Equipment to tag, track and collect biopsies from whales and dolphins: the ARTS, DFHorten and LKDart systems

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Method Article

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Abstract

Of all animals considered subjects for instrumentation for behavioral or physiological studies, cetaceans probably represent the greatest challenge to the engineer and biologist. Both the marine environment being harsh to electronics and the short time window available to attach instruments imply a need for innovative tagging solutions to facilitate better understanding of their life cycle, migration, physiology, behavior, health and genetics. Several sensor packages holding specific data loggers e.g., time depth recorders, position, orientation, acoustic and video recorders for short to medium term studies, as well as tags developed for large scale migration telemetry studies are available as off-the-shelf devices, or in many cases as custom made sensor packages. Deployment of those instruments is often the limiting factor for data collection. The Aerial Remote Tag System (ARTS) is a flexible system which can easily be adapted to deploy different tag sensor packages and biopsy collection devices. This paper presents the history and design of the ARTS, and accessories developed for instrumentation and biopsy sampling of cetaceans, such as the recent developed ARTS-LKDart for biopsy sampling. Deployment of archival tags usually requires radio tracking of the instrumented animal, or at least tracking of the tag for recovery. Thus, we also here describe the digital signal processing radio direction finder, Direction Finder Horten (DFHorten unit).

Background

When direct observation of biological processes is not feasible, the use of animal-attached sensor packages ranging, from fine scale sampling data-loggers to large scale telemetry tags using satellite technologies, is required to add to our knowledge of the life of marine mammals [1, 2], including our understanding of the physical environments they inhabit [3, 4, 5, 6, 92]. Deploying tags efficiently and having the right tools to enable reliable tracking and device recovery are needed to conduct such research. Vessel and staff time to conduct research on free ranging cetaceans is expensive, and optimal tools are important for the cost efficiency of marine mammal projects [7].

The ARTS (Aerial Remote Tag System) was first developed in Norway in 1997 by LKARTS-Norway and Restech Norway AS, for the Institute of Marine Research (IMR, Norway) in order to deploy radio tags on minke whales [8]. During the following decades several research groups have adapted this pneumatic launcher system to their marine mammal research projects, involving deployments of invasive anchor tags as well as non-invasive suction-cup tags, and for remote collection of biopsy samples. Thus, the ARTS has become a well-tested and established tool for deployment of tags and biopsy darts for cetacean research. Most research groups using the ARTS, work within satellite telemetry projects, using the ARTS to deploy satellite tags [10, 13, 14, 15, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38]. In addition, the ARTS launcher has been used to deploy larger sensor packages (Dtag, Ctag and HVTag) since 2009 [9, 10, 11, 12, 13, 14], as well as in projects using only light weight VHF tags [15]. To conduct controlled exposure experiment in behavioral response studies [14, 16, 17], there is a need for real-time tracking of focal animals to place a sound source in a specific location to conduct carefully designed exposures to tagged whales. In this type of field study, it is vital to know where the

focal animal is relative to the source, and this is now facilitated by using the digital radio direction finder DFHorten.

A combination of careful planning, effective research tools, and a team with the right training are key factors for successful field work [39]. The scope of this paper is to demonstrate improved tagging techniques for instrumentation of whales and dolphins with the use of the tagging system ARTS, and to demonstrate tracking abilities in using the signal processing radio direction finder, the DFHorten unit. In addition, we present a simultaneous tag and biopsy setup, and a new biopsy system, the ARTS-LKDart.

Methods

The ARTS system

Multiple failed tagging attempts using crossbows during a 1997 field effort to tag minke whales was the driving force behind the initial search for alternative deployment options. LK-Consult, later renamed LKARTS-Norway initiated collaboration with Restech Norway AS and the rifle manufacturer Rune Landrø (Norway). The first design of the launcher was built during winter 1997 and was followed up with laboratory testing the next year, resulting in the first ARTS ready for field tests (fig.1A, fig 2). The ARTS launches an arrow (carrier) with a grip designed to hold the tag during the flight, and then releases upon tag deployment. The grip is specially designed for each tag type. In collaboration with Villum Jensen (Danmark), the first ARTSCarrier (fig.1B, ARTSC) was developed for a bowhead whale project in West Greenland [40], and the following years further development resulted in a variety of different ARTS carriers and accessories with diverse applications, all unique and adapted to the shape and size of each instrument for optimal flight performance.

The basic of the ARTS is to deploy the instrument to the target (whale or dolphin) at distances from 5-20 meter, and then release the carrier from the tag. The carrier itself floats and can be recovered and reused. On some of the latest models of ARTS carriers a biopsy element is added which collects a biopsy upon the deployment of the tag. The ARTS is a pneumatic launcher, where launching pressure is adjusted (5-25bar) depending on the total weight of the ARTSCarrier and the sensor package, the species and the expected distance to the target. Thus, the expected distance to a target during approaches of a specific species will guide the setup of ARTSCarrier and will often be custom designed. Generally, lower pressures are preferred to reduce the impact on the animal and the risk of damage to the sensor packages, - this is a trade of with deployment precision and range.

During tagging approaches target species may be more or less evasive, keeping the tag boat at a distance – though whales may be more approachable in feeding and socializing contexts. For most species in any context, a boat approach within 20 meters is likely possible and the ARTS can be set up for tag deployments at 20-, 15-, 10- and 5-meter ranges with different sensor-packages. A typical field setup for a tagging project would be using a small tag boat to approach the whale and deploy the tag, however

also sailing boats, larger vessels, helicopter and even deployment from shore are platform-options during ARTS tagging.

