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Sonar-stimulating enrichment for bottlenose dolphins (Tursiops truncatus) in human care

Sabine den Ouden

Examiner, Matthias Laska
Supervisor, Mats Amundin

LINKÖPINGS UNIVERSITET

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Abstract

The use of sonar is an important behaviour of bottlenose dolphins (*Tursiops truncatus*) and is not challenged when they are in kept in human care, such as in zoos and dolphinariums. To stimulate the use of sonar, two enrichments were presented to the dolphins: a sonar-activated 'meandering' hose and boxes with buried fish and sonar targets buried in shell sand. When activated by sonar, the hose moved through the water and fish and/or gelatine strips could be ejected from it. Having the hose activated generally increased overall sonar activity as well as other acoustic parameters such as the number of click trains. During activation of the hose, the dolphins spent significantly more time observing the hose but had significantly less moments of direct contact with the hose. The ejection of food items increased the number of high-speed pursuits and the number of times small bubbles were made by the dolphins. With the shell sand boxes, exploratory behaviour was significantly positively affected by both the presence of the sonar targets and the location the boxes were in. So, it was not possible to draw any conclusions about the dolphins' ability to detect buried items using their sonar. In conclusion, the use of the meandering hose had a positive effect on sonar activity and exploratory behaviours and while the shell sand boxes did not seem to have the desired effect on sonar activity it was still a successful enrichment.

Keywords: Echolocation, Zoo, Dolphinarium, Exploratory Behaviour, Welfare

1 Introduction

The World Association for Zoos and Aquaria (WAZA) defines animal welfare as "how the animal experiences its own world and life through its association with pleasant experiences specific for that species … or unpleasant experiences" (*Our Approach to Animal Welfare - WAZA*, n.d.). WAZA also states that zoos must be centres for animal welfare (Mellor et al., 2015). One way that zoos and aquaria try to improve animal welfare is by introducing environmental enrichments (Wells, 2009).

Newberry (1995) defined environmental enrichment as modifications to a captive animals' environment that result in improvement of biological functioning. One way to improve biological functioning in animals under human care is through enrichment that stimulates selected species-specific behaviours (Wells, 2009). In bottlenose dolphins (*Tursiops truncatus*) one of their most important sensory inputs is related to sonar (echolocation) and species-specific behaviours associated with this (Au, 1993).

In the wild, odontocetes (the parvorder which includes bottlenose dolphins) use sonar in almost all aspects of their life, such as navigation, foraging, and hunting (Au, 1993). Even though the opportunity and need to use sonar is of vital importance for dolphins for navigation, foraging, and exploring their surroundings, the pools where dolphins under human care are kept are often barren, with few objects in the water column or on and in the pool floor.

Besides that, the water in the pools is to be clear and clean (ABTA, 2013; SPAW-RAC, 2006), which means that navigation and exploration in the pool can be based to a high extent on vision. Also, the pool environment is, in general, static, where the lay-out of the pool is well known to the dolphins, offering little novelty to explore. In zoos, most dolphins are fed thawed fish by hand in order to ensure the correct individualized food intake (EEAM, 2019) and ensure precise reinforcement of trained behaviours. The chlorine in the pool, necessary to control faecal bacteria, prevents keeping live fish, which eliminates natural foraging and hunting behaviour. Hence, most bottlenose dolphins under human care are not actively stimulated or challenged to use their sonar for navigating, exploring or hunting. Therefore, sonar must be stimulated with specifically designed environmental enrichment.

The use of sonar a crucial behaviour in a dolphin's life (Wisniewska et al., 2014) which is based on a dolphins' specialised auditory system and sound producing mechanism (Cranford et al., 2010; Cranford & Norris, 1996). Their sonar works by emitting trains of broadband, high frequency (20 – 100+ kHz) clicks. These clicks echo back to them if they hit an object, and dolphins use these echoes to gather information on potential prey and other objects in the water around them (Au, 1993). When echolocating, dolphins will not produce a new click before the previous click is echoed back to them and they have processed it. The time between clicks is called the inter-click interval (ICI) (Au, 1993). When locked on a target, the closer the dolphin gets to a target, the shorter the ICI will become as the click is echoed back quicker and quicker (Castellote et al., 2015; Nuuttila et al., 2013). When the ICI becomes shorter than 10 ms, the click trains are called 'buzzes'. These buzzes are typically observed in connection with foraging and hunting in wild dolphins (Nuuttila et al., 2013).

Not only is this sonar used when searching for and capturing food swimming in the water but possibly also to detect prey buried in the sea floor. Wild bottlenose dolphins near the Bahamas have been observed to scan the sea floor and then, possibly in response to some cue, dig their snout several decimetres into the coral sand, and come out of the sand again with a fish in their mouth (Rossbach & Herzing, 1997). These authors hypothesised that these dolphins used their sonar to locate the hidden fish.

To stimulate as much of the species-specific use of sonar and sonar-related behaviour as possible, two types of enrichment were offered to the dolphins of Kolmården Djurpark in Sweden.

The first enrichment is called the 'Meandering Hose'. It is based on the jet effect, where the water flow makes the hose move through the water in a meandering fashion. The hose in this set-up was connected to a high-pressure water outlet that can be opened by an electromagnetic valve. When the hydrophone attached to the end of the hose is exposed to sonar clicks, an acoustic switch activates the electromagnetic valve at the water outlet, which then opens for the water flow. If there are no sonar clicks detected for 1 second, the acoustic switch is deactivated, and the water flow will stop. This means the enrichment is interactive which makes this enrichment suitable to stimulate sonar activity in the dolphins, since the hose will not move if the dolphins do not use their sonar. The way the hose moves through the water simulates the movement of prey, and thus may thus stimulate hunting and foraging behaviours in the dolphins.

The second enrichment is called the Shell Sand Boxes. This enrichment is based on the findings of Rossbach and Herzing (1997) that dolphins may be able to detect fish buried in the seabed with their sonar. By presenting three identical boxes, one of which with fish and sonar targets buried in the shell sand, the dolphins would be stimulated to use their sonar to detect the sonar targets under the sand. This could then result in the dolphins learning to associate the sonar cue of the targets with the presence of fish and then focus on this box to extract the fish from the sand.

While the first enrichment is a sonar-activated enrichment, the boxes offer a discrimination task based on the use of sonar.

Two previous studies have been conducted in Kolmården Djurpark, one with just the meandering hose (Berglind, 2005) and the other with both the hose and one sand box (Kristensen, 2017).

During Berglind's (2005) study, the hose had three different states. It was either turned off, turned on (constantly) or interactive, where the hose was turned on based on sonar activity. During this research, nothing was ejected from the hose.

When Kristensen (2017) conducted their research some changes had been made to the hose. During their study, to load the fish or gelatine strips into the hose, the water flow had to be shut off, the fish or gelatine loaded, and then turned on again. This meant that there was a break in the hose interactivity while loading in the food items.

In the present study, food items could be loaded into the hose without having to shut off the water supply. This means that the hose was always interactive during the sessions with an activated hose.

In Kristensen’s (2017) study with the sand box, fish and gelatine were buried in the sand in separate sections created by Kristensen. Click detectors were placed below the sand box, in an attempt to monitor the dolphins’ search pattern, i.e., how they scanned the sand surface with their sonar beam. The results showed no indication that the dolphins detected the fish or gelatine lumps, since the search pattern was completely random. This may be explained by the fact that the swim bladder of thawed fish is collapsed and hence the target strength of such a fish is very low. The gelatine lumps were supposed to create a hollow in the sand, which might be possible for the dolphins to distinguish from homogeneous sand. Since this was not the case, in the present study, two air-filled containers, offering a very strong sonar target, were buried in the box with the fish to make the task easier for the dolphins.

During their research, Berglind (2005) found that overall sonar activity in the pool of the dolphins was low. However, when the meandering hose (then called ‘interactive hose device’) was introduced, sonar activity increased significantly. They also found that when the hose was in its interactive mode, the dolphins’ activity was the highest, and stayed on a high level over repeated presentations. When the hose was in its always on state, i.e. the water flow was not controlled by the dolphins, the presence and interest of the dolphins dropped when repeatedly being presented with the hose in this state. The results also showed that the hose stimulated hunting-like behaviour in the dolphins.

Kristensen (2017) studied both the meandering hose and a set up with one sand box. They showed that there were no significant differences in sonar activity or behavioural parameters between the different states of the hose: *non-active, full effect, full effect + fish,* and *full-effect + gelatine*. This means that the hose was inactive, interactive, interactive with fish ejected from the hose and interactive gelatine ejected from the hose, respectively. With the sand boxes they found no evidence that the dolphins detected the buried food items primarily by using their sonar.

Several research questions were central in the design of the present study.

For the meandering hose, the research questions focused on behavioural differences of the dolphins when interacting with the hose in the different states of the hose. Specifically, how the use of sonar when interacting with the hose was affected by the hose being either inactive, activated, and activated with fish and/or gelatine ejected from it. Besides this, there was also a focus on foraging- and hunting-like and exploratory behaviours when interacting with the hose and how this was affected by the different states of the hose.

With the sand boxes, the central research question was about the dolphins' ability to detect the buried air-filled containers and their ability to associate them with the fish in the same box. This would be answered by answering two sub questions. One about the dolphins' behaviour that might indicate use of sonar and one about whether the dolphins would be able to associate the echo from buried sonar targets with the presence of fish.

With the meandering hose enrichment, I expected that the use of sonar and the frequency of exploratory, and foraging- and hunting-like behaviours would increase when the hose is activated compared to inactivated. When fish and/or gelatine is ejected, I expected that the frequency and duration of these behaviours would increase. I expected there to be a difference in the abundance of sonar clicks and foraging- and hunting-like behaviours between the fish and the gelatine being ejected since dolphins may have individual preferences for which reward they find more attractive. I also expected that randomizing the fish and gelatine ejections and the timing of their ejections would increase the sonar activity compared to ejecting fish or gelatine with fixed intervals that are easier to predict.

With the shell sand boxes, the expectations were that the dolphins would be able to detect the air-filled containers, which provide strong sonar signal, and associate them with the presence of fish. This would be seen by more dedicated search for fish in this box compared to the boxes with only sand in them.

2 Materials and Methods

2.1 Study site

The data collection took place in the dolphinarium of Kolmården Wildlife Park in Sweden. There are three inter-connected pools: the Laguna and the Show Pool, with the Holding Pool in between (see Figure 1). The total water surface area is ca 2000m^2 and the total volume of the pool is 6400 m^3. The enrichment experiments were carried out in the holding pool.

The holding pool is square shaped and measures 13x13m. It has an adjustable floor that can change the depth between 5 cm and 275 cm. The channels connecting the holding pool to the other two pools have netted gates that can be closed to separate the dolphins from each other or prevent them from accessing selected pools. The holding pool area is off-limits for zoo visitors, except for guided tours with smaller groups. During the enrichment experiments, there were no zoo visitors in the holding pool area.

