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Novel technologies to monitor Māui and Hector's dolphins: DTAG feasibility trial

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Plain language summary

With funding from Fisheries New Zealand and support from the Department of Conservation (DOC), we trialled attaching short-term (24 hours) suction-cup recording tags (DTAGs) to Hector's dolphins in Te Koko-o-Kupe/Cloudy Bay.

We wanted to determine if DTAGs are a possible tool for monitoring this endangered species and could help answer research gaps identified by DOC's Threat Management Plan and Research Strategy.

We found these suction-cup DTAGs had little to no impact on Hector's dolphin behaviour.

We tagged 11 dolphins, and their tags stayed attached for 1.5 to 24 hours.

We gathered over 83 hours of data on this species, including:

- the first ever three-dimensional recordings of Hector's dolphin underwater,
- their night-time movements, and
- recordings of the different sounds they make and hear during a typical day.

Overall, such insights about these dolphins can influence how we manage them in relation to their various threats.

EXECUTIVE SUMMARY

Clement, D.[1]; Pavanato, H.[1]; Belonovich, O.[2]; Childerhouse, S.[3]; Constantine, R.[4]; Johnson, M.[5]; MacKenzie, D.[6]; Ogle, M.[7]; van Helden, A.[7]; Williams, R.[7] (2024). Novel technologies to monitor Māui and Hector's dolphins: DTAG feasibility trial.

***New Zealand Aquatic Environment and Biodiversity Report No. 327.* 34 p.**

The Hector's and Māui Dolphin Threat Management Plan (2020) and subsequent Hector's and Māui Dolphin Research Strategy (2021) highlighted several gaps in our knowledge about the subpopulations of these subspecies and the threats affecting them. Based on the Research Strategy, Fisheries New Zealand made funds available to explore novel technologies and approaches to monitor the subpopulations more extensively and on an ongoing basis. This project was awarded funding to undertake a feasibility study to trial attaching non-invasive digital acoustic recording tags (DTAGs) using suction cups to Hector's dolphins in Te Koko-o-Kupe/Cloudy Bay (hereafter Cloudy Bay). The main aims of the study were to deploy and assess the reactions of Hector's dolphins to this method of tagging and determine the feasibility of the use of DTAGs to address the multiple research priorities identified in the Threat Management Plan and Research Strategy. Criteria by which we evaluated the success of the trial included:

- successful attachment of tags
- dolphin behavioural response to tags
- retention of tags
- successful tag recovery
- data capture and utility.

We made 19 attempts to attach DTAGs to Hector's dolphins in Cloudy Bay over 8 days of fieldwork in February 2023. Out of these 19 attempts, 11 tags remained attached for 1.5–24 hours, with an average attachment time of 7.6 hours. We found that most dolphins had a low-level to no initial response (74%, 14 out of the 19 attempts) to the tagging method. Stronger responses occurred when the tag was poorly positioned (further back or down the dolphin's side) or when very weak contact was made. While such circumstances cannot be completely avoided, we noticed lower-impact responses from the dolphins as the tagger(s) became more familiar with the technique and gained experience interpreting the dolphin behaviour and movements.

Within the first 5 minutes after a tagging attempt, the tagged dolphins and/or associated group(s) were resighted approaching, or bow-riding with, the tagging boat at similar rates to those recorded before tagging. From 10 minutes onwards, groups with tagged individuals remained around or with the boats, mainly milling about and/or travelling. The strong attraction of Hector's dolphins to the boats, and the dolphins' low reaction to tagging, meant that when multiple dolphin groups remained with our research boats for more than 30 minutes, we had the opportunity to deploy more than one tag among the different groups.

All but one of the 11 tags detached passively from the dolphins, possibly due to contact with conspecifics or fast swimming. The remaining tag was actively released (i.e., the automatic release

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mechanism activated, causing the suction cups to be vented) after 24 hours. Of the three tags that remained attached for more than 10 hours, two stayed on overnight. Once they had detached, we were able to successfully recover all the floating tags using very high frequency tracking from the research boat and multiple elevated land-based sites. Our average recovery time was around 1.7 hours. Tag recovery was one of the trickier aspects of using DTAGs, and this factor will need to be an important consideration in future monitoring decisions.

All the tag sensors performed well and 100% of the deployment data were recovered and stored. With 83 hours of data, we gathered the first ever recordings of underwater diving behaviour, nocturnal movements, acoustic repertoire, and three-dimensional foraging behaviour for Hector's dolphin. The data from these tags also give us the first opportunity to decipher how these animals spend their time underneath the surface with other animals and away from human influence.

As our trial results indicate little to no impact of these methods on Hector's dolphin, we believe there is potential for significant information gains in the future if we move to larger-scale deployment programmes on both Hector's and Māui dolphins at the regional or subpopulation levels. Several insights into design options for a regular monitoring programme over a 3- to 5-year time frame are discussed along with general recommendations for future DTAG related considerations. Overall, this technology could provide our first insights into how these subpopulations may differ (or not) in their simple life history dynamics between regions, which may influence how we manage them in relation to their various threats.

1. INTRODUCTION

In 2021, the Department of Conservation/Te Papa Atawhai (DOC) developed the Hector's and Māui Dolphin Research Strategy (hereafter Research Strategy, Department of Conservation 2021) by eliciting researchers' views on priority knowledge gaps based on the existing subpopulations and the multi-risk assessment for the Hector's and Māui Dolphin Threat Management Plan (TMP) (Department of Conservation & Fisheries New Zealand 2020). Fisheries New Zealand also acknowledged that aerial survey methods, used to gather population data on this species, are limited when it comes to finer-scale monitoring capabilities and are not the right tools to address all knowledge gaps and the threats to the dolphins. To explore possible novel technologies and approaches to monitor these dolphin subpopulations more extensively and on an ongoing basis, Fisheries New Zealand made funds available to design trials to test and demonstrate innovative approaches to addressing the suite of objectives listed below.

1.1 Scope

Cawthron Institute, in conjunction with the experts from Aarhus University (Denmark), University of Auckland, and DOC, trialled attaching non-invasive digital acoustic recording tags (DTAGs, Johnson & Tyack 2003) using suction cups on Hector's dolphins. The main aim of the study was to deploy and assess the reactions of Hector's dolphins to the tagging method and determine the feasibility of DTAGs for simultaneously addressing multiple research priorities identified in the TMP and Research Strategy.

Background

Little is known about Hector's and Māui dolphin behaviour other than what has been observed from the surface. What is known has typically been collected from boat-based platforms that may alter the very behaviour being studied. More recently, passive underwater acoustic moorings have been used to detect and record the presence of nearby Hector's and Māui dolphins using their echolocation clicks (e.g., Rayment et al. 2009). From these acoustic data, inferences can be made about the dolphins' foraging behaviour while in the vicinity of the recorders (e.g., Brough et al. 2020). However, there are still many behavioural aspects about the underwater life of this species that have been difficult to record.

The solution may be in the use of non-invasive[8] animal-borne electronic instruments that can provide detailed, continuous data rather than snapshots in time or visual observations at the surface. Research undertaken by Stone et al. (1994, 1998) in the 1990s made one of the first attempts to understand Hector's dolphin subsurface movements and behaviours using animal-borne tags. These studies successfully attached non-invasive suction-cup VHF (very high frequency) tags to nine Hector's dolphins in Akaroa Harbour (Banks Peninsula) between 1993 and 1995 to study respiration rates and movement patterns and obtained data from seven of the nine tagged dolphins. While the tagging technique proved successful and provided a good alternative to more invasive tagging methods for Hector's dolphins (i.e., bolted satellite tags, Stone et al. 2005), suction-cup tagging has not been used for subsequent monitoring for this species. The lack of uptake of these early tags was likely due to their limited tracking ability and their inability to carry additional sensors. However, remote sensing tools and their capabilities have evolved exponentially since Stone et al.'s earlier studies.

Our study trialled the latest version of suction-cup tags, known as DTAG-4 tags (Figure 1). Similar suction-cup tags have been successfully deployed with other species of *Cephalorhynchus* (Sakai et al. 2011) in South Africa as well as many other cetacean species around the world. Recent studies overseas on harbour porpoises (a northern hemisphere species analogous acoustically to Hector's dolphin) have used DTAGs to collect fine-scale data on animals for up to 48 hours (or until automatically released, Wisniewska et al. 2016, Sørenson et al. 2018). The tags are able to collect a range of data, including:

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[8] Andrews et al. (2019) define invasive techniques or methods as a tag attachment that intentionally breaks the skin, regardless of the degree of the break.

- depth of dives (i.e., pressure)
- underwater acoustic behaviour (i.e., hydrophone sampling at 500 kHz, necessary to record the full bandwidth of Hector's dolphin vocalisations)
- three-dimensional movements using high-sampling-rate motion sensors (i.e., accelerometer, magnetometer)
- spatial location (i.e., snapshot GPS).

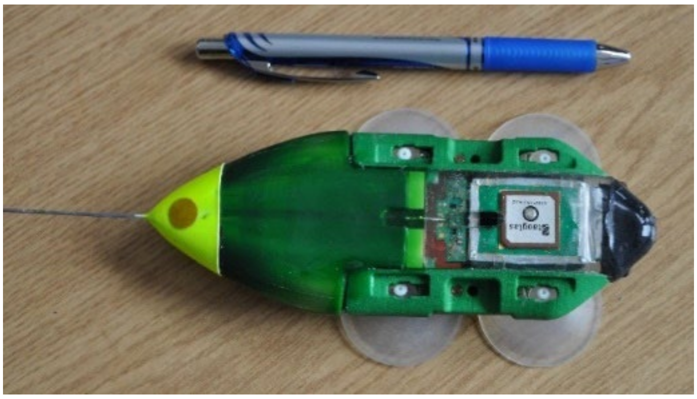

Figure 1: A photograph of the DTAG-4 (digital acoustic recording tags, Johnson & Tyack 2003) and its size relative to a ballpoint pen.

1.2 Objectives and aims

The objectives for the Fisheries New Zealand novel technology project PMM2020-07 are listed below.

Overall objective

Test and demonstrate the utility of novel detection technologies (including flown or underwater drones, deploying camera or acoustic sensors) and novel analytical tools (including artificial intelligence) to monitor important aspects of Māui and Hector's dolphin biology or behaviour in key locations.

Specific objectives

1. Design a trial to demonstrate the capability of a novel research platform or technology to collect important data for Māui or Hector's dolphins (see Appendix 1), as part of a regular monitoring programme. The trial description should include the means by which trial data will be processed and the criteria by which the success or failure of the trialled technology or platform will be evaluated.
2. Implement the trial described in Objective 1 in one or more identified priority locations (see Appendix 1).
3. With the results of Objective 2 and, in consultation with Fisheries New Zealand and DOC, design and present options for a regular monitoring programme to collect priority data at specified intervals over a 3–5-year time frame.

This report summarises the study findings in relation to the overall and specific objectives. More specifically, we provide summary data that demonstrate the feasibility of the approach and its ability to address the various research priorities. Criteria by which we evaluated the success of the trial include:

- successful attachment of tags
- dolphin behavioural response to tags
- retention of tags
- successful tag recovery
- data capture and utility.

It is important to note that the focus of the project was on demonstrating the viability of the technologies for data collection and not on the subsequent analysis of any data collected, which was outside the scope of the contract.

