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Evidence-based practice

# Goal-oriented behavioural and environmental enrichment in aquarium species

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**Abstract**
Environmental enrichment is a common tool used in zoo and aquarium settings to provide mental and physical stimulation to animals under human care. This paper aims to present a primary approach to goal-oriented environmental and behavioural enrichment following a simplified version of the SPIDER method for a diverse range of aquarium-housed species. The aim of the proposed goal-oriented environmental-enrichment programme is to stimulate behavioural diversity by providing controlled stimuli. This programme is easy to implement and can be used by animal care staff; it encompasses an easy evaluation form for daily monitoring and seeks to increase species-specific behavioural diversity. It is suggested that environmental enrichment programmes should be designed for the benefit of animal welfare; understanding how they affect animals under human care is essential to take informed decisions about which behaviours or situations to stimulate. An environmental enrichment protocol was developed which considers the ethology and biology of the species under consideration prior to implementation. Specific goals (i.e., behaviours and/or actions) were assigned to particular stimuli (enrichment devices) and the efficacy of the enrichment devices were assessed by reporting on the reactions of the animals. Over time, this protocol has made it possible to define a validated catalogue of enrichment devices for which specific goals and expected reactions are consistent. The increased behavioural diversity achieved with this programme is providing aquatic species with the choice to display species-specific behaviours.

## Background

International legislation and guidelines for fish under professional care are becoming increasingly detailed and do often recognise that environmental enrichment may be required to guarantee good welfare (Batt et al. 2005; Johansen et al. 2005; Council of Europe 2006; Näslund and Johnsson 2016).

Many studies suggest that environmental enrichment can affect, for example, behaviour, growth performance, survival and physiology of fish and aquatic invertebrates under human care (Smith 2006; Huntingford et al. 2007; 2012; Goosen et al. 2008; Kato et al. 2010; Costa et al. 2011). There is, nevertheless, much ambiguity with respect to the consistency of these effects. For these reasons, it is important to continue to investigate the effects of environmental enrichment on aquatic species.

The original definition of environmental enrichment by Shepherdson (1998) stated that enrichment is "an animal husbandry principle that seeks to enhance the quality of captive animal care by identifying and providing the environmental stimuli necessary for optimal psychological and physiological well-being".

Hughes and Duncan (1988) suggested that animals under human care have behavioural needs, and these are essential for the welfare of these animals (Young 2003). Goldblatt (1993) further suggested that behavioural engineering, linked with the performance of species-specific behaviours, may help to increase the complexity of environments in which animals are held under human care and to provide them with some control over it. Allard and Bashaw (2019) discussed the importance of giving animals choice and control over certain aspects of their environment to promote good welfare.

It is widely accepted that good welfare includes not only the absence of negative affective states but also the presence of positive ones and hence there is a need to identify and validate positive welfare indicators (Miller et al. 2020). While the concept of behavioural diversity has not been validated as a positive indicator of welfare, the review of Miller and colleagues suggests that it could be an important positive indicator for assessing welfare. Behavioural diversity is often found to be higher following animal management practices, such as providing environmental enrichment or an increased habitat complexity. Most studies have examined the impact of enrichment on behavioural diversity, as this was one of the original goals of enrichment programmes (Young 2003); however, there are very few studies on aquatic species.

An important consideration when developing the enrichment programme was that species-specific behaviours observed in the wild are commonly used as the basis for good animal welfare. Browning (2019) noted that behaviours observed in the wild are not necessarily a good welfare indicator for animals under human care. She stated that some natural behaviours may decrease welfare, while some behaviours not seen in nature may increase it.

It is long accepted that animals kept in aquarium settings need environmental enrichment to ensure their welfare (Bull 2002; Smith et al. 2004; 2006; Kihslinger and Nevitt 2006; Näslund and Johnsson 2016; Arechavala-Lopez et al. 2019). For example, undesirable behaviours, such as escape jetting (cephalopods achieving a high speed through the use of jetting propulsion, which in limited-size environments can become dangerous for the animal) and autophagy (consumption of the body's own tissues), can be decreased seemingly as a result of the use of enrichment (Beigel and Boal 2006). In addition, enrichment can increase the overall activity level of the animal, participating for a better display (Reihling 2001); providing variety in looking for and finding food could also lead to better welfare of the animals (Näslund and Johnsson 2016). A study by Kuba et al. (2010) showed that cartilaginous fish can be used to study the origin and evolution of cognitive traits using a tube test apparatus (environmental enrichment) and the water as an agent to extract food from the device.