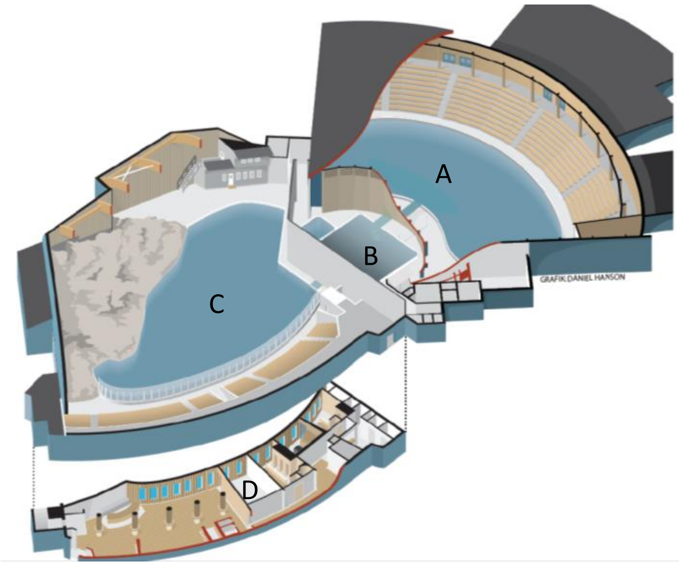

Figure 1 Layout of the pools in the dolphinarium of Kolmården Wildlife Park. A) Show Pool, B) Holding Pool, C) Laguna with underwater viewing, D) Conference facility with underwater viewing.

2.2 Subjects

At the time of the study the Kolmården dolphinarium housed twelve bottlenose dolphins (*Tursiops truncatus*), seven adult females, two adult males, one subadult female, and two subadult males. The dolphins were between 3 and 39 years of age.

2.3 Enrichment types

Two types of sonar-stimulating enrichments were used, a sonar activated "meandering" hose, and boxes where fish and sonar targets were buried in shell sand.

The meandering hose part of the study was carried out from July to October, and the shell sand box part in December.

2.4 The meandering hose

2.4.1 Equipment

The meandering hose was a 10m long, inner Ø45 mm, plastic wire reinforced plastic hose that was connected to a high-pressure water outlet. The hose was tied to a pillar, leaving approximately 4m of the hose submerged in the pool. At the mobile, submerged end of the hose, a hydrophone was attached. The hydrophone cable was inside a cable protector that was tied to the outside of the hose with pieces of shrinking hose and cable ties. This cable was connected to an electronics box containing an Etec A1001 preamplifier, a NewLeap click detector, an acoustic switch, and a power switch; the latter controlled an electro-magnetic valve at the water outlet (Figure 2). The click detector had a band-pass filter centred at 70kHz, which eliminated low frequency noise from triggering the acoustic switch.

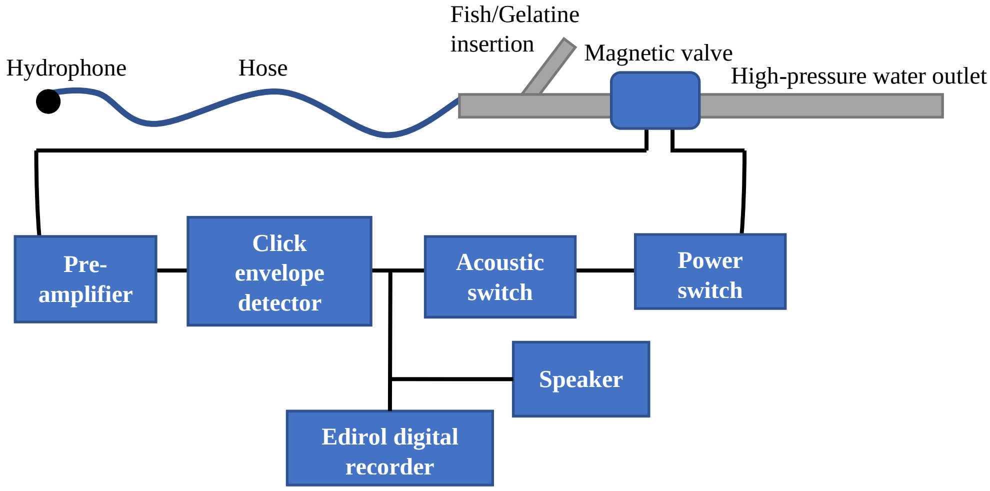

Figure 2 The mechanic and electronics set-up of the meandering hose enrichment. The black line indicates electronic cables and the thick grey bar the water system.

When the sonar of the dolphins was detected by the hydrophone, the acoustic switch was triggered, which activated the power switch, thereby opening the electro-magnetic valve on the water outlet. The fast water flow made the hose to move through the water in a "meandering" way. If sonar was not detected for 1 s, the water outlet closed and the hose stopped moving.

Between the electro-magnetic valve and the hose there was a manual valve system that made it possible to insert fish or gelatine strips into the hose (Figure 3), which would then be ejected into the water with the water flow. The fish used in this study were small, thawed blue whiting (*Micromesistius poutassou*). The gelatine strips were made with water and gelatine powder and died black with Dr Oetker black food colouring to make them more visible in the water.

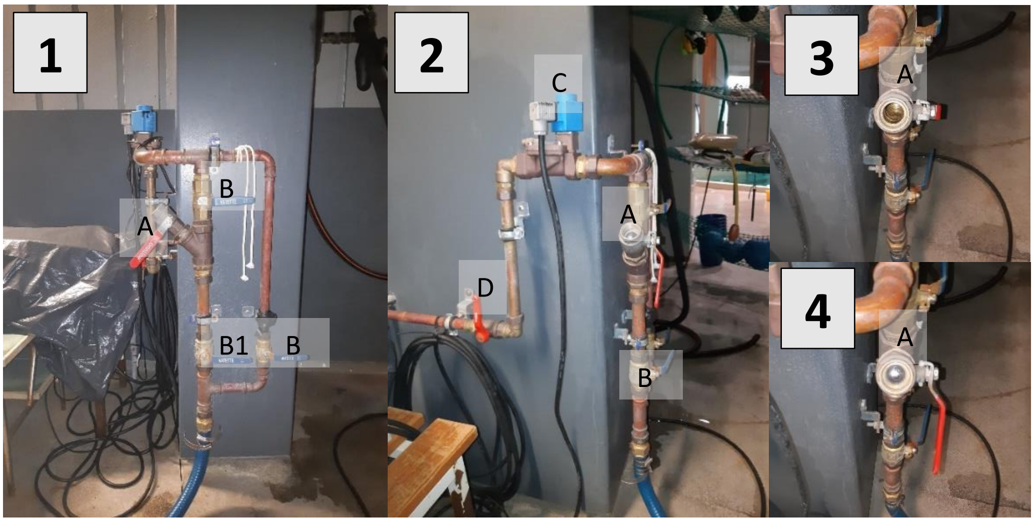

Figure 3 Picture of the valve system near the water outlet. 1) Front view, 2) Side view, 3) Close-up valve for injecting fish/gelatine open, 4) Close-up of the manual valve for injecting fish/gelatine closed. A) Valve and opening to insert fish/gelatine (loading valve), B1) Manual valve to close/open main water flow (main valve), B2) Manual valve to close/open branched water flow (branched valve), C) Electromagnetic valve connected to the electronics box, D) Valve to manually open/close the main water outlet (outlet valve).

The output from the click detector was recorded using an Edirol digital recorder (R-09 HR). The recordings were saved as .wav files

Two cameras, a GoPro Hero 4 and a GoPro Hero 7, were used to film the sessions, one under the water surface and one from above. The underwater Go Pro was placed inside a water proof plastic box (Claes Ohlson, article no 31-8544) attached to a wooden plank (Figures 4.1 and 4.2). The box was tilted slightly forward to improve the camera view of the experimental scene. This setup was then lowered into the water and secured to the pool wall using a one-handed bar clamp. The above view camera was attached to a wooden bar that was lifted above the pool (Figure 4.3).

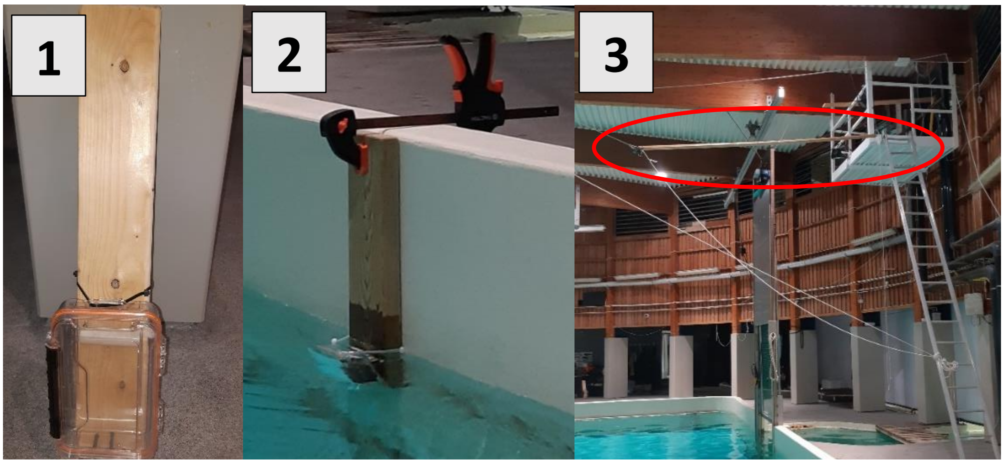

Figure 4 Pictures of the camera set ups. 1) The waterproof box for the underwater camera, 2) The camera in the water clamped to the pool wall, 3) The above view water camera, the red circle shows the camera mounted at the left end of the wooden bar, attached with a hinge to the elevated platform.

An interval timer app (Intervaly app, version 2.4.5) was used to keep track of time, to time the fish and gelatine ejections and to accurately measure and the duration of the sessions.

2.4.2 Stages

The meandering hose experiment was done in two stages, the All-or-Nothing stage and the Randomized stage.

In the All-or-Nothing stage, the water outlet was either manually closed or turned opened, and in the latter case, with either no ejections or ejections of fish or gelatine strips. The intervals between the ejections and the number of ejections were constant throughout the sessions. (See 2.4.3)

In the Randomized stage, the number and the timing of ejections of fish and/or gelatine strips were semi-randomized.

These two stages followed each other. First 12 sessions were conducted in the All-or-Nothing stage, followed by 12 sessions in the Randomized stage. Between these two stages, there was a 2-week break due to logistic reasons. After the 12 sessions of the Randomized stage, two more sessions in the All-or-Nothing stage were done (one with gelatine and one with fish ejected). This was done to increase statistical power to the data.

2.4.3 States

In the All-or-Nothing stage, the meandering hose had four different states.

1. Off: The water outlet was manually closed leaving the hose unresponsive to the dolphins' sonar.
2. On: The water outlet was opened when sonar clicks hit the hydrophone. No fish or gelatine strips were ejected.
3. Gelatine: The water outlet was opened when sonar clicks hit the hydrophone and four times (minute 3, 11, 19, 27) during the session 2 gelatine strips were ejected from the hose.
4. Fish: The water outlet was opened when sonar clicks hit the hydrophone and four times (minute 3, 11, 19, 27) during the session 2 fish were ejected from the hose.

In the Randomized stage, the meandering hose had three different states.

1. Off: The water outlet was manually closed leaving the hose unresponsive to the dolphins' sonar.

2. On: The water outlet was opened when sonar clicks hit the hydrophone. No fish or gelatine strips were ejected.
3. Fish/Gelatine: The water outlet was opened when sonar clicks hit the hydrophone and there were 2-8 ejections of fish or gelatine strips with semi-randomized intervals between ejections.

The semi-randomized schedules mentioned above were generated using the *sample()* function in R studio. These functions were then put in a *for* loop to generate a randomized order of states, intervals and a randomized order of fish or gelatine ejected in the 'On + Fish/Gelatine' state. This R script was given a seed that was semi-randomized, making all the orders and intervals semi-randomized as well.

2.4.4 Experimental procedure

All dolphins were allowed to participate during all the meandering hose sessions at the same time.

The day before a session with gelatine being ejected from the hose, the gelatine was prepared by the caretakers. On the day of the session, the gelatine was taken out of the mould and cut into strips of approximately 2x2x15 cm to fit into the loading valve.