2. OBJECTIVE 1 – TRIAL DESIGN

2.1 Trial location and timing

We based the field trial in Te Koko-o-Kupe/Cloudy Bay (hereafter Cloudy Bay, 41°25′ S 174°04′ E), off Blenheim and the Marlborough Sounds region, in February 2023 (Figure 2). While this location is not one of the subpopulations highlighted in Fisheries New Zealand's priority locations (Appendix 1), we selected a location that offered the best chance of success as the most efficient use of the limited budget and time available for the trial. Cloudy Bay is known for having a high density of dolphins (e.g., 650–950 animals) that are easy to locate and are reliably close to shore over the summer period (DuFresne & Mattlin 2009, MacKenzie & Clement 2014), which kept travelling and tracking costs to a minimum. This is a large bay with a range of depths, allowing us to spread sampling across different dolphin groups and areas.

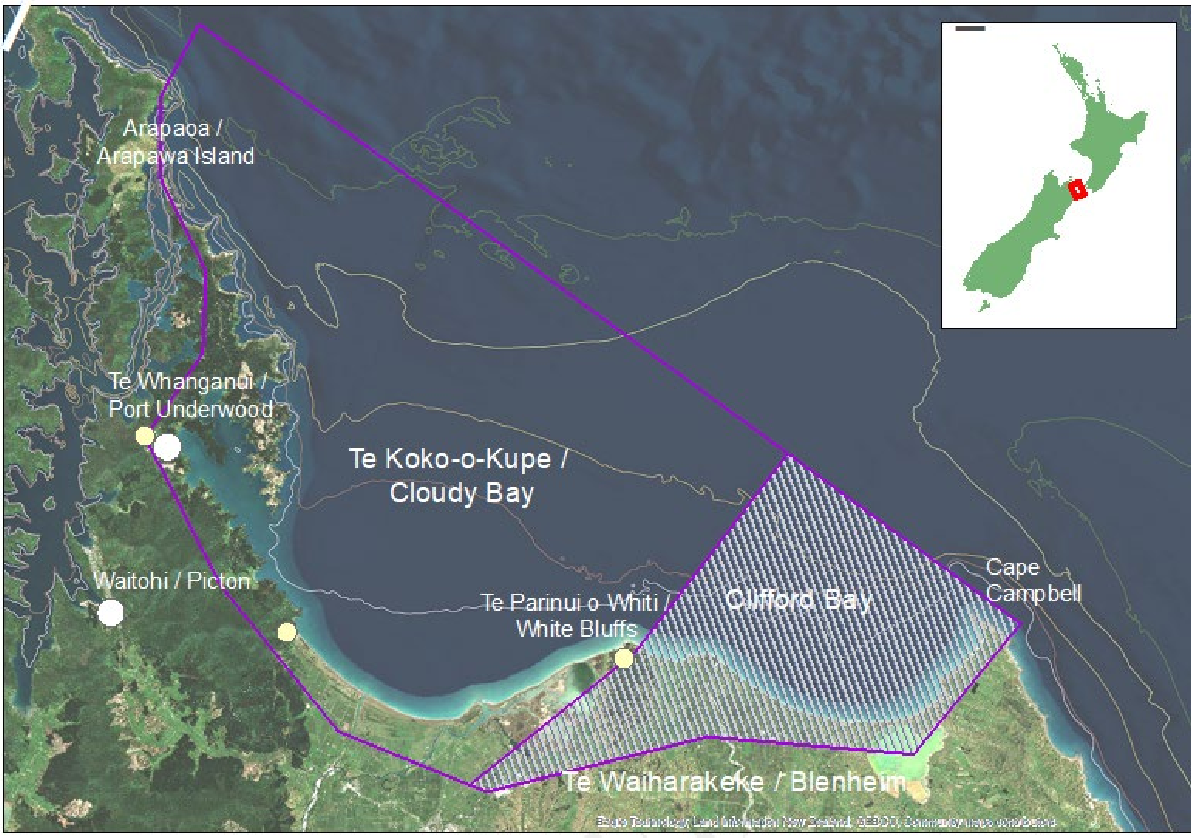

Figure 2: The operational area for the DTAG field trial in Cloudy Bay, with no tagging undertaken in Clifford Bay (hatched area). White circles indicate our shore and boat bases, and yellow circles are some of our VHF land-based tracking sites. Bathymetry depth contours of 20 m, 30 m, 50 m, 90 m, and 120 m are shown. (Note: the orientation of the map has been adjusted from north.)

DOC led consultation on our permit proposal with six Te Tauihu o Te-Waka-a-Māui iwi and hapū groups (Ngāti Koata, Ngāti Kuia, Ngāti Rārua, Ngāti Toa, Rangitāne, Te Ātiawa) whose takiwā includes Cloudy Bay. Out of respect for a request made by Ngāti Kurī hapū (Kaikōura), and as stated in our DOC permit, we did not undertake any tagging effort or attempts in Clifford Bay (south from White Bluffs/Te Parinui o Whiti) as this area is part of the takiwā of Ngāti Kurī. However, Ngāti Kurī did not object to us recovering any detached tags from Clifford Bay.

We originally planned a 3-week field trial to test the suction-cup attachment method and to record how Hector's dolphins responded to the attachment and the tag itself. As a feasibility trial, we aimed for a sample size of 30 to confirm that the technique is safe, has little or no impact, and provides useful data. With four DTAG units available, we hoped to deploy at least one tag each day, if possible. This sample size was intended to maximise the need to sample a range of individuals (to assess variability in behaviour) but also took into consideration the inevitable variability in attachment quality (i.e., duration and time periods—day or night). Thirty deployments from a regional population with an estimated abundance of 650–950 in the area (DuFresne & Mattlin 2009, MacKenzie & Clement 2014) represent 3–5% of total individuals, sufficient to determine the feasibility of the technique for Hector's dolphins.

However, the middle of our field trial was interrupted by Cyclone Gabrielle and the trip was also cut short by additional bad weather. As a result, we were able to undertake fieldwork on only eight days between 9 February and 21 February 2023.

2.2 Tagging

DTAGs

We used the DTAG-4, designed and custom-made by team member Dr Mark Johnson. Each tag consisted of a data logger, an integrated VHF transmitter encased in a float made of synthetic foam, which is a hard, incompressible resin embedded with glass bubbles for flotation that is frequently used in tag design (Figure 1). It has four 4-cm diameter rubber suction cups for attachment.

Over the last 20 years, DTAGs have been significantly developed to minimise any potential effects on the animals. For example, the following tag improvements have been made:

- tag mass is now very small at around 150 g, which is less than 25% of the original DTAG
- the size and stiffness of the suction cups has been reduced, leading to four rather than two cups being used, and in turn requiring lower vacuum (i.e., suction) pressure during attachment
- there has been development and testing of tag hydrodynamics in both flume tanks and on captive dolphins, leading to drag being reduced by more than 75%
- attachment mechanisms have improved, reducing the impact of tag attachment on individual dolphins.

The project design closely follows recommendations and guidelines for whale and dolphin tagging as proposed by Andrews et al. (2019). This review provides the most up-to-date and comprehensive set of guidelines for tagging projects and represents the international best-practice guidelines for tagging marine mammals.

Research vessels

We used two different research vessels during the field trial. Our primary research platform was a 16-m catamaran (*Blue Safari*), used when looking for possible tagging groups and from which to observe and document dolphin behaviour and reactions. It also served as our tag-recovery vessel as its marine certification allowed us to go further offshore (up to 12 nautical miles/approximately 22 km) if necessary.

The second vessel was our tagging boat, the *Aakron*, made available to us by DOC's Kaikōura office. The *Aakron* is a 5.2-m rigid-hull (fibreglass) inflatable with a centre console, a 60-hp motor and open bow. The *Aakron*'s open layout was ideal, allowing the tagger to be in the bow close to the water, where they could be near surfacing dolphins for tag-attachment opportunities.

Tagging approach

Each tagging day, *Blue Safari* set out from Te Whanganui/Port Underwood (hereafter Port Underwood) with the *Aakron* in tow. Once in Cloudy Bay, the catamaran travelled across the bay towards the south/southeast and White Bluffs region, following parallel transects to the shore. While searching for dolphins, the catamaran travelled at around 10–15 knots, with the research crew scanning for dolphins. Once a group of dolphins was sighted, the catamaran slowed. The dolphin group was quickly assessed according to our *a priori* criteria to determine if tagging should or should not be considered as outlined in our animal ethics and research permits[9].

These *a priori* criteria included the following:

- only adults will be tagged (i.e., no calves or juveniles)
- no mothers with calves will be tagged
- no individuals that are injured (e.g., shark bite) or in poor body condition will be tagged
- no individual will be tagged more than once
- only individuals that show no avoidance, alarm, agitation, or disturbance behaviour will be tagged; for example, repeated leaping and tail slapping or avoidance of vessels
- we will attempt to tag a variety of adult age and sex classes where possible (noting that is difficult to reliably age or sex a free-swimming dolphin).

The location (GPS coordinates), number of dolphins, presence of calves, and group behaviour prior to boat approaching, as well as the time, were noted initially while each group was being assessed. If a decision was made to try to deploy a tag based on the criteria above, behavioural observations were continued at regular intervals (as detailed below) while the *Aakron* crew prepared to launch.

The crew on the tagging boat consisted of a tagger (in the bow), a boat driver, and a recorder. The recorder wore either a GoPro camera, used a phone voice recorder, and/or manually recorded every tagging attempt and the details of tagging attempts, including the first tagging reactions. In addition to these criteria, we also set limits for attempting to tag a group, as below. If either of these criteria were reached, we left the group and/or area to find a new group:

- each group was followed for a maximum of 90 minutes
- no more than six tagging attempts were made per group.

If a dolphin was successfully tagged, a photo of the tag location and side of the body was taken (when possible) and the animal's initial behavioural reaction to the tagging itself was recorded by the recorder, tagger, and the research boat personnel (Table 1). Tagging reaction categories were based on Sakai et al.'s (2011) Heaviside's dolphin tagging study (a dolphin species from Africa, also within the *Cephalorhynchus* genus). After a deployment, the tagging boat immediately slowed and notified the research boat, which also attempted to take photographs or videos of the tagging attempt and then continued to track and observe any tagged animals according to the protocol.

[9] This project was completed under a Marine Mammal Research Permit from DOC (97501-MAR) and animal ethics approval from the Nelson Marlborough Institute of Technology Animal Ethics Committee (AEC2021-CAW03).

Table 1: A list of the different categories of initial dolphin reaction to tagging attempts. Categories are based on Sakai et al. (2011) and modified for Hector's dolphins.

Reaction categories	Description
No reaction	Dolphin behaviour after tagging attempt did not differ from what was observed before the tagging.
Low level	Dolphin behaviour changed slightly, but with no apparent vigorous response to the tagging attempt (i.e., dolphin dived and/or moved away from the boat but returned to the boat within minutes).
Strong but short	Dolphin changed its behaviour in a vigorous or forceful movement, such as a steep dive, tail slap, or splash, while moving quickly away from boat, but stayed in the general area and/or returned to the boat within minutes.
Strong and prolonged	Dolphin changed its behaviour in a succession of forceful movements, such as successive percussive behaviours with breaches, tail slaps, or when the entire group moved rapidly away from the boat, and avoided the boat afterwards.

Attachment method

DTAGs are attached through the simultaneous placement of the tag's four small silicone suction cups onto a dolphin's dorsal surface. To attach the tags to Hector's dolphins, we used a carbon-fibre pole (approximately 2- to 4-m long, adjustable[10]) that had a custom-made plastic tag holder allowing for quick release once suction cups were depressed and held. The tagging boat drove at the slowest feasible speed and at angles of approach that would avoid possible collisions with either target or non-target individuals and minimised disturbance to the dolphin groups.