Environmental enrichment devices are often artificial by nature as they are assembled using human-made materials. At the same time, such objects can be perceived as natural because they are intended to stimulate species-specific natural behaviours (Young et al. 1994; Kreger et al. 1998; Young 2003).

The idea of developing an environmental enrichment programme based on an ethogram arose from Fraser's consideration of animal welfare (Fraser 2008). By describing different concerns about animal welfare, he introduced three criteria: 'basic health and functioning', 'affective states' and 'natural living'. In the natural living section, Fraser emphasised that individual animals should be able "to lead reasonable natural lives by carrying out natural behaviours". Animals kept under human care should be allowed to express these species-specific behaviours, and environmental enrichment programmes are a tool to aid in achieving this overarching goal.

Environmental enrichment can encourage behaviours that do not necessarily influence welfare in a positive way. Animals can be exposed to frustration through enrichment, provided they can handle and cope with it. Additionally, considering the ethogram-based approach, it is important that environmental enrichment is goal oriented (Shepherdson et al. 1989; Dawkins 1990; Newberry 1995; The Shape of Enrichment ®; SPIDER; Mellen and MacPhee 2001; Young 2003; Alligood and Leighty 2015; Näslund and Johnsson 2016).

This paper presents a case study of environmental enrichment based on stimulating species-specific behaviours frequently observed in nature. More specifically, the main aim was to facilitate the expression of behavioural needs; that is, those behaviours that the performance of rewards in itself and that are controlled mainly by intrinsic factors (Hughes and Duncan 1988). Particular actions were assigned to each enrichment, and the reactions of the animals were rated. To the authors' knowledge, this is the first time a detailed environmental enrichment programme has been presented for aquatic species in such context.

## Action

The development of the six-staged environmental enrichment protocol began in 2014 and has since been implemented in over 10 facilities, both in aquarium and zoological park settings. Aquarists and zookeepers were provided with a two-day enrichment course, during which the basics of environmental and behavioural enrichment were discussed, and ethogram availability of the species housed was sought and developed. With this information and detail on observations regarding behavioural needs of the animals housed, a table was created to start the enrichment programme (Table 1). In this table, the action and the expected reaction were detailed to prevent interobserver variability as much as possible.

The range of species to which this programme has been applied is large and diverse, ranging from bottlenose dolphins (*Tursiops truncatus*) and pinnipeds (*Zalophus californianus*, *Otaria flavescens* and *Phoca vitulina*) to penguins (*Pygoscelis papua* and *Spheniscus humboldti*), sea turtles (*Caretta caretta* and *Chelonia mydas*), poison dart frogs (*Dendrobates* spp.), several species of sharks (*Carcharhinus melanopterus, Ginglymostoma cirratum, Hemiscyllium ocellatum, Chiloscyllium punctatum, Stegostoma fasciatum*), crustaceans (*Homarus gammarus, Odontodactylus scyllarus*), octopus (*Octopus vulgaris, Enteroctopus dofleini*) and teleosts (*Epinephelus marginatus, Salmo trutta, Pygocentrus nattereri*, etc.). These species are commonly found in zoological parks and aquaria but enrichment programmes are not commonly developed for fish and invertebrates; therefore, this paper focussed mostly on these species.

The aim was to develop the enrichment programme for long-term use, comprising monthly reviews and readjustment(s). The programme encompasses behavioural goals to be achieved through chosen enrichment devices which are then implemented, evaluated and assessed. The protocol can be summarised as follows:

***1. Species-specific behaviours and experimental ethogram in each facility***

The method is based on researching the general ethogram of the target species, as well as the particular behavioural repertoire expressed within the group or individual under consideration.

