Cruise Report

3S-2021 - Iceland Pilot study Trial

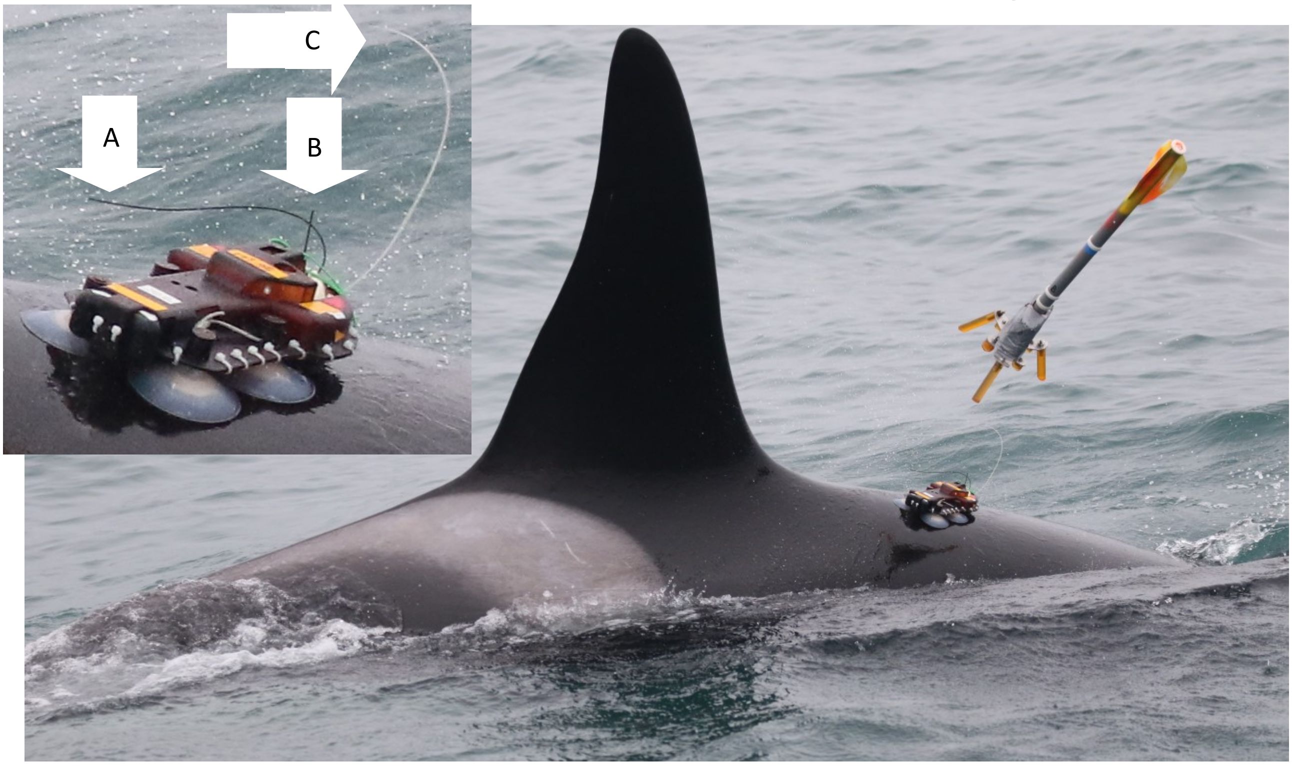

Figure 1: Successful ARTS attachment of a Mixed-Dtag+ to a killer whale. Inset box shows new LOTEK system antennas: A.) ARGOS transmitter; B) GPS receiver; C) VHF transmitter.

June 24 – July 23, 2021

Patrick Miller, Cruise Leader; Filipa Samarra, Field party Chief

Cruise Report prepared by:

Patrick Miller, Filipa Samarra, Paul Wensveen, Charlotte Curé, Lars Kleivane

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TRIAL OUTCOME

Overall, the pilot study trial was very successful, with excellent tagging outcomes success and tracking including four sound playbacks completed – all primary objectives achieved successfully. The facilities at U Iceland and team were outstanding. Everyone was well, no injuries or sickness. No major equipment was damaged or lost, though one Dtag3+ broke while attached to a pilot whale, and the Dtag3+ robot was broken after the last day during vessel transfer operations. Some Dtag core units did not function perfectly with corrupted depth data like we had in 3S-OPS 2019.

Nine Mixed-Dtag+ deployments confirmed their excellent performance in terms of attachment duration and compatibility with ARTS deployments. Attachment durations were less reliable for 4 Dtag3+ deployments and we cannot confirm that tag is ready for 3S operations in terms of attachment. One Dtag3+ broke on first deployment likely due to animal contact, and Dtag3+ was considered to be too fragile for use with ARTS. In contrast, Mixed-Dtag+ was deployed very successfully with both the pole and ARTS systems. In total, we had 10, 2, and 1 deployments on killer, humpback, and pilot whales respectively for a total of 145 hrs of on-animal tag time.

On-animal GPS-ARGOS functionality with the new LOTEK system was excellent for both tag types when tag placement was sufficiently high on the animal. We changed some of the recommended settings to receive a rapid rate of updates (every 1.5-3 minutes). ARGOS functioned to aid recovery with the Mixed Dtag+, but the Dtag3+ floated rather low in the water, and wind pushed the Dtag3+ so the cups oriented to the wind, and the ARGOS antenna was in the water.

While it took some time to achieve full functionality of the real-time goniometer, by the final deployment on a killer whale (Paul got an outstandingly good placement using ARTS for deployment oo21_202b) the system was working. The goniometer reception system worked well out to 1km with this good tag placement, but we couldn't get reliable locations at longer distances. Shore tests had good performance out to 2.5km.

We conducted playback experiments to 4 tagged killer whales. All four were exposed to pilot whale chorusing sounds, 2 to a broadband noise control, and 2 were exposed to CAS as a control sound. Data quality were outstanding, with very interesting outcomes. For the final experiment, we used real-time GPS-ARGOS locations from the goniometer alongside Logger to aid placing the source boat for the playbacks. A dedicated visualization tool to use goniometer locations in CEE planning tool will be required for the system to operate effectively in 3S4 sonar trials.

In conclusion; the smaller Dtag3+ failed to meet some of the tested capabilities, and would require modifications and further testing. In contrast, the larger Mixed-Dtag+ was demonstrated to work well for the key capabilities tested. We recommend that both tag types be improved and that another pilot study test is performed before the first 3S4 sonar trial. The Dtag3+ could be made more robust for use with ARTS, and a method to mitigate the impact of corrupt data periods should be tested. Additional steps to address before a 3S4 trial include: test distance for GPS-Goniometer reception on the HU Sverdrup II, extending to >1km if possible; integrate GPS locations in the GIS CEE planning software; and test IR systems for visual mitigation during night-time experiments.

OPERATION AREA

The operation area was waters near the island of Heimaey in the Westmann Islands, Iceland.

OUTOMES VERSUS CRUISE TASKS

Below is a summary of the outcome of the cruise tasks. Primary tasks had a higher priority than the secondary tasks. We tried to accomplish as many of the secondary tasks as possible, but they were given a lower priority.

PRIMARY TASKS

Primary task 1. to test the functionality of GPS-ARGOS linked tags (Dtag3+ and Mixed-Dtag+) to provide (near) real-time positional information of tagged cetaceans. Killer whales are the primary species, but long-finned pilot, humpback, and minke whales may also be tagged. Real-time reception and decoding of the ARGOS transmission will be tested, particularly the whale-antenna distances over which the signals can be successfully received and decoded. Tags will be attached with both the ARTS pneumatic launching system and hand poles. The retention times of the two tag types will be compared.

OUTCOMES: The new GPS-ARGOS system worked very well for all deployments with killer, pilot and humpback whales. GPS locations were received via ARGOS when tags were attached sufficiently high on the body of the tagged whale. GPS loggers also recorded position data reliably. Real-time reception of the GPS-ARGOS data using the Goniometer system was successful, with good performance to 1km distance when tags were ideally placed. Further than 1km, the performance of the Goniometer system seemed to degrade rapidly. It is not clear what factor was limiting this distance, and additional testing from Sverdrup is recommended prior to a sonar trial.