As Hector's dolphins often bow-ride or swim near boats, the tagger sat/straddled the bow of our tagging boat and attempted to place the tag on individuals that surfaced near or just under the bow to ensure the best placement. The tagger tried to place the tag on the back of the animal, slightly anterior to the dorsal fin. The tag is deployed by hand using the pole, and only a small amount of force is required to attach the tag to the dolphin. The tag is held in place by the four suction cups, which do not break the skin surface and attach via only moderate suction. Given that we were able to select only individuals that were bow-riding or were close to the boat, we did not have true randomisation in our selection procedure; however, we strictly followed the selection criteria above.

To avoid retagging individuals, we kept away from the same area in which dolphins had previously been tagged earlier that day or the previous day. We also limited the total time that the tagging boat attempted to deploy a tag with a particular or general group to 60 minutes. Dolphins were not captured or detained in any way. Since you cannot get very close to a dolphin unless it allows you to do so, we did not chase any dolphins, but rather moved slowly around the edges of the target group and allowed any interested dolphins to approach the vessel.

[10] The tagging pole was most successful when shortened to 2 m.

2.3 Data collection

Prior to tagging

As part of the overall project design, behavioural observations and individual photo-identification (e.g., a few dolphins have marks on their dorsal fins or bodies, allowing them to be individually identified) were collected from the main research catamaran, and with a drone (when possible), for all dolphin groups encountered prior to any tagging attempts. Once a candidate group had been selected using the *a priori* criteria (detailed above), we continued to record the group's predominant behaviour. We used similar but slightly modified group behaviour categories and definitions as described by the Sakai et al. (2011) tagging study on Heaviside's dolphins. Behaviours were defined as follows:

- socialising – characterised by various affiliative behaviours, including flipper rubbing, body contact, sexual behaviour, or vigorous activities such as synchronous leaps, chasing, and apparently playful behaviours
- milling – when dolphins moved in no apparent direction and frequently reoriented slowly within a group
- travelling – when dolphins moved steadily in a particular direction
- resting – low-energy activities when dolphins were close together, moved little, but occasionally submerged together for long periods.

Pre-tagging and follow-up behavioural categories included those behaviours listed above (with the exception of resting[11]) along with the following directional categories:

- bow-riding – dolphin swimming under or near the bow of the tagging vessel
- swimming away from boat – dolphins moving in a direction away from the tagging vessel either directly (travelling straight line) or indirectly (milling, drifting)
- approaching boat – dolphins moving in a direction towards the tagging vessel, either directly (travelling straight line) or following behind the boat.

Tagging attempts

As noted above, all tagging attempts were either videoed (using GoPros) or photographed by the tagging boat crew, if possible. The tagger and recorder immediately called out any reaction(s), which were then manually recorded on tagging data sheets, while the research boat also documented the individual animal's reactions as well as those of any associated animals (see Table 1). We also recorded and photographed the tag location on the body (when possible) to help understand potential reasons for any early tag release (e.g., poor deployment location) and any evidence of pressure marks or injuries from the suction cups.

Data collected during tagging attempts included the following:

- photos and, wherever possible, video from GoPros and/or drones of an individual's fin, body, and tag
- group/individual behaviour prior, during, and after tag placement (from boat and drone, whenever possible)
- individual age category or sex class (if distinguishable)
- maximum number of animals within a group
- deployed tag location/direction on dolphin's body.

[11] We assumed that resting behaviour was unlikely to happen once a group was approached and/or began to interact with the tagging boat based on previous experiences.

2.4 Post-tagging

Once a tag had been successfully deployed, the tagging boat slowed and/or moved away (> 100 m) from the tagged animal/group or returned to the research catamaran. The research catamaran then listened to the intermittent VHF pulse of the tagged animal, which is transmitted only when the animal surfaces, to ensure the tag was still attached. On a few occasions and for a limited amount of time, we were also able to follow the group at a distance using the drone to collect additional observations of group behaviour and interactions.

The research vessel remained in the area (anchored or drifting) with the group until we were confident that the tag had attached securely. Follow-up behavioural observations of the tagged individual and associated group continued at regular intervals (every 1, 3, 5, 10, 15, 20, and 30 minutes) for up to 1 hour whenever possible. Once the decision was made to leave and find another group, the catamaran continued to track the VHF signal at a distance (several kilometres) throughout our remaining time on the water. If the VHF signal became a regular beep, it indicated that the tag had been released from the dolphin and was floating on the surface.

If a tag was released soon after a tagging attempt (less than 10 minutes), it could be retrieved and prepared for redeployment on another animal as necessary. Otherwise, the tag was retrieved, its data were downloaded, and then it was prepared for redeployment the next day.

Recovery of tags

A VHF transmitter in the tag allows the device to be tracked and recovered. Tagged animals were tracked using up to five different VHF/Yagi antennae and receivers placed on the catamaran and from up to three different land sites (Figure 2). Elevated land-based stations were vital in determining and leading the recovery vessel to the location of the tag once it was released or had fallen off. The land-based sites helped direct the vessel to the floating tag if the tag was undetectable from the catamaran. The catamaran could then head towards the tag until it could detect it, at which point the crew could track the tag directly.

Land-based sites included two roadside locations on Port Underwood Road (near Pukatea/Whites Bay and Waikutakuta/Robin Hood Bay, and on Rahotia Saddle) (Figure 2). The other site was located on private land on the lower north-facing coastal foothills of White Bluffs/Redwood Pass near Waikārapi Lagoon. Tracking was also undertaken from the Mount Robertson Loop Track, the Wairau Diversion Reserve, and Rarangi Campsite/Rarangi Recreation Reserve. The final land locations used were dependent on their relative distance to the tag deployments, their elevation, and their accessibility.

Trial data could be processed from the DTAGs only when these were recovered from dolphins as they are data archival tags and do not transmit data remotely. We anticipated that tagged dolphins would stay in the general area based on historical home range data and the short-term nature of the deployments. Once the tag was recovered, the tag data were downloaded and archived, and the tag was recharged and made ready for redeployment as soon as possible—generally at least one day later, depending on the tag deployment length and recovery time. Dr Johnson has extensive experience in the analysis of these data, including the development of customised analysis packages. While large amounts of data were collected from the tags, the stated objective of this project was not to undertake any analysis of data but rather to provide a proof of concept for this novel approach. We therefore provide summary data that demonstrate the utility of this novel technology and approach in addressing the TMP research priorities and questions.

2.5 Project team

We relied on a very experienced team of marine mammal researchers for this trial. We drew on our existing research experience with DTAGs and suction-cup deployment methods (Drs Johnson, Childerhouse, Constantine), experimental design and analysis (Dr MacKenzie), and Hector's and Māui dolphin ecology (Drs Clement, Constantine, Childerhouse) to develop a robust trial to address the research questions and identify adequate and achievable sample sizes.

In addition to these researchers, the field research team consisted of several highly experienced members (Drs Pavanato and Belonovich, M. Ogle, R. Williams, and A. van Helden), each of whom has many years of experience handling vessels around dolphins and collecting data, and the ability to interpret the animal behaviour to minimise our impact. Dr Johnson joined the field project from Denmark to share his first-hand expertise and further train project participants in DTAG deployment and analysis techniques. The field trial was highly reliant on the experience of each of these team members and their familiarity with this species and/or their previous experience in deploying tags on marine mammals.

3. OBJECTIVE 2 – TRIAL RESULTS AND DISCUSSION

The DTAG feasibility trial took place in Cloudy Bay between 8 February and 23 February 2023. Our research team was based in Picton (Marlborough Sounds), while the two vessels were based out of Port Underwood (Figure 2). As noted in Section 2.1, our field time was cut short by Cyclone Gabrielle and subsequent storms near the end of our trip. As a result, we had a total of 8 days to run the trial: 4 field days between 9 February and 12 February, and 4 days between 18 February and 21 February 2023. Despite this reduction in field time, we were still able to gather the necessary data to allow us to evaluate the DTAG technology and method with Hector’s dolphin against our five main criteria (see Section 1.2).

3.1 Successful attachment of tags

For this study, a successful tagging attachment was judged by two criteria:

- the number of correct tag attachments versus the number of tagging attempts
- tag retention of more than 1 hour after attachment.

Overall, we had 19 tagging attempts over 8 days of fieldwork (Table 2). Of these attempts, 11 tags remained attached for more than 1 hour, equating to a successful attachment rate of 58% (Table 2). Those tags that remained attached stayed on the dolphin for 1.5 hours to 24 hours (Figure 3). In total, the tags were deployed on dolphins for just over 83 hours, with a mean tag-attachment time of 7.6 hours and a median attachment time of 3.8 hours.

On our first day of fieldwork (9 February 2023), a group of dolphins (comprising seven individuals) was encountered soon after we left the Port Underwood entrance. The dolphins immediately approached *Blue Safari* as the catamaran slowed and continued to swim in and around the hulls and around the boat. After working through our *a priori* criteria for a tagging attempt, we decided to try tagging from *Aakron*, but the chop made it too difficult from this smaller boat. As the dolphins were approaching and hanging around the stern of the catamaran, we decided to try to tag animals from the catamaran’s stern instead (Figure 4). While no tagging attempts were initiated, an unintentional touch of the pole occurred while a dolphin was subsurface off the stern of the catamaran (Table 2).

Table 2: A list of all tagging attempts (success or fail, *n* = 19) by date and time with the various details for each of the successful tag deployments (*n* = 11). The tag letter indicates which of the four tag units was used. * Indicates tagging attempts from *Blue Safari*.

Attempt ID	Deployment date	Total attempts per group	Tag	Deployment time	Release date	Release time	Success	Total deployment (hours)	Possible reason for tag release	Evidence of tag movement (N/Y)
1	09/02/23 *	1	D	NA	NA	Tag not deployed	No		Unintentional touch with pole	
2	09/02/23 *	1	D	15:19	09/02/23	15:25	No			
3	09/02/23 *	2	B	15:58	09/02/23	Straight off	No			
4	09/02/23	1	B	16:11	09/02/23	Straight off	No			
5	10/02/23	1	D	08:16	10/02/23	08:17	No			
6	10/02/23	3	A	08:26	10/02/23	18:38	Yes	10.2	Fast swimming in social interaction	N
7	10/02/23	2	C	08:41	10/02/23	10:03	Yes	1.5	Fast swimming during foraging	N
8	10/02/23	1	D	13:23	10/02/23	17:59	Yes	4.6	Fast swimming during foraging	N
9	10/02/23	1	B	13:27	10/02/23	Straight off	No			
10	10/02/23	1	B	13:44	10/02/23	17:32	Yes	3.8	Fast swimming, possible social interaction	Y
11	11/02/23	1	C	11:41	12/02/23	10:03	Yes	24.0	Programmed release	N
12	18/02/23	1	A	11:48	18/02/23	15:24	Yes	3.6	Fast swimming during foraging	Y
13	18/02/23	1	B	11:57	19/02/23	05:33	Yes	17.6	Fast swimming at surface	Y
14	18/02/23	1	C	12:17	18/02/23	Straight off	No			
15	18/02/23	2	C	14:51	18/02/23	Straight off	No			
16	20/02/23	1	A	10:36	20/02/23	13:54	Yes	3.3	Fast swimming during foraging	Y
17	20/02/23	2	B	10:59	20/02/23	13:41	Yes	3.7	Brief acceleration during foraging	Y
18	20/02/23	1	C	11:00	20/02/23	14:42	Yes	3.7	Brief acceleration at the surface	N
19	20/02/23	1	D	11:07	20/02/23	18:13	Yes	7.1	Fast swimming during boat interaction	Y

