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Environmental enrichment facilitates release and survival of an injured loggerhead sea turtle (*Caretta caretta*) after ten years in captivity

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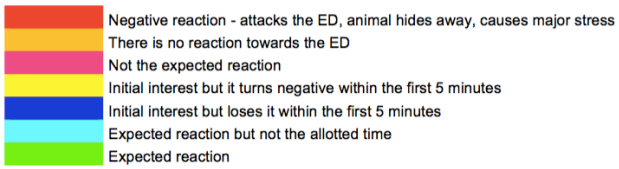
Abstract

In June 2006 a loggerhead sea turtle (*Caretta caretta*) was admitted to a rescue centre on the Mediterranean coast with severe fishing net entanglement in its fore right flipper. The flipper could not be saved and was amputated at shoulder joint level. The animal remained in captivity for 10 years due to concerns over its survival on release back to the wild. In 2016, an environmental enrichment programme was implemented to encourage the performance of wild-type feeding and locomotion behaviours, with the end plan of release. The enrichment programme lasted for two months. The enrichment devices achieved their goals of encouraging wild-type behaviours and avoidance of man-made items. After the enrichment programme had ended, the animal was successfully released back to the wild, its transmitting device showing that it crossed the Strait of Gibraltar four months post release, approached then the island of Madeira and the Azores and started crossing the Atlantic Ocean, where it was still emitting 10 months post release. This report indicates that the implementation of an environmental enrichment programme contributed to the successful release of an injured loggerhead turtle back into the wild after a long period in captivity and that environmental enrichment may facilitate the release of other turtles housed in captive environments.

Background

In June 2006, an entangled male loggerhead sea turtle (*Caretta caretta*) was found by a fisherman off the coast of Tarragona, Spain, and taken to a rescue centre on the Mediterranean Coast (CRAM, Fundació per a la Conservació i Recuperació d'Animals Marins). The animal had severe injuries in both front flippers and missing nails in the hind flippers. The body of the turtle was covered in barnacles. As barnacle load may be related to the health of the host turtle, as described in both loggerhead sea turtles and green sea turtles (*Chelonia mydas*) (Deem et al. 2009; Flint et al. 2010), this led to the conclusion that the animal may have been entangled for a long period of time. In addition, evidence suggests that loggerhead sea turtles are often immuno-suppressed and lethargic prior to colonisation by epibiotic barnacles (Deem et al. 2009). Once the net was removed it was found that the right fore flipper was hanging loose, being held only by a small amount of muscle and completely detached from the humerus, while the left one had a deep wound but did not affect the bone. The right flipper was amputated at the level of the shoulder joint, leaving only a small stump, while the left was saved after prolonged antibiotic and NSAID treatment. It was decided that the animal would not be released due to the length of recovery period of over two years required and due to having only three flippers, which was thought to prevent a successful release back to the wild. At the time of study, there were no publications or access to personal communications about the survival of three-flippered sea turtles in the wild. Ten years later, in 2016, management changes at the centre led to the decision to release the animal back to the wild, based on sightings of nesting sea turtles in Cape Verde with one or even two missing flippers over several years (A. Marco, personal communication, February 2016). A report on the recovery and release of loggerhead turtles in the Balearic Islands from 1998 to 2014 also stated that a loggerhead turtle with amputated fore flipper was released from the island of Cabrera and sighted in good health almost a year later off the coast of Algeria (Fernandez, 2014). In response, a

Figure 1. Description of reactions to the enrichment devices.



specific environmental enrichment programme was developed to encourage key species-specific behaviours to improve the chances of survival of the animal when released back to the wild.

Environmental enrichment is a dynamic process with the general objective of improving the welfare of animals by increasing their choices and encouraging the performance of species-specific behaviours (Newberry 1995). There are five recognised enrichment types, sensory, cognitive, structural, social and nutritional, according to The Shape of Enrichment®, although structural enrichment has also been named physical enrichment (Buchanan-Smith, 2010). Due to space limitations in the rescue centre and the goal of releasing the animal back to the wild, it was decided to focus on three enrichment types, nutritional, structural and sensory, with the goals to encourage natural feeding behaviour, to avert from man-made items and to respond to environmental conditions.

