

Application of Environmental Enrichment Strategies in Sea Turtles

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Environmental enrichment (EE) is a series of techniques and methods aimed to improve the welfare of animals in captivity and/or under rehabilitation. It uses external stimuli to enhance their psychological and physiological wellbeing to promote natural abilities and behaviors.

sea turtles

conservation

rehabilitation

welfare

environmental enrichment

1. Introduction

Sea turtles are important in maintaining the health and balance of various ecosystems in the marine and estuarine environments [\[1\]\[2\]\[3\]\[4\]](#). These reptiles are also valuable as sentinel, keystone and even used as flagship species, leading many of the conservation and restoration efforts of marine ecosystems worldwide [\[1\]\[2\]\[3\]\[4\]\[5\]\[6\]](#).

Most of sea turtle species are globally threatened to extinction, according to Appendix I of the Convention on International Trade in Endangered Species of Flora or Fauna (CITES Convention), and also the World Conservation Union (IUCN) [\[7\]\[8\]\[9\]\[10\]](#). The Leatherback (*Dermochelys coriacea*), Hawksbill (*Eretmochelys imbricata*) and Kemp's ridley (*Lepidochelys kempii*) sea turtles are classified as "Critically Endangered". This category describes species that have sustained "an observed, estimated, inferred or suspected reduction of at least 80% over the last 10 years or three generations, whichever is the longer". The Green (*Chelonia mydas*) and Loggerhead (*Caretta caretta*) sea turtles are in the category "Endangered" since they have shown "an observed, estimated, inferred or suspected population reduction of at least 50% over the last 10 years or three generations, whichever is the longer". In contrast, the Olive ridley (*Lepidochelys olivacea*) sea turtle is classified as "Vulnerable", since it has shown "an observed, estimated, inferred or suspected population size reduction of $\geq 30\%$ over the last 10 years or three generations, whichever is the longer" [\[11\]\[12\]](#).

Threats to marine turtle populations are mainly anthropogenic and include pollution of the marine environment, ingestion of plastic debris, fishery by-catch, harvesting adults and egg poaching, injuries by contact with fishing gear and boats, loss of habitat, entanglement and more [\[13\]\[14\]](#). Other threats are of natural origins, such as blooms of toxic algae, cold stunning, climate change, parasitism and infectious disease [\[1\]\[2\]\[4\]\[14\]\[15\]\[16\]\[17\]\[18\]\[19\]\[20\]\[21\]\[22\]](#).

Actions aimed to curb the threat of extinction include: (i) protecting all nesting beaches and the establishment of marine protected areas; (ii) reducing fisheries by-catch by at-sea and coastal fisheries through the implementation

of turtle excluder devices; (iii) addressing conservation policy actions; and (iv) supporting the sustainability of the traditional use of sea turtles [14][23].

Nonetheless, in certain specific areas, sea turtle populations are growing as a result of the success of various conservation efforts. In North Carolina, USA, accidental by-catch of sea turtles by inland or estuarine fisheries is an occurrence. A time-series analysis was carried out to assess the population size of the endangered Kemp's ridley and green turtle species [24]. By-catch by the estuarine gillnet fishery increased by 318% and 676%, respectively, when compared with reports of catches per trip from 2001–2005 and 2012–2016. The gillnet fishery has shown reductions in fish catches with time, probably due to the closure of fishing areas after a certain number of turtles are caught, thus restricting the number of trips and reducing fish harvest [24].

2. Environmental Enrichment (EE), Meaning and Usefulness

Environmental enrichment (EE) is a systematic, scientific approach to understanding and providing for the psychological and behavioral needs of captive animals or those undergoing rehabilitation in captivity [25][26][27][28][29]. This is a discipline based on the fields of ethology, psychology and animal science, intended to provide novel ways of environmental welfare for captive animals [25]. The EE identifies and provides the environmental stimuli needed or provides choices in the environment to increase behavioral opportunities for optimal psychological and physiological wellbeing [25][28][29]. The EE uses tools such as inanimate objects, social agents (conspecifics or conspecifics) or sensory material (scent trail or alarm-call playback) to encourage the performance of normal or natural behavior patterns [25]. The use of EE increases the biological relevance of an enclosure and enhances the welfare of captive species by reducing the performance of abnormal repetitive behavior or stereotypies or correcting other deficiencies. It is increasingly being used in a proactive manner to create a rich, stimulating environment [26][28][29][30]. Providing stimuli in the environment is necessary for developing the expression of the appropriate behavioral and mental activities of a species in a monotonous environment. The goals of environmental enrichment are to: (i) increase behavioral diversity; (ii) reduce the recurrence of abnormal behavior; (iii) increase the range of normal behavior patterns; (iv) increase positive utilization of the environment; and (v) increase the ability to cope with challenges in a more normal way [29]. It is important to provide the appropriate EE according to the specific biology (to the extent to which it is known) of the species under consideration [25][26]. The EE strategy needs to be well planned to achieve its goals; otherwise, it can be more damaging than beneficial [28].

2.1. EE as Tools against Boredom and Stereotypies

The application of EE programs represents an improved opportunity for animals to display conventional species-specific behaviors producing wellbeing in captivity or rehabilitation, and better animal management. In the beginning, these programs were primarily applied to terrestrial mammals and were rarely used in non-mammalian species such as reptiles. Characteristics of such EE programs include setting objectives based on natural and species-specific behaviors, individual animal history including constraints of captivity and/or rehabilitation. These programs also require methods to quantify and evaluate the effectiveness of the enrichment [25].