***2. Goals to be reached or behaviours to be stimulated***

The general species ethogram and the specific behavioural repertoire defined during Phase 1 are then compared to identify species-specific behaviours that positively influence welfare but are not displayed by certain individual animals. These behaviours


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are then targeted by the enrichment programme through specific enrichment devices to facilitate the animal or group of animals to display their behavioural diversity spectrum. At this stage, and in the general context of welfare of animals under human care, the global idea is to promote and/or encourage the display of species-specific behaviours within a group of animals or an individual.

### *3. Defining a detailed enrichment programme*

The enrichment devices are categorised into the five enrichment types described in The Shape of Enrichment ®: cognitive, social, sensory, structural and nutritional.

It is important that enrichment devices are used randomly and not always at the same time of the day to prevent them from becoming routine for the animals. In detailing the action to be taken, the animal care team need to set the device use time based on the expected reaction from that particular species and its biology. Nocturnal species will not react to enrichment devices provided in the middle of the day and on the contrary, enrichment provided at night will be of little use to species active during the day.

This monitored enrichment programme was also designed to prevent animals from being trained to react the expected way, as the goal of the programme is to stimulate certain behaviours and to give the animals the choice of interacting or engaging with the environmental device, hence giving them control in that particular moment (Allard and Bashaw 2019). Therefore, specific rules are given and are to be followed throughout the programme (Figure 1).

### *4. Observation and reporting of the reactions of the animals*

A protocol to assess the results and the consequences of each chosen enrichment device was created. During enrichment implementation, the animal keepers/aquarists have to record the reactions of the animals to the enrichment device provided (Table 1).

Reactions of the animals are to be recorded by the animal staff, classified into six possible outcomes or reactions towards the enrichment devices, A to F (Figure 2). This scale extends from the 'expected reaction' (A) being observed throughout the whole dedicated timeslot defined in advance, to a 'negative' reaction (F), for example, aggression or fear. The outcome categories also include 'not expected' reactions or 'no reaction'. To facilitate the application of this method as part of the daily management of the animals, categories were colour coded (Figure 2).

The reaction categories enable an evaluation of the efficacy of the enrichment device. The evaluation sheet therefore encompasses all the information required to assess efficacy: date, keeper's name, enrichment device used, enrichment type, detailed description of the actions to be taken, goal of enrichment, description of the expected reaction, description of the observed reaction and a final evaluation of the enrichment device.

### *5. Analysis and readjustment(s)*

A general review of the programme is performed on a monthly basis to identify the real impact of the enrichment devices and to evaluate the need for improvement and/or readjusting. If an expected behaviour is not obtained in a consistent manner for several individual animals, the programme has failed to stimulate the desired behaviour and the specific environmental device needs to be re-assessed.

The systematic records taken of animal reactions has enabled the strengthening of the model over the years and a consolidation of the links between each intended goal and each enrichment device used, as well as the expected behaviours or reactions to each of these devices.

| No. | Rule |
|---|---|
| 1. | Behaviours should not be reinforced by the keepers. |
| 2. | Choice should be given to an animal whether or not to interact with the provided enrichment device. This will help understanding if the goal/s is/are achieved. |
| 3. | The animal should not be asked to bring back enrichment device/s. |
| 4. | Professional care staff should not interact with the animal during environmental enrichment sessions unless specified in the actions to be taken. |
| 5. | Preparation of the enrichment devices, especially nutritional ones, should not be visible for the animal. |
| 6. | Time of the day for environmental enrichment sessions should be chosen randomly and based on the biology of the species. |
| 7. | Environmental enrichment sessions should be evaluated by professional care staff. |

**Figure 1.** Simplified rules to follow while implementing the species-specific goal-oriented enrichment programme.

| Code | Colour | Reaction |
|---|---|---|
| F10 | | Negative: animal attacks the object and/or hides away and/or shows distress. |
| E8 | | No reaction: animal does not show any kind of reaction to the enrichment device. |
| D5 | | Not the expected reaction: animal does something different than the goal. It is not necessarily bad since we might have stimulated a different behaviour than that originally intended. |
| C3 | | Expected reaction at first but then turns negative. |
| B2 | | Expected reaction but not for the planned time. |
| A1 | | Expected reaction. |