Action

An environmental enrichment programme was developed, based on a study conducted by Therrien et al. (2007), where six different behaviours (resting, pattern [repetitive] swimming, random swimming, focussed behaviour, orientation and non-categorised) were described in response to the presence or absence of enrichment devices for three loggerhead sea turtles and one green sea turtle. This project adapted the methods of the Therrien study to the specific needs of the focal animal and based on the responses to a previous environmental enrichment programme implemented in 2014, where, for a period of six months, seven different enrichment devices (ED) (of nutritional, sensory and structural/physical types) were randomly provided and the reaction of the animal monitored and evaluated.

Prior to initiation of the enrichment programme, the turtle was moved to a new pool, 4 m in diameter, and located in a sheltered area away from other sea turtle enclosures and with reduced regular human contact. For four days, the animal was offered the usual diet of defrosted sea bass, herring, sardines, squid and mussels, and was weighed to monitor appetite. During this acclimatisation period, daily monitoring using a web cam was conducted and the animal showed no loss of appetite or signs of distress (such as increased respiratory rate, rapid swimming, swimming against the wall of the pool, trying to climb out or prolonged immersions). Once it was concluded that the animal had adjusted to the new enclosure, the enrichment programme started.

A plan was developed that over two months, 14 different enrichment devices would be provided, with days in between when no devices would be provided and the usual diet would be offered or the animal fasted. Whether the animal received its usual diet or fasted was determined by the reaction of the animal towards the offered ED, especially if it was nutritional enrichment. A different ED was presented each day at a random hour of the day. In order to minimise human interference, a web cam was used to observe the responses of the turtle towards the different ED. Two persons completed daily monitoring of the reactions towards the ED and evaluated responses using categorised descriptions of expected reactions to each ED (Figure 1).

If the animal did not respond to the ED in the expected way, the order of ED exposure was changed accordingly, to ensure proper food intake throughout the programme. The plan was set up in a flexible way so that ED could be changed based on the animal's reaction towards the enrichment provided the previous day, thus minimising any undesirable responses to the ED. For example, if the reaction to a buoy had been to try to escape from the pool, for the next two days of the programme no ED would be provided. In such a situation, the animal would have been blood sampled to check for stress hormones and leukocyte values. The plan was to blood sample the animal once a month to ensure parameters remained within range while feeding on novel live food and being confronted with novel objects, such as buoys, that the turtle would possibly find at sea. Over the 10 years the animal had been at the rescue centre, yearly blood samples had been taken, resulting in a database of normal values for this individual. This made comparisons possible during the two-monthly plan.

Consequences

The sea turtle responded as expected to all ED provided (Table 1). It fed very well on live crabs, sea urchins and jellyfish in the expected time frame given and from the very beginning. It reacted as expected when confronted with a big fish cadaver, biting off chunks for the time frame given. It could distinguish manmade from natural objects: it avoided the manmade objects provided, including buoys and boat defences, but did not avoid novel natural objects: instead it used rocks to rub its carapace and approached a log floating on the surface of its pool. Artificial rain made no difference to its random swimming and breathing pattern (Table 2). Blood analyses were performed twice while the programme was underway, resulting in normal values. The animal was weighed twice during the study; one month from the start of the enrichment programme the turtle weighed 89.7 kg; and on the day of release, two months after the enrichment programme started, it weighed 90 kg. As the enrichment programme had involved the provision of food that the animal had to search for and process and an increase in physical activity due to being housed in a larger tank, this increase in weight further encouraged the decision to release the animal.

