REPORT NO. 3512

# POP2019-01 ELECTRONIC DEVICES TO ASSESS DISTRIBUTION, DIVING AND FORAGING BEHAVIOUR OF HECTOR'S DOLPHINS

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# POP2019-01 ELECTRONIC DEVICES TO ASSESS DISTRIBUTION, DIVING AND FORAGING BEHAVIOUR OF HECTOR'S DOLPHINS

## CLIENT 1ST DRAFT

SIMON CHILDERHOUSE, OLIVIA JOHNSON



Prepared for Department of Conservation, Conservation Services Programme

CAWTHRON INSTITUTE
98 Halifax Street East, Nelson 7010 | Private Bag 2, Nelson 7042 | New Zealand
Ph. +64 3 548 2319 | Fax. +64 3 546 9464
www.cawthron.org.nz

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# 1. INTRODUCTION

Dolphins, as a whole, are challenging to study as they spend most of their time underwater, can be highly mobile and often occur in remote and inaccessible areas. However, an understanding of dolphin biology, ecology, physiology, and behaviour is essential if these species are to be managed and protected effectively. Likewise, effective implementation of appropriate mitigation methods for anthropogenic activities is also necessary requires these data (Andrews et al. 2019). Such challenges can be partly addressed through the use of animal-borne monitoring instruments (i.e. bio-logging tags or tags). There are a wide variety of different types of tags that can be used to undertake research on dolphins. For example, environmental (e.g. water temperature, salinity), physiological (e.g. heart rate, body temperature) and behavioural (e.g. dive depth and duration, acceleration, geographic position) data can be collected from tags while on the animal.

Tags are now forming an important tool in increasing our understanding of dolphins and contributing to improvements in their conservation and management. Yet, while tags can provide insightful data about dolphins that have been previously been difficult or impossible to collect, tagging does present potential risks to tagged individuals. These risks include potential alteration of the physiology and behaviour of tagged individuals that can lead to negative outcomes for that individual. These same impacts can affect the interpretation of the data, making it essential that any impacts are identified and their potential influence on the resulting data understood. These potential impacts are a vital consideration when weighing the benefits and costs of any tagging programme.

The Cawthron Institute was contracted by the Department of Conservation (DOC) to undertake a literature review of marine mammal electronic device use internationally and to provide recommendations for the potential use of these devices to assess Hector's dolphin behaviour (*POP2019-01)*. This project forms a part of the Conservation Services Programme Annual Plan 2019-2020.

## 1.1. Project scope

This report will assess current electronic tagging technology used in cetacean monitoring and provide recommendations of a low-risk method that can be used in future research involving Hector's dolphins. The project has three main objectives:

1. an international literature review of marine mammal tagging practices
2. identify operational, biological, and environmental factors that are relevant to the investigation of the fine-scale distribution, diving and foraging behaviour of Hector's dolphins
3. provide recommendations on the most effective method for use in assessing Hector's dolphin behaviour.

# 2. METHODS

This project has three separate but closely related components. Descriptions of the methodology of each component are provided in the following sections.

## 2.1. Review and analysis of international tagging literature

The review of existing literature on tagging covered the following source material: international scientific literature, government agency commissioned reports, conference proceedings, commercial research and results from industry and scientific trials. In this field of research, there is also a considerable body of grey literature that is difficult to source but which is a large and valuable source of relevant information in this area. These sources were also reviewed through direct searching of conference, workshop, meeting, and observer programme reports, which are often not well referenced in electronic databases.

Electronic search engines and databases were used including: Web of Science, Current Contents, Google Scholar, and general internet searches, using keywords such as: bio-logging, radio-tagging, satellite tagging, tagging, telemetry, dolphin, PTT, animal movement and tracking.

Individual references were evaluated and reviewed against the following criteria:

4. level of scientific rigor
5. level of proven efficacy
6. caveats and uncertainties in methods
7. impacts of tagging on animal health
8. relevance to Māui and Hector's dolphins
9. costs and benefits.

Review results were then used to identify the most promising papers and reports for understanding the potential for these devices to be used in future behavioural research with Hector's dolphins. The results from the review of each reference were summarised in an Excel spreadsheet allowing fully searchable access to the record summaries. A copy of this spreadsheet is available from DOC upon request[1].