Some animals in the wild are wide-ranging and opportunistic feeders, but once in captivity, they are prone to developing abnormal behavior patterns such as pacing or stereotypic swimming. Likewise, some marine turtles in the wild exhibit similar behaviors since they migrate long distances and are strong pelagic swimmers. Hence, in captivity, they often display stereotypic swimming patterns. Many captive turtles on display in aquaria come from the wild and may have special needs because of previous injuries or diseases. Such needs must be provided within a safe and healthy environment, thus making effective EE even more challenging [27]. Due to these issues, it is difficult to develop EE programs for sea turtles in captivity/rehabilitation since their natural behavior and natural history are largely unknown, although some behaviors related to foraging, hunting, socializing and sensory biology are little known. Concerning their natural history, sea turtles are known to have a varied diet, a long lifespan and require up to 50 years to become sexually mature [27].

It is complicated to establish a relationship between the performance of stereotypic behavior and wellbeing, although it is suggested that it is not a linear relationship. The performance of stereotypies may not correspond to the current well-being because stereotypies may be an effect of previous suboptimal environments. Hence, stereotyping may be a mechanism of coping with an aversive environment. Thus, individual animals that perform stereotypies in suboptimal environments may well have better welfare than those that do not perform stereotypies in the same environment. Although stereotypies are a bit more correlated with wellbeing, a survey showed that 68% of environments causing stereotypies were associated with diminished welfare. Therefore, the meaning of stereotypies in environments such as zoos or rehabilitation centers should be taken seriously as a warning sign of potential suffering, but it should not be taken solely as an index of welfare. Stereotyping animals should be considered at high risk of suboptimal welfare [26].

The EE can be divided into different categories. These include the nutritional, physical, sensory, occupational (including training) and social [26][30]. These categories comprise eight types of enrichment: feeding, structural (enclosure rotation and/or renovation), tactile, olfactory, visual, auditory, social and human-animal [29]. These types of enrichment can be classified in more than one category and are not mutually exclusive. The end goal of enrichment should be to attempt to incorporate all of these types at some point in an enrichment plan [29]. This allows the animal multiple choices of interacting with the EE [30]. For example, a food puzzle (nutritional) where the animal must extract food from a plastic tube may also provide sensory, occupational and (indirectly) social enrichment [30].

Most enrichment programs are specifically designed to meet certain environmental and individual conditions of objectives, such as avoiding boredom (through the introduction of movable items such as food, sensory or cognition), or fixed enrichment items (such as the renovation of enclosures) [28]. To increase animal activity such as rotating from enclosures, stimulate hunting or foraging behavior (through the use of a puzzle feeder), increase time to feeding activities such as search (scatter or hide food), capture (live prey), extract (puzzle feeder), handle and process food (vegetation/browse, ice blocks with food, whole food, carcasses) and increase variability of feeding times or the number of feeding times per day [26]. Many of the enrichment items used in daily scheduled activities are movable items such as toys, puzzles, hidden food, frozen food and other different feeders. Social stimulation can also be a source of enrichment, thus providing social interactions (interspecific, intraspecific, and human-

animal) for captive animals by allowing them to see or touch other animals ^[28]. The EE interventions have proved efficient in reducing undesirable behavior or stereotypies and have increased behavioral diversity in the performance of species-specific behaviors ^[31].

2.2. EE Drawbacks

Despite the fact that EE has been shown to improve the welfare of animals in captivity and/or under rehabilitation, some issues have been raised that could slow or complicate the interpretation of its utility. The application of EE methods will never replace other aspects of welfare such as poor enclosure design, lack of healthcare or other poor management activities. Enclosures are important for increasing the correct stimulation for the animals, but they lack the sufficient stimulating effect to provide different types of enrichment to the subjects. EE is an important aspect of positive animal welfare but cannot fix care deficiencies alone, resulting in poor welfare. Nonetheless, EE plays an essential role in the stimulation of a broad spectrum of natural behaviors ^[26].

An aspect that complicates the evaluation of the efficacy of EE methods is the experimental design of EE applications. When different EEs are simultaneously applied to produce positive effects in the subjects, this setup does not let determine which of the EE forms was the most influential in producing the positive result ^[26]. Another issue is the report of only successful EE strategies for the situations of their subjects. This fact also limits the ability to determine which EE methods were beneficial and which ones were not. Designing studies testing the effect of different EE forms, including those that may be thought not to influence stereotypies in the animals, would help to determine whether all EEs work equally well and why ^[26].

It is possible that EE may not correct certain stereotypies that have begun as a result of different situations (increased crowd size, onset of breeding season, background noise such as traffic or construction or any combination of these and other factors) since they were not designed to mitigate the underlying causes driving such stereotypies ^[29]. Other situations in which EEs may not work include stereotypies that probably developed from situations of unavoidable stress or fear, poor environments, or the inability to fulfill species-appropriate activities. Some stereotypies may not reflect current conditions but remain from past experiences ^[29].

The cost of EE programs is another drawback since most settings have an insufficient budget to apply the actions and programs planned by the administration. Financial support from the government to zoos and other settings where animals are kept captive for exhibition or rehabilitation is also scarce, making it difficult to provide such programs. An alternative to reduce costs includes the use of recyclable materials to build EE items or to collect food items in natural areas or wildlife reserves, and the possibility to see or be close to other conspecifics are cheap and effective EE methods for many species ^[28].

In conclusion, EE is a set of methods that can improve animal welfare and promote natural behaviors under captivity and/or rehabilitation conditions. EE may also help rehabilitated turtles with amputated flippers and/or long-time captive turtles to be successfully released back to the wild to perform their biological functions, and probably to reintegrate into their natural populations. This would contribute to the conservation of the species. EE techniques

may be implemented as complementary protocols in rescue and rehabilitation centers around the world to improve the welfare of captive/rehabilitating animals, thus enhancing conservation efforts for threatened or endangered species.

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