ARTS – development and design

The total production of the whale tag launcher ARTS is (as of March 2022) 53 units since the pilot was constructed in 1997, and it has become an international standardized field tool in research projects working with telemetry and behavior studies of whales and dolphins. During the past 10 years ARTS have also been delivered with tagging-related accessories in a complete ARTS package (n=15) including a specific design for the deployment of larger archival tags (fig. 3B and 3C, ARTS-SD).

The ARTS is based on technology owned by Restech Norway AS and is a reconstruction of a PLT® line thrower [8]. The stock resembles a shotgun stock (fig 1A) where the air-fill handle enables the tagger to choose the launching pressure (fig 3D). The air-fill handle is a two-way valve, allowing the filling or release of air from the pressure chamber. The air-fill handle can be constantly connected to the pressure tank on a fixed platform using a long flexible high-pressure hose attached to the quick coupling on the unit. In some cases, a smaller air tank carried along side, or in a backpack setup, is convenient if the tagger position needs to be flexible. In these cases, the hose can also be disconnected from the ARTS, since the valve has a closing function. The standard barrel dimension is 38mm in diameter and 840mm long, however custom-made barrels are available (diameter: 12mm to 90mm), with variable length. The ARTS comes in different versions depending on tags, carriers and aiming device. A complete ARTS package (ARTS-SD) includes a standard ARTS (ARTS-S) setup for satellite tag deployments (Fig. 3B) and an aiming bar for the launching of larger sensor packages which have a hyperbolic trajectory and need a different aim device (ARTS-D) (Fig. 3C).

ARTS deployment of satellite tags

In telemetry projects using satellite tags the original ARTS carrier (fig.1B) is a commonly used setup [15,18,27,31,46]; however other carrier systems have been developed in the last decade [20,23,47]. The original ARTSC has been modified to a variety of satellite tag molds. The ARTSC standard is 650mm long, with a body of Polypropylene (DURAPIPE superFLO ABS 32mm PS EN ISO 15493), an outer diameter of 32mm and inner diameter of 28mm, and three polycarbonate steering fins of (Lexan 2mm) attached with flexible Flex-Master glue (Partsmaster, USA). It is a simple carrier, easy to handle and easy to use. When operating at close range, the ARTSC can be deployed without any safety line, and thus recovered after deployment. However, for many projects a tethered system is preferred, where the tag can be easily recovered if the deployment is unsuccessful in a miss or a bounce off the whale. Especially the latter can result in the loss of tags if the safety line is not used since the carrier does not float with the satellite tag still attached.

Another safety system for lighter tags (WC; SPOT5 mold 177) is a galvanic time releaser (GTR) mounted on a string between the tag and the carrier (fig. 5A). Other carriers have been developed for implant tube tags (fig. 5B and 5D)), and the latest ARTSTBC is designed for both Wildlife Computer SPLASH 302 and SPOT 303 tags. This tethered ARTS-carrier is especially designed for deployments up to 20 meters, typically for approaches from larger vessels. It is designed with an integrated physical stopper in order to utilize increased pressures giving greater accuracy, while simultaneously collecting a biopsy sample.

In 2015, LKARTS-Norway developed a carrier for the Wildlife Computer LIMPET tag SPLASH 292 (fig.5C). This carrier was specially developed for the off-range beaked whale study (ORBS) project studying Northern bottlenose whales [14]. This setup will also be equally useful for tagging other relatively small cetaceans like pilot whales, killer whales, minke whales, and beaked whales, or on larger whales where it is desirable to deploy the tag to the dorsal fin.

ARTS deployments of archival tags

The initial idea of launching a larger sensor package using the ARTS was conceived in 2006 while suffering through long days trying to tag herring-feeding killer whales in Vestfjorden, Norway, using the traditional hand-held pole to deploy the DTAGv2 [41]. Killer whales were routinely approachable to within 10-15m, however for hand pole tagging one needs to be within 5-8m. LKARTS-Norway, with support from the 3S program (The Sea mammals and Sonar Safety program studying behavioral responses to naval sonar in six species of cetaceans), started dry tests during the 3S-2006 cruise [42]. Following 3 years of development and testing the ARTS-DTAGv2 setup, the LKCv2 carrier (fig. 3C) became a fully operational system in 2009 [43]. We were then able to deploy DTAGs to killer whales at more than double the standard pole distances [43]. From 2012 a new and larger manometer (Figure 6) was made an optional accessory for the ARTS, enabling finer control of the deployment pressure and hence better deployments.

Additionally, several aiming devices have been tested in order to improve accuracy when using heavier tag systems with a hyperbolic curved flight (fig. 3C; 7A and B).

The launching of the tag and impact on the whales poses stress to the tag electronics and housing. We found that the G-forces when launching the DTAGv2 using the ARTS at 6-8 bar pressure at distances of 5-10 m, are well within the impact forces during pole tagging. While the impact forces when ARTS launching the DTAGv2 using 10-12 bar pressure at distances of 5-10 m are in the upper part of the forces measured during pole tagging (fig. 8). These tests were performed to ensure that the risk of tag damage or impact on the whale were not significantly greater when deploying the DTAGv2 using the ARTS compared to the well-established method of deploying the tags with a long handheld pole [43].