In the morning of days with fish being ejected from the hose, the caretakers selected small blue whitings from the batch of fish of that day. The selected fish were approximately 15 cm long.

Generally, the netted gates between the pools were open. However, there were some session where the netted gate to the Laguna was closed for cleaning purposes.

Just before a session, the electronics were turned on and checked that they still worked properly. The hose was unrolled and laid out next to the pool. Then, the wooden bar with the above view camera was lifted and its view was checked using the GoPro Quick app (version 8.10). The sound recording of the Edirol recorder was then started, after which both camera recordings were started at the same time (the above view one using the GoPro Quick app). Finally, the underwater camera was lowered into the pool and secured to the pool wall with the clamp. If one or more of the dolphins seemed very interested in or was physically touching the camera box, I stayed next to the camera until they lost interest and swam away. Then the hose was lowered into the water and right after the main water outlet was opened, the interval timer was started. The interval timer was set with 1-minute intervals for 30 minutes, every minute it made the phone vibrate.

In sessions where the hose was inactive, so the water flow did not get started by the dolphins, the timer was started a few seconds after the hose was put in the water.

When it was time for a fish or gelatine strip ejection, the branched valve (B2 in Figure 3.1) was opened, and the two main valves (B1 in Figure 3.1) were closed. Then the loading valve was opened and either 2 fish or 2 gelatine strips were inserted into it. The loading valve was then closed, the two main valves opened, to allow the fish/gelatine to be ejected with the water flow, and the branched valve was closed. The timing of the opening of the two main valves and the closing of the branched valve was done according to the fixed or semi-randomized schedule (See Appendix A). If at the time of the opening of the valves the hose was not activated by the dolphins, the fish/gelatine would be ejected at the next activation of the hose.

The loading valve compartment could only fit two fish and if the second fish was too long to be completely inserted, a bit of the tail was broken off to make it fit.

During the sessions, I interacted as little as possible with the dolphins and the enrichment. Only when the hose came out of the water I put it back again or if the camera box was being touched by one of the animals I would hold it in place.

After 30 minutes the session was ended. First, the main water outlet was manually closed, after which the hose was taken out of the water. Then, the underwater camera was taken out of the water and turned off. The electronics and recorder were turned off, and finally the above view camera was lowered and turned off.

After sessions where fish or gelatine strips had been loaded into the hose, it was rinsed out with fresh water to make sure that no pieces of fish or gelatine were left in it. The underwater camera set up was also rinsed with fresh water to remove salt.

2.4.5 Acoustic parameters

Several acoustic parameters were selected to be tested from the sound data.

- The total number of clicks in the sound data of each session.
- The ratio of 10 ms buzzes in the sound data of each session. Calculation: number of clicks with an ICI < 10 ms divided by the total number of clicks.
- The ratio of 2 ms buzzes in the sound data of each session. Calculation: number of clicks with an ICI < 2 ms divided by the total number of clicks.
- The number of click trains of each session. Calculation: Consecutive clicks with an ICI < 100 ms are considered one click train. If a click had an ICI > 100 ms, it would be counted as a new click train.

- The average number of clicks per click train in each session.
- The number of click trains with more than 100 clicks in each session.
- The number of click trains with more than 500 clicks in each session.
- The ratio of how many of the click trains with more than 100 clicks were click trains with more than 500 clicks in the click train in each session. Calculation: The number of click trains with more than 500 clicks divided by the number of click trains with more than 100 clicks

2.4.6 Ethogram

Several behaviours have been chosen to be observed. Each behaviour has been categorized into different behaviour types and has a description. In parentheses it also states in what unit the behaviour was recorded.

These behaviours were recorded per individual to be able to identify which individuals interacted with the enrichment. However, the statistical analysis of the behaviours was done on the group level.

Table 1 Ethogram for the Meandering Hose enrichment with descriptions of each behaviour.

Behaviour Type	Behaviour	Description
Exploratory Behaviour		
	Observing (seconds)	Being within 2 body lengths of the enrichment with head facing towards the hose.
	Direct Contact (seconds)	Directly touching the hose with body part, e.g. beak, body, pectoral fins or tail fin.
Social Behaviour		
	Physical Contact (frequency)	Direct contact with another dolphin. This can be beak to body or body to body.
	Snapping (frequency)	Direct contact with a conspecific with open mouth. Can also be with open mouth in the beginning of the contact

		and closing in the moment of contact (biting).
Foraging Behaviour		
	High-speed pursuit (frequency)	Fast swimming when observing the hose. Usually started by a powerful movement with the fluke to get up to speed. Can be done while the hose is active, chasing the tip of the hose, or after an ejection and towards the fish or gelatine strip.
Bubbles		
	Bubble Burst (frequency)	A 'cloud-like clustering of bubbles' formed from the blowhole by releasing a large amount of air (Moreno & Macgregor, 2019). See Appendix C for visualizations.
	Small Bubbles/Bubble Trail (frequency)	A long and thin stream (line) of small bubbles ejected from the blowhole (Moreno & Macgregor, 2019). See Appendix C for visualizations.

2.4.7 Processing of Recordings

The audio and video files were compared to each other to synchronize and crop the audio files to the exact time and length of the video files. The cropped sound files were then opened in Audacity® Cross-Platform Sound Editor (Windows) and converted from stereo sound to mono. The recorded output from the envelope detector was the negative envelope of the sonar clicks. To allow for automated analysis using the amplitude detector in Raven (see below) these negative spikes were converted into positive spikes.

The timing of the sonar clicks was extracted using the amplitude detector module on Raven Pro 1.6 (Cornell Lab of Ornithology; www.birds.cornell.edu/raven). This was then imported into Excel, where inter-click intervals (ICI) longer than 100 ms was used to separate click trains. It was then possible to calculate the duration of trains and the number of clicks per train. The former is used to classify the type of echolocation, where “buzzes” with ICI < 10 ms were distinguished from ‘regular’ click trains with ICI from 10 ms to 100 ms.

The GoPro video footage was processed using VLC Media Player**.** The behaviours were manually noted down and put into an Excel file.

2.5 Shell sand boxes

2.5.1 Equipment

Three plastic boxes (dimensions: 60x80x40 cm) were used (Figure 5.1 and 5.2). There were 2 drainage holes in both short sides, 17cm above the bottom and one drainage hole in the bottom, covered with a drain strainer supplemented with a filter to allow for a quick draining of the water when the boxes were lifted out of the water (Figure 5.3). All boxes were filled with approximately 90L of coarse grain shell sand, originating from northern Norway.

Figure 5 Close-up of one of the shell sand boxes. 1) Top-down view. 2) Short side view. 3) Close up of the filter covering the drainage hole.

In one of the boxes two Aquaclick 100 click logger casings (24 cm length and a diameter of 9 cm; Aquaclick Group Ltd, UK) were attached to the bottom of the box with cable ties and were covered with 3-5 cm of shell sand (Figure 6.1 and 6.2). The Aquaclicks were air filled (dimension of the air compartment: diameter 6.8 cm by length 15 cm), and thus offered a strong sonar target. In this box, six fish (blue whiting *(Micromesistius poutassou*) and herring (*Clupea harengus*)) were buried in a horizontal and lateral position in each session (Figure 6.3). They were also buried 3-5 cm in the sand.

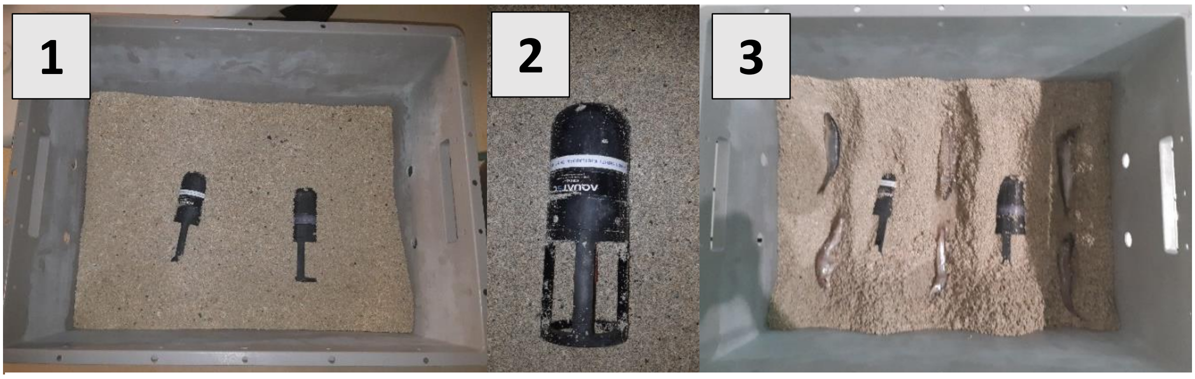

Figure 6 Pictures of the organisation of the shell sand box with the two sonar targets inside. 1) The positioning of the two targets in the box. 2) Close up of the sonar target. 3) The positioning of the fish in the box.

Two GoPro cameras, a GoPro Hero 4 and a GoPro Hero 7, were used to film the sessions, one under the water surface and the other from above, with the same arrangement as during the Meandering Hose sessions (see above).

2.5.2 Session Procedure

During the Shell Sand Box sessions, only seven dolphins were allowed to interact with the boxes at the same time. This was because the caretakers had separated the two adult males with 3 adult females from the rest of the group. Since there was not enough time to do sessions with both groups separately, I decided to focus on one group which consisted of four adult females, one subadult female, and two subadult males.

The preparation for a session was started as soon as the holding pool was empty and both netted gates and the two wooden safety gates were closed. The latter was an extra safety measure so the dolphins could not get trapped underneath the lifted platform in case one of the net gates broke. Then, the lifting platform was raised to a depth between 10 and 5 cm and the removable barrier preventing dolphins from sliding up on the scale was removed. The boxes were put on a hand truck and rolled into the holding pool using wooden ramps placed on either side of the scale. The boxes were put in a line (2.5 meters from the wall with the camera box), with approximately 1.5 meters in between them and in such a way that all three boxes were visible on both cameras (Figure 7.1 and 7.2). The box to closest to the pool wall (position Left) was put approximately 1.5 meters from the pool wall. The box with the sonar targets was put into the position pre-determined by a semi-randomized order (Appendix B). Then the fish were put into the box with the targets and covered with 3-5 cm of sand. Some water was also scooped into the box to make sure that the fish would stay buried under the sand surface. The ramp inside of the pool was removed and the scale barrier was put in place again. After that, the platform was lowered to a depth of about 20 cm. The water was allowed to gently flow into the boxes, to prevent them from floating and the inflowing water from uncovering the fish and the sonar targets. When the boxes were completely filled with water, the platform was lowered all the way down to a depth of about 275 cm. Then, the safety gates were raised. The cameras were put into the water and lifted into the air, respectively. Lastly, the netted gate to the Show Pool was raised, giving the dolphins access to the boxes.