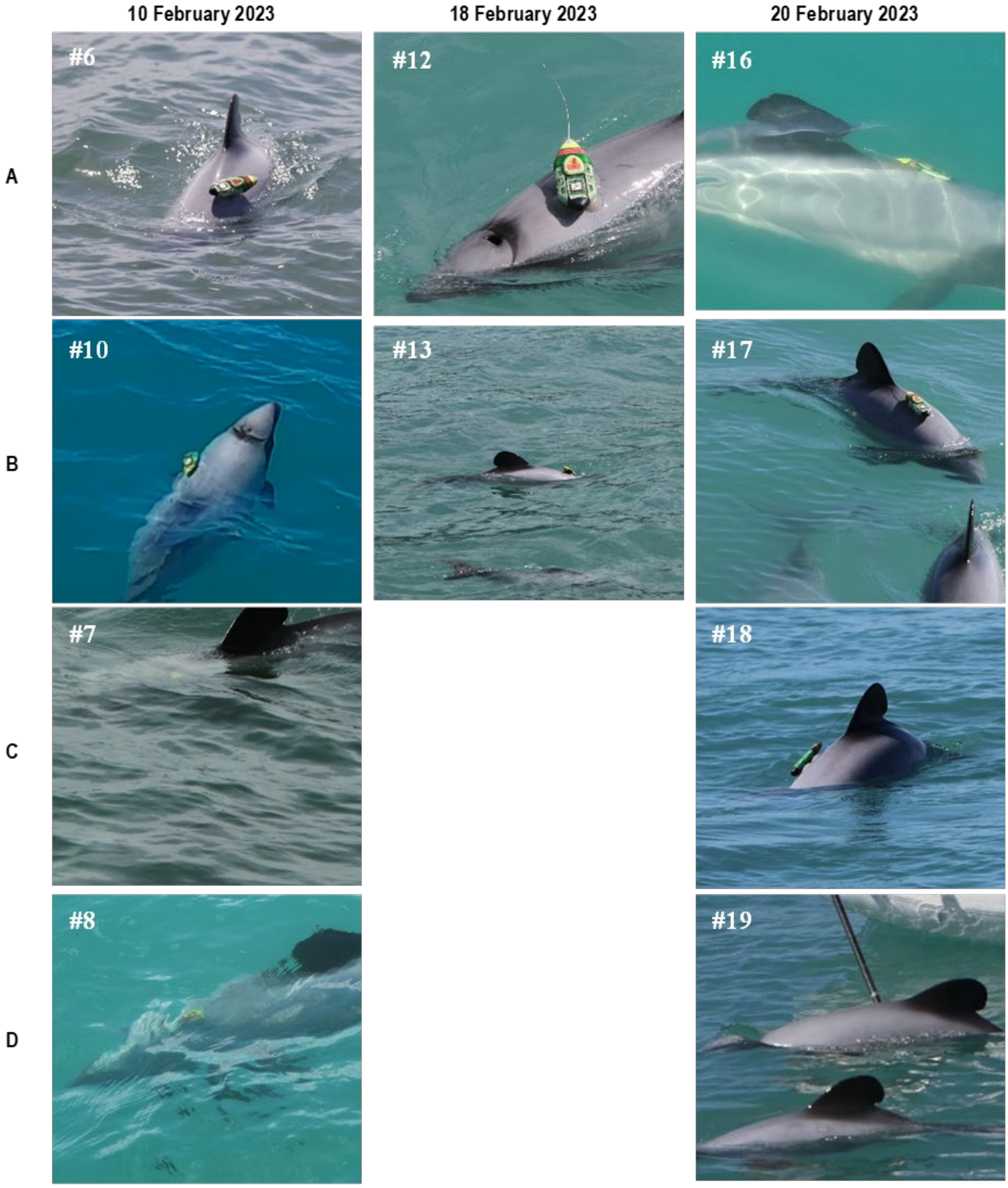

Figure 3: Photographs of the tag position on 10 of the 11 tagged dolphins. The attempt ID number from Table 2 is listed on each photograph. Note that we did not have a clear photo of the tagged animal on 11 February 2023 (ID #11). Each date is listed at the top of the column and the tag letter is listed on the left side of each row to match with Table 2.

Figure 4: Left, Dr Mark Johnson (Aarhus Institute) and right, Mike Ogle (DOC) position themselves for a tagging attempt off the stern of the *Blue Safari*, our main research platform.

When the next group was encountered (eight animals), tagging from the stern of the catamaran was again attempted while the smaller tagging boat was being prepared. Two separate tagging attempts were made, which lasted less than 6 minutes (Table 2). It was noted that due to the extra height from the back of the catamaran, dolphins had more opportunity to spot and move away from the pole as it moved towards them. In this position there were also few opportunities in which a dolphin broke the water surface to breathe near enough to a tagger.

After these failed deployments from the catamaran, the decision was made to tag from the *Aakron*, as originally intended, given its opportunity to encounter dolphins surfacing near the bow and at closer proximity to the tagger. Subsequently, all 11 of the successful tagging attempts were performed from the *Aakron*.

Dr Johnson, as the team member with the most experience in attaching DTAGs, was the primary tagger for the first 4 days of fieldwork. Two other researchers, M. Ogle and Dr Childerhouse, also attempted and successfully deployed tags (Figure 5). We had intended to train all team members in tagging techniques, but we ran out of time due to the shortened fieldwork period.

Figure 5: Various tagging techniques used off the bow of *Aakron* to successfully place DTAGs. Left top, Dr Mark Johnson (Aarhus Institute); right top, Mike Ogle (DOC); bottom middle, Dr Simon Childerhouse.

3.2 Dolphin behavioural response to tags

As part of the trial, we wanted to observe and record the initial responses of the individual dolphins to the tagging attempt and then to the tag itself. As discussed in Table 1, we used predetermined and slightly modified tag responses and behavioural categories, based on Sakai et al. (2011), to assess the dolphins' reactions and behaviours to the tagging method. Specifically, we looked at the following criteria:

- severity of initial behavioural response to the attachment attempt (e.g., movement away from vessel, active jumping to dislodge tag, etc.)
- length of time to return to pre-tag behaviour (noting that pre-tag behaviour may already be influenced by the tagging vessel approach)
- similarity of immediate post-tagging behaviour with long-term behaviour (e.g., many hours post-tagging).

Severity of response

Most of the initial reaction behaviours observed on tagging were categorised as **low level** (58% of tagged dolphins; 11 out of 19 attempts; Figure 6), and included responses such as flinching, rolling, and swimming away from boat for a few seconds to several minutes (Figure 7, top row). Most animals in this category returned to the boat, either bow-riding or joining a group near the boat within a few minutes. Of the few dolphins (16%) that displayed **no reaction** to tagging, we note that the tags came off immediately from two of three dolphins in this category (Figure 6). The lack of reaction in these cases is likely due to the pole not touching the dolphin strongly enough for the tag to stick to its body and elicit a response.

One of our protocol criteria was that further deployments would be reviewed and potentially ceased if we detected significant behavioural modifications (i.e., strong sustained and/or successive responses) during the first 10 deployments. Approximately a quarter of tagged dolphins (26%; five out of 19 attempts) responded in a **strong but short** manner and duration (Figure 6, Figure 7 bottom row). This type of response was mainly characterised by a rapid swim burst, tail splash, or steep dive away from the boat. However, in three instances the dolphins were sighted back bow-riding or near the tagging boat less than 5 minutes later.

On two separate occasions the tagged dolphins sped off and/or dived, followed by a jump. In the first instance, it was unclear if the tag stuck initially and then fell off when the dolphin sped away, or detached immediately (miss), as there was no tag seen on the jumping dolphin. On the second occasion, the tagged dolphin repeatedly jumped (four times), landing in a manner that dislodged the tag. In this case (Table 2, #9 DTAG-B on 10 February), the tagger commented that all four suction cups had not attached simultaneously and half of the tag may have been loose and moving on the animal's right side just above its pectoral fin (Figure 7, bottom right). This reaction was classified as strong but short instead of strong and prolonged, because the dolphin and its associated group remained in the area and continued to interact with the tagging boat afterwards.

In three of the five cases (60%) when stronger responses were observed, the tag placement (dolphin's side, below the dorsal fin) or poor tag contact (tag suction cups did not make good, simultaneous contact) appeared to be a contributing factor. Nonetheless, these results confirm that if a dolphin is significantly disturbed by the tag, then it can shed it fairly easily by repeated leaps out of the water.

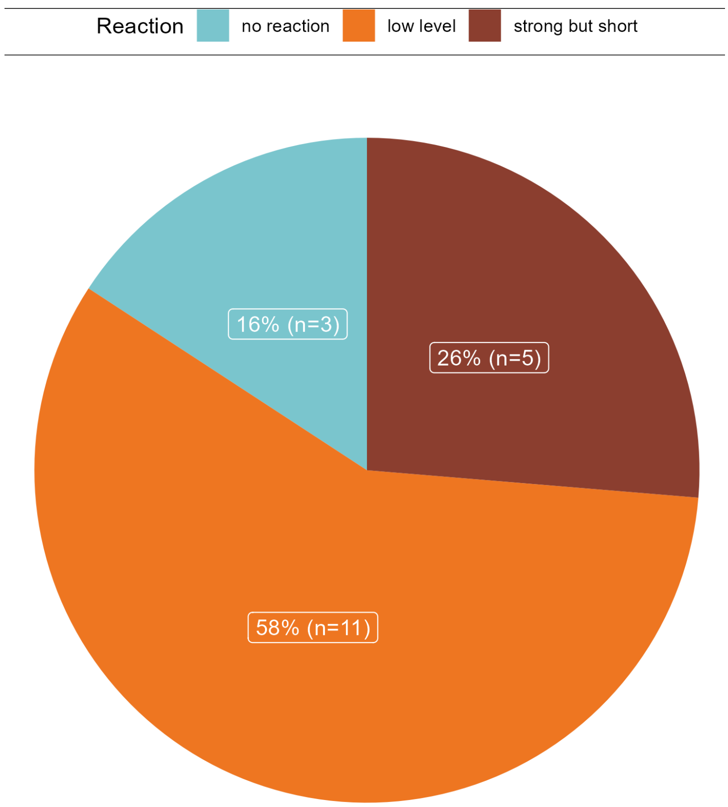

Figure 6: Pie chart of immediate reaction to tagging, defined as no reaction (blue), low level (orange) and strong but short (brown).

Figure 7: The top row photos are examples of a low-level reaction (#10 DTAG-B on 10 February, and #17 DTAG-B on 20 February); the bottom row photos are examples of a strong but short reaction (#8 DTAG-D on 10 February, #19 DTAG-D on 20 February, and #9 DTAG-B on 10 February).

Pre-tag versus post-tag behaviour

Given the natural attraction of Hector's dolphins to vessels, it was not unexpected that all groups were initially spotted either jumping, porpoising, or travelling purposefully towards the catamaran (Figure 8). This attraction soon switched from the catamaran to the launched tagging boat, with 70% of pre-tagging groups approaching the boat and engaging in bow-riding behaviour. In conjunction with the individual responses of the tagged dolphin to a tagging attempt (as described above), most groups immediately swam away from the boat or dived when a tag was deployed, while some individuals within a group continued to bow-ride (Figure 8). However, group responses were short-lived and group members soon returned to bow-ride or mill around the boat(s).

Once a tagging attempt occurred, the tagging boat stopped or slowed and remained in the area to try to resight the tagged dolphin as soon as possible. Our initial protocol was to have the large boat remain away from the tagging boat and dolphin groups, and to try to observe or follow from afar (approximately 1 km). However, even with the engine off, the dolphins were strongly attracted to the catamaran. Often the tagging boat ended up working less than 100 m from the catamaran, which allowed multiple observation platforms of dolphin reactions.