Field results from 2009 showed that DTAGs launched with 7-8 bars pressure at 9-12m range gave the highest success rate, especially when working with killer whales, and the average tag on whale time (TOWT) for ARTS deployed tags were comparable to TOWT using the pole system [43].

During the development of the ARTS-DTAG setup a rugged version of the DTAG housing was built at WHOI (Woods Hole Oceanographic Institution, USA) and the ARTS carrier was modified in order to soften the impact of the tag on animal. During cruises in Norway, Iceland and Brazil in the period from 2009 to 2020 the ARTS launcher was successfully used to deploy DTAGs on pilot, killer, northern bottlenose, sperm, minke, Bryde's (*Balaenoptera brydei*), sei (*Balaenoptera borealis*), fin (*Balaenoptera physalus*), blue (*Balaenoptera musculus*) and humpback whales [9,11,12,14,43,44,45].

At present the basic ARTS carrier, LKC, is operational with several archival tags (Table 1). Some of these tags (DTAGv2 and DTAGv3) are shown in figure 9, with their respectable specialized carriers the LKCv2 & LKCv3. For the details of various setups with tags and carriers we refer to field reports and publications [7,9,11,12,41,42,43,48,49,50,51,52,53].

Table 1

An overview of operational ARTS, carrier systems and biopsy darts

System	Carrier	Year	Testing	Tags
ARTS-S	ARTSC	1997		Wildlife Computer satellite tag; mold177
ARTS-S	ARTSC	2001		Advanced Telemetry Systems VHF tag; MM100 Series
ARTS-S	ARTSC	2012		LKARTS-Norway archival tag; CTag
ARTS-S	ARTSLC	2014		Wildlife Computer satellite tag; LIMPET SPLASH292
ARTS-S	ARTSLBC*	2017		Wildlife Computer satellite tag LIMPET SPLASH292
ARTS-S	ARTSTBC*	2020		Wildlife Computer satellite tags; SPOT303/SPLASH302
ARTS-D	LKCv2	2009		Woods Hole Oceanographic Institution archival tag; DTAGv2
ARTS-D	LKCv2b	No	2011	DTAGv2 with barb attachment
ARTS-D	LKBCv2*	2012		LKARTS-Norway archival tag; HVTag
ARTS-D	LKCBv2*	2014		Sea Mammal Research Unit archival tag; MixedDTAG
ARTS-D	LKCBv3*	2015		Univ. Of Michigan?? archival tag; DTAGv3
ARTS-D	LKCv2	No	2015	LKARTS-Norway archival tag; HVCamTag
ARTS-D	LKCBv2*	2021		Sea Mammal Research Unit archival tag; MixedDTAG+
ARTS-S	LKDart10	2012		LKARTS-Norway biopsy dart
ARTS-S	LKDart21	2021		LKARTS-Norway biopsy dart

** Carriers including a biopsy part with biopsy tips from CETA-Dart (Finn Larsen, Danmark)*

In the 3S program, the objectives were to study behavioral changes to naval sonar pulses in 6 whale species inhabiting Norwegian waters (killer (*Orcinus orca*), long-finned pilot (*Globicephala melas*), sperm (*Physeter macrocephalus*), Northern bottlenose (*Hyperoodon ampullatus*), humpback (*Megaptera novaeangliae*) and minke whale (*Balaenoptera acutorostrata*)). The new ARTS-DTAG setup was an important tagging novelty for this program [7,9,11,12,14,15,42,43,48,49,54].

ARTS and custom biopsy darts

The LKDart was developed during 2010 in order to able to take biopsy samples through the blubber layer of large cetaceans. These darts are launched with the ARTS system, typically using biopsy tips from Finn

Larsen (CETA-dart, DK). In 2010 the LKDart was successfully tested using variable biopsy tips from 20 to 80mm, and the ARTS-LKDart biopsy system was operational from 2012 [56,57]. In figure 12 is shown the LKDart (fig.10A), with the 2010 and the 2021 versions, and details of the tip attachment as well as a sample collected with an 80mm biopsy tip (fig 10B). Furthermore, the LKTDart (fig.10C) a tethered (25m) dart setup designed especially for use from larger vessels was functional as of 2017.

In 2012 a design of a system to enable the collection of a biopsy sample simultanouasly with the deployment of DTAGv2 was initiated. Today this setup using the LKBC carrier is operational, and can be seen in figure 11A. A recent design of the ARTSLC (for LIMPET tag deployments), also includes a simultaneous biopsy collection. This carrier, now named ARTSLBC, was operational from 2017 (Fig. 11B).

DFHorten – a digital signal processing radio direction finder unit

An increasing number of the tags deployed with the ARTS system are archival tags in projects using controlled exposure experiments to study changes in whale behavior, where it is vital to know in real time and control the position of the tagged animal. The signal processing radio direction finder, the DFHorten unit (fig. 12A), was developed for this purpose, to make it possible to track and follow VHF signals and thereby visually record positions of a focal tagged whale, collect relevant environment data, presence of intraspecifics and interspecifics around the focal tagged whale, as well as social behavioral data. The total production of the DFHorten is at present (as of March 2022) 17 units.