## 2.2. Assessment of tagging methods and other considerations

Based on the data collected in the literature review, expert advice and our own experience, the following issues were assessed and summarised:

[1] Electronic spreadsheet available from csp@doc.govt.nz

- Review of previous dolphin tagging work undertaken in New Zealand
- Review and comparison of different tagging methods including strengths and weaknesses, time frame for results, and also a brief consideration of methods other than tagging
- Review of potential impacts on animal health and other considerations.

All of these issues are summarised in the electronic spreadsheet but only the key issues are summarised in the report.

## 2.3. Comparison of methods

Summary tables were compiled providing a comparison of methods based on the review of all the references and analysis undertaken as part of the other two objectives. Recommendations about potential methods for addressing a range of research questions are also provided.

# 3. RESULTS

## 3.1. Literature review findings

A total of 36 papers and reports were included in the literature review spanning the period 1972 to 2020. Most (78%, n = 28) of the papers were from the last 10 years and reflect a relatively rapid increase in dolphin tagging studies worldwide, consistent with increasing availability of tags to researchers (e.g. commercially produced and available). Two recent papers provide excellent and complementary overviews of marine mammal tagging globally:

- Andrews et al. (2019) focuses on summarising the best practice guidelines for cetacean tagging developed by many of the leading taggers in the world. While the document doesn't provide advice or information about specific techniques and tags, it describes an excellent process for the evaluation of tags and tagging programmes with the aim of supporting the development of tagging programmes that are consistent with international best practice and genuinely consider all the potential costs and benefits.
- McIntyre (2014) is a comprehensive review of 620 published research papers on marine mammal tagging, most of which were on pinnipeds, which were not covered in our review. The main conclusions were that most tagging research was strongly biased towards pinnipeds (e.g. > 75% of references). Dolphin tagging research only comprised 26 of all references (e.g. < 5%), highlighting the limited amount of dolphin tagging work being conducted in proportion to other marine mammal species. This review concludes that the explanation for the limited number of studies on dolphins was due to the difficulty in attaching devices but notes that the number of dolphin tagging studies have been increasing in recent times as attachment methods improve. Overall, the results presented indicate that a comparatively small proportion of biologging studies on marine mammals directly address applied conservation questions, and that the use of biologging technologies is still underrepresented in conservation and management science.



### *3.1.1. Scientific rigor*

One of the issues considered in this review was the scientific rigor of the research as a useful measure of the potential efficacy/value of the reference. While our assessment of rigor is subjective to a degree, it does provide high-level and consistent means in which to rank references' scientific standards, and provides an indication of how well the reference follows scientific protocols (e.g. experimental design, appropriate statistical analysis, robust results and conclusions). This assessment is important in providing later context for determining how useful and accurate results are from individual studies. For example, a significant result from a study with a high degree of scientific rigor is likely to be more robust (and useful) than one from a study with a low level of scientific rigor. A summary of the highly relevant papers identified in the literature review is provided in Table 1.

Table 1. Summary of references useful to consider in the development of a Hector's dolphin tagging programme