After a tag was deployed, we had assumed the tagged dolphin or group would likely move away. Our intention was to leave them alone to reduce our possible disturbance and to encourage them to return to normal, pre-tag behaviour as soon as possible. However, in all but one deployment, the dolphins returned and remained attracted to the tagging vessel as well as to the catamaran. As shown in Figure 8, groups were frequently seen approaching the tagging boat and bow-riding in the first 5 minutes after tagging. While less milling and more travelling were observed, by the 5-minute interval behaviours were similar to those observed pre-tagging.

We continued to collect detailed behaviour information, with most encounters lasting on average 20 minutes but ranging from less than 1 minute (missed attempts) to more than 30 minutes. From

10 minutes onwards, groups mostly remained milling and/or travelling around the boats. Because of this attraction, we decided to modify our original protocol. When encountering multiple dolphin groups (e.g., new groups joining after the initial sighting), instead of leaving the area once a tag was deployed, we stayed and attempted to deploy further tags if dolphin(s) returned immediately to the tagging vessel and/or the tagged individual remained in the vicinity. However, we still maintained our original tagging conditions that limited our encounter to less than 90 minutes and no more than six tag attempts per group.

On five occasions, we deployed multiple tags among multiple groups (i.e., total group sizes of 8–35 dolphins), taking care to avoid other tagged individuals and their companions. The dolphins' attraction to the vessels also gave us the opportunity to follow the tagging boat and dolphins with a drone over 2 different days. Further drone use was hampered by a restricted flying area, due to the proximity of Blenheim's airports, the weather and limited availability of drone pilots.

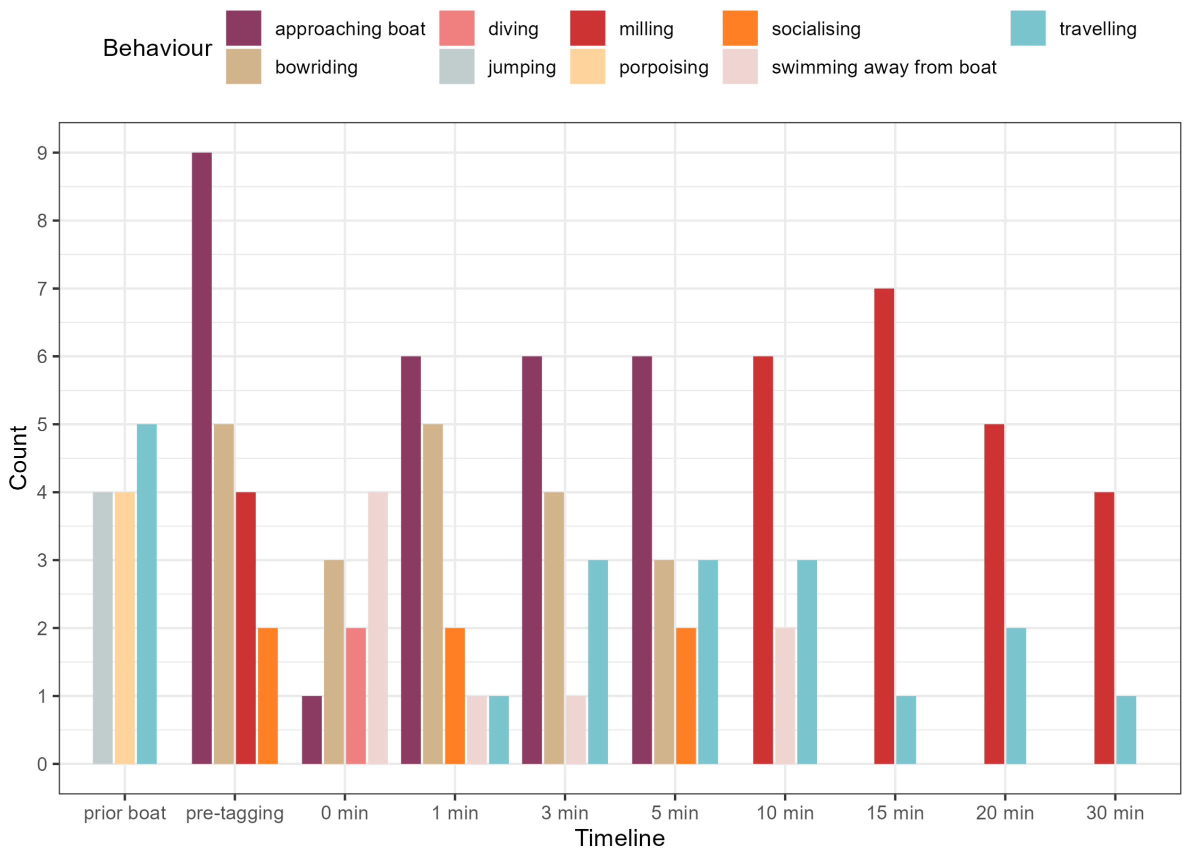

Figure 8: Bar plot of observed behaviour of groups prior to boat approach, during the tagging attempt (0 minutes) and up to 30 minutes after tagging. Note that sample sizes differ as they include all groups and attempts, successful or missed.

Longer-term behaviour

It is possible that attaching a DTAG to a dolphin may modify its longer-term behaviour and how it interacts with other dolphins (i.e., beyond the initial response to the tagging itself). For instance, we observed other dolphins in the group swimming over and next to the tagged dolphin, perhaps even bumping or rubbing it. Several controlled experiments on captive dolphins have shown that they can modify their behaviour when faced with tag-induced drag (e.g., Davis et al. 1999, Blomqvist & Amundin 2004, van der Hoop et al. 2014). However, we note that with short-term deployments (less than 24 hours), any minor behavioural impacts are expected to return to normal soon after the release of the tag. Andrews et al. (2019) investigated the potential effects of suction-cup tagging on a range of species from a long-term database and found no evidence of any significant effect of non-invasive tagging on dolphin health or survival.

For this report, we have not yet processed the tag sensor data to assess these questions. To understand how tags may be affecting these animals, future work will compare the initial 30–60 minutes of sensor data (post-tagging) to subsequent hours, depending on the deployment duration. One question is whether there is a distinct 'acclimation' period in which dolphin behaviour noticeably changes post-tagging or if it is a more gradual process. However, to address these questions, we first need to work through how we intend to interpret and categorise the sensor data into inferred behaviour types, as discussed further in Section 4.2.

3.3 Retention of tags

Maximum retention of tags is an important aspect of the viability of this method given these are short-term (no longer than 24 hours in this study) attachment methods. We therefore assessed tag-retention time with the following criteria:

- are tags released passively (i.e., they fall off) or actively (i.e., they detach at the programmed time)?
- average length of retention.

Passive vs. active release

In all but one of the 11 deployments, the DTAGs passively detached from the animals. DTAG-C was deployed on the morning of 11 February and remained in place for 23 hours, after which the suction cups were actively vented (Table 2, ID #11). We did not attempt to test whether tags could remain in place longer. While previous work suggested that dolphins within Cloudy Bay remained in the general area for at least the summer months, we were unsure whether an individual might move out of the bay area after a day or two. If a tag were released into Cook Strait, the prevailing currents would make recovery much more difficult. Given these factors and the weather conditions at the time, we did not programme tags to actively remain on a dolphin for more than 24 hours.

Average retention

Of the tags that came off passively, the average retention time was just under 6 hours, with tags retained between 1.5 hours and 17.6 hours (median = 3.8 hours; Table 2). From an acoustic perspective, even a few hours of recordings from one individual dolphin are invaluable in terms of understanding the temporal and spectral dynamics of echolocation clicks and their associations with certain behaviours. For example, foraging attempts and their outcomes (success/failure) can be analysed from simultaneous changes in the accelerometer and echolocation data. From these data, we have already discovered that Hector's dolphins are not as acoustically 'quiet' as once hypothesised (e.g., Dawson 1990, 1991).

We can also use these shorter deployments to assess if and when the animals return to a 'baseline state' (i.e. behaviour without interference of research boats) after the tagging attempt and once the vessels have left the area. All previous Hector's dolphin behavioural data were collected from the research vessels interacting with the group and from the surface or at stationary underwater listening stations only. The DTAG data provide the first opportunity to decipher how these animals spend their time underneath the surface with other animals and away from boat influence. For instance, we could examine average and maximum dive depth as well as dive duration. The data from these tags also provide the first insights into Hector's dolphin fine-scale behaviour (socialising, resting, foraging) and movements at night (tracks are shown in Figure 9). Of the three tags that remained attached for more than 10 hours, two stayed on overnight.

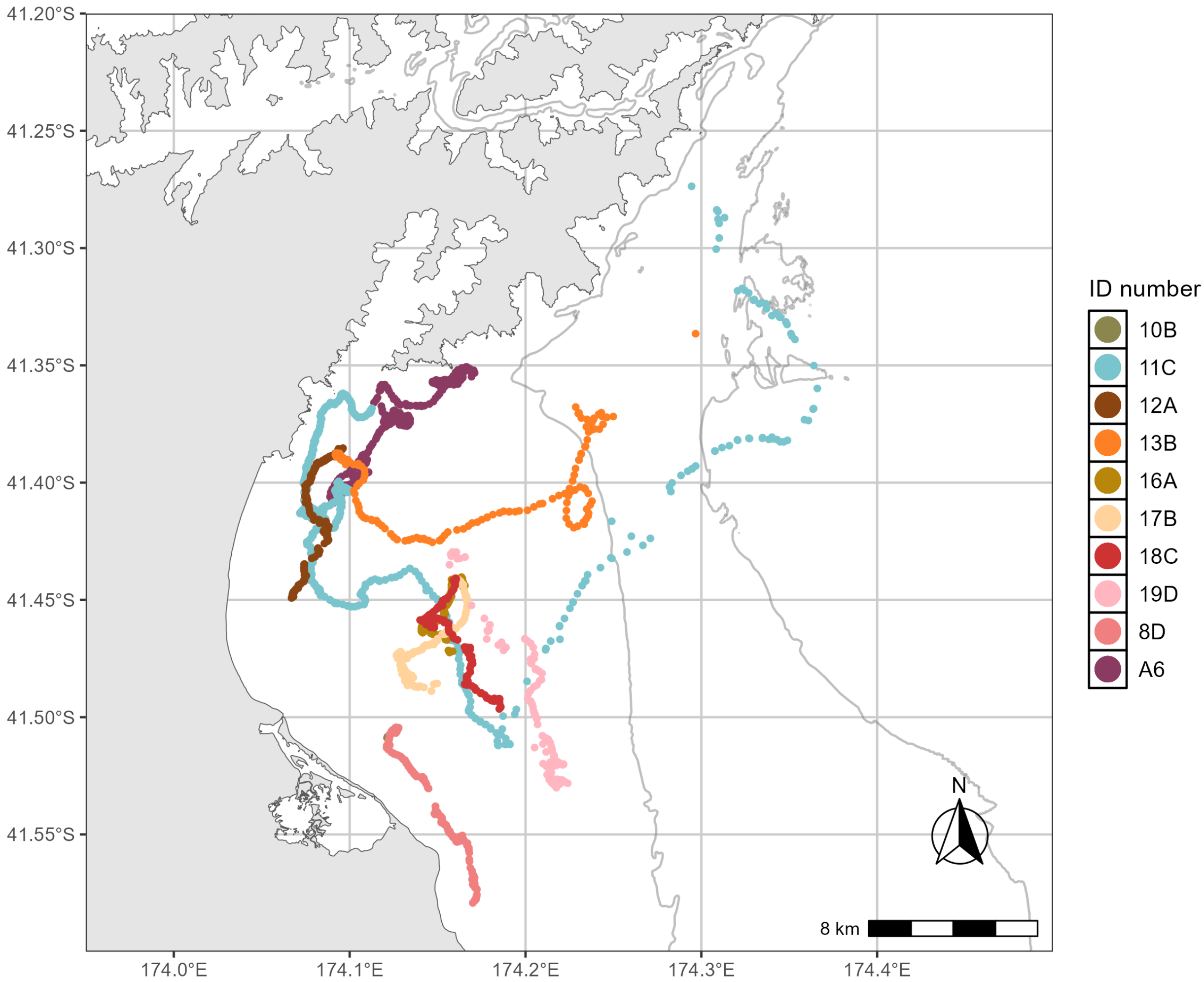

Figure 9: GPS tracks of 10 of the 11 deployments (while tags attached to animals) off Te Koko-o-Kupe/ Cloudy Bay. The 50 m and 100 m bathymetric contours are shown as continuous grey lines. Note that tag 10B is virtually completely covered by tag 8D and no GPS data were gathered for tag 7C because the GPS antenna was positioned too low on the animal to break the water surface to send a signal.