The DFHorten is a tracking device, connected to 4 Yagi antenna elements pointing in 4 different direction 90° apart (fig. 13A, B and C), and further connected to a speaker and a radio receiver [57]. The unit has a front panel with LED lights in a circle with 24 red diodes (15 degrees between diodes), and a cross of 9 red diodes on each cardinal direction (fig.12B and C). The four antennas are connected to separate channels and the DFHorten unit switches between the four channels within a 16ms cycle. The signal strength of the two channels receiving the weakest signal is discarded and the signal strength of the two channels receiving the strongest signals are weighted in a digital processing chain. The best estimate of direction is indicated with 15° resolution on the outer diodes (fig.12B and C). The signal strength on all four antennas will be shown on the LED cross. To indicate the quality of the incoming signal the centered LED will flash, indicating that you have had a good signal reception. For optimal performance 2-4 pulses are required. However, multiple, longer and stronger VHF pulses would increase the range and performance of the DFHorten unit. The DFHorten function well with the radio receivers ATS 2000 (Advanced Telemetry Systems, USA) and the R-1000 (Communications Specialists Inc., USA). The advantage of using the DFHorten becomes evident in poor weather or when it is dark, as well as during recovery of a floating tag. The unit is operational to a maximum of 2 nm depending on the antenna height and electromagnetic noise of the platform [7,9,11,12,16,17,42,43,44,45]. For detailed description of the DFHorten unit we refer to the manual [57]. We are currently in the testing phase of using the DFHorten

box also to apply to satellite tag signals, thus being able to track satellite tagged whales and dolphins in real-time.

Results

Key outcomes

Several ARTS carriers and biopsy darts have been developed the last two decades to enable use of the ARTS with different tags for different purposes (Table 1). In multiple studies the ARTS have been one of the principal tagging systems (Table 2). Additionally, in parallel different carriers have been modified and/or developed in various projects [13,51,59,95].

A conservative estimate of 11 baleen whale species (minke, humpback, Bryde's, sei, fin, blue, pygmy blue (*Balaenoptera musculus brevicauda*) grey (*Eschrichtius robustus)*, bowhead (*Balaena mysticetus)*, North Pacific right (*Eubalaena japonica)* and southern right whale (*Eubalaena australis)* and 7 odontocetes species (common bottlenose, white-beaked (*Lagenorhynchus albirostris)*, long-finned pilot, killer, northern bottlenose, Baird's beaked (*Berardius bairdii)* and sperm whale] have been tagged with the ARTS system worldwide (2022). Key scientific publications, where the sampling of data has been attained using the whale tag launcher ARTS, the processing radio direction finder DFHorten and or the biopsy setup ARTS-LKDart, are presented below.

Table 2

An overview of species and publications from several studies using the ARTS system

	Telemetry projects using satellite tags	Behaviour studies using archival tags
Species	Reference number of publication	Reference number of publication
Minke whale	15,18,41,58	7,9,15,43,48
Bryde's whale	44,45	44,45
Sei whale	22,31,44,45,75,77,78,94	44,45
Grey whale	19,87,88	
Fin whale	69,75,79,80,82,94	13
Blue whale	18,23,34,38,69,70,71,72,73,74,75,76,94	13,54
Pygmy blue whales (Balaenoptera musculus brevicauda)	23	
Humpback whale	21,23,24,27,28,30,32,59,60, 61,62,63,64,65,66,67,68	7,9,44,45,48,50,51,53
Bowhead whale	25,35,36,40,83	51
North Pacific right whale	84	
North Atlantic right whale	59	
Southern right whale	47,85,86	
Bottlenose dolphin	44,45	
Long-finned pilot whale		11,52,53
Killer whale	33,45,91	11,12,42,43,52
Northern bottlenose whale	14,16,54	14,16,54
Sperm whale	89,90	13

We outline the study on killer whales [12], northern bottlenose whales [14,16] and minke whales [17], since these species are relatively difficult to tag. The DFHorten unit was a key tool for successfully completed controlled experimental exposures as part of these studies [14,54]. Other studies are master theses and doctoral theses in progress using the HVTag data on humpback whales from Norwegian fjords [50]. Furthermore, projects on the body condition of cetaceans where DTAGv3 and Mixed-DTAGs were deployed using the ARTS system [16].

Results from ARTS deployments of LIMPET tags reveal a mean tag on whale time (TOWT) for killer whales of 47 days (n=12), with the highest TOWT of 103 days [33]. Although few LIMPET tags were

involved (n=8), the TOWT on northern bottlenose whales was comparable when comparing deployments using the ARTS with the Dan-Inject system [54]. During the PMC-SB (Projecto de Monitoramento de Cetaceos na Bacia de Santos) project in Brazil the same carrier including a biopsy tip (ARTSLBC) with deployments on common dolphin, killer, sei, Bryde's and fin whale resulting in TOWT from 1 day to 38 days [44,45].

The IWC paper SC/60/PFI 8 [15] demonstrates the power when combining research tools as the whale tag launcher ARTS and the radio direction finder DFHorten unit. This effective combination of tools is also well documented in the Body condition, 3S1 and 3S-ORBS projects at Jan Mayen [14,16,54].

The ARTS-LKDart system is well demonstrated in an Icelandic project, where more than 70 biopsy samples of killer whales were collected [55,56], while the carriers LKBCv2 and the ARTSLBC are still in process and are at present collecting a biopsy sample at roughly 50% of the deployments [16,45].