| Reference number | Year | Full reference | Type of reference | Species | Attachment and tag type | Scientific rigor | Efficacy in addressing research question | Cost of research |
|---|---|---|---|---|---|---|---|---|
| 2 | 2019 | Andrews, R. Baird, R. Calambokidis, et al. (2019). Best practice guidelines for cetacean tagging. Journal of Cetacean Research and Management. 20. 27-66. | Review - guidelines | Various | Various | NA | Variable | NA |
| 5 | 2016 | Carter, M. Bennett, K. Embling, C. Hosegood, P. Russell, D. 2016. Navigating uncertain waters: a critical review of inferring foraging behaviour from location and dive data in pinnipeds. Movement Ecology (2016) 4 [25]. 20p. | Review - summary | Pinnipeds | Various | NA | NA | NA |
| 27 | 2016 | Nowacek, D. Christiansen, F. Bejder, L. Goldbogen, J. Friedlaender, A. 2016. Studying cetacean behaviour: new technological approaches and conservation applications. Animal Behaviour 120 (2016) 235-244 | Review - summary | Various | Various | NA | NA | NA |
| 22 | 2014 | McIntyre, T. 2014. Trends in tagging of marine mammals: a review of marine mammal biologging studies, African Journal of Marine Science, 36:4, 409-422 | Review - summary | Variety | Various | NA | NA | NA |
| 36 | 2012 | Walker,K. Trites, A. Haulena, M. Weary, D. 2012. A review of the effects of different marking and tagging techniques on marine mammals. Wildlife Research, 2012, 39, 15–30 | Review - summary | Various | Various | NA | Variable | NA |
| 34 | 2020 | Teilmann, J. Agersted, M. Heide-Jørgensen, M. 2020. A comparison of CTD satellite-linked tags for large cetaceans - Bowhead whales as real-time autonomous sampling platforms. Deep–Sea Research I 157 (2020) 103213 | Research - tagging | Bowhead whale | Consolidated, satellite tag | Low | Variable | $500,000 |
| 3 | 2018 | Balmer, B. Zolman, E. Rowleset al. 2018. Ranging patterns, spatial overlap, and association with dolphin morbillivirus exposure in common bottlenose dolphins (Tursiops truncatus) along the Georgia, USA coast. Ecology and Evolution. 2018; 8: 12890–12904 | Research - tagging | Common & bottlenose dolphins | Bolt-on, satellite | Low to moderate | Moderate to high | $50,000-$100,000 |
| 1 | 2015 | Andrews, R. Baird, R. Schorr, G. Mittal, R. Howle, L. Hanson, M. (2010). Improving Attachments of Remotely-Deployed Dorsal Fin-Mounted Tags: Tissue Structure, Hydrodynamics, in Situ Performance, and Tagged-Animal Follow-Up. Grant number: N000141010686. www.alaskasealife.org | Research - tagging | Various small and medium cetaceans | Suction cup, satellite | Low to moderate | Moderate to high | $100,000-300,000 |
| 29 | 2014 | Reisinger, R. Oosthuizen, C. Peron, G. Toussaint, D. Andrews, R. de Bruyn, N. 2014. Satellite Tagging and Biopsy Sampling of Killer Whales at Subantarctic Marion Island: Effectiveness, Immediate Reactions and Long-Term Responses. PLoS ONE 9(11) | Research - tagging | Killer whales | Anchored, satellite | Moderate | Moderate | $500,000 |
| 32 | 2005 | Stone, G. Hutt, A. Duignan, P. et al. 2005. Hector's Dolphin (Cephalorhynchus hectori hectori) Satellite Tagging, Health and Genetic Assessment. Submitted to the Department of Conservation (DOC), Auckland Conservancy. 1 June 2005. 77 p. | Research - tagging | Hector's dolphins | Bolt-on, satellite | Moderate | High | $100,000 - 300,000 |
| 39 | 1998 | Stone, G. Hutt, A et al. 1998. Respiration and Movement of Hector's Dolphin from Suction-cup VHF Radio Tag Telemetry Data. Journal of Marine Technology Society 32: 89-93 | Research - tagging | Hector's dolphins | Suction cup, VHF | Moderate | Moderate | $100,000 - 300,000 |

Of the 26 references for which rigor could be assessed (e.g. review and other non-experimental studies were excluded), only 7 (27%) were estimated to have moderate or high rigor. This low number is perhaps directly linked to three main issues:

1. Sample size — Tagging studies can be very expensive to undertake and therefore, it is often challenging for tagging research to achieve large sample sizes. Small sample sizes can limit the value of a study's findings as it is unclear if the results are likely to be representative of the wider population, while levels of uncertainty are often very large or not even possible to estimate. Most of the tagging studies (e.g. > 75%) considered had a sample size of less than 20 individuals. However, there are some notable exceptions. Andrews et al. (2015) reported on 307 tag deployments of LIMPET tags over a ten-year period focused on eight different cetacean species with an average number of species of almost 40 individuals. The size of this programme is unusual and was likely possible as the authors are the developers and manufacturers of these tags (i.e. they likely had access to these tags at lower than normal commercial rates). Overall, it appears that sample size considerations in tagging studies are more driven by budget limitations than experimental design considerations.
2. Sample selection — Most studies do not sample a representative cross section of the population due to limited sample sizes, and in some cases limited access to a full cross-section of individuals. McIntyre (2014) identifies that over 70% of reviewed tagging studies were undertaken on adult age classes and were heavily biased towards females. While this does not limit the applicability of the collected data to the group of individuals that were sampled, it does mean that these data often cannot be extrapolated to other age and sex classes, which can be significantly different ecologically.
3. Complex metadata — Analysis of spatial tracking and other tagging data can be statistically complex and computationally demanding. As computing power and statistical analysis methods have improved over time, more robust use of tagging data can be undertaken allowing for more sophisticated and comprehensive analyses of tagging data.