The ARTS tagging system was successfully used with the Mixed-Dtag+, and that tag could be made somewhat smaller thanks to the light weight of the LOTEK GPS-ARGOS units. Unfortunately, after a Dtag3+ unit broke during its first pole deployment (likely due to contact from nearby pilot whales) the current form of the Dtag3+ was considered too fragile for use with ARTS. Closer coordination with U Michigan would be required to lead to modifications that could make the Dtag3+ deployable using the ARTS system.

Retention times of the Mixed-Dtag+ (Dtag2 suction cups) were reliable, with 6/9 deployments lasting until the scheduled release time. Only 1 of 4 Dtag3+ deployments remained attached until the scheduled release time. Two of the shorter deployments with each of the systems was unusual (tagged underwater, or tag failure), so 6/7 (86%) for the Mixed-Dtag+ and 1/2 (50%) for the Dtag3+ is our best estimate of attachment lasting until the programmed release time. This confirms the acceptability of the Mixed-Dtag+ system in terms of tag retention, but more deployments would be needed to confirm performance of the Dtag3+.

Primary task 2. track the location of tagged whales after tagging, to compare against position information provided by the GPS-ARGOS system. Tracking will primarily be done using UAV drones, with visual tracking as a back-up.

OUTCOME: Visual tracking using Logger software was successfully accomplished for tagged whales, with good quality tracks matching positions provided by the GPS-ARGOS system. Weather and staffing limitations meant that we did not use UAV drones for tracking.

Primary task 3. Conduct playback experiments with natural sounds (e.g. long-finned pilot whale sounds) to tagged killer whales, using the locations provided by the GPS-ARGOS system. This will validate the functionality of the new tag systems to perform in controlled exposure experiments planned for the full 3S4 study. Visual surface observations will be collected before, during and after playbacks.

OUTCOME: Four playback experiments transmitting chorusing pilot whales sounds were successfully carried out to tagged killer whales, with visual tracking and behavioural observations. A control signal was also transmitted during each experiment, either broadband noise (N=2) or CAS (N=2).   The experiments were setup using visual sightings input into Logger, and real-time locations from the goniometer provided useful locations for the final experiment conducted.

SECONDARY TASKS

Secondary task 4.   Deploy video or camera and heart-rate measuring tags using hand-poles

OUTCOME: A tag was shipped by Dr Kagari Aoki from U of Tokyo, and tagging was attempted on the final day of the field effort.

Secondary task 5. Collect sightings, photographs, and acoustic recordings of target species and other cetaceans encountered. Record UAV video to: a) observe the social context of a focal tagged whale and its group, including recording surface behaviour of tagged and non-tagged whales, b) make photogrammetry measurements of tagged and non-tagged whales.

OUTCOME: Extensive sightings and photographs of the encountered animals were successfully obtained. As noted above, UAV drones were not used. However, visual observations of group-level behaviour was conducted during playback experiments.

Secondary task 6. Collect echosounder survey data of herring in the study area, using a SIMRAD EK-60 or EK-80 echosounder system.

OUTCOME: This was not done as the system was not ready.

7. Collect biopsy samples of whales in the study area

OUTCOME: This was not done as so much of the focus was on tagging, rather than biopsy.

CHRONOLOGICAL OUTCOME

17-23 June	Miller and Hayward arrive Iceland, COVID requirements, set up equipment
24 June	First day tagging from Golli. Dtag oo21_175a deployed.
25 June:	Curé arrives in fieldsite. Dtag oo21_175a recovered.
26 June:	Bad weather day
27 June:	Poor weather, whales seen from shore, but not from Golli
28 June:	Bad weather day
29 June:	Tagging attempted, but no tag attached
30 June	Bad weather day
01 July	Attempted to Dtag Pilot whales. Deployed Dtag oo21_182a Setup Fridrik
02 July	Dtag oo21_182a recovered. Dtag oo21_183a deployed.
03 July:	Dtag oo21_183a recovered, oo21_184a deployed. First playback experiment

04 July:	Dtag oo21_184a recovered.
05 July:	Dtag oo21_186a deployed.
06 July:	Dtag oo21_186a recovered. Dtag gm21_187a deployed.
07 July:	Dtag gm21_187a recovered from Fridrik with damaged housing. Dtag oo21_188a deployed
08 July	Both vessels attempted tagging. Dtag oo21_188a recovered. Dtags oo21_189a and mn21_189a deployed, Second playback experiment completed
09 July:	Dtags oo21_189a and mn21_189a recovered. No further effort, bad weather
10-17 July:	Bad weather. Shoreside testing / refinement of goniometer system
18 July:	Both vessels tagging. Dtags oo21_199a, and mn21_199a deployed. Third playback experiment completed
19 July:	Dtags oo21_199a, and mn21_199a recovered from Fridrik.
20 July:	Bad weather day
21 July:	Both boats attempted tagging. Dtags oo21_202a and oo21_202b deployed. Fourth playback experiment completed. Attempted unsuccessfully to deploy video – heart rate tag.
22 July:	Golli recovered Dtag oo21_202b. Last day of 3S project field effort.
23 July:	Data backup and packing equipment
24 July:	Miller, Hayward, and Kleivane departed fieldsite

Suction cup tag deployments of Dtag3+ and mixed-Dtag+

Tagging was carried out using a pole from the Golli (below, left), and using the ARTS system from a specially-installed safety barrel on the bow of the Fridrik (below, right). Both systems were successfully used during the trial. Behavioral responses to tagging were typically none or mild – one response of 2 (on a 0-3 pt scale) was observed, possibly due to the tag not releasing smoothly from the pole-attachment robot.

Figure 2. Golli (left panel) and Fridrik (right panel) were the two vessels used in the trial.

As detailed in table I below, a total of 13 deployments were made, 10 with killer whales, 2 with humpback whales and 1 with pilot whales.

Table I. Mixed-Dtag+ and Dtag3+ deployments during the 3S-2021 pilot study trial.

Date	Deployment ID / method	Tag-on time and location	Response	Hrs on animal	Tag type	GPS / ARGOS	Why released	Playback	Comments
24.06.2021	oo21_175a Pole	19:03 63.37112N 020.35333W	2: tail slap w splash	16.1	Mixed DTG+ 330c	None 215143	Off as program	No	Tag went low on a large male. Pressure data noisy
01.07.2021	oo21_182a Pole	15:21 63.36680N 020.31760W	1: brief flinch	3.31	Mixed DTG+ 329c	Many 215144	Off early	No	Tagged through the water
02.07.2021	oo21_183a Pole	12:46 63.34381N 020.39904W	1: tail swish	9.8	Mixed DTG+ 330c	Many 215143	Off early	No	Some noisy pressure data. Juvenile
03.07.2021	oo21_184a Pole	12:46 63.34381N 020.39904W	1: tail swish	19.9	Mixed DTG+ 329c	Many 215144	As program	YES	Some noisy pressure data. Female IS064
05.07.2021	oo21_186a Pole	13:59 63.37892N 020.37011W	0	6.0	DTG3+ 332hc	none 220593	Off early	No	Low on left side Some noisy mag data? No ARGOS during recovery
07.07.2021	oo21_188a Pole	13:33 63.34381N 020.39904W	0	0.17	Mixed DTG+ 330c	None 215143	Off early	No	Not a good stick on tagging, went on low
08.07.2021	oo21_189a Pole	17:32 63.44183N 020.60843W	0	17.5	Mixed DTG+ 330c	Many 215143	At scheduled time but a bit early	YES	Some noisy pressure data
18.07.2021	oo21_199a ARTS	16:37 63.45995N 020.60479W	1 quick flinch	17.2	Mixed DTG+ 311c	Many 215144	Program	YES	Covered in herring eggs upon recovery
21.07.2021	oo21_202a Pole	17:22 63.45995N	1 tail flick	0.05	DTG3+ 332hc		Off quickly	No	Adolescent, rather small. Tag low on

		020.60479W							right side
21.07.2021	oo21_202b ARTS	18:34 63.46114N 020.60742W	0	17.5	Mixed DTG+ 311c	Many 215144	Program	YES	Great attachment high on body.
06.07.2021	gm21_187a Pole	16:38 63.46535N 020.63508W	0	2.3	DTG3+ 311c	Many 220591	Off early	No	Tag broken upon recovery. Possible contact sounds in recording
08.07.2021	mn21_189a Pole	16:22 63.44504N 020.60900W	0	19.55	Mixed DTG+ 329c	Many 215144	Program	No	Humpback feeding with killer whales. Some noisy pressure data.
18.07.2021	mn21_199a Pole	17:55 63.45848N 020.60540W	0	15.1	DTG3+ 332hc	Many 215143	At scheduled time but a bit early	No	Feeding with killer whales, same whale as mn21_189a

Table II. Performance of the tag (Mixed-Dtag+ vs Dtag3+) and deployment systems (Pole and ARTS) in terms of retention to the tagged animal (Did the tag remain attached until the release time?). "Normal" deployments excluded unusual cases such as tag breakage, and tagging through the water, and should be considered the best estimate of retention rate for normal tagging effort.