Discussion And Conclusions

What are the research questions, and how to collect datasets needed to answer these questions? Good logistics in planning for field operation involving sampling, tagging and tracking of whales or dolphins is the first step to successful results. Effective field equipment is an important element, however probably the most important factor is the operators and the team structure, and that all team members know the operation and the details of the field work. Many of these elements are discussed in "Best practice guidelines for cetacean tagging" (39). In a tagging situation the key element is the team composition and good communication, where often the key operator is the driver for placing the tagger in a good launching situation. Camera or video documentation of tagging attempts and debriefing among the team are vital to improve and to be better prepared for the next tagging approach, in order to reduce the time close to each animal, hence increase the tagging efficiency.

The aim and result of this paper was to highlight the history and use of the whale tag launcher ARTS and its accessories as well as the processing radio direction finder DFHorten. Due to the greater tagging range compared to standard hand pole deployments, the ARTS system has proven to be an efficient tool, and is particularly useful in projects studying fast moving animals that are difficult to approach by a tag-boat. The whale tag launcher ARTS is used worldwide in telemetry projects using satellite tags and in field operations deploying archival tags. Several ARTS-carriers have been developed during the last two decades to allow deployments of satellite tags and archival tags to whales and dolphins. All to better understand the complex of cetacean behavior and life cycles, and in addition collect oceanographic information (92) that is urgently needed for an improved understanding of climate and ocean variability. In projects deploying data loggers a processing radio direction finder, the DFHorten unit, has proven to be especially valuable in certain aspects of the tracking operation, and for recovery of a floating tag. Finally, both the simultaneous collecting of a biopsy sample during tagging, and LKDarts have been a part of the development of the ARTS systems.

Appendix 1: Recommendations for use of the ARTS

After substantial tests in a controlled laboratory setup of the ARTS-DTAG, followed by several in situ deployments during multiple sea trials, range versus pressure was determined in order to obtain successful deployments without damaging the electronics of the tag or harming the animal. In addition, recommended application when deploying satellite tags and biopsy sampling is included in this overview.

1. When launching intermediate sized tags like DTAGv2 or HVTag with the ARTS a standard launching pressure should be in the range from 7.5 to 9.5 bar, often using 8.8 bar at ranges of 12-14 meters. For the DTAGv3, which is a smaller tag, the pressure would be 1 bar lower, while for heavier tags (e.g., Mixed-DTAG) the pressure range would be from 8 to 11 bar.

2. When launching satellite tags with a total weight from 300g to 700g, the launching pressure should be in the range from 10 bar to 24 bar depending on species, the range, carrier- and anchor design. Deploying tags at a range of 10 -15 meters the pressure would be in the range from 12 - 18 bar, for sperm whales about 5 bar more. However, with the new ARTSTBC carrier, deployment pressure should be 2-8 bar higher, depending on species.

3. When deploying the LIMPET satellite tag (SPLASH 292) from Wildlife Computer with the ARTSLC carrier, recommended launching pressure out to 10 meters and 15m are at 9 bar and 11 bar, respectively.

4. During biopsy sampling using the ARTS-LKDart setup at very close range < 7m the barrel pressure should be less than 6 bar, while at ranges out to 12 meters and up to 20 meters the standard launching pressure should be 6-8 bar and 8-10 bar, respectively. For longer ranges exceeding 20 meters the recommended launching pressure is 10-12 bar.

Note that these are only recommendations, and that each project is responsible for the safety of people, animals and equipment. Stay safe and trust your research tools by training and practice.

Abbreviations

ARTS - Aerial Remote Tag System - a pneumatic whale tag launcher

ARTS-S - ARTS satellite

ARTS-D - ARTS datalogger

ARTS-SD - ARTS satellite and datalogger (complete ARTS package)

ARTSC - the original carrier for ARTS deployments of satellite tags

ARTSTBC - the tethered ARTS carrier for Wildlife Computer tags in the 300 series, with simultaneous biopsy sampling

ARTSLC - the ARTS carrier for LIMPET satellite tag (SPLASH 292) from Wildlife Computer

ARTSLBC - the ARTS carrier for LIMPET satellite tag (SPLASH 292) from Wildlife Computer with simultaneous biopsy sampling

DFHorten - Directional Finder Horten - a processing radio direction finder produced

in Horten

DTAGv2 - Johnson and Tyack 2003

DTAGv3 - Miller et al. 2015;2016

HVTag - Horizontal and Vertical Tag, a suctioncup tag including Wildlife Computer logger (TDR10-F-297C) and a VHF beacon (Advanced Telemetry Systems MM100 Series). The taghouse size similar to the DTAGv2. Kleivane et al. 2013

LKCv2 - the ARTS carrier for deployments of DTAGv2, Mixed-DTAG and Mixed- DTAG+

LKBCv2 - the ARTS carrier for DTAGv2, Mixed-DTAG and Mixed-DTAG+ with simultaneous biopsy sampling

LKCv2b - the ARTS carrier for DTAGv2 with barb attachment

LKBCv3 - the ARTS carrier for DTAGv3 with simultaneous biopsy sampling

LKDart10 - the biopsy dart for the ARTS system, developed in 2010

LKDart21 - a new version biopsy dart for the ARTS system, 2021

LKTDart - the tethered biopsy dart for the ARTS system

Mixed-DTAG - Miller et al. 2015;2016

Mixed-DTAG+ - Miller et al. 2021

Declarations

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Ethics approval and consent to participate

During the development of the ARTS system, all animals were handled by experienced professionals under permits

Consent for publication

Not applicable.