We noted that very few of the references clearly stated a hypothesis as to what biological or ecological questions were being tested. Instead, many studies seemed to be more exploratory in nature (i.e. a desire to just get some tags out and see what would happen). While there is nothing inherently wrong with this approach if there is little or no impact on the animal, it can lead to poorly designed studies and less robust results. This observation is likely related to McIntyre's (2014) discussion around a noted paucity of tagging research with explicit conservation and/or management implications despite most references claiming that the research was to actually to address such a need (i.e. researchers state that the research is to meet a conservation or management need, but it actually doesn't).

Given that dolphin tagging is rarely undertaken, any data that come out of a tagging research programme are likely to be novel, new, and publishable regardless of the quality of the research. However, it is possible that this may have led researchers into complacency and therefore, they didn’t spend enough time developing hypotheses, carefully thinking about issues such as experimental design, analysis methods, optimal sampling strategies and sample size considerations and, perhaps most importantly, whether the research has actual conservation and management benefits.

### *3.1.2. Tag efficacy*

While there are many ways to measure efficacy, the definition used in this review was an assessment of the length of attachment duration weighted by the potential or likely level of impact on the tagged animal. As with scientific rigor, this is a relatively subjective measure but is useful in identifying those references that are likely to be highly informative, but with little impact to the individual.

Of the 19 references able to be assessed, 11 (58%) were scored as being of moderate or high efficacy. It is also important to note that while these studies were assessed as being ‘successful’, some still had significant caveats or uncertainties associated with their work, which makes it challenging to determine whether a result was actually robust. It is difficult to quantify the impact of many of these caveats. While a report’s results may appear positive, they may retain some fundamental issues that make the conclusions uncertain (see the following section for a list of caveats and uncertainties identified).

One issue that arose while assessing efficacy of the various studies was the influence that the two main tag attachment methods, sub-dermal anchors and suction cups, had on this definition of efficacy. Specifically, anchors had a longer attachment time but with a higher impact, whereas suction cups had a shorter attachment time but with a considerably lower impact on some species. As a result of this relationship, it was more difficult to reliably identify less or more effective tagging studies due to the strong influence of attachment type.

### *3.1.3. Caveats and uncertainties in methods*

Given the wide breath and scope of the literature as well as the inherent challenges in undertaking tagging studies, it is no surprise that a range of caveats and limitations were identified. The key message is that all of these issues need to be considered in the development of any future tagging project. While these issues do not necessarily invalidate the results found in all cases, they do make it more difficult to provide definitive conclusions to inform decision-making. We have suggested an evaluation framework to that consider these issues in Section 3.5.

A complete list of all caveats and uncertainties identified by reference are available in the full electronic table of results file. Some of the key issues are listed below:

- inadequate description of methods and results
- inappropriate use of analysis methods (e.g. lack of independence of data, autocorrelation, pseudo-replication)
- too small sample sizes to detect a statistically meaningful result (e.g. low statistical power)
- lack of a control in studies (i.e. how representative of normal behaviour is the behaviour of a tagged individual?)
- poor representativeness of tagged animals across whole population (e.g. selection bias based on age, sex, location, behaviour)
- lack of a consistent application of an experimental approach including random elements to design
- inappropriate pooling of results across locations and individuals
- lack of testing of seasonal and/or different behavioural states (e.g. breeding, migratory, feeding)
- poor follow up studies of tagged individuals to investigate potential short, medium, or long-term impacts
- accuracy of locational information inappropriate to the research question (e.g. variability in the accuracy of a location fix is greater than size of the area being investigated)
- lack of independent oversight and reporting of tagging studies' impacts on animals
- exclusion of some individuals from analyses as seen as outliers or exhibited unusual/unexpected behaviour
- little monitoring of other covariates that could be useful as explanatory variables (e.g. oceanographic features, behaviours relating to breeding, migration, reproductive status)
- poor reporting of 'failures' (e.g. tags that didn't transmit or collect data, attachments methods that failed, etc.)
- open sharing of data on tag development limited (e.g. proprietary tags mean experiences [positive or negative] are not shared with the research community).



## 3.2. Review of dolphin tagging research in New Zealand

While marine mammal tagging has been used widely around the world, there have only been a few projects in New Zealand over the last 40 years. Six New Zealand-based dolphin tagging projects have been reported in the literature and are summarised in Table 1. In addition to these dolphin projects, four whale tagging projects have been undertaken in New Zealand water and / or whales (e.g. Childerhouse et al. 2010 – southern right whales; Constantine et al. 2015 – Bryde's whales; Goetz et al. 2018 – blue whales; Reikkola et al. 2018 – humpback whales).