3.4 Tag recovery

Our ability to successfully recover each tag, and the duration it took to find them, was an important part of this trial because all the data are stored on the tags themselves. Hence, we looked at the following criteria:

- are tags easily recovered after detaching?
- average time to recovery (time from detachment to boat retrieval).

Tags from all 19 tagging attempts/deployments were recovered using VHF tracking receivers. When a DTAG detaches from a dolphin, it floats vertically in the water with the antenna mostly out of the water (Figure 10). The tag sends out a steady and regular VHF signal beep at this point, rather than being silent or sending an intermittent beep as when the tag is submerged and/or the dolphin is briefly at the surface, respectively. At the end of a tagging day or when returning to Port Underwood, the crew of the catamaran would use a VHF receiver on-board the vessel to check each tag and take a bearing if possible. After returning to land and travelling back to Picton, the crew would then stop at Rahotia Saddle to listen and take any bearings from an elevated location (Figure 11).

 

Figure 10: Photographs from Te Koko-o-Kupe/Cloudy Bay on 9 February 2023 of a DTAG's position in the water when unattached and awaiting recovery.

We made the decision not to attempt tag recoveries overnight given we had no easy access to nearby land tracking sites and had a considerable drive to get the necessary crew to Port Underwood and the recovery boat (*Blue Safari*) from our accommodation (at least 30 minutes; Figure 2). Instead, depending on the time we returned from tagging (before or after 7pm), crew members would return to Rahotia Saddle after dark between 8pm and 11pm to listen for any tags that may have detached and/or get bearings when possible. We also had VHF tracking teams out on at least one land site before or soon after first light to begin tracking the next day (Figure 11). While a daytime-only recovery method proved effective for this trial, tags are commonly recovered at night in overseas operations and this could be undertaken in any future New Zealand operations given appropriate resourcing, personnel, and vessels and adequate safety procedures.

The actual recovery time from setting out with the boat to find and recover a tag took on average 1.7 hours, ranging from 36 minutes to 4 hours. As we chose not to recover tags at night, our total recovery time (including overnight) averaged around 10.3 hours from the time the deployed tags detached to them being picked up by boat, often the next day. While tag recovery was fairly quick once the boat was launched, it is important to be aware of, and plan for, potentially longer recovery periods, as in this trial. This factor was an important consideration when choosing to undertake tagging on a particular day as we had to be aware of the weather forecast for that or subsequent days (depending on the auto-release time) and whether any conditions might hinder our chances of recovering any deployed tags. For example, we did not deploy any tags after 11 February due to the imminent arrival of Cyclone Gabrielle.

Figure 11: Dr Mark Johnson (Aarhus University) tracking the deployed DTAGs from the Rahotia Saddle (upper left) and other land-based VHF tracking sites around To Koko-o-Kupe/Cloudy Bay.

3.5 Data capture and utility

Our final criteria focused on how well the tags performed at capturing and storing the sensor data and whether this information could be interpreted easily to answer the target research questions:

- what percent of time data were captured and successfully stored?
- adequacy of data – can the data collected be used to address the target research question?
- can the data be used to answer any other priority research questions?

Tag data capture

Preliminary checks and diagnostics found that, in all deployments, the tags and their sensors performed as expected. There were no problems with the sensors and all associated data were downloaded and backed up. The only sensor that did not achieve 100% data capture was the GPS sensor. As noted earlier, when the tag antenna was positioned too low or slipped down on the dolphin's body, it did not break the water surface when the dolphin came up to breathe and therefore could not receive GPS satellite signals. This scenario can be problematic for gathering fine-scale movement data and also for VHF tracking the dolphin and tag during longer-term deployments (e.g., multiple days) and until the tag detaches.

Adequacy of data for conservation and management

Even though the severe weather meant that we tagged fewer individuals than intended, the dolphins' responses to tagging and the preliminary information gathered confirm that DTAG technology has the capability to help address some of the significant gaps in our understanding of Hector's and Māui dolphins and hence lead to improved conservation and management. With only 83 hours of data, we still gathered the first ever recording of underwater diving behaviour, diurnal/nocturnal movements, acoustic repertoire, and three-dimensional foraging behaviour for Hector's dolphin and individuals within the Cloudy Bay subpopulation.

Suction-cup tagging has the potential to address the following research priorities/questions that have been identified in the TMP and Research Strategy:

- description of behaviour, including foraging
- analysis of how dolphins use the water column: depth, direction, and activity (i.e., % time spent)
- quantification of inferred underwater behavioural budgets and energetic requirements
- comparison of daytime versus night-time behaviour and movement shifts
- recording individual acoustic vocalisation behaviour
- description of spatial use patterns
- analysis of short-term alongshore and offshore habitat use
- description of interactions with fisheries
- understanding of factors that potentially influence dolphin capture in trawl and other fisheries (e.g., mean foraging depths, length of dives, benthic vs. pelagic foraging)
- understanding potential overlap with deep set net activity (e.g., in 100 m depths or greater)
- description of behaviour directly relevant to the estimation of abundance
- analysis of mean, maximum, and minimum dive/surface times across time of day and weather conditions to help improve estimates of availability bias for aerial survey data.

In addition, combining the various sensors with simultaneous vocalisation data can help give context to these results and pose further questions (e.g., proportion of time spent foraging vs. foraging success, prey types). For example, Dr Johnson used the accelerometers and hydrophone data together to quickly identify several instances where the dolphins found and chased after prey and was then able to determine whether the dolphins caught or missed the prey. Using this same information, Dr Johnson and overseas collaborators have begun to estimate the size of the prey being chased by the tail-beat vibration of the prey fish as well as understanding the energetic requirements of the dolphins.

In addition, we found examples of dolphins swimming along the bottom upside down or on one side, a behaviour also observed in tagged narwhals (Dietz et al. 2007). Whether the Hector's dolphins use this position to assist in hunting prey is still unknown, but further analysis of these data, including how the tag is released (Table 2), will likely help answer this question. Each of these examples represents a significant increase in our knowledge and will be of benefit to the management of this species.

Other research questions

As our trial results indicate, the methods we used had little to no impact on Hector's dolphin. We believe there is potential for significant information gains in the future if we move to larger-scale deployment programmes on both Hector's and Māui dolphins, particularly at regional or subpopulation levels. For example, our current understanding of home ranges and diets of Hector's dolphin are based on a few detailed studies undertaken around Banks Peninsula. The current TMP then assumes that Hector's dolphins in all other regions behave in the same way. However, the oceanography and ecosystems around an east coast headland region such as Banks Peninsula are expected to be quite different to a west coast region or a large bay off Cook Strait where other subpopulations live. Hence, this technology could provide our first insights into how this species may differ between regions in terms of life history dynamics (e.g., proportion of time spent diving and foraging, foraging depths), which may significantly influence how we manage the subpopulations in relation to their various threats.

In addition to the research priorities highlighted in the Research Strategy, we believe that collecting acoustic data from a device attached to Hector's dolphins will provide valuable information on the vocalisation behaviour that this species exhibits in different areas and during different activities. Most existing studies of the acoustic behaviour of the species has come from passive acoustic monitoring

(PAM) devices that are in fixed positions; hence they only capture the types of sounds emitted by dolphins in a specific location. A better understanding of the type of sounds both Hector's and Māui dolphins can produce within a behavioural context will enable clearer interpretation of the data collected using PAM devices.

Particularly tantalising from a future monitoring perspective is the prospect of gaining further insight about the sounds produced by individual dolphins. Establishing the rate at which certain sounds are emitted by individuals (and how these vary) is a key component of estimating dolphin density from PAM arrays. Individual sound production rates are difficult to estimate reliably from PAM recordings but can be measured directly in tag recordings. The intensity and density of certain sounds or cues (Marques et al. 2009) could then be estimated from data collected at a PAM array and combined with the estimate of the cue rate produced by individual dolphins to obtain an estimate of dolphin density in the region. In addition, actual dolphin density could potentially be estimated directly from PAM array data if it is found that individuals have a unique acoustic signature of some description. We do not see examination of the data for a unique signature as part of this specific project, but rather a future potential extension that could use the data collected in this project from DTAGs.

Further examples of potential future uses are discussed in the Sections 4 and 5.

4. OBJECTIVE 3 – MONITORING OPTIONS

Large-scale monitoring programmes could be designed where DTAGs are used as a primary method of data collection for Hector's and Māui dolphins or where DTAGs are used as a secondary method to provide additional context for the main results. Designing a monitoring programme with DTAGs as a primary data source would likely require a large number of DTAG deployments (i.e., greater than 100) and deployment times over multiple days. Due to the cost and labour required in such a scenario, we do not see DTAGs as a primary monitoring tool that could be implemented at relevant and regular scales for monitoring abundance or distribution of subpopulations. However, we do see DTAGs as a useful tool that can provide greater insight into the natural history of Hector's and Māui dolphins, which will be complementary to the monitoring data collected using other platforms, such as aerial surveys and boat-based mark-recapture surveys (using either genetics or photo-ID).

In this section, we focus on DTAG use as a secondary method to help with Fisheries New Zealand's large-scale population monitoring questions, particularly behavioural and foraging aspects, as it is likely to be the more feasible approach given the current technology. Some of the key questions associated with large-scale monitoring that DTAGs could provide insight on include:

- do dolphins change their behaviour in response to different survey platforms (e.g., level of attraction to boats, avoidance of helicopters)?
- how do they use the water column?
- how much time is spent foraging, and how do they forage?
- how frequently do they move between onshore/offshore areas or different water depths?
- what types of activity do they undertake in different areas, including in turbid water?
- how much time is spent near the surface such that they would be visible during an aerial survey (i.e., availability)?
- how do all of the above vary diurnally, seasonally, by age class and sex, or other individual characteristics?

Here, we outline some of the general issues that need to be carefully considered with respect to using DTAGs for this purpose, and then make more specific recommendations on how DTAGs could be most usefully integrated into current monitoring efforts of Hector's and Māui dolphins.

4.1 Regular 3- to 5-year monitoring programme

Deployment duration

The deployment duration of a DTAG is a key consideration when designing a study to augment a monitoring programme for Hector's dolphin, particularly when diurnal patterns are of interest. In this initial trial, deployment durations tended to be relatively short: more than 50% of the successful deployments lasted less than 4 hours, and approximately 20% lasted greater than 12 hours (Figure 12). Therefore, if the intent is to obtain quality information about changes in an individual's behaviours over longer time frames (e.g., spanning daytime and night-time hours), the variation in deployment durations must be considered. For example, if more than 12 hours of data from approximately 10 individuals needs to be obtained, then 50 successful deployments may be required.