Competing interests

Lars Kleivane have mutual interest with Restech-Norway and ASJ Electronics to the systems ARTS and DFHorten, respectively.

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Authors' contributions

LK initiated and drafted the manuscript and PHK, PM, AB and NØ commented on text and figures, and edited the manuscript. All authors read and approved the final manuscript.

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Lars Kleivane have mutual interest with Restech-Norway and ASJ Electronics to the systems ARTS and DFHorten, respectively.

Figures

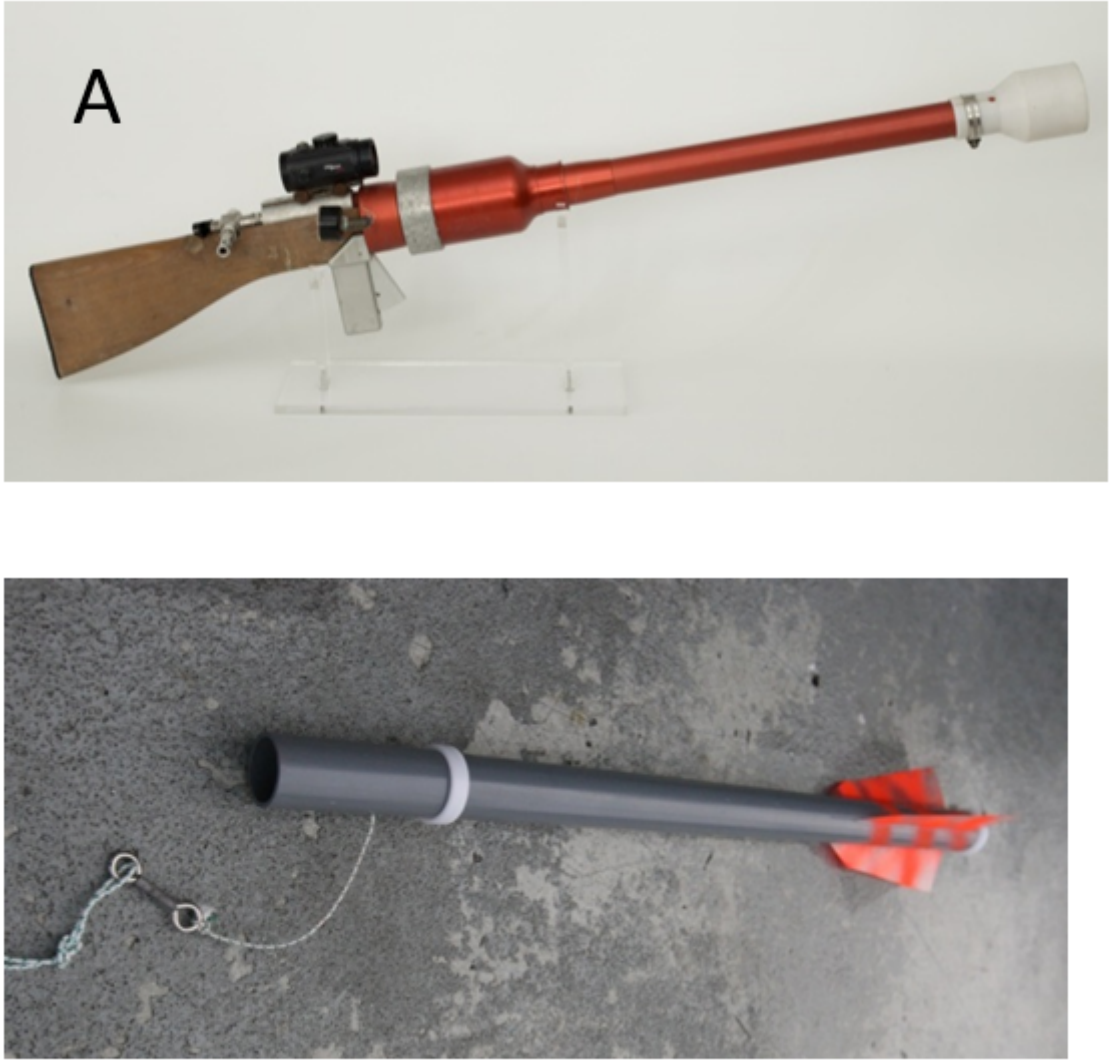

Figure 1

Early prototype of A - the ARTS (1998) and B - the ARTSCarrier, with a Galvanic Time Release line (1998). Photo by Tom Are Mathisen and Lars Kleivane.

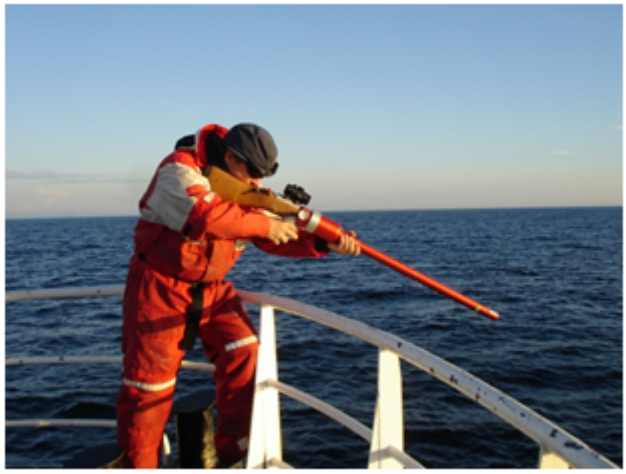

Figure 2

Here is a typical ARTS setup from the bow of a larger vessel with an elevated platform, often used when deploying satellite tags to baleen whales. Photo by Paul Ensor.