To monitor the success of the release, a satellite tag was attached to the turtle's carapace. The transmitter was a solar powered satellite tag Desert Star 18 g device (163910 http://desertstar.com/tt/) and was attached to the carapace with a neoprene-silicone attachment on an acrylic base-coat and treated with an antifoulant to prevent algal growth (Mansfield et al. 2012). Four months post-release, the turtle was recorded to cross the Strait of Gibraltar and swim into the Atlantic Ocean after having followed the Mediterranean Coast from Catalunya southwards. It has been reported that the Strait of Gibraltar is a bottleneck for smaller turtle species and is thought to be a common location for amputee or weaker animals (Revelles et al. 2007). Recording the released turtle at this location suggests that it was able to cross the difficult currents of the strait with only one fore flipper. The transmitter was still emitting 10 months post release, with the turtle having approached the Azores and Madeira in its way to the middle of the Atlantic Ocean, over 3,500 km in a straight line from the release site (Figure 2).

Table 1. Example of the first 10 days of the established environmental enrichment programme 2016 (also includes an Assessment column).

Date	Enrichment device / Action	Enrichment Type	Expected Reaction	Obtained Reaction	Observations
19/07/2016	Luna moved to different setting, one hour observations post transport and then 10 minutes every hour until the end of the day to ensure proper adaptation to new pool. Weight 87,7 Kg.		Adaptation to new pool, not to bite the walls, not to get entangled with the nails anywhere.	Moves around the pool in both directions. Moves the available rocks from the edge of the pool towards the middle of it.	
20-22/7/16	Adaptation, normal diet		Should eat everything	Eats 100% of the diet	
23/07/2016	Fasting				
24/07/2016	Normal diet is interrupted. 6 live sea urchins are introduced to the pool early in the morning. If the turtle has not eaten them until 17:00 p.m., retrieve all urchins but one.	Nutritional	Luna should show interest in the urchins after 30 minutes of having put them in the pool. Ideally Luna should eat them within 5 hours.	6 Urchins are introduced in the pool at 8:00 a.m. There is no reaction for the first 15 minutes, but the turtle eats two of them between 12:30 and 13:00 p.m. and one more at 16:00 p.m. Out of the three remaining ones two are taken out and one is left in the pool during the night. The turtle eats that last one as well.	
25/07/2016	Introduce two big yellow fishing buoys in the pool, for a maximum of ten minutes if it is really stressful.	Structural	Luna should dive and get away from the buoys	Luna dives and has no contact with the buoys, maintaining itself at the bottom and at the other side of the pool.	
	At 13:00 p.m. put a big piece of fresh dead fish in the pool. It should be left in the pool until next day. Water quality needs to be monitored.	Nutritional	Luna should show interest within the first 30 minutes, smelling at it, and eat it partially thorughout the afternoon and night.	A 4,5 Kg piece is intoroduced in the pool at 13:00 p.m. There is no reaction at first, but after one hour the animal has started eating, biting off chuncks, and moves the piece around the pool actively. It only eats 150 grams.	
26/07/2016	5 Live jelly fish are introducds in the pool at 9:00 a.m.	Nutritional	Luna should eat them in maximum 3 hours.	No jellyfish are to be seen after one hour.	If the jellyfish die and Luna deosn't eat them, pull them out at the end of the day.
27/07/2016	Normal diet because the big fish was not eaten.		Should eat everything.	Eats 100% of its diet.	
28/07/2016	Normal diet.		Should eat everything.	Eats 100% of its diet.	
29/07/2016	Hide 10 fresh mussels and 10 fresh sardines within the live rocks of the pool, leave them until next day.	Nutritional	Luna should move around the rocks smelling the food. It should eat everything until next day.	No mussels or sardines can be found the next morning.	Do not hide in excess to prevent frustration or a negative reaction.
30/07/2016	Introduce a round wooden log at the surface of the pool. Maximum 30 minutes if the animal scratches itself against it, 10 minutes if it dives away from it, or less if the turtle shows high stress levels and swimms against the walls of the pool. Weight: 85,8 Kg.	Structural and sensory	Luna should either dive away or scratch itself.	Once introduces the Luna swimms around it in a relaxed manner, but after 6 minutes it swimms away from it and the log is retrieved.	make sure the log has no paint or debris in it.
31/07/2016	Introduce 10 live crabs in the pool. Constant monitoring for two hours.	Nutritional	Luna should show interest within the first 30 minutes and eat the crabs throughout the day.	The turtle eats all the crabs in less than 30 minutes.	No live crabs will remain in the pool without supervision.
01/08/2016	Create artifical rain for 30 minutes. Fasting day.	Structural and sensory	Luna should not show fear or stress.	The animal comes out to breath normally and shows no stress or fear, swimming in a relaxed manner.	