	Pole	ARTS	TOTAL	Total "normal" Deployments
Mixed-Dtag+	4/7	2/2	6/9 (66%)	6/7 (86%)
Dtag3+	1/4	Not tested	1/4 (25%)	1/2 (50%)

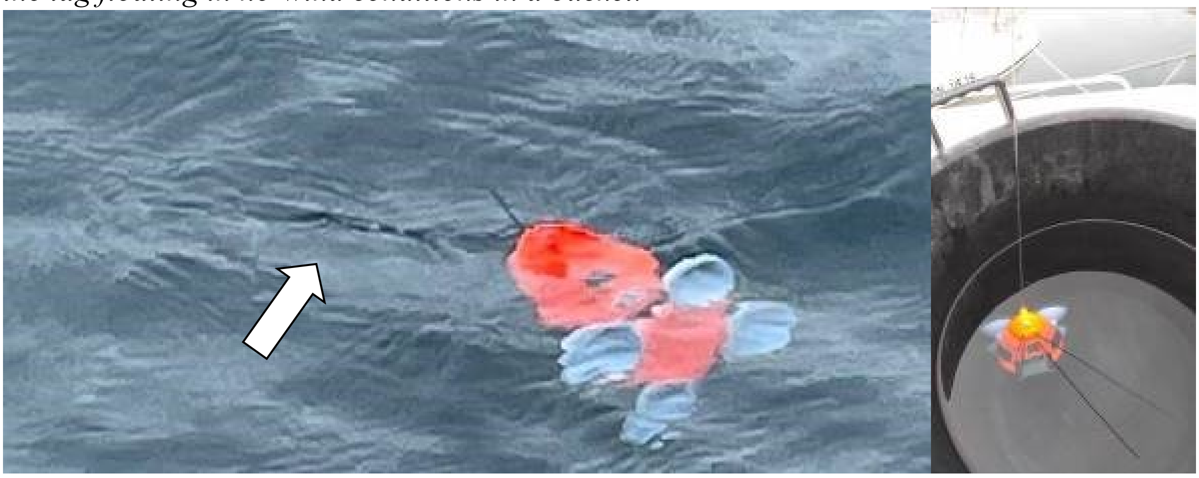
Comparison of Dtag retention performance

As shown in Table II, above, tag retention performance was very good for the Mixed-Dtag+ (which uses larger Dtag2 suction cups), but less effective with the Dtag3+ (with state-of-the-art Dtag3 cups). More testing with the Dtag3+ would be needed to confirm the retention performance of the Dtag3+

ARGOS functionality during tag recovery

One important functionality of these tags is the availability of ARGOS locations to support tag recovery. The Dtag3+ units arrived later than the core units (for the Mixed-Dtag+), so were used for the first time on 05 July for a tag deployment on a killer whale oo21_186a (Table I). The tag detached early from the animal – after 6 hours, and very limited ARGOS fixes were achieved after the tag detached. The tag was recovered using the VHF signal, and we noted during recovery that the ARGOS antenna was in the water, explaining the lack of ARGOS signals while the tag was off the animal.

Figure 3. Left panel shows the Dtag3+ floating at sea in light winds with the ARGOS antenna in the water (white arrow) with the suction cups toward the wind. Right panel shows the tag floating in no-wind conditions in a bucket.



Broken Dtag3+ during second deployment

The second deployment of the Dtag3+ was on 06 July to a pilot whale. The tag attachment appeared normal (Fig 4A), and the tag was positioned very high on the dorsal fin (Fig 4B). Excellent GPS and GPS-ARGOS performance was confirmed during the early period of time when the tag was attached. However, the tag detached very early – after just 2.3 hrs of attachment time. No ARGOS signals were received from the floating tag, and VHF signals were less strong than normal.

Upon recovery we found the tag had broken (Fig 4C left, middle), and the core unit was just barely attached to the VHF flotation unit by the silicon used to glue the core unit into the housing. Syntactic foam along a section of the Dtag3+ had broken (Fig 4C, right). As the tag functioned well immediately after tagging, we conclude the tag most likely broke due to contact with another animal while the tag was attached. The audio recording included rubbing-like sounds consistent with animal contact.

This event demonstrated the rather fragile nature of the Dtag3+, as the force required to break the small section of syntactic foam (Fig 4C, right) is very little, it was concluded that the Dtag3+ was too fragile for safe deployment using the ARTS system and no attempts were made to attach the Dtag3+ using the ARTS system (see next section).

Figure 4A. Dtag3+ attached to pilot whale using normal pole tagging procedures.

Figure 4B. the Dtag3+ attached to the pilot whale near the front of the dorsal fin. This is a location where body contact with other whales is possible.

Figure 4C. Left panel shows the Dtag3+ was floating at sea with a broken housing. The right-panel below shows the broken areas of syntactic foam.

<u>Development of the ARTS carrier for use with the Dtag3+</u>

LKARTS-Norway developed an ARTS-DTAGv2 carrier in the period from 2006 to 2008, and this setup was operational from 2009. In 2013 this system was modified to the DTAGv3, and the ARTS-DTAGv3 carrier was operational from 2014. The new DTAGv3+ (holding in addition to the core DTAGv3 sensors, a module with FastLockGPS, PTT satellite - and a VHF beacon) is slightly bigger than the Dtag3 with a slightly different shape. During winter 2021, prior to the pilot study trial, a new ARTS carrier (ARTS-DTAGv3+) was designed and 2 units were produced for lab testing in Norway, and in field testing in Iceland during July 2021. The lab tests performed well, although the ARTSv3+ dummy was broken during the testing period. The DTAGv3+ broke between the DTAGv3 core unit, and the flotation, holding the other sensors. However, it was possible to assemble the tag with tape and finalize the lab tests. The system was operational in the lab and tested at distances of 12 meters at 9 bars pressure. The flight curve is less arched, which should give similar precision as the ARTS-DTAGv3 setup, and better precision than the ARTS-DTAGv2 and the ARTS-MixDTAG setup. This is mainly due to the difference in size and the weight of the different tags. Early May 2021, the problems with the dummy tag were communicated to Alex Shorter, and the need of casting the DTAGv3+ in a similar way as the former DTAGv3, in one rigid unit, strong enough for ARTS deployments. Upon arrival to Vestmannaeyjar, Iceland, in July 2021, the actual DTAGv3+ had been deployed using the hand pole, and there were still issues with the casting of this tag and the rigidity. To be able to make use of ARTS with the Dtag3+ further, a stronger assembly of the DTAGv3 core unit and the float with the other sensors is required. This can be done by either casting it in a flexible epoxy substrate, like the DTAGv3, or by making a housing similar to the MixDTAG, with the 2 modules (DTAGv3 and float with FastLockGPS, PTT and VHF beacons), inside the housing material.