Figure 3

Panel A shows an early prototype of the ARTS (2004) and Panel B shows an ARTS model for deployments of satellite tags (ARTS-S, 2007). The ARTS model for deployments of larger sensor packages (ARTS-D, 2012) with an offset sighting bar is shown in panel C, while details of the main components on the ARTS housing, with the valve function, pressure control (small manometer), trigger and standard aiming device (Riflescope ZOS), is shown in panel D. Photo by Tom Are Mathisen.

Figure 4

Standard ARTS (ARTS-S) kit with 2 barrels (840mm), one small pressure bottle with a reduction valve and a 2,5m long pressure hose, one aiming sight (Riflescope ZOS), and the ARTS pressure chamber (lower right), a quick shoulder shaft and a quick connector to the pressure tank. Photo by Tom Are Mathisen.

Figure 5

The use of different ARTS-Carriers when deploying satellite tags, illustrated in A (ARTSC) with GTR release line, a satellite tag from Wildlife Computers (SPOT5 mold 177) and anchor from IMR (Institute of Marin Research , Norway); B (ARTSC1) a setup with the same satellite tag but with different carrier design, with an anchor from NRISFS (National Research Institute of Fisheries Science, Japan); in C the ARTSLC for the Wildlife Computer LIMPET Tag SPLASH 292, anchors from Wildlife Computers not illustrated. In D the ARTSTBC, a tethered system including a biopsy tip, for Wildlife Computer tags SPOT303/SPLASH302. Photo by Lars Kleivane.

Figure 6

This figure shows a detail of the larger manometer setup (left) and a field view (right). Photo by Paul Ensor

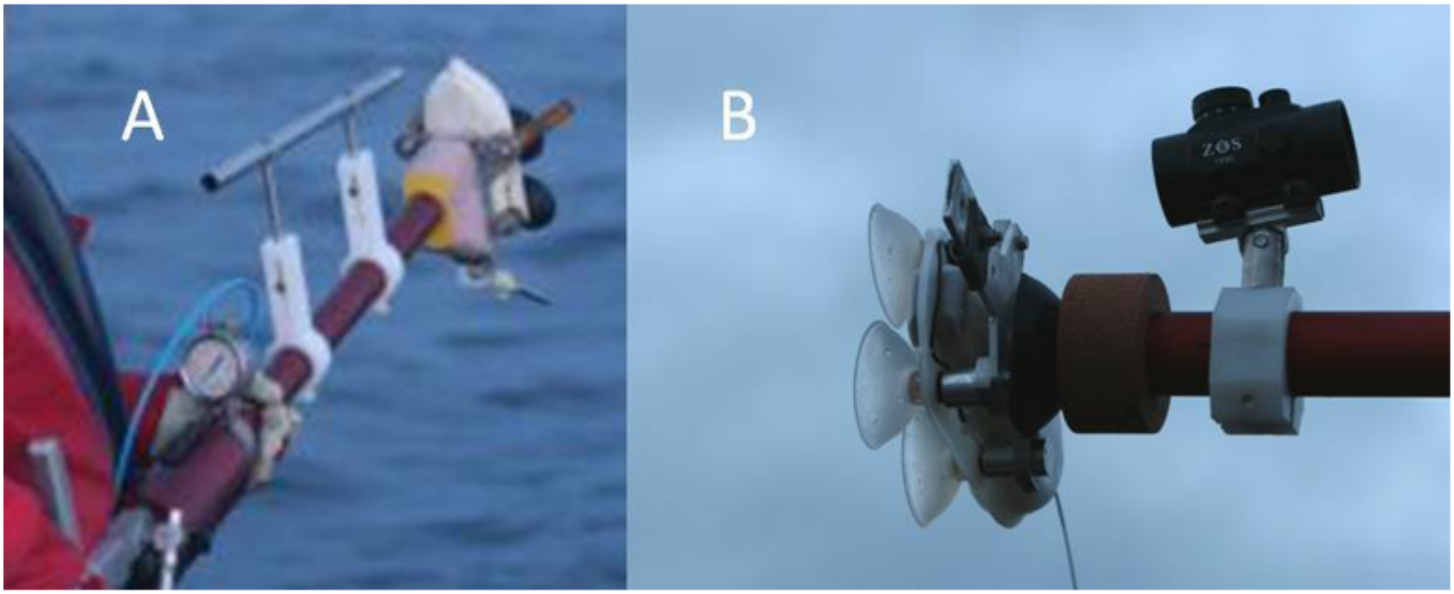

Figure 7

. In this figure we illustrate different aiming devices tested during the developpment of the ARTS-DTAG system. For heavy tags which will have a hyperbolic flight trajectory either a elevated aimbore (A) or an aimpoint (B) can be used. Photo by Christopher Hinchcliffe.

Figure 8

Stress tests on DTAG electronics during deployment from two different tagging systems (Handheld pole and ARTS). Stress is measured as acceleration or deceleration (g) using an accelerometer placed on a dummy tag representing the electronics of the DTAGv2.