**Figure 2.** Six possible outcomes or possible reactions of the animals towards the enrichment devices used.

**Table 1.** Action, goal and expected reactions to enrichment.

| Date, time, who | Species | ED | Action | Enrichment type | Goal | Expected reaction | Obtained reaction | Comments | Evaluation |
|---|---|---|---|---|---|---|---|---|---|
| 21 Jan 2019, 1430, CZ | Spiny lobster *Panilurus elephas* | Feeding rings | Three feeding rings are prepared with anchovies and saithe inside; do not exceed 50% of their daily diet. Place the rings at the bottom of the tank. These rings are to be left in the tank for maximum 15 mins. | Nutritional | Increase the time they spend looking for food/obtaining food. Give choice over what they want to eat. | The spiny lobsters should seek and find the food in the rings on the floor of the aquarium, choose what they want to eat and spend at least 15 mins trying to get the food out of the rings. | The lobster (and fish) were interesed in the devices and spent the planned time getting food out. No aggression occurred. | Rest of animals in the tank were interesed too. | A1 |
| 22 Jan 2019, 1300, CZ | Green sea turtle *Chelonia mydas* x 2 | Brush | Two brushes are held by one aquarist on the water surface to allow the sea turtles to scratch their back (10-15 mins); do not follow the animal with the brush. Remain static and only brush if the animal approaches. If they bite the brushes, remove them from the pool and place them back in a few seconds later. | Sensory | Provide the animals with the opportunity of scratching off algae and dead dermal cells from their carapace, as they would do in the wild with rocks | The turtles will come to the surface and rub their carapace actively against the brushes within 5 mins of them being introduced. They might try to bite them. | The turtles approach the brushes and used them in less than 5 mins, almost immediately. They didn't bite them. | They want more than 15 mins! | B2 |
| 23 Jan 2019, 1130, CZ | Common octopus *Octopus vulgaris* | Matryoshka doll | Provide a variety of foods, depending on availability, inside the Matryoshka doll; do not exceed 15% of the daily diet. Place the doll inside the tank and let it sink to the bottom on its own (15 mins). | Nutritional, structural, sensory and cognitive | Increase foraging time and exploratory behaviour, stimulate cognitive abilities | Octopus should approach the ED in less than a minute and find out how to open the doll and eat the food in less than 10 mins. Expected reaction would be for it to catch it in mid water and not let it float down to the bottom. | ED was taken and opened in less time than expected. | The difficulty of the ED could be increased. Maybe by adding three dolls? | A1 |
| 24 Jan 2019, 1000, DA | Rays *Raja* spp. and large fresh water species displays | Feeding pipes | Three 60 cm long performated PVC pipes, 75 mm in diameter, are provided. Pipes are filled with a variety of food; do not exceed 50% of the dail diet. They are placed on the bottom of the tank, as far apart as possible, and left for 15 mins. | Nutritional and sensory | Increase foraging time and olfactory sense, stimulate exploratory behaviours and cognitive abilities by getting them to find out how to get the food out of the pipes | The rays should approach the feeding pipes in less than 2 mins and start rolling on them to get the food out. In the case of fish, larger specimens should push the pipes so that food falls through the holes and can be eaten. | ED was accepted and the rays got the food out together, same with the fish. | At times there was strong competition; all animals tried to get food from one pipe. Maybe supply more ED? | A1 |
| 25 Jan 2019, 1230, DA | Gentoo penguins *Pygoscelis papua* | Air bubbles | Two diving bottles are to be placed at the bottom of the tank and then opened. This involves diving. Facilities with an inbuilt bubble system can just turn it on (15-20 mins). | Structural | Stimulate exploratory behaviour and increase physical excercise | The penguins should go into the water within 5 mins of the bubbles appearance, should not be afraid of them, but circle around them and try to hunt them with the beaks. Some might let them caress their bodies (spa like). | The entire group reacted as expected, although 3 were more reluctant to go into the water, it took them 7 mins to dive in. | Enrichment should be less than 20 mins, otherwise the animals lose interest. | A1 |

