e.g. food odours), food (e.g., ice blocks, live prey, puzzle feeders), social (e.g. interaction with other individuals), and physical (e.g. waterfalls, rocks, scratchers, hiding areas, floating objects) are provided. We report valuable baseline data for green turtle activity in a rehabilitation setting and demonstrate that the provision of enrichment can promote desirable behaviours in this species. Reducing stress and promoting active and natural behaviours are crucial to maximising the success of animals released back to the wild, particularly those that are held in captivity for prolonged periods. We therefore recommend an intensification of the quantitative study of sea turtle enrichment activities and captive behaviours, both of which to date have been understudied.

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