Figure 9

Several sensor packages have been adapted with specialized carriers. In panel A the LKCv2 with the DTAGv2; panel B LKCv3 with the DTAGv3; panel C Show the DTAGv3; while panel D the DTAGv2b with barb attachment and a GPSFastlock mounted on the top of the tag. Panel E Show the Mixed-DTAG and in panel F an example of the ARTS-DTAG system using a LKCv2 deploying a Mixed-DTAG+ on a killer whale. Photo by Tom Are Mathisen, Lars Kleivane and Nicholai Xuereb

Figure 10

Skin and blubber biopsy collection using the ARTS to launch LKDart21 and LKDart10 (panel A). Panel B shows a blubber sample collected with a Finn Larsen biopsy tip, 80mm long. Panel C show the tethered setup for the LKDart, the LKTDart, while panel D and E demonstrate biopsy sampling of a northern bottlenose whale and humpback whale, respectively, using the LKDart10. Photo by Lars Kleivane and Saana Isojunno.

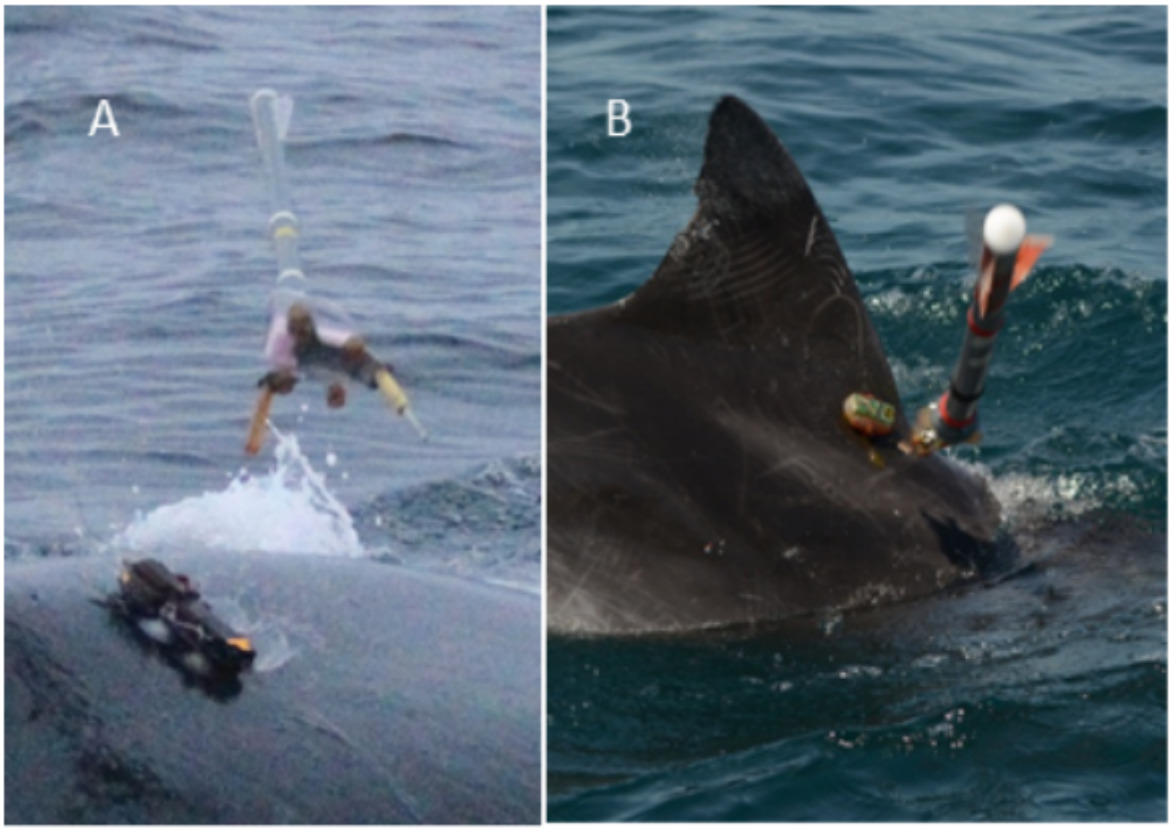

Figure 11

Left panel (A) the Mixed-DTAG deployed to a humpback whale simultaneously collecting a biopsy sample. Right panel (B) a LIMPIT tag (WC, SPLASH 292) deployed to a bottlenose dolphin (Tursiops truncatus) simultaneously collection a biopsy sample. Photo by Christopher Hinchcliffe and Leonardo Wedekin.

Figure 12

In panel A the DFHorten kit is shown in detail with a speaker, cables for 12V connection, the DFHorten unit, and space for a R-1000 receiver (Communication Specialist, Inc., USA). Panel B and C show the directional display of the DFHorten unit. Photo by Lars Kleivane.

Figure 13

This figure shows a tracker boat (A) with the DFHorten rigged in a weatherproof box ahead of the front glass and with 4 5-elemet Yagi antennas. In this setup the weather box can be regulated so that the upper bridge and the cabin can read the DFHorten output. In (B) the antenna rig is at the top of a sailingboat mast, including both antenna frequencies for the DTAGv2 (148Mhz) and the DTAGv3 (219Mhz). In panel C the antenna rig is at a top of a larger vessel, and in panel D the operator is adjusting the R-1000 radio receiver. Photo by Lars Kleivane.