Table 2. List of all enrichment devices used during the programme.

Enrichment type	Enrichment device	Action	Expected Reaction
Nutritional	Live sea urchins	6 live sea urchins are introduced to the pool early in the morning. If the turtle has not eaten them until 17:00 p.m., retrieve all urchins but one.	Luna should show interest in the urchins after 30 minutes of having put them in the pool. Ideally Luna should eat them within 5 hours.
Nutritional	Live crabs	Introduce 10 live crabs in the pool. Constant monitoring for two hours.	Luna should show interest within the first 30 minutes and eat the crabs throughout the day.
Nutritional	Two kilos of different types of fish (herring, mackerel, mussles, clams, red mullet, etc.) thrown into the pool	Introduce a mix of species in the pool, all in one place.	Luna should eat everything within a maximum of 8 hours.
Nutritional	Fresh mackerel distributed at different points of the pool	Throw several whole mackerel at different areas of the pool.	Luna should actively swimm, looking for the fish and eating it all within 5 hours maximum.
Nutritional	Live crabs and hidden sardines between the rocks of the exhibit	Hide 5 live crabs and 10 fresh sardines within the live rocks of the pool, leave them until next day.	Luna should move around the rocks smelling the food. It should eat everything by next day.
Nutritional	5 Kg piece of fish	Put a big piece of fresh dead fish in the pool. It should be left in the pool until next day. Water quality needs to be monitored.	Luna should show interest within the first 30 minutes, smelling at it, and eat it partially thorughout the afternoon and night.
Nutritional	Live jellyfish	Introduce a maximum of 5 jellyfish in the tank.	Should be eaten within 3 hours maximum
Nutritional	10 mussles and 10 fresh sardines hidden between the rocks of the exhibit	Hide 10 fresh mussels and 10 fresh sardines within the live rocks of the pool, leave them until next day.	Luna should move around the rocks smelling the food. It should eat everything until next day.
Structural	1 meter long boat defense, white, floating on the surface	Introduce a long boat efense in the pool for a maximum of 10 minutes if it is really stressful.	Luna should dive and get away from the defense
Structural	Two yellow fishing boys	Introduce two big yellow fishing buoys in the pool, for a maximum of ten minutes if it is really stressful.	Luna should dive and get away from the buoys
Structural/Sensory	Wooden log on surface of pool	Introduce a round wooden log at the surface of the pool. Maximum 30 minutes if the animal scratches itself against it, 10 minutes if it dives away from it, or less if the turtle shows high stress levels and swimms against the walls of the pool.	Luna should either dive away or scratch itself.
Structural/Sensory	Artificial rain	Create artifical rain for 30 minutes.	Luna should not show fear or stress.
Structural/Sensory	Live rocks	Introduce live rock in the pool.	Rocks should be used to scartch itself, also moving them around would be a desirable behaviour, since food will be hidden in between the rocks.
Sensory	Noise	Expose Luna to noise from a CD recorder mimiking ships.	Luna should either not show any reaction or dive away from it.