The first tagging research on dolphins in New Zealand was aimed at investigating the distribution and abundance of Hector's dolphins in the Marlborough Sounds region between 1978 and 1982 (Baker 1983; Cawthorn 1988). There are few details of this research provided in the published material, but additional information was provided in email correspondence from Dr A. Baker (to S. Childerhouse) in 2004 (Appendix A). The project involved pinning individually numbered tags to the dorsal fin. A tail grab was used to capture dolphins and a cradle to lift them onto the vessel. Dolphins settled quickly after capture, sat in the cradle quietly during the 3–4 minutes of attachment, and often reappeared after release and starting bow riding. There were resightings of 9 individuals, mostly over 1–3 months after capture, with one resighting after two years and another after nearly five years.

Würsig et al. (1991) and Cipriano (1992) tracked ten individual dusky dolphins at Kaikoura during the winter of 1984 and spring-summer of 1987–88. The tags were pinned to the dorsal fin and had radio transmitters attached to describe movement and diving behaviour. Data show movements around Kaikoura (and as far north as Cape Palliser at the southwest tip of North Island) as well as providing information on dive times and locations.

Stone et al. (1998) tagged nine free-swimming Hector's dolphins with suction cup tags containing radio transmitters at Akaroa. The aim was to describe movements and behaviour. Movement data showed that dolphins spent time in Akaroa Harbour before moving out in the late afternoon or evening and then returning the next morning. Respiration rate data were also collected. These data supported previous studies which described a diurnal pattern of movement for this species. Respiration rates and parameters were also provided.

Table 2. Summary of New Zealand dolphin tagging studies reported in the literature.

| Reference | Species | Tag type | Research question | Attachment method | Attachment type | Sample size |
|---|---|---|---|---|---|---|
| Baker (1983) & Cawthorn (1988) | Hector's dolphins | Individual ID number | Distribution, abundance | Live capture | Pinned to dorsal fin | 23 |
| Würsig (1991) & Cipriano (1992) | Dusky dolphins | VHF transmitter | Distribution, dive behaviour | Live capture | Pinned to dorsal fin | 10 |
| Stone et al. (1998) | Hector's dolphins | VHF transmitter | Distribution | Free swimming | Suction cup on flank | 9 |
| Schneider et al. (1998) | Bottlenose dolphins | Dive recorder & VHF transmitter | Dive behaviour | Free swimming | Suction cup on flank | 5 |
| Stone et al. (2005) | Hector's dolphins | Satellite transmitter | Distribution | Live capture | Pinned to dorsal fin | 3 |
| Pearson et al. (2017, 2019) | Dusky dolphins | Satellite & VHF transmitter, camera | Dive & social behaviour | Free swimming | Suction cup on flank | 8 |

Schneider et al. (1998) tagged five bottlenose dolphins in Doubtful Sound in 1995. The tags were attached with a suction cup to free-swimming dolphins. The tag included a radio transmitter and time-depth recorder to describe movement, dive, and other behaviours. The tagging was relatively unsuccessful with little dive or movement data collected as dolphins showed strong reactions to the attachment of the tag and generally swum rapidly and/or leapt until the tag dislodged.

Stone et al. (2005) tagged three Hector’s dolphins with satellite transmitters to describe movement data at Banks Peninsula in 2004. Dolphins were captured and tags were pinned to the dorsal fin. All three satellite tags transmitted for more than three months providing information on movements and distribution. The authors concluded that Hector’s dolphin was a suitable candidate for satellite telemetry studies and that the risk to this species from capture, handling and tagging seems to be low.

Mattlin and Murdoch (2010)[2] describe an approved and funded project to undertake satellite tracking of Hector’s dolphins at Cloudy and Clifford bays to investigate overlap with potential threats, but the project was never undertaken.

Pearson et al. (2017, 2019) tagged eight free swimming dusky dolphin at Kaikoura using a suction cup tag to research movement and social behaviour in 2015. Data collected included dive and social behaviour, prey, and physiology.

[2] Reference: NIWA website accessed at https://niwa.co.nz/publications/wa/water-atmosphere-1-july-2010/balancing-act-for-hector%E2%80%99s-dolphins

While not directly relevant to this project, it is useful to note that there is regular and widespread use of tags for the tracking and research of other many other kinds of marine wildlife in New Zealand including seabirds, turtles, penguins, seals, sea lions, fish and sharks. In many cases, the basic tag technology used for these species is the same general design as for dolphins, although the attachment mechanisms vary significantly. In addition, there is considerable overlap in analytical methods between all these species as fundamentally the data collected by tags are the same, irrespective of the species the tags are placed on.