**Table 1.** Action, goal and expected reactions to enrichment (continued).

| Date, time, who | Species | ED | Action | Enrichment type | Goal | Expected reaction | Obtained reaction | Comments | Evaluation |
|---|---|---|---|---|---|---|---|---|---|
| 29 Jan 2019, 1130, CZ | Arctic char *Salvelinus alpinus*, stickleback *Gasterosteus aculeatus*, rudd *Scardinius erythrophthalmus* , Nase *Chondrostoma nasus* | Food ball | 50% of their daily diet is placed inside a perforated ball and put in the tank. It should be fixed to stay in the mid-column or deeper; avoid the surface to prevent fish gulping air. One ball is sufficient for a small group, but increase the number with fish numbers (10 mins). | Nutritional and structural | Increase foraging time and stimulate olfactory senses. | The animals should swim towards the food ball(s) and start pushing them to get the food. None of the animals should be left separated from the group. | All animals went into hiding and did not explore the ED in the given time. | Animals were scared of the ED | F10 |
| 31 Jan 2019, 1330, DA | Mediterranean moray eel *Muraena helena* | PVC pipe fitted on the inside with fake algae or artificial grass | Place a PVC pipe in the corner of the tank; ensure its diametre is bigger than a moray eel and twice as long. Put it into the display prior to feeding time. Leave for about 2 hrs. | Structural and sensory | Stimulate exploratory behaviour, provide different hiding/ shelter places, give different substrates to choose from, alter the environment for a short duration of time. | Moray eel should start exploring the device and go in and out several times, even stay in it for an extended period of time. | Whilst the moray eel showed interest and explored the pipe, it did not go in. | Maybe extend allotted time? | D5 |
| 06 Mar 2019, 1245, CS | Pacus and Cardinal fish | Ice bomb | Freeze 25% of the daily diet in ice balls, pieces of fish can stick out of the bomb; ensure balls are sufficiently big that they can't be swallowed whole. At least one bomb per fish should be provided on the surface of the water simulataneously, outside of feeding time (15 mins). | Sensory and structural | Increase exploratory behaviour. Allow access to floating food items and exposure to different textures. | Animals should appraoch the ice bombs and attempt to feed from them, push them and then as they melt take the food. No aggreession should be seen or more bombs will be needed. | All animals approached the bombs immediately and pushed them all over the tank. All the food is consumed. | Rapid melting. Next time a higher amount of ED | A1 |
| 14 Mar 2019, 1130, CS | big bellied seahorse *H. Abdominalis* garden eels *Heteroconger hassi*, small tropical reef fish species, discus *Symphysodon discus* | Live mysis inside a bottle | Place live mysis inside a transparent bottle that has one hole on the top. Tie it to a weight and place it in the tank in mid water. Animals can see the mysis moving inside the ED (20 mins). | Nutritional, structural and cognitive | Increase foraging time, stimulate exploratory behaviour. | Seahorses and small tropical fish should go near the bottle and discover the mysis leave through it's hole and hunt them. Fish might bump the bottle to stimulate the mysis to come out. Garden eels will wait for the mysis to leave the bottle and then forage for them in the substrate. | High success. | Seahorses might need more time. | A1 |
| 05 Apr 2019, 1530, RP | poison dart frog *Phyllobates terribilis* | Live drosophila inside a bottle | Place live drosophila inside a transparent bottle with several holes on its lid. Place it in the middle of the terrarium, away from plants and water (30 mins). | Nutritional, structural and cognitive | Increase foraging time, stimulate exploratory behaviour and cognitive abilities to try and get the flies out of the bottle. | Frogs should approach the ED within 5 mins of it being introduced and start bumping it with their head and/or tongue to try and get the flies out. All the flies should be eaten in 30 mins. | High success. | Not more time needed | A1 |
| 10 Apr 2019, 1000, DA | Gentoo penguins *Pygoscelis papua* | Water jet | Place two hoses or water jets in the exhibit, at the rim of the pool and spraying towards it. Both should have different pressures (15 mins). | Sensory and structural | Allow the penguins to feel different water pressures to rub against. Increase exploratory behaviour and physical excercise. | The entire colony should go under or to the side of the jets/sprays and play with the water, letting it fall on their bodies. Penguins to roll and groom themselves underneath the water. | All animals ended up going under the water jets, some seemed to enjoy it more than others. | | A1 |

Additionally, and to allow future statistical analysis of the implemented enrichment programme through a distance matrix, a given factor was assigned to each reaction category (Figure 2) from 1 for 'expected reaction' to 10 for 'negative' reaction. These analyses allow a readjustment of the enrichment devices used to assure efficacy.