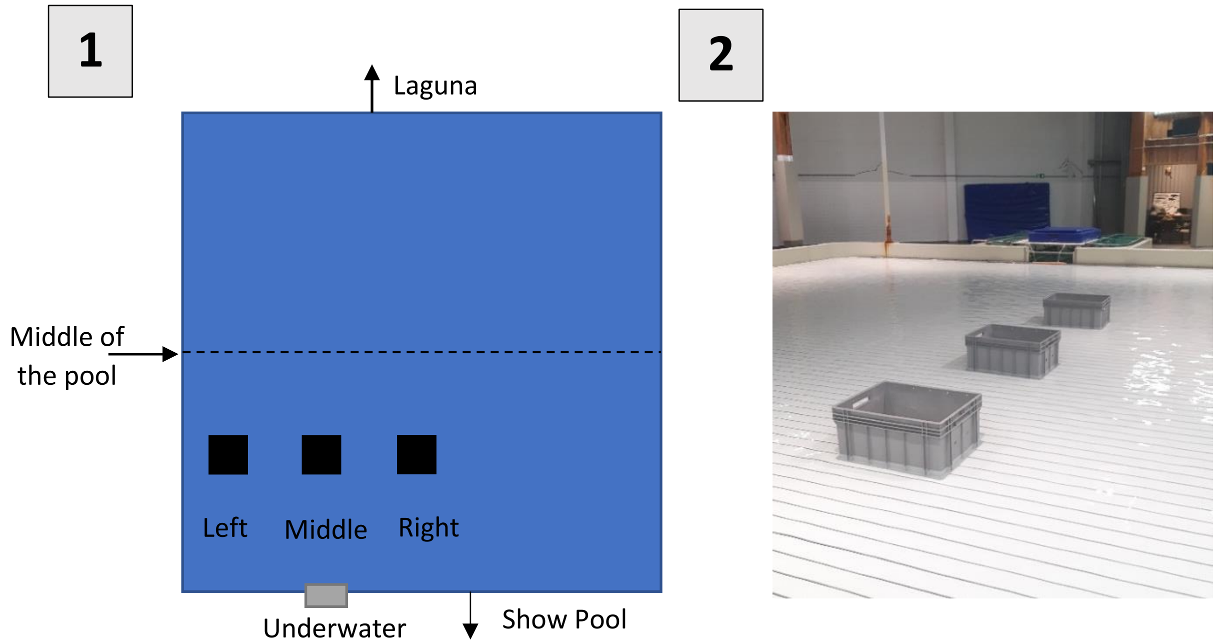

Figure 7 Overview of the lay out of the boxes in the pool. 1)A schematic drawing of the 13x13m holding pool seen from above. The dotted line indicates the middle of the pool. The black squares indicate shell sand boxes and their corresponding label. The arrows at the top and the bottom indicate the channels to the Laguna and the Show Poo respectively. The grey box indicates the position of the underwater camera. 2) Picture of the position of the boxes in the pool, before the platform was lowered.

The time of a session started when the first dolphin came through the channel into the holding pool. This was done to make sure that the dolphins knew they had access to the holding pool again and that they realized that the boxes were in place, thus giving them the full 30 min session time to interact with the boxes. After a complete session the camera was taken out of the water and the above view camera was lowered, and both recordings stopped. The dolphins continued to have access to the boxes because the dolphins could not be gated out of the holding pool until the end of the caretakers' one-hour lunch break. The experiments were carried out during this time, to avoid any distraction caused by the caretakers' presence in the holding pool area.

After the dolphins were gated out of the holding pool, the net and safety gates were lowered again. The platform was raised to a depth between 10 and 5 cm. The box with the sonar targets and fish was then checked, and any fish that was not taken by the dolphins was counted and removed. The water in the boxes was allowed to drain out of the boxes. Once the water was mostly out of the boxes, they were put onto the hand truck and taken out of the water using the ramps as above. After this, the ramps were removed and the barrier was put back onto the scale. The lifting platform was lowered to a depth of about 275 cm whereafter the safety gates were raised once more. The net gate was later opened by the caretakers during one of the next training sessions. Lastly, the underwater camera box and the hand truck were rinsed with fresh water as well as the sand in the box that had the sonar targets and fish.

A total of 8 sessions were carried out.

2.5.3 Ethogram

Several behaviours have been chosen to be observed. Each behaviour has been categorized into different behaviour types and has a description of said behaviour. In parentheses it also states in what unit the behaviour was recorded.

These behaviours were recorded on a group level.

Table 2 Ethogram for the Shell Sand Box enrichment with descriptions of each behaviour.

Behaviour Type	**Behaviour**	**Description**
Exploratory Behaviour		
	Observing In the Box (seconds)	Body oriented in a vertical position above the box with head inside the box.
	Observing Above the Box (seconds)	Body oriented in a vertical or horizontal position above the box, with head pointed towards the box but not being inside the box.
	Observing Outside the Box (seconds)	Body oriented horizontally within a body length of the box. Head pointed towards the box.
Social Behaviour		
	Snapping (frequency)	Direct contact with a conspecific with open mouth. Can also be with open mouth in the beginning of the contact and closing in the moment of contact (biting).

Foraging Behaviour		
	Tail-Slap (frequency)	A big, fast sweeping motion with the tail fluke, causing a powerful turbulence in the water.
Bubbles		
	Bubble Burst (frequency)	A 'cloud-like clustering of bubbles' formed from the blowhole by releasing a large amount of air (Moreno & Macgregor, 2019). See Appendix C for visualizations.

2.5.4 Processing of Recordings

The video recordings were opened in VLC media player where the above- and underwater videos were opened simultaneously (media>open multiple files>show more options>play another media synchronously) and played synchronously. Behaviour was noted, written down and timed according to the video time stamps and put into an excel file.

2.6 Statistical analysis

Statistical analysis was done in R Studio (Windows Version 2022.02.0+443).

For the Meandering Hose, Kruskal-Wallis tests were used to assess if the median of one of the states differed from another. If this resulted in a $p \leq 0.05$, a Wilcoxon's Rank Test was used to test all the possible pairwise combinations of the different states. These tests were done for both the acoustic parameters and the behaviour parameters.

For the Shell Sand boxes, linear models (function *lm* in R) were made for every behaviour parameter. The response variable in the models were the different behaviour parameters (each parameter had its own model). The explanatory variables in all of the models were whether a box had the sonar targets and fish in them and the position (Left, Middle, Right) of the boxes. A two-way ANOVA was performed on these models to analyse the effects of absence/presence of sonar targets and fish and the position of the boxes on the frequency or duration of the behavioural parameters.

3 Results

3.1 Meandering Hose

3.1.1 Sound Data

For the total number of clicks, the median of the Off sessions was significantly lower than the median of the On sessions (Wilcoxon's Rank Sum Test, $p < 0.05$). The median of the Off sessions also was significantly lower than the medians of both the Fish sessions and the Fish/Gelatine sessions (Wilcoxon's Rank Sum Test, $p < 0.01$). Besides this, the median of the On sessions was significantly lower than the median of the Fish sessions (Wilcoxon's Rank Sum Test, $p < 0.05$) for the total number of clicks. The median of the Gelatine sessions was also significantly lower than the medians of both the Fish and the Fish/Gelatine sessions (Wilcoxon's Rank Sum Test, $p < 0.05$). (Figure 8)

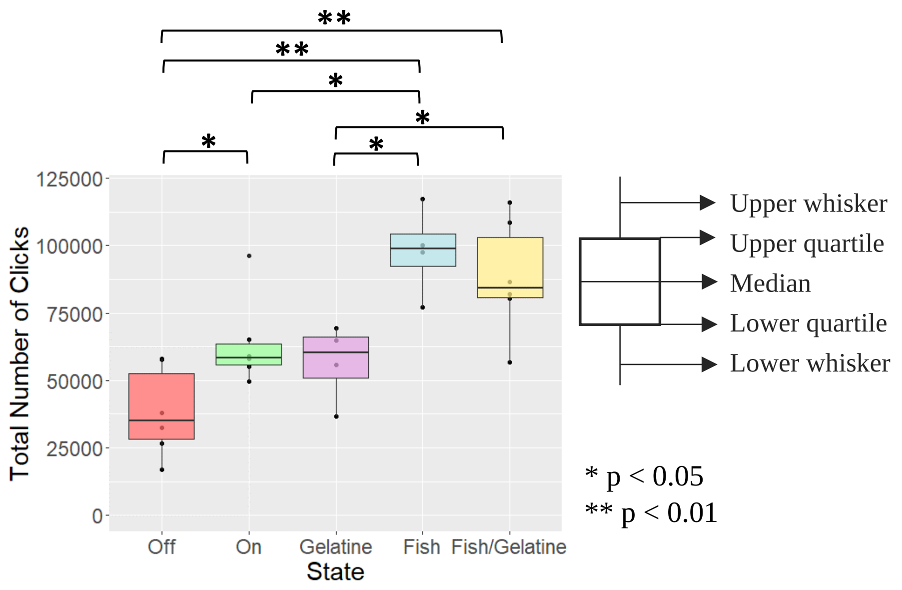

Figure 8 Boxplots of the total number of clicks per session for all the states of the hose. The dots are all the individual data points, any dots above the upper whiskers or below the lower whiskers are outliers. The square brackets above the graph show which states showed significant differences between them.

For the number of click trains, the median of the Off sessions was significantly lower than the medians of both the Fish sessions and the Fish/Gelatine sessions (Wilcoxon's Rank Sum Test, $p < 0.01$). In addition, the median of the On sessions was significantly lower than the median of both the Fish sessions and the Fish/Gelatine sessions (Wilcoxon's Rank Sum Test, $p < 0.05$). The median of the Gelatine sessions was also significantly lower than the medians of both the Fish and the Fish/Gelatine sessions (Wilcoxon's Rank Sum Test, $p < 0.05$) for the number of click trains. (Figure 9)

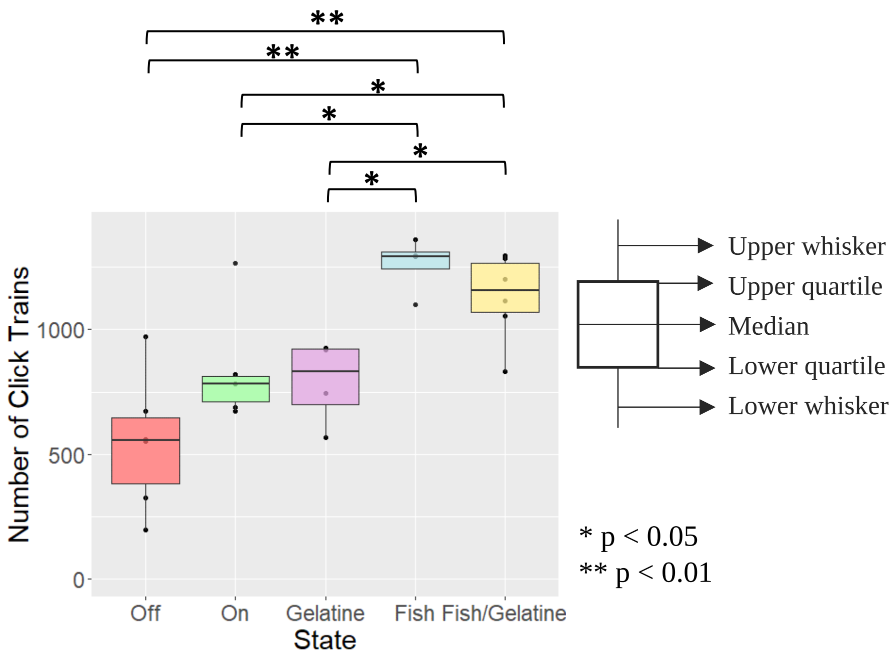

Figure 9 Boxplots of the number of click trains per session for all the states of the hose. The dots are all the individual data points, any dots above the upper whiskers or below the lower whiskers are outliers. The square brackets above the graph show which states showed significant differences between them.