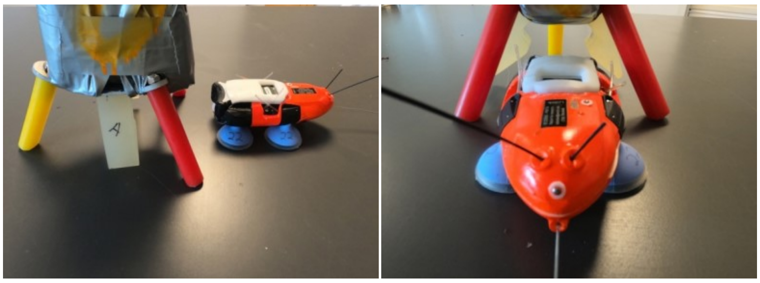


Figure 5. Two views of the newly built ARTS carrier for use with the Dtag3+. The carrier system was fully tested in the lab but was not used in the field as the Dtag3+ was considered too fragile for ARTS deployments.

GPS logging, GPS-ARGOS, and GPS-Goniometer tracking of whale position

As detailed in Table I, performance of the new LOTEK GPS was excellent, with many locations, for all tag placements that weren't low on the body. Essentially GPS positions were logged as expected by the software program – initially set to every 4 minutes, later modified to provide more locations. A subset of the logged GPS positions were relayed successfully via the ARGOS system with reliable performance whenever ARGOS satellites were available.

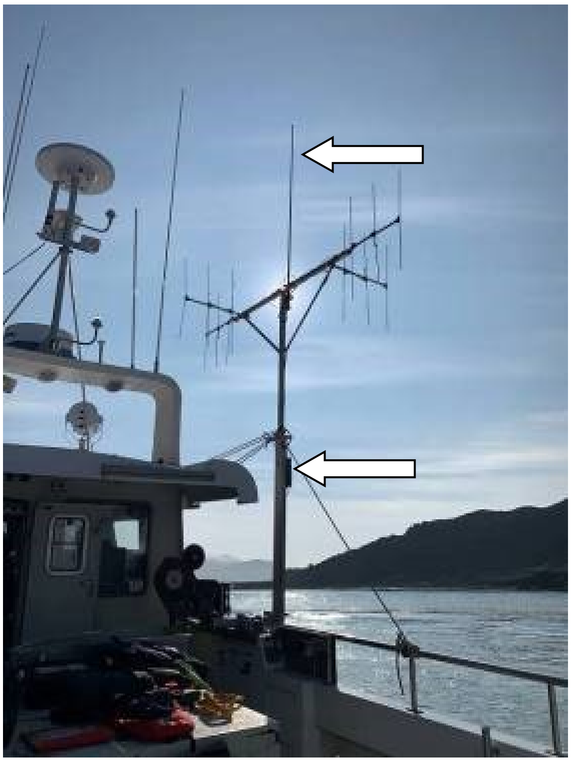


Figure 6. A custom +5dB vertical antenna for receiving GPS-ARGOS transmissions was affixed to the Fridrik (upper arrow). The antenna signal was filtered in a conditioning box (lower arrow), before being sent to the Goniometer.

For GPS-Goniometer tracking of whale position, a custom Goniometer antenna was mounted on Fridrik (Fig 6), along with a standard VHF antenna array for use with a DF Horten Automatic Direction Finder. The signal from the Goniometer antenna was filtered in a conditioning box (Fig 6) before being input to the Gonio2 goniometer. The antenna, conditioning box, cables and Gonio2 goniometer were all purchased from CLS ARGOS. Data from the Gonio2 was input into a dedicated laptop computer where it was processed with custom software provided by LOTEK. The output of the LOTEK software was a standard set of GPS strings, formatted to be readable by standard plotting tools. We visualised the GPS locations of the tracked whales using openCPN chart plotting software.

Real time tracking using the GPS-Goniometer system on Fridrik was attempted on 6 days and shore tests were conducted on 3 days (Table IV). All data including from Goniometer and Boat GPS received by the system and the output (AIS) stream with decoded whale positions were logged and stored in data files. During the first three days of effort, details of the data stream and openCPN plotting system were refined. By the final three days of use, the system was operational and we were able to view tag positions via the Goniometer real time on board Fridrik (fig 7). The final tag deployment (oo21_202b – see Fig 1 on cover page) was placed high on a male killer whale, and provided an excellent test case to evaluate the performance of the realtime GPS-Goniometer system with an ideal tag placement. Careful inspection of received locations was carried out alongside visual (Fig 8) tracking stored in Logger software during the 4th and final playback experiment (next section).

Date	Tag	Argos ID	On-animal data	Start time	Stop time	Comment
04-Jul						Land tests
06-Jul	gm21_187a	220591; 2BF58F2	No	13:40	18:02	First day operational after receiving updated software
07-Jul			No	16:43	17:42	Tag search and recovery
08-Jul	oo21_189a	215143; 2444479	Yes	11:59	18:06	Playback experiment
	mn21_189a	215144; 244448B	Yes	11:59	18:06	
09-Jul						Land tests
18-Jul	oo21_199a	215144; 244448B	Yes	15:02	20:56	Playback experiment. Some positions at 1km. Most positions from MN tag with high placement
	mn21_199a	220593; 2BFAD13	Yes	15:02	20:56	
19-Jul			No			Tag recovery. No Goniometer data received
20-Jul						Long-range land tests
21-Jul	oo21_202b	215144; 244448B	Yes	11:59	22:36	Playback experiment. Many positions with good placement

Table III. Notes on GPS-Goniometer tests completed during the pilot study.

We found that positions were reliably received when the tagged whale as within 1km of the tracking boat. Positions were less reliable beyond 1km. Possible limiting factors for the range of GPS reception include: electrical noise, goniometer antenna, software, ARGOS antenna angle. We strongly recommend more testing and refinements to achieve the maximum possible distance, particularly with tests from Sverdrup prior to a 3S4 sonar trial.

Figure 7. OpenCPN screenshot of tag positions on 18 July, 2021. The red boat is the position of the Fridrik, and green circles indicate a distance of 1km and 2km from the receiving vessel. The positions of the tag (not on the whale during this sequence) are indicated with yellow triangles.