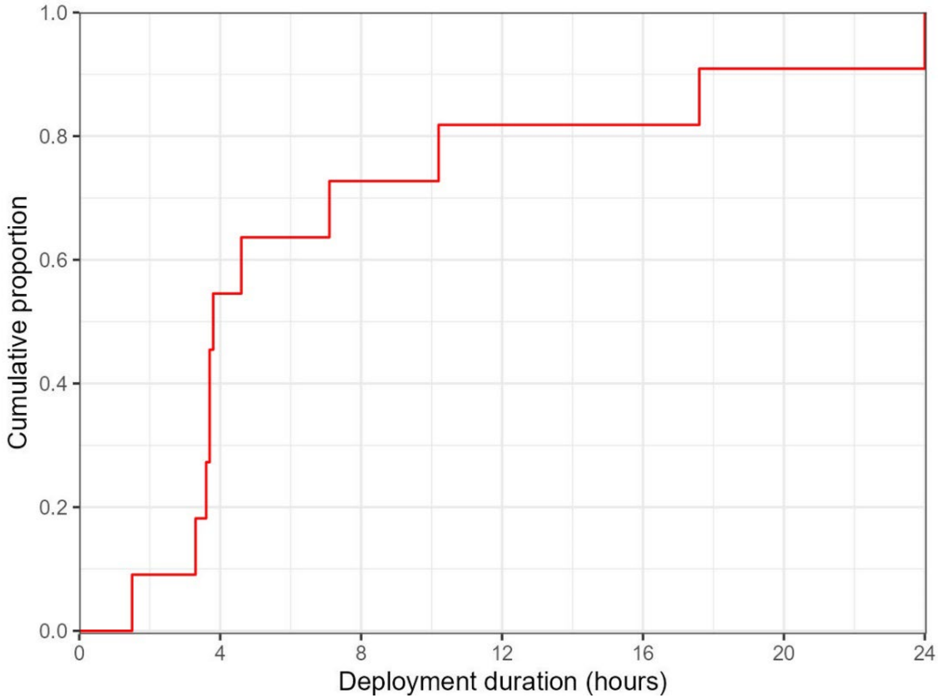

Figure 12: Cumulative proportion plot of the number of hours DTAGs remained attached to Hector's dolphins during the feasibility trial.

Sample size

It is always difficult to give explicit advice on required sample sizes as it strongly depends on:

- the study objective
- the level of variation in the quantity of interest
- the desired level of precision, or certainty, of results.

The **study objective** is fundamentally important in determining the sample size. A well-defined objective helps researchers decide the specific parameters and characteristics they need to measure, thereby influencing the number of samples required.

- What is the main quantity of interest?
    - How is it going to be integrated into the monitoring to provide improved context of the monitoring results?
- What is the desired scope of inference?
    - Are data from a few individuals likely to provide sufficient insight into the quantity of interest to simply indicate that Hector's dolphins are capable of certain behaviours, or
    - Are insights required at (sub-) population scales— that will need data to be collected from a greater number of individuals? For example, data from a greater number of individuals

will be required to address specific questions such as what proportion of time do dolphins typically spend in different parts of the water column?

Furthermore, greater sample sizes will be required where an objective of the study is to identify differences or changes in the quantity of interest (e.g., diurnal patterns or gender differences). Sample size requirements would increase almost linearly with every additional comparison that is stated to be of interest.

The **level and nature of variation** in the quantity of interest is also crucial. Smaller samples will be sufficient when the level of variation is relatively low and larger sample sizes when variation is relatively higher. Note that 'relatively' is in reference to the desired level of precision or certainty, as defined by the study objective. Larger samples sizes are required when there is greater variation, simply to improve the likelihood that the data are representative of the full distribution of possible values.

By considering the nature of the variation, it may be possible to implement protocols to control for those sources of variation or to reduce the effects of those sources of variation. For example, if females with calves are thought to forage differently from other dolphins, then tagging may focus on only one of the two groups rather than collecting data from both. Similarly, when it is suspected that there is substantial temporal or spatial variation, surveying could be limited to certain times or places to reduce the level of variation in the data. However, if data collection is targeted in this manner, those groups, times, or places that are excluded are also excluded from the scope of inference. Therefore, any considerations of this nature should be made in the context of whether they conform with the study objective.

The required sample size will also depend on the **desired level of precision, or certainty**, for the study, which should be defined as part of the objective. Larger sample sizes will be required when a greater level of precision is desired (e.g., smaller standard errors or higher power for statistical hypothesis tests), although there is typically a decaying rate of return of information content to sample size; hence, required sample sizes can increase quickly as the desired level of precision increases. For example, standard errors and sample size often have an inverse square-root relationship, such that to halve the size of a standard error, the sample size will often need to be quadrupled. Therefore, moderate gains in precision may be gained by moderate increases in sample size, but large sample sizes may be required for more precise results.

Table 3 presents a very general guide to the sample sizes that may be sufficient to achieve different levels of certainty for a quantity of interest. These values are based on expert opinion and experience and are provided solely to temper expectations on how much data may need to be collected. The table is not intended to replace a more detailed sample size assessment that should be conducted as part of a study design process. As noted above, it is important to consider the expected deployment duration in combination with the sample size requirements. For example, to obtain sufficient night-time data to assess diurnal patterns, the number of deployments may be five times greater than the values given in Table 3 as the trial results suggest only 20% of successful deployments last longer than 12 hours. Also note that the sample size is not necessarily equivalent to the number of deployments, depending on the quantity of interest and scope of inference (e.g., if interest is dive-cycle behaviour for a small number of animals, sample size may be the number of dive cycles observed).

Table 3: Sample size that may be sufficient to obtain a given level of certainty for a quantity of interest, based on expert opinion and experience.

Sample size	Level of certainty
10–20	Indicative
20–30	Low
40–60	Moderate
80–100	High
150+	Very high

Temporal and spatial considerations of fieldwork

Spatial and temporal aspects of the field effort to locate and tag dolphins should align with the study objective(s). Given the objective, the fieldwork should be designed to ensure (to the maximum extent possible) that all dolphins within an area, and population, of interest are exposed to the survey effort. The temptation to survey only in areas with more dolphins to increase chances of encountering enough dolphins to get sufficient deployments, for example, should be avoided. Without detailed knowledge about Hector's dolphin movement patterns, the area of interest should be systematically surveyed to ensure good coverage of the field effort across the entire area of interest. This may necessitate that some survey effort is devoted to low-density (e.g., offshore) areas to tag dolphins found in those areas, especially if there is interest in comparing dolphin movement, or other behaviours, in such areas to those in high-density areas (e.g., inshore).

The time at which surveys are conducted is also relevant, particularly given the potential range of deployment durations (Figure 12). For example, where interest is in diurnal patterns, it is important to have sufficient data from both daytime and night-time periods, and ideally data from both periods for the same dolphin. Given that relatively few DTAGs remained attached for greater than 12 hours during the trial, a good portion of the survey effort would therefore need to be conducted as late in the afternoon as practical to increase the chances of tags remaining attached to animals overnight and some into the morning of the following day. However, some effort will be required earlier in the day to ensure that a sufficient number of tags are deployed to cover the daytime hours. That is, the fieldwork will need to be planned with two main periods of activity: early morning and late afternoon.

4.2 Monitoring recommendations

The following recommendations have been made in the absence of a clear objective for how DTAGs might be incorporated into a monitoring programme; hence, some may not be appropriate for particular future objectives.

Stakeholder consultation

We recognise and acknowledge the kaitiaki role and special relationship of mana whenua with marine mammals and, that Hector's and Māui dolphins/tutumairekurai are taonga. Any future Hector's and Māui dolphin monitoring programme would benefit greatly from mana whenua partnership and involvement in its development. Culturally appropriate protocols and data sovereignty are important issues that need thorough consideration and input from mana whenua partners. The final programme should incorporate an overview of local iwi and community interests, as well as cultural advice in terms of fieldwork, methods, sampling sites, and data collection itself. Hence, any future monitoring study involving DTAGs, as well as other methods, with Hector's and Māui dolphins should be determined through a collaborative partnership with mana whenua and agreed upon well in advance of any government-issued contract proposals.

DTAG monitoring opportunities

The two key aspects of dolphin biology we believe would be most beneficial to provide context to current, and historical, monitoring results for Hector's and Māui dolphins are:

- spatial and temporal variation in dive cycles
- inshore/offshore movement patterns.

Dive-cycle behaviour determines the proportion of time dolphins are near the surface and, therefore, their availability to detection by aerial survey platforms. Present estimates of availability have been collected either during survey flights using a circle-back method or with dive-cycle information collected from helicopter surveys. Helicopter surveys can be conducted only relatively close to shore, and there is the potential for a helicopter to disturb the natural dive-cycle behaviour due to its noise and down draught. The circle-back method can be conducted at any point during survey flights, although it does require relatively large sample sizes (e.g., 100+) to obtain reasonably precise estimates of availability due to the binary nature of the resultant data. In addition, the sample size requirements increase if spatial, or temporal, differences in availability are of interest. Because of the scalar effect availability estimates have on abundance estimates, substantial, unaccounted-for differences in availability may lead to misleading inferences about abundance. Therefore, an improved understanding of dolphin dive-cycle behaviour and whether it varies with spatial environmental features, such as water depth or turbidity, will provide insight into potential spatial variation in availability.

Most boat-based mark-recapture surveys are conducted using one or two alongshore transects rather than a design with more even spatial coverage, such as those used in distance sampling surveys. A key assumption of mark-recapture methods is that all individuals within the (sub-) population of interest have a non-negligible, and ideally equal, probability of being encountered during each survey period. In practice, this means that dolphin movement patterns result in a 'well-mixed' population and all individuals regularly move through the region of the survey transects. At present, there are few data that allow the reasonableness of this assumption to be evaluated, and fine-scale movement information collected with DTAGs would provide some insight, particularly when individuals are tagged throughout their offshore range.

A secondary aspect that movement data would provide insight into is diurnal behaviour. All monitoring data have been collected during daylight hours, and it remains largely unknown whether dolphins use the same areas during the night, or whether there is a systematic shift in their distribution (e.g., greater use of offshore areas at night).

Possible locations to conduct initial surveys include Clifford Bay and Cloudy Bay, or around Banks Peninsula. Clifford Bay and Cloudy Bay are suggested due to the level of previous monitoring and other surveys that have been conducted in the region, including the initial trials that provided a head start on any sample size requirements. Substantial monitoring and surveys have been conducted around Banks Peninsula, and there is greater variation of water depths in the vicinity that may be advantageous to assess possible differences in dolphin behaviour due to water depth.

In terms of sample size, we would recommend a minimum of 30–50 deployments for each location, spread throughout the day and area (if this conforms with the study objective). If diurnal effects are also of interest, then we would recommend a minimum of 100 deployments, with about 50% of deployments covering the night-time period. While ideally all survey work would be conducted in a single season to reduce the possibility of inter-season variability caused by climatic condition or other sources of variation, in practice this is not likely to be feasible. Data could be collected across multiple seasons if needed, with the advantage that they could be analysed between seasons to assess the amount and suitability of the data collected to date. However, the study objective should be the main determinant of all design-related questions, such as location, time of year, sample size, and spatial and temporal coverage of the survey effort.

5. STUDY SUMMARY

Based on our five assessment criteria, the dolphin responses to tagging and the preliminary information gathered confirm that DTAG technology has the capability to help address some of the significant gaps in our understanding of Hector's and Māui dolphins and, hence, lead to improved conservation and management. Placing electronic tagging devices on these dolphins is one of the few cost-effective methods that can provide data on most aspects of the proposed TMP priority research questions (e.g., information related to prey and feeding behaviour, fine-scale movements, night-time behaviour). Suction-cup attachment methods are the only electronic tag options that are considered to be non-invasive (Andrews et al. 2019). The tag is simply deployed by hand using a pole and only a small amount of force is required to attach the tag to the dolphin's skin. Based on the attachment success rate of these tags on Cloudy Bay Hector's dolphins, we envision this tool being used as part of a larger toolbox of methods supporting future subpopulation monitoring programmes to improve decisionmaking, as indicated by the TMP science strategy priorities and the DOC Conservation Services Programme's medium-term research plan objectives.