Furthermore, the median of the Off sessions was significantly lower than the median of the On sessions (Wilcoxon's Rank Sum Test, $p < 0.05$) for the number of click trains with more than 100 clicks. Besides this, the median of the Off sessions was significantly lower than the medians of both the Fish sessions and the Fish/Gelatine sessions (Wilcoxon's Rank Sum Test, $p < 0.01$). The median of the On sessions was significantly lower than the median of both the Fish sessions and the Fish/Gelatine sessions (Wilcoxon's Rank Sum Test, $p < 0.05$). Lastly, for the number of click trains with more than 100 clicks, the median of the Gelatine sessions was also significantly lower than the medians of both the Fish and the Fish/Gelatine sessions (Wilcoxon's Rank Sum Test, $p < 0.05$). (Figure 10)

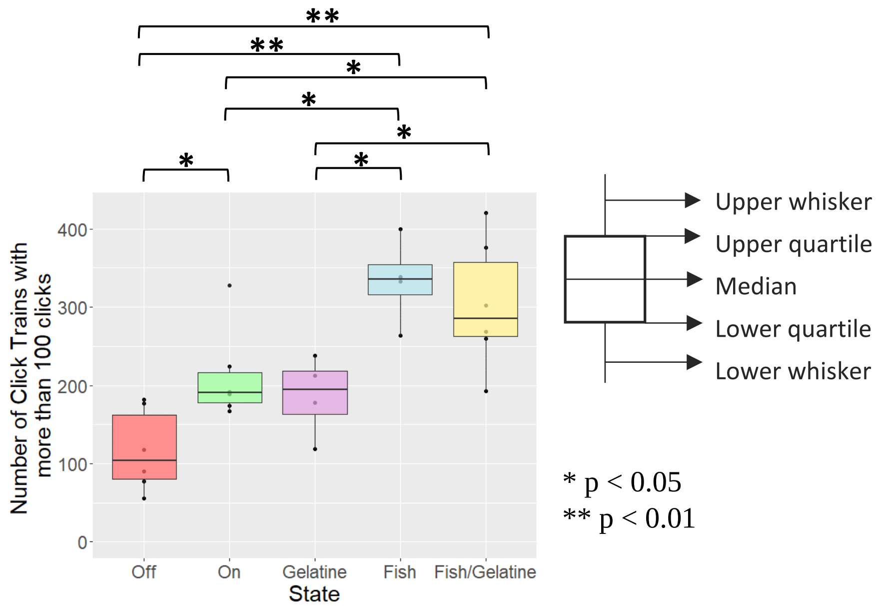

Figure 10 Boxplots of the number of trains that have more than 100 clicks for all the states of the hose. The dots are all the individual data points, any dots above the upper whiskers or below the lower whiskers are outliers. The square brackets above the graph show which states showed significant differences between them.

Finally, for the ratio between the number of click trains with more than 500 clicks and the number of click trains with more than 100 clicks, the median of the Off sessions was significantly higher than the medians of all the other states (On, Gelatine, Fish, and Fish/Gelatine) (Wilcoxon's Rank Sum Test, $p < 0.01$). (Figure 11)

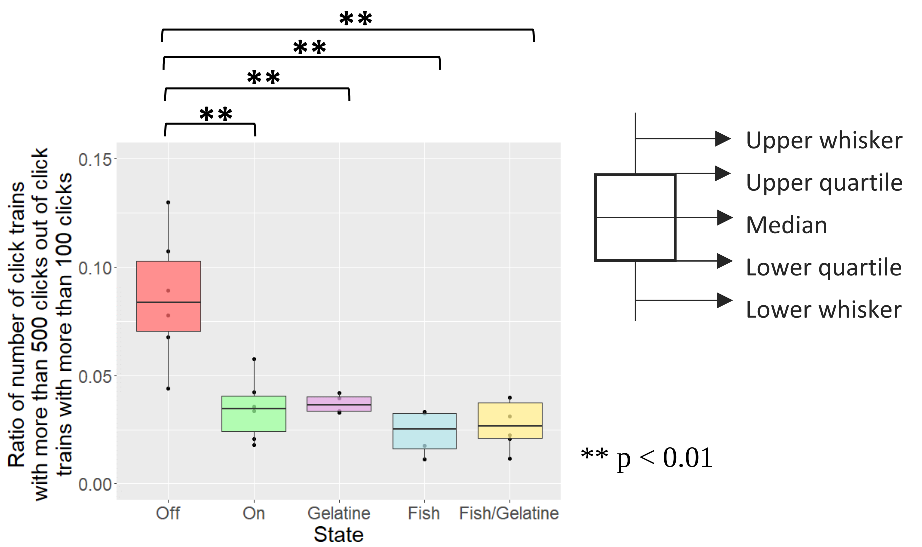

Figure 11 Boxplots of the ratio between the number of trains with more than 500 clicks and trains with more than 100 clicks for all states of the hose. The dots are all the individual data points, any dots above the upper whiskers or below the lower whiskers are outliers. The square brackets above the graph show which states showed significant differences between them.

Statistical analysis was also performed for the 10 ms buzz ratio, the 2 ms buzz ratios, the average number of clicks per train, and the number of click trains with more than 500 clicks. When comparing the medians of these parameters between the different states, the statistical tests came back with non-significant p-values. (See Appendix D)

3.1.2 Behavioural Data

For the seconds spent observing the hose the median of the Off sessions was significantly lower than the median of the On sessions, the Fish sessions, and the Fish/Gelatine sessions (Wilcoxon's Rank Sum Test, $p < 0.01$). Plus, the median of the Gelatine sessions was significantly lower than the medians of both the Fish and the Fish/Gelatine sessions (Wilcoxon's Rank Sum Test, $p < 0.05$). (Figure 12)

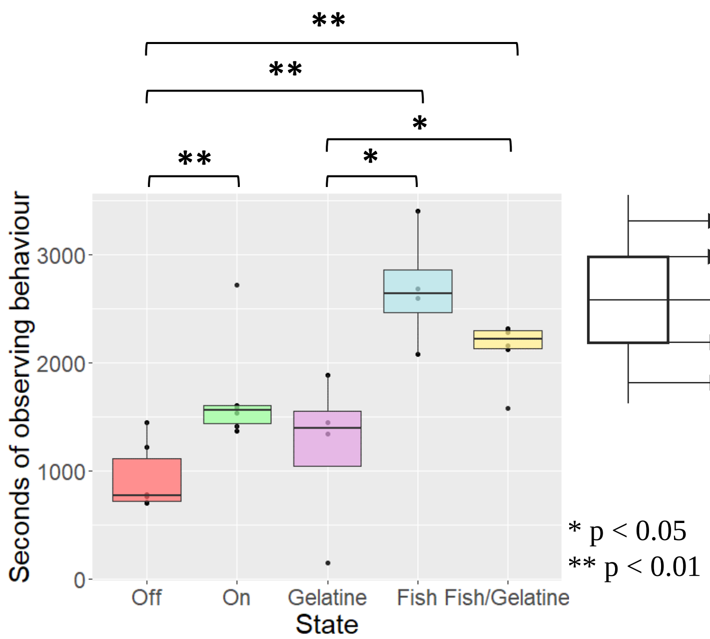

Figure 12 Boxplots of the seconds per session spent observing the hose for all states. The dots are all the individual data points, any dots above the upper whiskers or below the lower whiskers are outliers. The square brackets above the graph show which states showed significant differences between them.

Also, for the number of times the dolphins made direct contact with the hose, the median of the Off sessions was significantly higher than the median of the Gelatine sessions (Wilcoxon's Rank Sum Test, $p < 0.05$) and significantly higher than the medians of the On sessions, the Fish sessions, and the Fish/Gelatine sessions (Wilcoxon's Rank Sum Test, $p < 0.01$). (Figure 13)

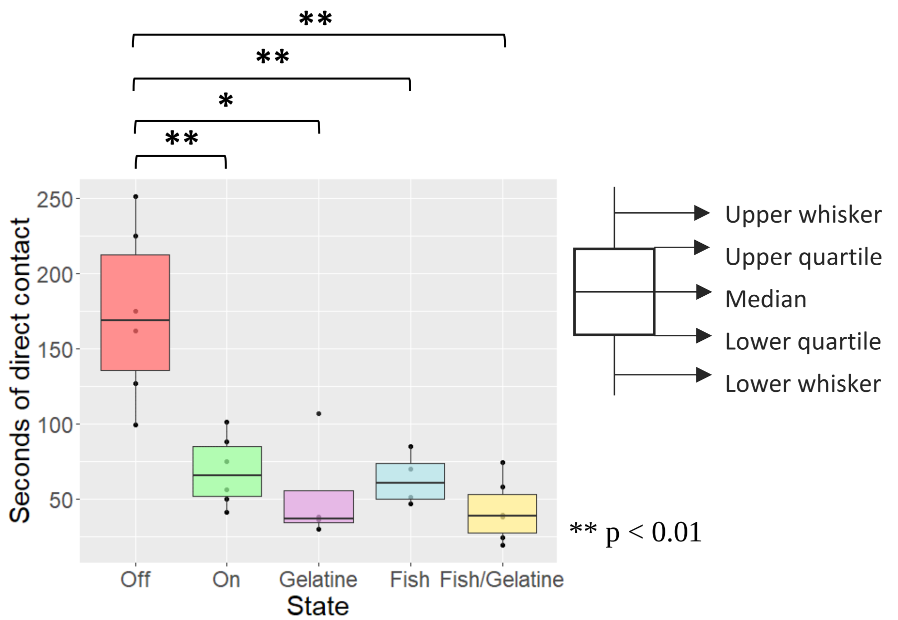

Figure 13 Boxplots of the number of seconds per session the dolphins made direct contact with the hose for all states. The dots are all the individual data points, any dots above the upper whiskers or below the lower whiskers are outliers. The square brackets above the graph show which states showed significant differences between them.

Furthermore, the median of the Off sessions was significantly lower than the median of the Fish sessions (Wilcoxon's Rank Sum Test, $p < 0.01$) and lower than the medians of the Gelatine sessions and the Fish/Gelatine sessions (Wilcoxon's Rank Sum Test, $p < 0.05$) for the number of high speed pursuits done by the dolphins. In addition, the median of the On sessions was also significantly lower than the median of the Fish sessions (Wilcoxon's Rank Sum Test, $p < 0.05$). (Figure 14)

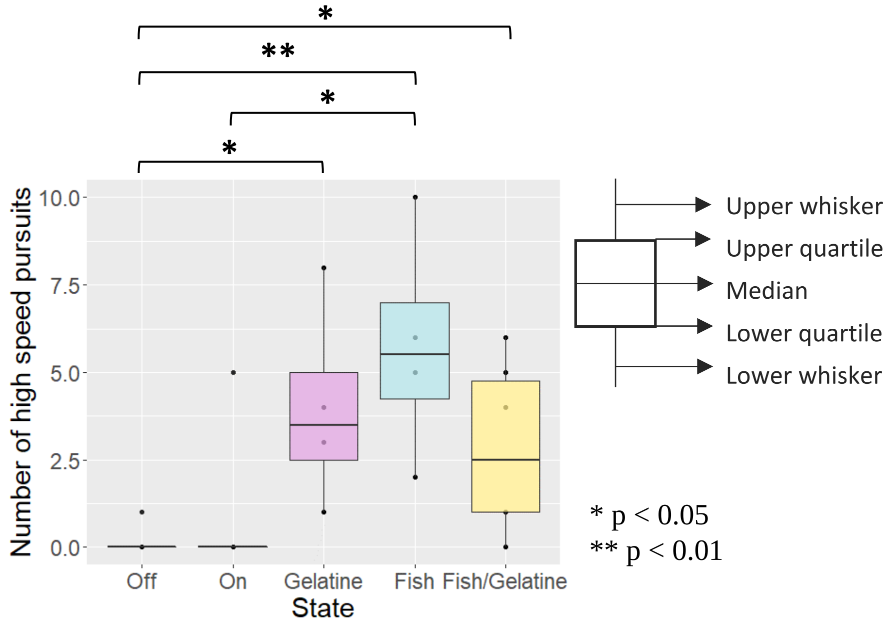

Figure 14 Boxplots of the number of times per session the dolphins were observed to do a high-speed pursuit per session for all states. The dots are all the individual data points, any dots above the upper whiskers or below the lower whiskers are outliers. The square brackets above the graph show which states showed significant differences between them.