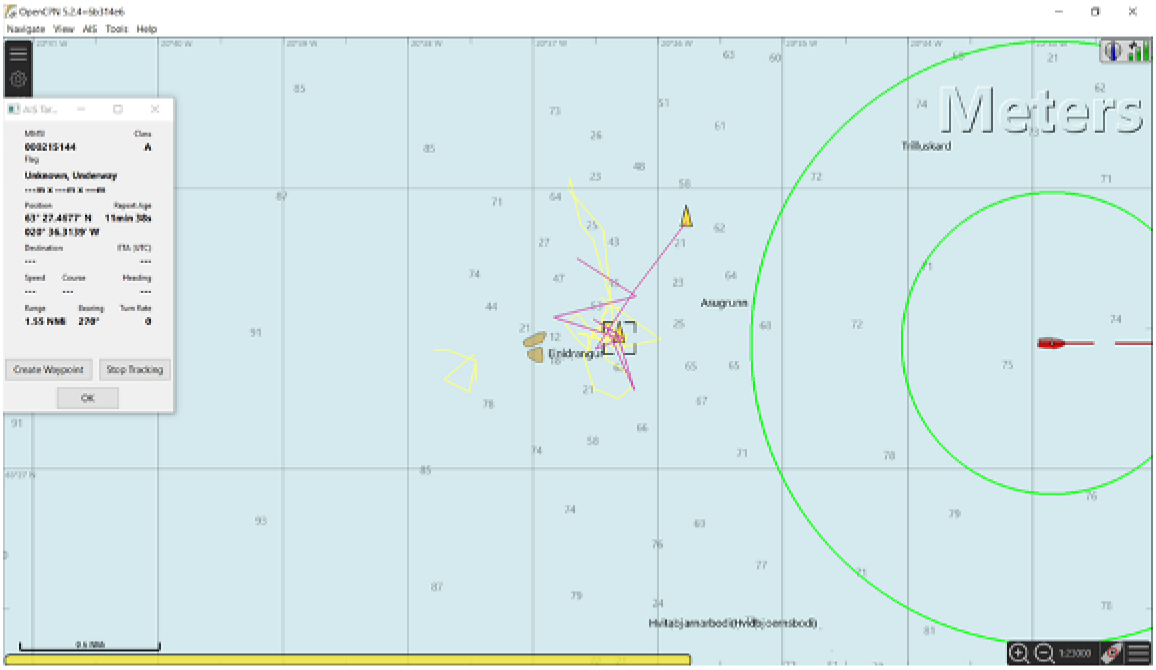
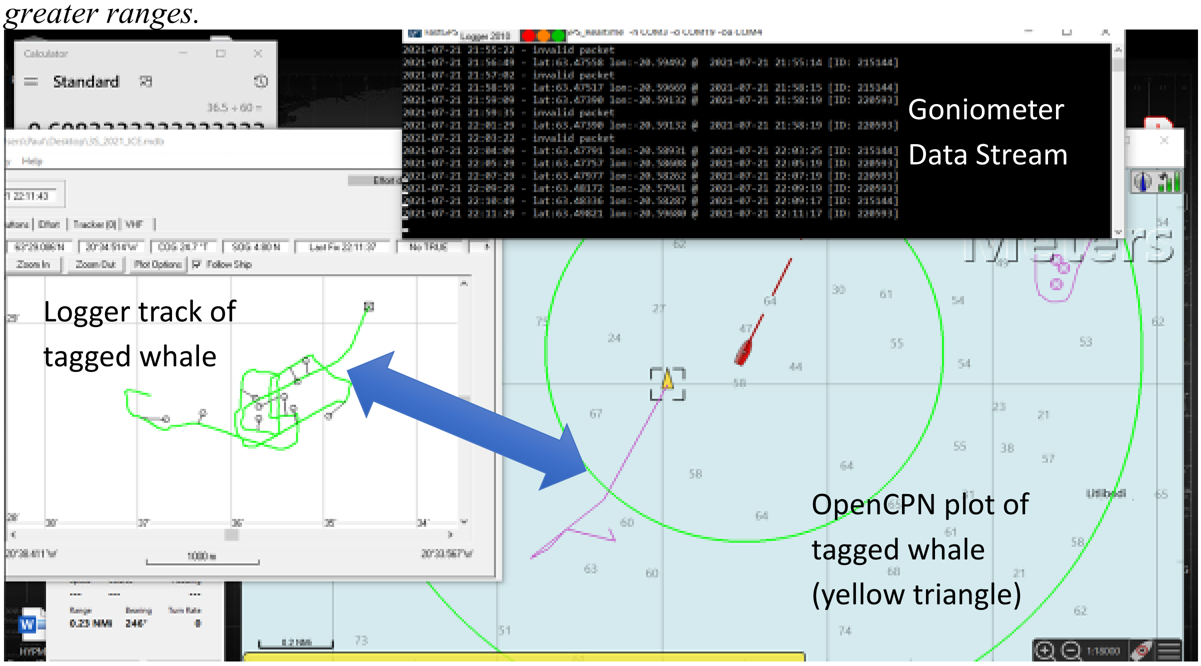


Figure 8. OpenCPN and Logger screenshot of tag positions on 21 July, 2021. The matching positions between the visual and Goniometer GPS track just prior to the taking of the screenshot are illustrated (blue arrow). Goniometer-GPS locations were regularly available when the whale was within 1km of the tracking boat, but performance decreased sharply at greater ranges.



Conclusions of comparison between Mixed-Dtag+ and Dtag3+

The smaller Dtag3+ failed to meet some tested capabilities (Table IV), and would require modifications and further testing for use in a 3S4 sonar trial. Changes to make the tag more robust and increase flotation would make the tag somewhat larger, and the retention of those suction cups may not be as successful at Dtag2 suction cups used in the Mixed-Dtag+.

In contrast, the larger Mixed-Dtag+ was demonstrated to work well for the key capabilities tested in the pilot study trial (Table IV). Another option would be to reduce the size of the Mixed-Dtag+ by designing a smaller housing but retaining use of Dtag2 suction cups. A slightly smaller Mixed-Dtag+ should be small enough for use with the target species identified for 3S4 sonar trials.

Tag capability	Mixed-Dtag+	Dtag3+
GPS-ARGOS (and GPS logging) on-animal	For both tag types the GPS-ARGOS system (and GPS logging) worked very well so long as tags were placed high on the body of the whale.	
GPS-Goniometer, on-animal	For both types of tags attached high on the whale body, the GPS-Goniometer system worked reliably to 1km.	
ARGOS for recovery	Reliable	Not working, antenna in water
Use with Pole	Both tag systems were deployed successfully with a hand-pole	
Use with ARTS	Functioned well	Tag was too fragile to attempts
Retention times	Very good – 86% until 16-19 hr release time	Uncertain – 50% (1/2) until release time, more data needed
Core unit data quality	The same core units are used in both systems, and some corrupted data periods (as observed in 2019) were noted for 5/13 deployments	

Table IV. Outcome of key capability tests carried out in the pilot study trial.

For several capabilities the two tags types did not differ. GPS functionality worked well for both tag types when tags were sufficiently high on the body. Both were deployed successfully with a hand-pole. Some corrupted data periods were noted for core units (used in both tag types), which had been noted in the 3S-OPS 2019 sonar trial. It is not known what causes these irregular data errors, or how to reduce their occurrence.

Playback of natural sounds and control stimuli to Dtagged killer whales

We conducted a total of 4 playback experiments (Table V), each of which contained a primary test stimulus (natural sounds of calling long-finned pilot whales), and a control stimuli (broadband noise N=2; and 1-2 kHz CAS signals as used in previous 3S experiments N=2). To ensure quality of the experiments, visual tracking and scoring of behaviour was carried out, alongside real-time tracking via the Goniometer-GPS system. The standard 3S design was used with the playback boat positioned ahead of the travelling killer whale, at an offset of 30-60° from their direction of travel. In some experiments, the animals were actively feeding upon herring, so their direction of travel was somewhat erratic.

Table V. Summary data for playback experiments conducted to tagged killer whales.

Date	tag ID	Resight #	playback stimulus	UTC time start	UTC time end	playback boat position start	playback boat position end
03/07/2021	oo21_184a	308	PW 1 (2015_18_07d/e)	19:00:37	19:15:37	N63°20.981 W020°27.961	N63°20.916 W020°28.053
03/07/2021	oo21_184a	308	Noise 1 (2015_18_07d/e)	20:13:25	20:28:25	N63°19.972 W020°28.068	N63°19.929 W020°28.282
08/07/2021	oo21_189a	310	Noise 2 (2016_21_07)	19:18:29	19:33:30	N63°27.998 W020°34.960	N63°28.038 W020°34.680
08/07/2021	oo21_189a	310	PW 2 (2016_21_07)	20:19:38	20:34:39	N63°29.621 W020°34.539	N63°29.694 W020°34.405
18/07/2021	oo21_199a	311	PW 3 (gm21_187a/2015-07-07a)	19:27:03	19:42:05	N63°27.911 W020°37.506	N63°27.9142 W020°37.044
18/07/2021	oo21_199a	311	CAS	20:26:56	20:41:52	N63°27.667 W020°37.294	N63°27.647 W020°36.931
21/07/2021	oo21_202a	312	CAS	20:41:07	20:56:02	N63°27.994 W020°38.950	N63°28.033 W020°38.720
21/07/2021	oo21_202a	312	PW 1 (2015_18_07d/e)	21:57:11	22:12:13	N63°28.374 W020°36.459	N63°28.413 W020°36.258

The quality of data collected during the playback experiments was very high, with good tag recordings and visual tracking throughout each experiment (Fig. 9). In the final experiment, GPS-Goniometer locations were assessed continuously alongside locations plotted by Logger (Fig 8), and locations always matched.

The good performance of the GPS-Goniometer system within 1km range demonstrates that GPS locations provided by the LOKEK GPS-ARGOS system can be used for conducting controlled-exposure experiments (CEE) in a future 3S study. To be fully useful, however, positions from the GPS-ARGOS and GPS-Goniometer systems need to be plotted within the CEE planning tool to be used in a 3S4 study.