5.1 Lessons learnt

The success of this feasibility trial, despite the interruptions caused by Cyclone Gabrielle (as well as delays caused by the COVID-19 pandemic), is attributed to the collaborative effort of all the team members and their associated organisations. We recommend that any future work with DTAGs and Hector's dolphin involves experienced crew. A vessel similar to DOC's *Aakron* vessel was perfectly suited to the tagging work, and the skipper's boat skills and the staff's knowledge of the animals was invaluable in achieving the number of successful tagging attempts. In addition, the DOC members were extremely proficient in VHF tracking, which ended up being the more difficult part of the tagging processes.

The collaboration between institutes was also key to the study's success. By bringing together those researchers in Aotearoa New Zealand with expertise in this species and in tagging methods (or similar techniques such as biopsy sampling) with Dr Johnson and his DTAGs, we were able to quickly assess and adapt our methods and protocols to best suit the animals as well as testing the capabilities of the tags. More importantly, Aotearoa New Zealand researchers and DOC staff could train in the tagging methods and learn tips and trouble-shooting techniques under the guidance of Dr Johnson, the developer of the DTAG and one of the most experienced taggers in the world.

Tagging expectations

We initially hoped to deploy at least one tag a day and up to 30 over the course of a 3-week trial period. Based on our successful attachments, our tagging rate was 1.4 per day. While a rate of one tag a day was achievable, we discovered that any deployment plans were highly dependent on how long the previous deployments lasted, how quickly tags could be recovered, and, as anticipated, the weather forecast. For example, a tag that was deployed for only a few hours could be recovered, downloaded, and prepared for another tagging attempt on the same day if this occurred early enough in the day. However, any tag with more than 1–2 hours of data would take longer to download and prepare, and deployment would need to wait until the next day. In the end, our field days generally comprised a tagging day (with all four tags deployed) with collection of any early releases, followed by a recovery day with tagging attempted later only if tags were available.

Behavioural responses

We noted that the responses of the dolphins to tagging attempts improved with time and tagger experience. It took a day or so for taggers to get used to how the dolphins swam alongside the tagging vessel and how and where to best place themselves on the bow (taking into considering health and safety as the primary factor). Tagger experience is a key factor in the success of any tagging programme, and training was an important component of this project.

The attraction of multiple groups of dolphins to the boats also made it difficult to tag a single group and then move on. At one point we had more than 35 animals around the boats. Hence, we made the decision to try to deploy as many tags as possible while the responses of tagged animals remained at a low level or short in duration, and while following our *a priori* criteria and protocol conditions (i.e., 90-minute limit and no more than six attempts).

Tag retention

While observing groups after tagging, we noted that tags could shift slightly on the animal's body. On 10 February, DTAG-B (Table 2, Figure 3, ID #10) was placed more on the side of the dorsal fin rather than on top and in front of the fin. Over the course of our behavioural observations, the tag slid from a parallel position to a perpendicular one. As a result, the GPS antenna did not break the surface or record location data for most of the deployment. In another case, on 11 February, DTAG-C (Table 2, ID #11) stopped sending GPS signals after 18 hours into its 24-hour deployment, likely due to the tag slipping out of position.

In addition, three of the four tags deployed on the 20 February all detached within an hour of each other in the afternoon, a time that coincided with increasing winds and a steep, short chop forming across most of the bay. As we were out tracking the detached tags in these conditions, various groups of Hector's dolphins followed the catamaran downwind, leaping and surfing through the waves next to us (Figure 13). The fourth tag released later, at around the same time as we were attempting to recover tags. Based on these observations, we guessed that the tags were sliding off or releasing due to the sheer force produced by the combination of swimming speed, leaping through waves, and wave power.

Figure 13: Hector's dolphins surfing and swimming alongside *Blue Safari* in steep chop while team members were recovering tags on 20 February.

To test this assumption, Dr Johnson had a cursory look at the accelerometer data to see if we could determine when and/or how a tag was released. The results are listed in Table 2. As expected, most tag data showed either fast swimming or brief, quick acceleration by the animal right before the tag detached. Based on acceleration data, five of the tags also showed evidence of sliding on the dolphin's body at some point in the deployment.

Overall, we concluded that proper placement and attachment of the tag are essential to achieving longer deployment times. Tags that were deployed more on the side or curved part of the dolphin's back tended to slip or release sooner than those on the flatter portion of the dorsal surface in front of the dorsal fin. Also, shorter deployment times were not always associated with a particular initial behavioural reaction (e.g., strong or low level) by the animal (Table 2).

Tag recovery

The main limitation in DTAG recovery is that VHF tracking is currently the sole tool for finding the tags. This factor will need to be taken into consideration if the tags are to be used in other regions around Aotearoa New Zealand. For instance, Cloudy Bay has several elevated coastal cliffs on both sides of the bay that are accessible by road (some 4WD only). Having a variety of accessible land sites meant we were able to triangulate better on a floating tag than from just a single land site. Even with this advantage, it was challenging to find tags in choppy sea conditions.

Tag tracking with the VHF receivers was straightforward on a good weather day. We encountered some difficulties when tags detached near the cliffs north of Port Underwood (10 February) and near White

Bluffs (20 February) as both the trackers on the boats and at land sites often encountered interference or wave bounce from the nearby cliff faces. This interference made it essential to have at least one (but preferably two or three) land sites so that a second and different bearing to the floating tags could be obtained. We also noted that the received signals from two of the four tags (C and D) were not as clear or as strong as the other two. This may have been because these tags had slightly shorter antennae, which made it harder to have a clear line of sight to them in large swell or rough chop.

At this point in time, replacing the VHF transmitters with 'live' transmitters (i.e., satellite, GPS) has disadvantages in terms of size and weight that would be added to the tags themselves. However, this technology is becoming increasingly more efficient and smaller, which means eventually the capability to track these tags remotely through cell phone towers (or other transmitters) will be possible.

Future tagging projects

Any future projects will need to consider that the DTAGs currently use VHF tracking tags and receivers that operate outside normal frequency bands used in Aotearoa New Zealand. Hence, Dr Johnson brought his own receivers and antennae from overseas for this trial.

We also note that, as our ability to reliably attach DTAGs with little impact to individuals has been demonstrated, the electronic package within the tag can be modified with different sensors (e.g., turbidity sensor) to collect different types of data to address a range of future research questions. Other potential projects might involve: (i) controlled exposure studies to investigate the effectiveness of fishery mitigation approaches such as acoustic deterrent devices (ADDs) on gillnets or (ii) tagging dolphins that follow trawlers.

5.2 Preliminary data collected

With the tag data collected from this trial, it is possible to start addressing some of the TMP priority research questions for the Cloudy Bay's Hector's dolphin subpopulation as well as several additional questions related to the tags themselves. To do this, some initial processing steps are necessary, including:

- review/catalogue all photographs of individual dolphins (tagged or not) and compare these between days
- review all footage for any evidence of suction-cup marks (small circular patterns, discoloration), blisters, light swelling of the skin, or broken skin due to tagging
- interpret/categorise the sensor movement, accelerometer, and acoustic data into inferred behavioural types (e.g., travelling, resting, foraging, long dives, short dives) using Dr Johnson's decades of experience of interpreting tag data
- compare the inferred behavioural types with the corresponding visual observation data taken during and after the tagging attempts, then use these inferred behavioural types to analyse the animal's response to the tags at 30 minutes, 1 hour, and 2 hours post-tagging
- analyse the GPS data to look at how far the animals travel (horizontal distance vs. vertical distance) over the course of set intervals (hour, daylight, night-time)
- interpret/categorise the acoustic data.

5.3 Conclusions

This feasibility study found that DTAGs can be successfully deployed on Hector's dolphins to enable us to investigate aspects of their life history and behaviour that have not previously been observable. Tag deployment does not appear to cause significant stress to the dolphins with normal behaviour resuming within minutes of a tagging attempt. Further work is required and advice provided to improve tag deployment and retention to maximise their value in future studies. Overall, this technology provided some new insights into how subpopulations of this species may differ (or not) in their simple life history dynamics, which may influence how we manage them in relation to their various regional threats.

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As noted throughout this report, the success of this study is attributed mainly to a highly skilled, very professional team of people, who were all involved because they care about this species and its future protection. DOC made staff available from the National Office in Wellington, Golden Bay/Mohua, and Kaikōura, as well as equipment and resources to help this project succeed. This project would never have survived the COVID-19 fall-out without the determination of both Philip Heath (Fisheries New Zealand) and Anton van Helden (DOC National Office), who kept the internal wheels turning forwards despite our many obstacles. Thanks especially go to Beryl Archer, John Hebberd, and the crew of the *Blue Safari*. The catamaran's workspace and flying bridge were the perfect research platform for this study, especially for the drone work, and enabled us to endure the long hours necessary to complete the project. We were also extremely fortunate to have Richie Robinson join us for part of the field trip. What little drone work we were able to undertake is all credited to him and his drone-driving skills.

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APPENDIX 1

Priority data and locations identified by Fisheries New Zealand in the original tender PMM2020-07.

Māui dolphins
Prompt detection and recovery of beach-cast Māui dolphin carcasses is a very high priority, to understand what threats are responsible for dolphin deaths. Roughly 5–7 Māui dolphins are thought to die each year from all causes. A very small proportion of those carcasses are recovered and available for necropsy. This may be because large portions of the coastline on which bodies are most likely to become beach-cast, e.g., between Manukau and Raglan, are inaccessible to beachgoers, and rarely visited, especially in winter. If AI-equipped drones are capable of patrolling this coastline to photograph and ID beach-cast carcasses, this may substantially increase the availability of carcasses for necropsy.

North Coast South Island (NCSI)
Very little is known about Hector's dolphins in this area (i.e., Golden Bay and Tasman Bay). The number of dolphins residing here (or whether NCSI Hector's dolphins are a separate subpopulation at all) and their spatial distribution are largely unknown. Large-scale surveys using aerial or underwater drones may be feasible to inform preliminary estimates of spatial distribution and population size; initial trials would need to be focused in areas in which dolphin detections are expected to be most likely, based on other available data. Alternatively, if there are locations where dolphins can already be located reliably, then AI-equipped drones may be capable of actively following dolphin pods to record their movement and behaviour. In any proposal relying on cameras, acquisition of ID-quality photographs to begin to identify individual dolphins is a high priority, to populate an eventual photo-ID catalogue.

South Coast South Island (SCSI)
Hector's dolphins off the SCSI appear to be located predominantly within Te WaeWae Bay, an area in which the population size has been estimated with reasonable certainty (MacKenzie & Clement 2019). The existence of a small, relatively spatially contained subpopulation may offer opportunity for more intensive monitoring of dolphin behaviour or population demographic parameters. Priority research questions could include characterising fine-scale dolphin movements, including in reaction to fishing vessels, and monitoring annual variation in reproductive success by counting calves vs. adults.

Kaikōura
The local population of Hector's dolphins around Kaikōura is of interest due to its potential overlap with fishing effort. The ability to characterise dolphin movements and habitat utilisation on a fine scale is of particular priority.

Other priority locations
For Māui dolphins and for any small relatively discrete subpopulation of Hector's dolphins, the ability to estimate population size, to collect ID-quality photographs, and to monitor key demographic parameters (e.g., calf production) are of particular interest.