Lastly, for the number of times the dolphins produced small bubbles, the median of the Off sessions was significantly lower than the median of both the Fish sessions and the Fish/Gelatine sessions (Wilcoxon's Rank Sum Test, $p < 0.05$). (Figure 15)

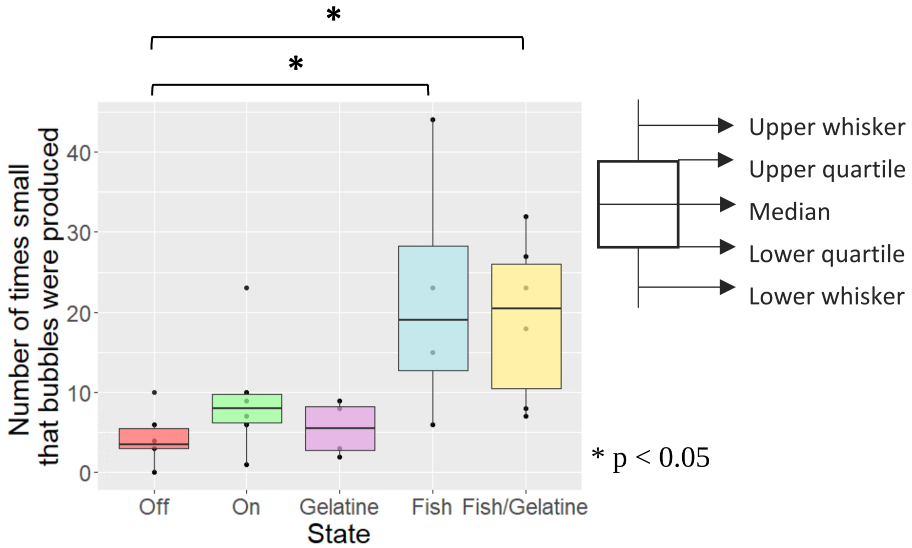

Figure 15 Boxplots of the number of times per session the dolphins were observed releasing small bubbles from the blowhole per session for all states. The dots are all the individual data points, any dots above the upper whiskers or below the lower whiskers are outliers. The square brackets above the graph show which states showed significant differences between them.

Statistical analysis was also performed for the number of times the dolphins had physical contact with a conspecific, the number of times the dolphins snapped at each other, and the number of bubble bursts the dolphins produced. When comparing the medians of these parameters between the different states, the statistical tests came back with non-significant p-values. (See Appendix D)

3.2 The Shell Sand Boxes

The presence of the sonar targets and fish had a significant positive effect on the seconds spent observing in the box ($F_{(1, 20)} = 7.4$, $p < 0.05$) but the position of the box also had a significant effect on this behaviour ($F_{(2, 20)} = 10.7$, $p < 0.01$). Most observing in the box was done in the Right box and the least observing in the box was done in the Left box. (Table 3)

Table 3 Table of the number of seconds spent observing in the box for all the sessions. The session number and box position are noted. The blue cells indicate the box in which the sonar targets and fish were buried. The bold values are the highest values of that session.

Session number	Position		
	Left	Middle	Right
1	363	**388**	288
2	380	**441**	432
3	281	573	**592**
4	93	720	**730**
5	**541**	484	539
6	199	506	**753**
7	224	519	**683**
8	332	**383**	332

The models also showed that the presence of the sonar targets and fish had a significant positive effect on the number of seconds spent observing above the box ($F_{(1, 20)} = 14.0$, $p < 0.01$). But, the position of the box had a significant effect on the duration of this behaviour ($F_{(2, 20)} = 7.5$, $p < 0.01$) where most observing above the box was done above the Right box and the least observing above the box was done above the Left box. (Table 4)

Table 4 Table of the number of seconds spent observing above the box for all the sessions.. The session number and box position are noted. The blue cells indicate the box in which the sonar targets and fish were buried. The bold values are the highest values of that session.

Session number	Position		
	Left	Middle	Right
1	126	**296**	100
2	163	**203**	198
3	198	179	**306**
4	98	185	**285**
5	179	189	**190**
6	126	169	**261**
7	176	175	**312**
8	137	117	**143**

Statistical analysis showed that the presence of the sonar targets and fish had a significant positive effect on the seconds spent observing outside of the box ($F_{(1, 20)} = 6.4$, $p < 0.05$). However, the position of the boxes also showed to have a significant effect on this behaviour ($F_{(2, 20)} = 6.5$, $p < 0.01$), where the Right position had the highest mean compared to the Left and Middle positions. (Table 5)

Table 5 Table of the number of seconds spent observing outside the box for all the sessions. The session number and box position are noted. The blue cells indicate the box in which the sonar targets and fish were buried. The bold values are the highest values of that session.

Session number	Position		
	Left	Middle	Right
1	22	243	**368**
2	340	249	**365**
3	212	247	**280**
4	151	239	**420**
5	295	**375**	356
6	224	328	**523**
7	375	346	**580**
8	**278**	227	207

The presence of the sonar targets and fish had a significantly positive effect on the number of times the dolphins snapped at each other ($F_{(1, 20)} = 7.2$, $p < 0.05$). The position of the boxes did not have a significant effect on the this behaviour ($F_{(2, 20)} = 1.4$, $p = 0.26$). (Table 6)

Table 6 Table of the data of the number of times the dolphins snapped at each other for all the sessions. The session number and box position are noted. The blue cells indicate the box in which the sonar targets and fish were buried. The bold values are the highest values of that session.

Session number	Position		
	Left	Middle	Right
1	1	**2**	0
2	0	**5**	1
3	0	1	**2**
4	0	0	**4**
5	**4**	2	1
6	0	**1**	**1**
7	**1**	**1**	**1**
8	0	0	0

Lastly, the number of bubble bursts observed was significantly positively affected by the presence of the sonar targets and fish ($F_{(1, 20)} = 7.2$, $p < 0.05$), while the position of the box did not have a significant effect on the frequency of this behaviour ($F_{(2, 20)} = 1.4$, $p = 0.26$). (Table 7)

Table 7 Table of the data of the number of bubble bursts that were observed for all the sessions. The session number and box position are noted. The blue cells indicate the box in which the sonar targets and fish were buried. The bold values are the highest values of that session.

Session number	Position		
	Left	Middle	Right
1	1	**3**	1
2	2	**5**	1
3	**3**	2	1
4	0	1	**3**
5	**6**	4	4
6	5	4	**10**
7	1	2	**14**
8	1	**3**	0

Neither the presence of the sonar targets and fish nor the position of the box had a significant effect on the number of tail slaps that was observed. (See Appendix D)

4 Discussion

4.1 The Meandering Hose

For the meandering hose part of this study, I wanted to investigate behavioural differences when the hose was used in its different states. The focus was on the sonar activity and exploratory and foraging- and hunting-like behaviours and how the frequency of these behaviours were influenced by the inactivation (Off sessions), activation (On sessions) of the hose and how they were affected by the ejections of fish and/or gelatine strips (Gelatine, Fish, and Fish/Gelatine sessions).

I expected that the use of sonar and the frequency of exploratory, and foraging- and hunting-like behaviours would increase when the hose was in an active compared to an inactive state. The ejection of food items was expected to increase the frequency and duration of these behaviours even more.

The data collected and observations made in this study showed several clear effects of the meandering hose on the sonar activity and behaviour of these dolphins. There was a high general interest in the hose, which was shown by the high overall sonar activity and high proportion of time spent observing and interacting with the hose in all sessions, regardless of which state it was in. From my observations I can also conclude that this interest stayed high throughout the sessions, sometimes the dolphins continued interacting with the hose until it was removed from the water at the end of a session.

The results showed that the total number of clicks, the number of click trains and the number of click trains with more than 100 clicks were positively affected by having the hose in an active state. However, for the proportion of click trains with more than 500 clicks out of the trains with more than 100 clicks there was a negative effect on this parameter when the hose was in an active state.

The behavioural analysis showed similar trends as the significant results of the sound data. Significantly more time was spend observing the hose, there was a higher frequency of high-speed pursuits, and a higher frequency of small bubbles that were produced from the blowhole in the active states compared to the inactive state. However, the number of times direct contact was made was the highest during the Off state.

It was not expected that for the 10 ms buzz ratio and the 2 ms buzz ratio the differences between the sessions in different states would be non-significant. Sonar buzzes are associated with prey capture in, among others, dolphins (Ridgway et al., 2015; Wisniewska et al., 2014). That is why it was expected that when the hose was in an active state, thus simulating a prey fish, the two buzz ratios would be higher. A possible explanation for this can be in one of my observations. During Off sessions (inactive), I observed dolphins pushing the hose with their nose right at the tip of the hose with the hydrophone attached to it and push it in front of themselves. Echolocating at such a close target would result in very short Inter Click Intervals (ICI) that would classify as buzzes. In the inactive state this behaviour was dominating, thus generating high buzz ratios.

Two other results could be explained by the same factor. These are the non-significant results for the differences between the states for the number of click trains with more than 500 clicks and the significant differences for the ratio of click trains with more than 500 clicks of the click trains with more than 100 clicks. This is because when the hose is in an active state it could have been harder for the dolphins to keep aiming their sonar at the hydrophone at the end of the moving hose than when it was resting inactive in the pool. With the hose moving in and out of the sonar beam, the click trains could be broken up into shorter click trains. While during the inactive state, the click trains would mostly be broken up by the dolphins swimming away from the hose enrichment.

Even when parameters showed clear, significant differences between sessions, there was still a high variation in the data with occasional outliers. This shows that, even if the state of the meandering hose significantly affected behaviour and sonar activity, there seem to be other factors at play when it comes to the dolphins' behaviour. Some of these effects could be identified, albeit not backed up by statistics: the presence/absence of people walking around the pool, various social interactions between the dolphins like chasing, overall activity level of the dolphins on that day, and whether the netted gates between the pools were open or closed.

Dolphins are social animals, living in flexible fission-fusions societies (Shane et al., 1986) and solitary dolphins often seek contact with humans (Nunny & Simmonds, 2018). Besides this, in a dolphinarium humans are the suppliers of food, enrichment, training and frequent social interactions for the dolphins. This means that it is not surprising that human activity around the pools and interactions with conspecifics affect the activity around the hose enrichment. One of these interactions was the synchronized swimming of certain individuals. It is thought that synchronous swimming (also called contact swimming) strengthens the bond between the dolphins performing this behaviour together (Connor et al., 2006). This meant that during my study, when individuals were engaged in synchronized swimming they would both score similarly in the observed behaviours in that sessions, while they might score very differently if they were not swimming synchronously. So, social interactions between the dolphins seemed to be one of the reasons for the big variations in the data.

Another aspect that might have affected the variation in the data, is the fact that there was an unplanned break when carrying out the Randomized Stage of the hose enrichment. This was due to me being ill which caused a break of almost three weeks. When the experiments resumed, this long break probably caused the extraordinarily high activity in the last two sessions (two Fish/Gelatine sessions).