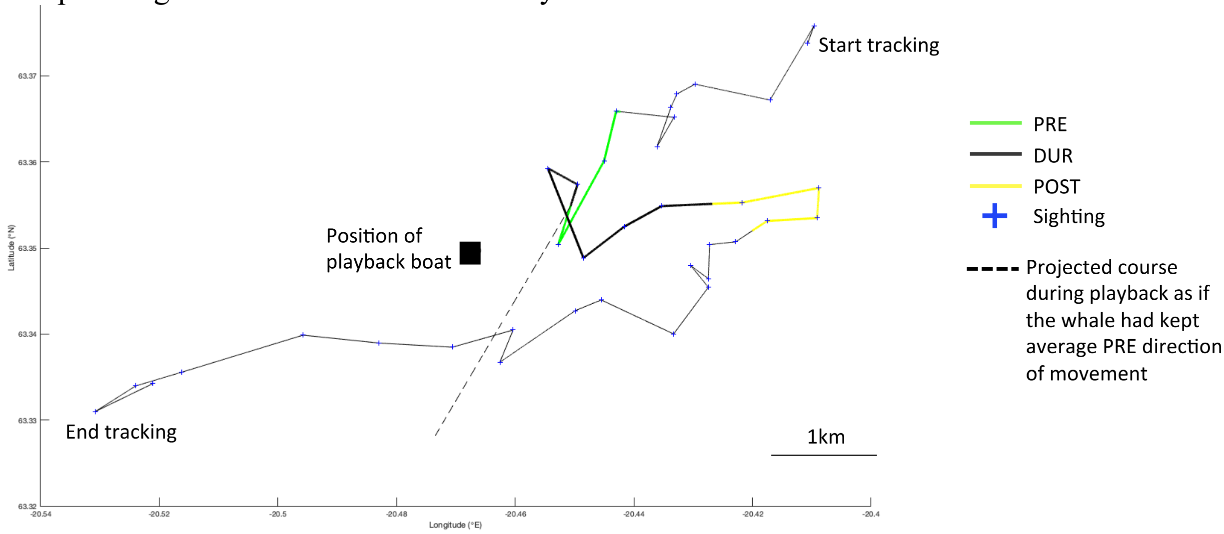


Figure 9: Horizontal track (using sighting data recorded on Logger) of tagged whale oo-184a exposed to playback of pilot whale sounds on 3 July, 2021. Each period PRE, DUR, POST – playback lasted 15min and are indicated respectively in green , black and yellow on the track. The dotted line represents the projected course of the whale during playback if it had continued to travel in the average same direction as during the 15min-PRE period. Position of the playback vessel (Golli) is indicated by a black square. In this example, the whale clearly changed direction away from the playback source during playback and returned to its previous travel direction before the end of the POST period.

Post-trial debrief recommendations

At the end of the trial, the entire field team assembled to provide feedback and discuss ideas of how to improve operations. The suggestions are listed below.

<u>Logistics:</u>
Very good logistics for the shore activities, housing, and office / lab space.

WhatsAPP communication was very effective. It was helpful to have access to the mobile phone network.

Team effort was excellent, with junior members taking over more tasks. More time for dedicated training could increase the pool of sufficiently skilled workers for many jobs. More plenary meetings could help in this regard also.

Daily plans were made following discussions between Miller and Samarra. Wider Iceland Orca Project (IOP) goals linked and separate from 3S were not always clearly specified how resources would be used. Being clear in the cruise plan, with more discussion on this point would improve joint understanding. Efforts in collaboration with IOP may need to be organized differently for future field efforts.

The Shore Station was very beneficial for spotting whale and tag recovery when the ARGOS wasn't working.

The Fridrik was a very good and safe boat, barrell was good for tagging. Communication between the tagger and driver wasn't great. Dedicated communication system between taggers and driver would improve. Also would improve communication (and keep observers blind) during the focal follows for playbacks.

Fridrik driver can't see very well. A driving console on the roof would improve performance.

The minimum speed of Fridrik was so fast that we needed to turn a lot and box the animal. Use a compass rather than course over ground would enable slower driving. Or change Fridrik to have a lower minimum speed.

Would be nice to be further from the whale, so improved Goniometer and VHF tracking would enable the boat to be further away.

The Golli was excellent for tagging and better for communication than Fridrik. A dedicated communication system between taggers and driver would improve. Would improve safety to have an AIS system on board the Golli.

<u>VHF Tracking:</u>
DF Horten tracking wasn't working great. Could be either antennas or the DFHorten box owned by Miller. Antennas could be 3m higher. Miller DF Horten box should be refurbished. Perhaps the boat could be noisy, AIS and other sources.

<u>Goniometer</u>:
Fridrik could have been noisy, so setting the filter could improve.

Short directional antenna worked as well as the omni-directional antenna. Not sure why. Needs to be checked before going onto SVERDRUP.

A user-friendly interface for the goniometer antenna would aid visualisation of whale tracks.

UAV-drone
Could have been useful in some of the follows, but not all of them. Weather was limiting.

Tags
The performance of Dtag3+ was disappointing. The dummy sent in advance wasn't a perfect match to the final tag. The Dtag3+ was very fragile, likely broke on animal contact. Too fragile for ARTS use. ARGOS for recovery wasn't functional.

Mixed-Dtag+ was very effective, but could be made somewhat smaller and lighter.

Pins to hold suction cups in place for both types of tags were unnecessarily difficult. Correct tools and pins would improve.

Tagging:
The killer whales seemed to see the pole. Try countershading the pole. Using the ARTS on the Golli would likely be very effective.

Science:
Mapping the prey field would be useful. Particularly during experiments, but also for baseline data.

APPENDIX I: Cruise plan published prior to conducting the trial.

Cruise Plan

3S-2021 pilot study Trial

June 24 – July 23, 2021

Patrick Miller, Cruise Leader; Filipa Samarra, Field Party Chief

The 3S-2021 pilot study trial is primarily funded by UK DSTL, with additional support from the US Living Marine Resources (LMR), French DGA and RANNÍS.

PROJECT OBJECTIVE

The 3S (Sea Mammals, Sonar, Safety) 2021 pilot study trial has a focus of pioneering key methods to be used in a larger 3S4 study. The proposed 3S4 study has the goal to study the responses of multiple simultaneously tagged whales to continuous active sonar transmissions. This requires real-time location information of tagged individuals, and automatic relay of the tagged-whales' positions also has the benefit of enabling experiments to be conducted at night and in rough weather.

The overall objective of the pilot study is to demonstrate effectiveness of a new Dtag system allowing realistic exposures of several animals simultaneously over an extended period. This technology will also reduce cost and allow exposures during night-time and in rough weather. The system will be tested on study species to be addressed in a full 3S4 study.

CRUISE TASKS

The primary objective of this pilot study trial is to test and validate methodology intended to be used during the 3S4 full scale BRS trials proposed for 2022-24. Primary tasks have a higher priority than the secondary tasks. We will try to accomplish as many of the secondary tasks as possible, but they will be given a lower priority if they interfere with our ability to accomplish the primary tasks.

Primary tasks:

1. to test the functionality of GPS-ARGOS linked tags (Dtag3+ and Mixed-Dtag3+) to provide (near) real-time positional information of tagged cetaceans. Killer whales are the

primary species, but long-finned pilot, humpback, and minke whales may also be tagged. Real-time reception and decoding of the ARGOS transmission will be tested, particularly the whale-antenna distances over which the signals can be successfully received and decoded. Tags will be attached with both the ARTS pneumatic launching system and hand poles. The retentions times of the two tag types will be compared.

2. track the location of tagged whales after tagging, to compare against position information provided by the GPS-ARGOS system. Tracking will primarily be done using UAV drones, with visual tracking as a back-up.

3. Conduct playback experiments with natural sounds (e.g. long-finned pilot whale sounds) to tagged killer whales, using the locations provided by the GPS-ARGOS system. This will validate the functionality of the new tag systems to perform in controlled exposure experiments planned for the full 3S4 study. Visual surface observations will be collected before, during and after playbacks.