***6. Creation of a validated catalogue of proven and goal-orientated enrichment devices***

Based on pilot studies and initial developments, it has been possible to develop catalogues of enrichment devices for various aquatic animals. An example of those enrichment devices obtained from validated catalogues for several species can be found in Table 2.

## Consequences

The methodology described above has been followed over the last six years at regular intervals in all participating facilities and with a broad range of species. It is expected that the defined validated catalogues of enrichment devices will be an important tool facilitating the stimulation of particular species-specific behaviours. For example, the use of enrichment devices such as feeding pipes for rays (*Raja clavata, R. montagui* and *R. undulata*) has proven useful in stimulating their sensory organs and encouraging a foraging behaviour that they would exhibit in the wild (Feist and Anderson 1991; Anderson and Wood 2001; Borneman 2009; Corcoran 2015). While using this enrichment item, the expected reaction was consistently observed and recorded, and it is advised to implement this enrichment when

**Table 2.** Examples of validated enrichment devices for different aquarium species

| Species | Enrichment device | Enrichment type | Goals | Behaviours |
|---|---|---|---|---|
| *Panilurus elephas* spiny lobster | Feeding rings | Nutritional | Increase time species spend looking for food/obtaining food. Possibility of choice over the food. | Foraging behavioural diversity |
| *Pagurus* sp. hermit crabs | Different substrates with or without embedded food | Sensory | Increase exploratory time and foraging behaviour. Possibility of choice over different substrates. | Foraging, locomotory and sensory behavioural diversity |
| *Chelonia mydas* green sea turtle | Brush | Social and sensory | Choices for interaction with professional care staff. Choices for exploratory and sensorial body interactions. | Exploratory, sensory and locomotory behavioural diversity |
| *Pygoscelis papua* Gentoo penguin | Air bubbles | Structural | To motivate exploratory behaviour and increase physical exercise. | Exploratory and locomotory behavioural diversity |
| *Salvelinus alpinus* Arctic char | Food ball | Nutritional, structural and social | Increase time species spend looking for food/obtaining food. Possibility of choice over the food. Socio interactions between individuals. | Foraging, locomotory and social interactions |
| *Muraena helena* Mediterranean moray eel | Food pipe | Nutritional, structural, sensory and cognitive | Increase time species spend looking for food/obtaining food. Possibility of choice over the food. Socio interactions between individuals. | Foraging, locomotory, exploratory and social behaviours |
| Pacus and cardinal fish | Food "bombs" | Nutritional and sensory | Increase time species spend looking for food/obtaining food. Possibility of choice over the food. | Foraging, exploratory and locomotory behavioural diversity |
| *Hippocampus abdominalis* big belly seahorse | Alive Mysis inside a bottle | Nutritional and structural | Increase time species spend looking for food/obtaining food. Possibility of choice over the food. | Foraging, exploratory and locomotory behavioural diversity |
| *Phyllobates terribilis* poison frog | Alive Drosophila in the bottle | Nutritional, structural and cognitive | Increase time species spend looking for food/obtaining food. Possibility of choice over the food. | Foraging, exploratory and locomotory behavioural diversity |
| *Diodon* sp. puffer fish | Mussels glued together with coral paste and shells filled with omnivore gel | Nutritional and sensory | Increase time species spend looking for food/obtaining food. Possibility of choice over the food. | Foraging, exploratory and locomotory behavioural diversity |
| Salmonids | Underwater currents | Structural and sensory | Stimulate group cohesion and physical exercise. | Social and locomotory behavioural diversity |
| *Octopus vulgaris* common octopus | Pipe maze | Structural and sensory | Stimulate exploration and physical exercise. | Exploratory and locomotory behavioural diversity |
| *Hommarus gammarus* European lobster | Pipe with holes | Sensory and nutritional | Olfactory stimulation and looking for food/ obtaining food. | Exploratory and foraging behavioural diversity |
| *Electrophorus electricus* electric eel | Rain | Sensory | Stimulate exploration and hunting behaviour. | Exploratory and locomotory behavioural diversity |