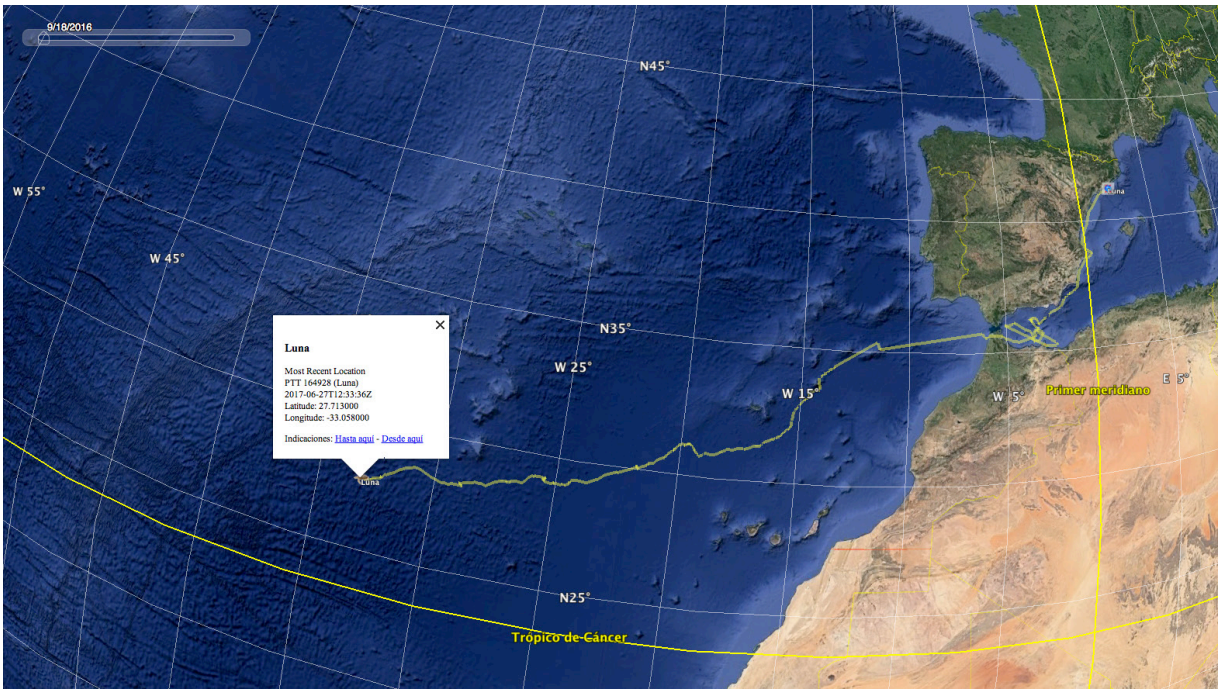


Figure 2. Satellite locations of the sea turtle since its release and to the beginning of June 2017.

Conclusion

This case report provides evidence that an injured loggerhead turtle can be successfully released into the wild, even after losing a limb and being housed in captivity for 10 years. The success of the release is also suggested to be complemented by the implementation of an environmental enrichment programme prior to release. These findings are important, as there are a significant number of sea turtles that have been kept in rescue centres for several years and are not released based on the assumption that they would have reduced survival success. Indeed, animals in captivity are likely to be less active than their conspecifics in the wild and this may reduce their fitness. However, the extent to which physical activity is reduced in captivity depends on several factors, including the space available to the animals and whether an adequate environmental enrichment programme is being implemented. Research conducted on captive elephants (*Loxodonta africana*), for example, has reported that individuals kept in large enclosures and provided with an enriched environment are less likely to develop obesity due to being more active (Kurt and Kumarashinge, 1998). To the best of our knowledge, there are no published studies on the effects of environmental enrichment and space allowance on sea turtle physical activity, but it seems likely that the environmental enrichment programme described in this paper may have benefited the animal since release, through an increase in physical activity and promotion of wild-type feeding behaviours.

The described husbandry practices could be applied by other rescue centres that house rescued animals in inadequate facilities for long periods due to long recovery times and for animals for which release would be deemed unsuccessful due to the injuries suffered.

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