Secondary tasks:
4. Deploy video or camera and heart-rate measuring tags using hand-poles

5. Collect sightings, photographs, and acoustic recordings of target species and other cetaceans encountered. Record UAV video to: a) observe the social context of a focal tagged whale and its group, including recording surface behavior of tagged and non-tagged whales, b) make photogrammetry measurements of tagged and non-tagged whales.

6. Collect echosounder survey data of herring in the study area, using a SIMRAD EK-60 or EK-80 echosounder system.

7. Collect biopsy samples of whales in the study area

MAIN LOGISTICAL COMPONENTS

Vessel 1: MV Friðrik Jesson

Length: 12m. Base of operations, real-time GPS-ARGOS (CLS goniometer antenna) and VHF tracking (DFHorten system), ARTS tagging platform, . Platform for launching UAV drones, and lowering CTD and visual tracking.

Skipper: Georg Skæringsson
Email: georg@setur.is
Mobile phone: +354-488-0102
Science crew: 5 max

Engine: Volvo 750 HP (diesel); 220V power available; Max/cruising speed: 17/13.0 knots

Vessel 2: Golli

Techno marine (http://www.technomarine.pl/) with Suzuki 200 HP 4-stroke outboard motor. This second vessel will serve as a second platform to search for and tag whales, and as the source boat during playbacks

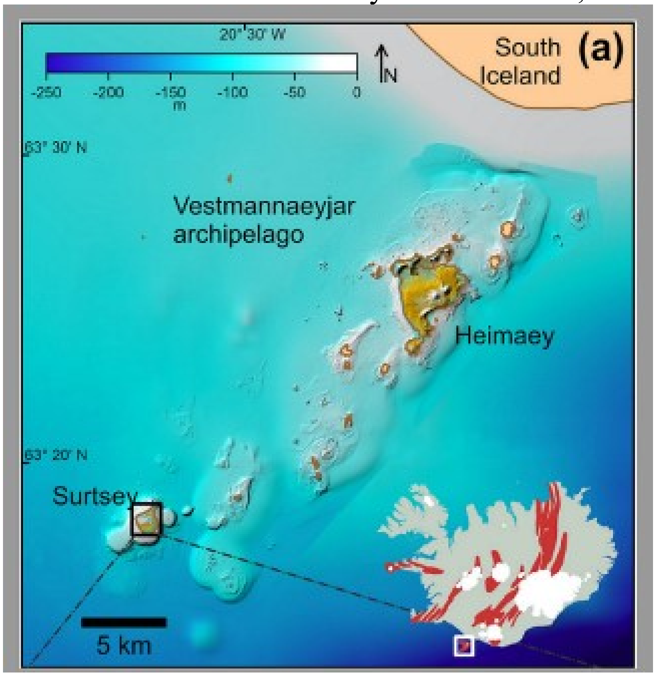
'Mixed-Dtag+ and Dtag3+'

Suction-cup attached whale tags, attached using poles or ARTS launchers. Left image is the Mixed-Dtag, which will be modified to Mixed-Dtag+ by inserting the same GPS-ARGOS system as in the Dtag3+. Note this tag system uses Dtag2 suction cups. Right image is the Dtag3+ which uses Dtag3 suction cups. Both tag systems will contain: Dtag3 core unit (audio, depth, 3-axis accelerometer, 3-axis magnetometer, programmable release); LOTEK integrated GPS-ARGOS logger; VHF transmitter, flotation. In addition to two mixed-Dtags, which is the priority tag for testing performance and recording baseline data, we have two additional suction tags (heart-rate tag, video camera tag) that can be used during the trail.

'DJI Phantom-4 UAV drone'

Video-recording drone with flight logs to record position and altitude. Custom procedures are used to safely launch and recover the drone at sea.

OPERATION AREA
The primary operation area will be the waters of the Westmann Islands southern Iceland. The area is a long-term field site, with large numbers of killer whales and other species sighted during the summer months. A shore-based sighting station near the southern tip of the main island will be used to visually locate animals, and to assess weather conditions.



Above: Map of the Westmann Islands archipelago. Right: the view from the landstation looking southwest over the Westmann Islands. A separate science team under management of F. Samarra will run visual effort from the shore station.

SAILING SCHEDULE
17 June: Miller arrives at fieldsite early to enable fulfilment of quarantine requirements
18 June: Charlotte Curé arrives Iceland to enable fulfilment of quarantine requirements
24 June: finalize organization of gear, set up boat and check all systems
25 June: Start of full operations with whales
28 June: Lucie Barluet de Beauchesne (student/Cerema) arrives Iceland to fulfil quarantine
4 July: Charlotte Curé departs Iceland, Lucie Barluet de Beauchesne replaces Charlotte.
1st July: Lars Kleivane arrives Iceland
7 July: Mathilde Massenet (student/Cerema) arrives Iceland to fulfil quarantine
13 July: Lucie Barluet de Beauchesne departs Iceland, Mathilde Massenet replaces Lucie
22 July: Last day of full research operations
23 July: Break down and pack equipment for shipment
24 July: Science team departs Westmann Island

STUDY ANIMALS
The primary target species is killer whales, with secondary species long-finned, humpback, and minke whales expected to be available for study. Individuals of the target species will be chosen opportunistically from animals found in the study site.

SCIENCE CREW LIST / ROLES

NAME:	Primary Role	Secondary Role	Tertiary Role
Patrick Miller	Cruise leader	Tagger / Tag technician	GPS-ARGOS/ Drone pilot
Paul Wensveen	Tagger	GPS-ARGOS tracking	Tag technician
Filipa Samarra	Field party chief	Land Station	Photo-id/biopsy
Charlotte Curé	Playback experiments (responsible)	VHF and visual tracking	
Lucie Barluet de Beauchesne	Playback experiments (operator)	VHF and visual tracking	
Mathilde Massenet	Playback experiments (operator)	VHF and visual tracking	
Alexandra Yingst	Golli boat driver		
Anna Selbmann	Visual observer	Playback experiments	Dtag technician
Kagari Aoki (to be confirmed)	Camera / heart-rate tags	Visual observer	CTD
U Iceland staff (TBD / Rain Miller)	Drone flyer	Visual observer	VHF tracking
Nicholai Xuereb	photo-ID/drone assistant	land or boat: observer/	
Rosemary Connelli	land or boat photo-ID/observer		
Tatiana Marchon	land or boat: photo-ID/observer		
Ellen Hayward	Tag technician	Shore station	observer
Lars Kleivane	Tagger/biopy	VHF tracker	GPS-ARGOS tracking

DAILY WORK PLAN

We will work at sea for a maximum of 8 hours each day, with Friðrik Jesson returning to dock each night. The research team will be responsible for their own meals. A daily planning meeting will be held each evening to determine the specific plan for the next 24 hours.

If tags were deployed on whales the previous day, recovery of any tags deployed the previous day will be given a high priority to be sure of safe recovery of the loggers.

Searching phase

The shore-station team will start by searching for whales at the start of each day. As much as possible, searching will be conducted first from the shore station and vessels will only be used once sightings of target species are confirmed. .

Before and during the search phase, tags should be prepared so they are ready in 'grab and go' mode for use upon encountering animals –. Tags will be programmed for 20 hour attachment time and with a 'release by' time, so they will detach by late afternoon the next day.

Tagging phase
Once a target species is encountered, we will observe and record the overall group characteristics and start taking identification photographs. If weather conditions allow, we will commence tagging operations. Tagging can occur from both vessels. During approach, the driver should drive parallel to animals, driving as slowly as possible and approaching from the side. The photographer will take images of the animals, and document whether or not there is a calf within the group. The photographer should attempt to photograph the tagging operation. Neonates cannot be tagged.

In addition to assessing the success or failure of each tagging attempt, it is critical to document the response of the animal to the operation, following the 1-4 point scale below:

1 No reaction: whale continued to show the same behaviour as before the biopsy or tagging attempt;
2 Low-level reaction: whale modified its behavior slightly, e.g. dived rapidly or flinched;
3 Moderate reaction: whale modified its behavior in a more forceful manner but gave no prolonged evidence of behavioral disturbance, e.g. tail slap, acceleration, and rapid dive;
4 Strong reaction: whale modified its behavior in a succession of forceful activities, e.g. successive percussive behaviours (breaches, tail slaps).