Also, not all sessions were carried out in the same way. If the dolphins were restless or if in a previous enrichment session there were behavioural problems in the group, a trainer was asked to supervise the session. This trainer was then sitting close to the pool (< 2 m) and observed the whole session, without interacting in any way with the dolphins. Still, their presence had a clearly distracting effect on some of the dolphins. In a few sessions one of the netted gates was closed, restricting access to the Laguna or the Show Pool, which may have affected the dolphins. Also, not all the sessions were done at the same time of day. Most were scheduled during the lunch break of the trainers in order to avoid any distraction from the presence of the trainers. However, due to logistics, some sessions had to be done in the beginning or at the end of the day. Most likely this affected the dolphins' response and interaction with the hose.

A behaviour that is interesting to note is that of the subadult female Alana. When I was setting up all the equipment for a hose session, she occasionally showed some anticipatory behaviour. She would be in a vertical orientation with her head out of the water, either oriented towards me or towards the hose. Sometimes she even heaved herself partly out of the water and tried to grab the hose that was still on land. It was evident that she was eager to interact with the hose. Watters (2014) stated that anticipatory behaviour can be an indicator of how an animal perceives an upcoming reward, so more anticipatory behaviour is shown if the upcoming event is seen as rewarding. He also stated that when anticipatory behaviour is shown at high levels this might be indicative of negative welfare of the animal. This is supported by another study on bottlenose dolphins, which showed that higher levels of anticipatory behaviour were linked to a more negative affective state in the animal (Clegg & Delfour, 2018). It was hypothesised that this can be because the anticipated situation is seen as even more rewarding if their overall affective state is more negative. On the other hand, Jensen et al. (2013) showed that anticipatory behaviour, when not abnormal or stereotypic, does not seem to be an indicator of negative effects on the welfare of dolphins. Based on my observations, this behaviour showed that the enrichment was seen as rewarding (at least by Alana) and could therefore be a positive influence on the dolphins' welfare.

The use of sonar is an important species-specific behaviour for bottlenose dolphins. Stimulating this behaviour in dolphins under human care could affect their welfare positively. The dolphins in my study learned how to use the enrichment independently, which suggests that this enrichment can be effectively used for dolphins almost immediately without a training period. Something that should be noted, however, is that some of the dolphins already interacted with the hose during the two previous studies done with his enrichment. Using the meandering hose as an enrichment that is regularly presented to dolphins (and possibly other odontocetes) could increase their welfare in zoos and dolphinariums and is therefore recommended.

4.2 The Sand Shell Boxes

For the shell sand box part of this study, I wanted to investigate the dolphins' ability to detect buried sonar targets and whether they would be able to associate this with the presence of fish. I expected that if this would be the case, that my results would show an increase in exploratory behaviour around the box with the sonar targets in them compared to the other two boxes with just sand in them. Plus, I expected that the position of the boxes would not influence the frequency or duration of the behavioural parameters and that comparing the different positions with each other would not result in significant differences.

The results show that for the duration of all observing behaviours both the presence of sonar targets and fish and the position of the boxes affect the duration of these behaviours. Both the frequency of bubble bursts and snapping were significantly positively affected by the presence of the sonar targets and fish and were not affected by the position of the box. However, for the number of tail slaps, neither the presence of sonar target nor the position of the box affected the frequency of this behaviour.

There was an unequal distribution of the position of the box with the sonar targets in it, this box was in the Left position 4 times, in the Middle position 1 time, and in the Right position 3 times. This explains why for some behavioural parameters, both the presence of the sonar targets and the position of the boxes influenced the frequency or duration of a parameter. If the presence of the sonar targets would have been the main factor that influenced the frequency/duration of the parameters, I would expect to see the Middle box having the lowest values and the Left and Right box the highest values. However, this is not the case. For the parameters observing inside the box, observing above the box, observing outside of the box, and for the number of bubble bursts, the highest average of the parameters were in the Right box and the lowest averages in the Left box. While for the parameter snapping at conspecific, the Middle box had the highest average. This suggests that the position of the box influenced the frequency or duration of the behavioural parameters. A reason for this could be that the dolphins preferred to have more space while interacting with the boxes, since the Right box had the most open space around it compared to the Left and Middle boxes. It could also be that because the Right box was the closest to the channel to the Show Pool, it was the box that was the easiest to interact with since it was the nearest box when coming from the Show Pool.

An interesting behaviour to note is that of the tail slap. When this enrichment was first introduced during Kristensen's (2017) study, this behaviour was not observed. During their study, they observed the dolphins blowing water on the sand to uncover the fish buried in the sand. When talking to the caretakers of the dolphins, I found out that between Kristensen's study in 2017 and the current study, they introduced another enrichment which may have stimulated the behaviour of the tail slap. This new enrichment was an imitation of sea algae with a plastic tube where a fish was put in. At one point, one of the dolphins started to slap this enrichment with her tail to get the fish out of the tube. This behaviour was then, slowly, adopted by the other dolphins until (almost) all the dolphins exhibited this behaviour. It seems likely that the dolphins used the knowledge of the effect of a tail slap on that algae enrichment and used it while interacting with the Shell Sand Boxes. This reasoning is based on the fact that when I did a test session of the Shell Sand Boxes, to see if everything worked correctly, the first tail slap could be observed withing one minute of the dolphins getting access to the enrichment and was done by multiple dolphins. Unlike the use of the tail slap with the algae enrichment which gradually spread through the group, the tail slap with the boxes was done by multiple dolphins immediately, suggesting prior knowledge of this behaviour and its potential effects.

From my observations and my data, it seems that the dolphins used brute force to find the fish instead of their sonar to detect the targets and associate them with the presence of fish. This is why, for future studies on these boxes, it is recommended to train the dolphins how to interact with this enrichment using their sonar.

The potential of the shell sand enrichment is there, it is both a sensory and cognitive challenge for the dolphins. First using their sonar to become familiar with the acoustic signal it gives and then learning to associate this signal with fish buried in sand. However, in its current state this is not yet fully effective in these ways. Nevertheless, the dolphins still engaged with this enrichment for prolonged periods of time (max. 1,5 hours) and showed interest in it immediately when introducing the boxes. Further developing and improving the shell sand boxes could increase animal welfare when presenting dolphins (and potentially other odontocetes) with this enrichment.

5 Conclusion

In conclusion, the sonar-activated Meandering Hose had a clear positive effect on overall sonar activity as well as on some exploratory and foraging- and hunting-like behaviours when in its active states. The fixed ejections of fish and the randomized ejections of fish and gelatine increased this effect even more, while just the ejection of gelatine strips did not increase this. The only behaviour that was reduced in duration in the active states was direct contact with the hose. Implementing this enrichment as a permanent part of the enrichment repertoire would increase the sonar activity of the dolphins and give them an increased opportunity to explore the use of their sonar in an environment that is generally not acoustically stimulating for them. This would lead to improved animal welfare, which is what we should strive for when it comes to animals in human care.

Even though the Shell Sand Boxes results were inconclusive, the enrichment was still considered successful. The interaction with the boxes was high and continued over long periods of time (up to 1.5 hours) and no dolphin seemed to have negative experiences with the boxes. To use the full potential of this enrichment in stimulating sonar activity, training would be necessary for the dolphins to be taught to detect these sonar targets. There is potential for this enrichment in its sonar-stimulation aspects if time is put into training the dolphins on how to interact with the enrichment.

6 Societal and Ethical Considerations

It is important to evaluate the effects of enrichment on animals in human care. Enrichment is given to animals to increase their welfare by, for example, challenging them mentally or allowing them to display more species specific behaviours. If the enrichment that is given is not evaluated, you might assume that it is increasing the animals' welfare but in reality it might not be used the way it was intended to be used. By evaluating enrichment, you can verify whether the desired effect (increase in welfare) is actually being realised or whether the enrichment needs to be adjusted to achieve the desired effect.

For dolphins, sonar plays a significant role in their life, but dolphins under human care do not live in an environment that is acoustically stimulating or challenging. Therefore creating and offering enrichments that stimulate the use of their sonar may have important positive effects on the welfare of these animals.

None of the dolphins were forced to participate in these experiments. They had free access to other pools if they did not want to interact with the enrichments.

Before introducing any enrichment, all the components were cleaned with a Virkon S solution. All the parts were also checked for any sharp edges that could hurt the dolphins and for parts that could be broken off and swallowed by the dolphins. All aspects of the experiments were supervised by the caretakers and were approved by the zoo veterinarians.

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Appendix

Appendix A: Meandering Hose

All-or-Nothing stage schedule

Order of the states used in these sessions is shown below.

Session number	**State**
1	On + Gelatine
2	On
3	Off
4	On + Gelatine
5	Off
6	On + Fish
7	On
8	On
9	On + Fish
10	Off
11	On + Gelatine
12	On + Fish
25	On + Gelatine
26	On + Fish

Randomized stage schedule

Order of the states used in these sessions is shown below. After the 'On + Fish/Gelatine' the number of ejections for that session, the order of fish/gelatine and the time (in minutes) of ejections are listed.

Session number	**State + Comments**
13	On
14	On + Fish/Gelatine; number of ejections: 2,;order: Gelatine, Fish; Timestamps: 11, 28 minutes
15	On + Fish/Gelatine; number of ejections:7; order: Gelatine, Fish, Gelatine, Gelatine, Gelatine, Gelatine, Fish; Timestamps: 1, 6, 11, 12, 14, 17, 19 minutes

16	On
17	Off
18	On + Fish/Gelatine; number of ejections: 4; order: Fish, Fish, Gelatine, Gelatine; Timestamps: 10, 11, 15, 23 minutes
19	On
20	On + Fish/Gelatine; number of ejections: 7; order: Fish, Gelatine, Gelatine, Fish, Fish, Fish, Fish; Timestamps: 3, 12, 19, 21, 22, 25, 27 minutes
21	Off
22	Off
23	On + Fish/Gelatine; number of ejections: 8; order: Gelatine, Gelatine, Gelatine, Gelatine, Fish, Gelatine, Fish, Fish; Timestamps: 3, 7, 16, 18, 23, 25, 26, 28 minutes
24	On + Fish/Gelatine; number of ejections: 2; order: Fish, Fish; Timestamps: 6, 26 minutes

Appendix B: Shell Sand boxes

The position of the box with the sonar target and the fish is shown below. See Figure 10.1 for the positioning of the boxes and what the names in the order mean.

Session number	**Group 1**
1	Middle
2	Left
3	Left
4	Right
5	Left
6	Right
7	Right
8	Left

Appendix C: Bubble Visuals

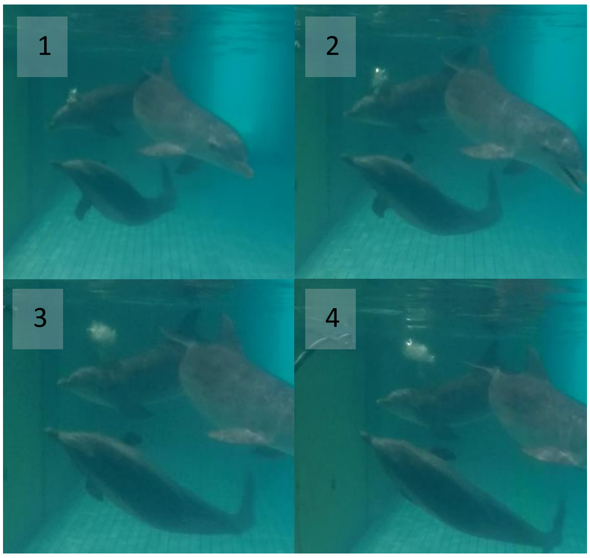

Figure 16 Visualization of a bubble burst in chronological order (1-4).

Figure 17 Visualization of a small bubbles/bubble trail in chronological order (1-4).