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the resulting behaviour is sought. Also, the provision of feeding containers for lobsters (*Homarus gammarus*), hidden in sand, stimulated the desired effect in the lobster. As observed in nature, the lobster dug out the device and found a way of obtaining the food inside using its claws. Similar enrichment protocols and devices were developed for starfish (*Asterias rubens*), increasing foraging behaviour and feeding time up to five times, although more research is warranted with this group since the reactions of tropical versus cold water species has not been yet compared. Artificial rain was provided to trigger hunting behaviour in an electric eel (*Electrophorus electricus*), by combining the trickle of water with food being supplied on the surface. This encouraged the performance of a natural behaviour, in this case hunting, and releasing electricity throughout the whole process. An aquatic mantis shrimp (*Odontodactylus scyllarus*) was offered different substrates to build its nest, hence increasing choice and control over its environment. Sticklebacks (*Gasterosteus aculeatus*) were offered a floating food ball to allow for longer feeding times; this intervention has worked every time it has been implemented, which is over 20 times to date.

In grazing fish that swim in schools it is very important to offer several grazing stations, as nutritional enrichment devices, to prevent competition. In mixed-species tanks with predators and prey sharing one environment (i.e., teleosts and sharks), enrichment should not allow for easier access to the prey species, and this needs to be taken in to account when planning how to present enrichment. For example, a floating rock covered by herbivore gel diet increases the time small fish spend foraging, acting as a grazing station, and stimulates physical movement of small fish, but it may also turn into a lure for teleosts that sharks could subsequently feed on. Several stations have to be provided simultaneously to prevent this from happening.

In the case of mixed-species tanks of a smaller size, it is also important to place grazing stations away from anemones for the enrichment device to be successful. Anemones can irritate and sting, and fish will avoid going near them. The use of mussels glued with coral paste for any member of the Diodon family has proved beneficial in increasing foraging time and keeping teeth trimmed without the need of human intervention. In tanks where prawns and fish live together, competition for food is sometimes an issue and some species cannot diversify their foraging behavioural repertoire. An enrichment device aimed to make it more difficult for the prawns to get the food and the provision of a floating food dispenser for the fish swimming in mid-column could allow for these foraging behaviours to arise.

Some species are less prone to stimulation and do not always exhibit the expected reactions when faced with an enrichment device. This might be due to the prey/predator status, and the composition of the tank; more research is needed in these particular areas.

Seahorses do not seem to be easily stimulated except when offered food in a variety of devices. A hanging structural enrichment device designed to result in sensory stimulation in black tip reef sharks (*Carcharhinus melanopterus*) was not at all successful, while feeding pipes designed for bottom-dwelling sharks, such as brown banded bamboo sharks (*Chiloscyllium punctatum*) or nurse sharks (*Ginglymostoma cirratum*) triggered a non-expected reaction in the black tip reef sharks, resulting in the entire group of eight animals speeding towards the bottom of the tank to smell, push and grab the food that came out of the pipes. Such findings also support those of Näslund and Johnsson (2016), who describe the need for further investigation to better understand the importance of species-specific behavioural diversity in aquarium settings.

While these data have not yet been statistically analysed, the preliminary patterns offer an optimistic insight into the fact that natural behaviours can be stimulated with man-made objects in an array of aquatic species. The validated species catalogues created from standardised observations enable the identification and validation of enrichment devices that stimulate certain behaviours under known conditions (number of sessions, duration, etc.). Determining which behaviours are missing from any behavioural repertoire of a group of animals or an individual animal, it is possible to determine which enrichment devices to use to stimulate behaviours with a positive welfare influence .

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