The tagger should attempt to place the tag high on the back just under or near the dorsal fin. Tag attachments low on the body are not desirable as they preclude testing of the GSP-ARGOS system.

Once a tagging attempt is successful, a datasheet noting the information should be completed and attempts should then be made to deploy a second tag on a different individual.

During the tagging phase, one person on Friðrik Jesson should monitor the VHF frequency of each tag before it is deployed. This is to confirm that the VHF transmitter is working before the tag goes onto a whale, and to listen in case any tag comes off the whale prematurely.

Data sheets for each deployment should be completed promptly to assure that no information is lost.

Once tagging effort is ceased, the tag boat can be used for secondary data collection, including identification photographs, biopsy samples, and/or echosounder data.

Tracking, observation, and photogrammetry phase
Once a tag is deployed, the Friðrik Jesson should move to track the tagged whale using the real-time GPS-ARGOS system, supported by VHF tracking, while additional tagging is attempted. The Friðrik Jesson may intentionally move away from the tagged whale to test the distance over which real-time GPS-ARGOS receptions function.

If weather conditions allow, we will commence the use of UAV drones to fly above focal tagged whales to make video recordings from overhead. These observations don't need to be continuous, but can potentially continue for as long as the tags remain attached, so drone flyers and handlers may need to rotate throughout the day. Each drone flights will last as long as possible given the battery duration, and spare batteries and SD cards will be available to swap them out after each flight. Care is needed during launch and recovery phases to reduce vessel motion, so the ship may need to be driven down-wind in certain circumstances.

The primary objectives of the drone flights are 1.) to track and record video images of the social context of tagged whales (20m minimum altitude above whales); and 2.) to take photogrammetry images (5m minimum altitude above whales).

At the end of each lower-altitude photogrammetry flight, it is critical to document the response of the animal to the operation, following the 1-4 point scale below:

1 No reaction: whale continued to show the same behaviour as before the drone flight;
2 Low-level reaction: whale modified its behavior slightly, e.g. dived rapidly or flinched;
3 Moderate reaction: whale modified its behavior in a more forceful manner but gave no prolonged evidence of behavioral disturbance, e.g. tail slap, acceleration, and rapid dive;
4 Strong reaction: whale modified its behavior in a succession of forceful activities, e.g. successive percussive behaviours (breaches, tail slaps).

If conditions do not allow UAV drone flights, tagged whale positions will be tracked visually.

Tag-recovery phases / data download and backup
Detached tags will be recovered using the VHF signal to approach the tag, followed by visual sighting of the floating tag. A pole with a net will be set up for recovering floating tags. Suction cups should be inspected for any sloughed skin before tags are disassembled for data download and battery change. When necessary, ARGOS receptions can be used to locate the detached tag floating at sea.

VHF frequencies of the deployed tags should be routinely checked to listen in case they come off the whale. Checks of ARGOS fixes can be made to help ascertain the position of the tagged whale. Once the tag detaches, it is expected that a larger number of higher-quality ARGOS fixes should be made, which should be used to guide the boat close enough to detect the floating tags using VHF.

All tag data must be checked that it has downloaded properly and has been backed upon on at least two different hard drives before it is deleted from the recording device.

MANAGEMENT AND CHAIN OF COMMAND
Operational issues
Operational decisions such as decisions on sailing plan and crew dispositions are made by the Field Party Chief, Filipa Samarra. Scientific decisions , e.g. which types of tags to deploy, and priorities of a secondary tagging effort versus conducting playbacks are ultimately made by the Cruise Leader, Patrick Miller, after seeking advice from the rest of the team and the skipper.

Safety issues
The skipper of Friðrik Jesson will make the final decisions on safety issues. Always remember: 'Safety First'!

TRIAL RISK ASSESSMENT

The Friðrik Jesson is fully equipped with all required safety equipment to conduct the operations within the study area. The University of St Andrews Health and Safety Office has created a safety risk assessment for the activities to be undertaken on board which must be understood and signed by all members of the science team and the skipper.

PERMITS

Appropriate permits for working with the target species in the study site have obtained from the Marine and Freshwater Research Institute (Hafrannsóknastofnun), by Filipa Samarra. All UAV drone flights will be carried out following Icelandic Law: drones may not be flown within 1.5km of a domestic airport or airfield. Drones may not fly greater than 120 meters above the ground or sea-level, and no closer that 150m from any other vessel operating at sea. See: https://www.icetra.is/aviation/drones/information-material-on-drone-operation/

ENVIRONMENTAL IMPACT AND RISK ASSESSMENT

Risk Inventory: The pilot trial will be conducted during the second half of June through the first half of July, 2021. This is a time when many marine mammals are expected to be present in the study area, and other human users of the area may be present . Echosounders will only be used >1km from any tagged whales, so the effect of those acoustic transmissions is expected to be negligible. Other environmental impacts of the trial will primarily stem from usage of the research vessels within the study area, and the impact of our research activities on the study animals.

The impact of the research vessels on the environment will be mitigated by driving at optimal speeds to reduce fuel consumption, and use of standard procedures to strictly regulate the disposal of waste materials. The impact of our activities on marine mammals is expected to be minor, and consist only of short-term behavioural disturbance. The activities to be conducted in the study area have authorization from the Hafrannsóknastofnun,, and have been ethically approved by the University of St Andrews Animal Welfare and Ethics Committee. Details of mitigation procedures to limit our impact on the study animals are detailed in the next section.

ANIMAL RESEARCH MITIGATION PROCEDURES

We have specified the following mitigation procedures to limit the potential impact of our research on the study animals.

Active echosounder will not be used closer than 1km from a tagged whale.

Close approach by for tagging and biopsy sampling:

Approaches by the vessel will be made at minimal possible speed. We should not manoeuvre to stay within 10m of any individual whale for more than 10 minutes.

Behavioural response monitoring:

During each tagging or biopsy attempt, and each low-altitude photogrammetry drone flight, the reaction to the procedure will be carefully observed and recorded using the 4-pt scale used by Hooker et al., 2001.

1 No reaction: whale continued to show the same behaviour as before the procedure;
2 Low-level reaction: whale modified its behavior slightly, e.g. dived rapidly or flinched;

3 Moderate reaction: whale modified its behavior in a more forceful manner but gave no prolonged evidence of behavioral disturbance, e.g. tail slap, acceleration, and rapid dive;
4 Strong reaction: whale modified its behavior in a succession of forceful activities, e.g. successive percussive behaviours (breaches, tail slaps).

If any animal in the group exhibits a level 4 response to a procedure, we will cease conducting that procedure, and cancel subsequent procedures in the study plan. For example, if a whale responds with a strong reaction during tagging, then no further tagging attempts, biopsy attempts, low-altitude drone flights, or playback experiments will be conducted with that animal.

TRIAL READINESS REVIEW

All equipment and materials required for the research effort have been obtained or are scheduled for delivery in time for the project start. The research team has been trained as necessary for the activities and procedures to be carried out during the trial. The 3S board approved this cruise plan on 14 May 2021 as ready for execution in the time-frame specified.

TRAVEL AND ACCOMMODATION

The entire team will stay in Heimay, Westmann Islands in rented accommodation arranged by Filipa Samarra.

Travel can be either by car from Keflavik via ferry to Heimaey, or alternatively via airplane flight from the Reykjavik national airport to Heimaey. The team will have a rented vehicle available for moving equipment, shopping, and other movements on Heimaey.

EQUIPMENT PACKING FOR SHIPMENT AT THE END OF THE CRUISE

The bulk of research gear from St Andrews will be shipped under a CARNET. The same items shipped there, must be returned after the end of the trial.

SHIPPING ADDRESS TO WESTMANN ISLANDS:

University of Iceland c/o Filipa Samarra
Thekkingarsetur Vestmannaeyja
Aegisgata 2
IS-900 Vestmannaeyjar, Iceland

Phone number: (+354)4880100 / (+354)8528027
VAT number for University of Iceland: 19133