Appendix D: Box plots of non-significant parameters

Sound Data

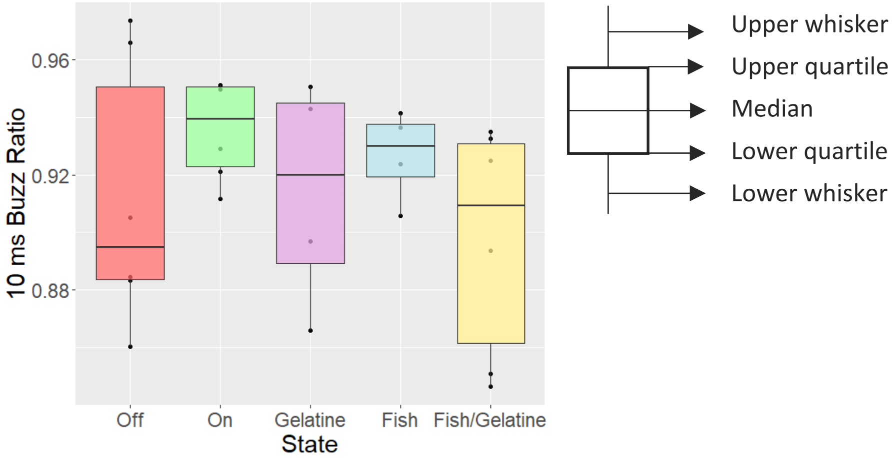

Figure 18 Boxplots of the buzz ratio of the number of ICI < 10 out of the number of ICI < 100 per session for all states. The dots are all the individual data points, any dots above the upper whiskers or below the lower whiskers are outliers.

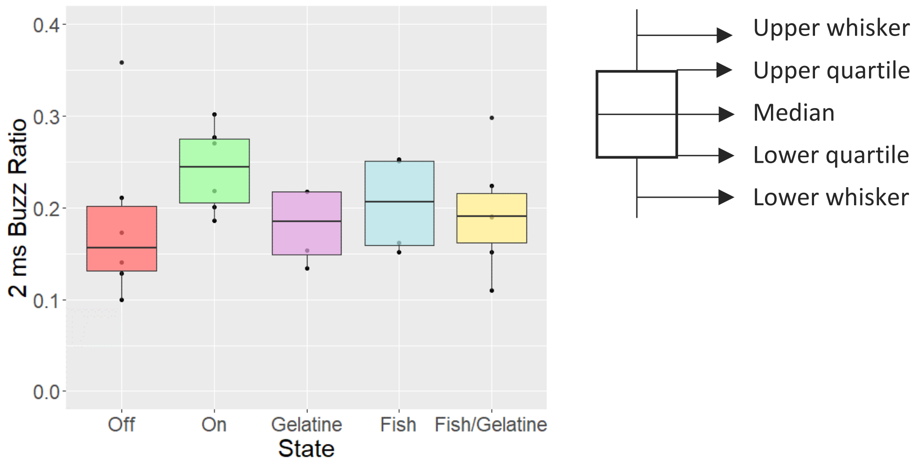

Figure 19 Boxplots of the buzz ratio of the number of ICI < 2 out of the number of ICI < 100 per session for all states. The dots are all the individual data points, any dots above the upper whiskers or below the lower whiskers are outliers.

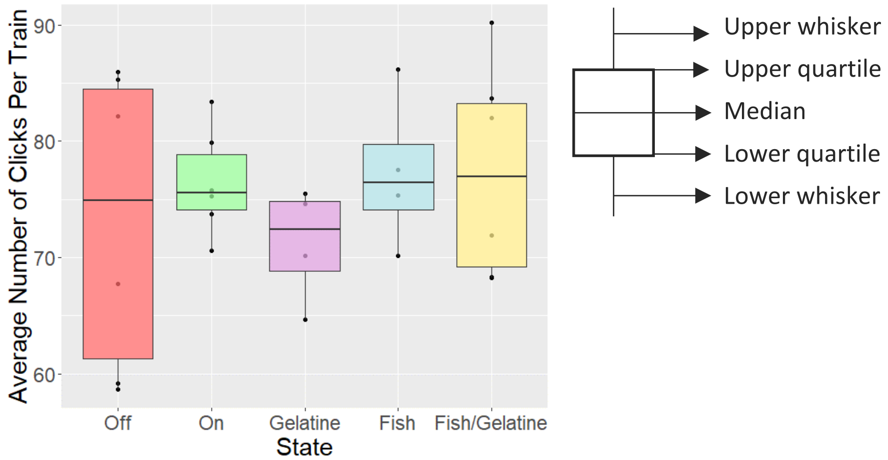

Figure 20 Boxplots of the average number of clicks per click train per session for all states. The dots are all the individual data points, any dots above the upper whiskers or below the lower whiskers are outliers

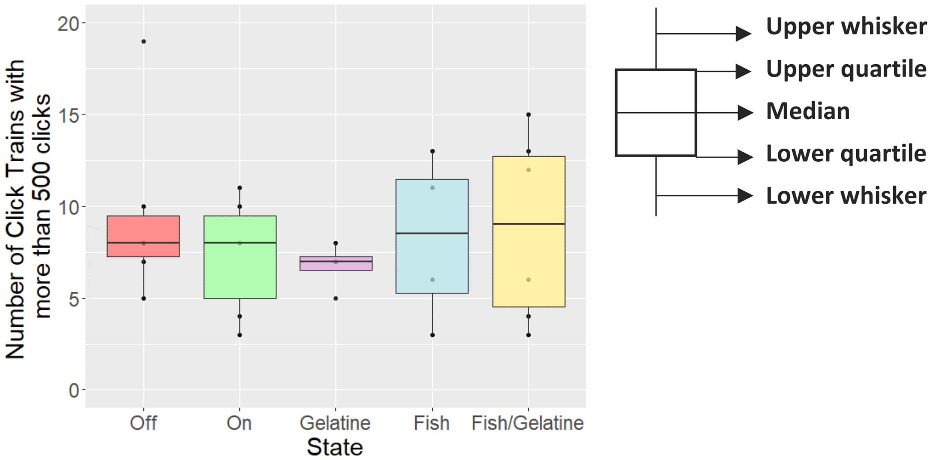

Figure 21 Boxplots of the number of trains that have more than 500 clicks per session for all the states of the hose. The dots are all the individual data points, any dots above the upper whiskers or below the lower whiskers are outliers.

Behavioural Data

Meandering Hose:

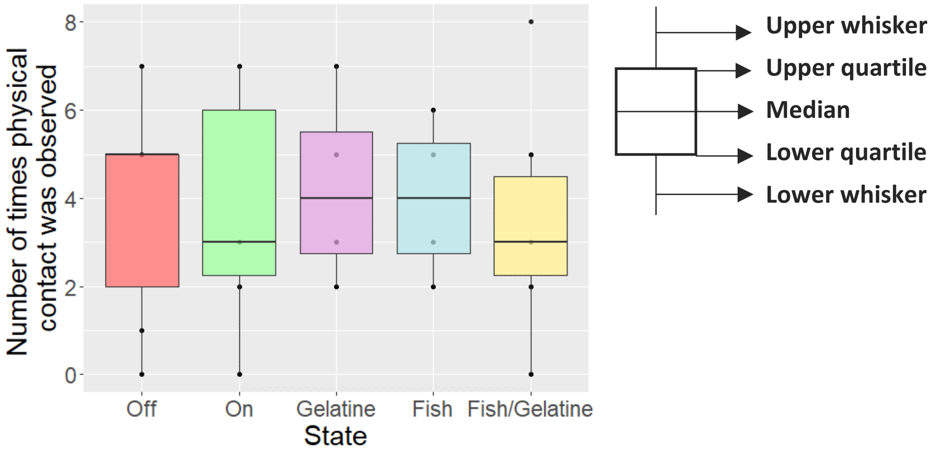

Figure 22 Boxplots of the number of times physical contact between dolphins was observed per session for all the states of the hose. The dots are all the individual data points, any dots above the upper whiskers or below the lower whiskers are outliers.

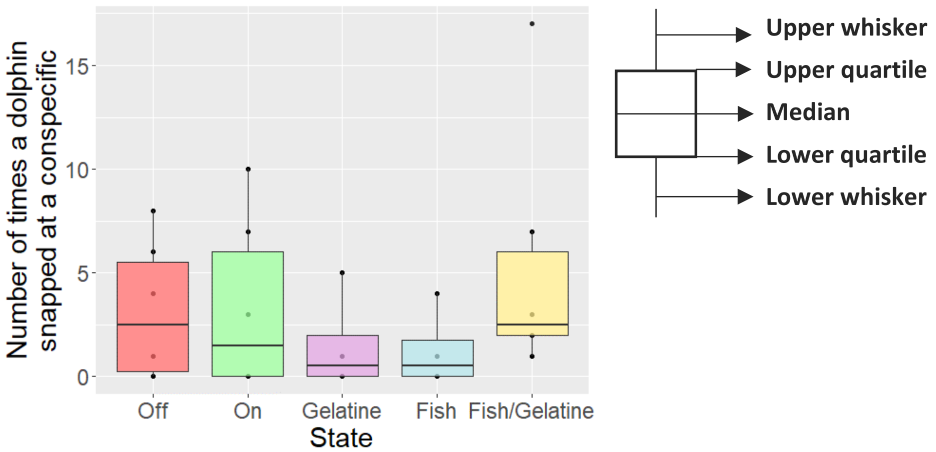

Figure 23 Boxplots of the number of times a dolphin was observed to snap at a conspecific per session for all the states of the hose. The dots are all the individual data points, any dots above the upper whiskers or below the lower whiskers are outliers.

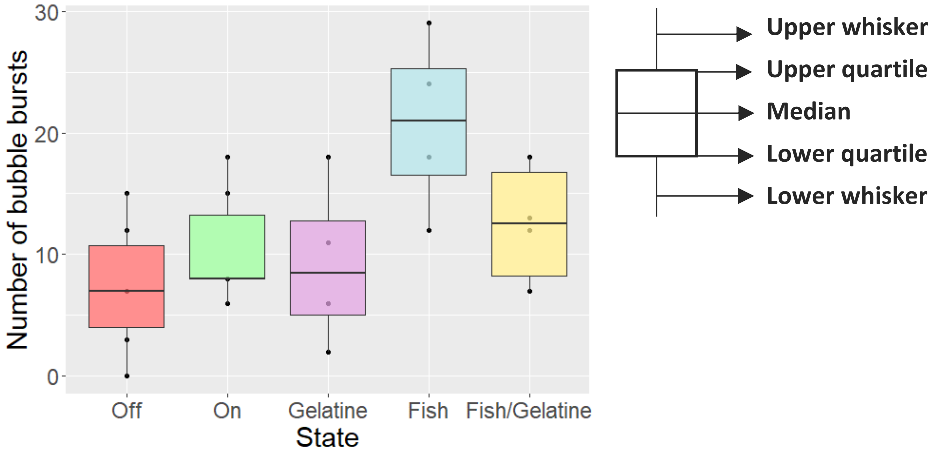

Figure 24 Boxplots of the number of times a bubble burst was produced by a dolphin per session for all the states of the hose. The dots are all the individual data points, any dots above the upper whiskers or below the lower whiskers are outliers.

Shell Sand Boxes

Table 8 Table of the data of the number of tail slaps that were observed for all the sessions. The session number and box position are noted. The blue cells indicate the box in which the sonar targets and fish were buried. The bold values are the highest values of that session.

Session number	Position		
	Left	Middle	Right
1	0	20	**23**
2	8	7	**11**
3	12	5	**21**
4	**14**	2	**14**
5	**23**	20	22
6	15	18	**32**
7	23	20	**35**
8	**28**	10	26