## 3.3. Comparison of different tagging methods

### *3.3.1. Tag instrumentation*

There is a large variety of tag types available and these have been grouped into similar types to simplify assessment. Table 3 (e.g. tags providing location data) and Table 4 (e.g. tags providing data other than location data) provide summaries of the different kinds of tags reported in the literature. In addition, there are short descriptions of the common use of each tag type plus advantages and disadvantages. The data presented in these tables come from a summary of all the literature reviewed with several key references providing useful summaries of different tag types (e.g. McIntyre 2014; Carter et al. 2016; Nowachek et al. 2016; Andrews et al. 2019).
The type of tag that is optimal for a research project will be strongly driven by the research question; therefore, there is no such thing as a best tag. It is essential that prior to any research project, a clear and concise research question or hypothesis is developed so that the different available tag types can be evaluated to assess which will best meet the research needs. While the research question will be the primary driver for the choice of optimal tag, the choice will also be influenced by many other factors including:

- what level of animal impact is considered acceptable?
- temporal and spatial coverage required to address the research question
- existing data that may already be available
- available expertise
- social license (critically including iwi perspectives)
- availability of devices (e.g. some are commercially available and others only available through collaborations with designers/manufacturers)
- locational coverage (e.g. Argos, GPS-GSM, VHF)
- cost.

There are a range of possible research questions relevant to Hector's dolphin conservation and management that tagging could address, but these decision-making processes must be undertaken comprehensively, addressing the factors above, to ensure that the appropriate tag choice(s) is made.

A wide range of tag providers offer a huge variety of tags and attachment mechanisms. The list below includes commercial suppliers (who sell to the public) and also research organisations (who may not sell to the public but often collaborate on projects). It is important to review and compare many different providers and tag models before settling on the most appropriate model. Tag suppliers include:

- Starr-Oddi Marine Device Manufacturing: http://www.star-oddi.com/
- Sonotronics Underwater Ultrasonic Tracking Equipment: http://www.sonotronics.com/
- Wildlife Computers: http://www.wildlifecomputers.com/
- Microwave Telemetry Inc. Bird and Fish Tracking Transmitters: http://www.microwavetelemetry.com/
- Sirtrack Wildlife Tracking Solutions: http://www.sirtrack.com/
- Lotek Fish and Wildlife Monitoring Systems: http://www.lotek.com/
- Vemco underwater acoustic telemetry transmitters and receivers: http://www.vemco.com/index.php
- Sea Mammal Research Unit: http://www.smru.st-and.ac.uk/
- Cefas Technology Ltd (CTL): http://www.cefastechnology.co.uk.

Table 3. Summary of types of tags providing location information reported in the literature.

| Device | Example tag models | Location derivation | Data transmission | Common applications | Typical battery duration | Approx. Weight (g) | Advantages | Disadvantages |
|---|---|---|---|---|---|---|---|---|
| Radio tag | Mariner Radar (early studies); Advanced Telemetry Systems MM100 series | Very High Frequency (VHF) or Ultra high Frequency (UHF) | Acoustic telemetry; radio signal (VHF/UHF) | Early pinniped studies; short range studies; relocation for data logger recovery | 6-12 months | 80-200 (early studies; 30) | Smaller & lighter than Argos/GPS units. No need to retrieve. Can be used to re-encounter specific individuals on a colony for recovery of archival devices | Device must be in line-of sight range of base station(s) and/or mobile receiver(s) to record locations. Signal can be interrupted by terrain. |
| GPS logger | SIRtrack F1G | Fastloc GPS | Archival | Mainly individuals with restricted ranges (e.g. lactating females otariids during pup provisioning) | 3 weeks to 6 months | 215 | Fast and accurate location estimates. Lighter than telemetry units. Salt-water switch turns the tag off when the animal dives/ hauls out to extend battery life. | Must be recovered to extract data, therefore often needs to be deployed in conjunction with VHF transmitter to facilitate re-encounter on the colony. Study limited to specific timescales (e.g. premoult, breeding females) |
| Argos relay tags | SMRU 9000x SRDL; Wildlife Computers Mk10 SPLASH Tag; Telonics ST-10 PTT | Argos | Argos | Very widely used. Long range pelagic pinnipeds in remote locations | 12 months | 370 | Can integrate other sensors such as wet-dry, CTD, or accelerometer. Useful in remote areas where no GSM coverage available. Complete data record can be retrieved if tag recovered. | Not all locations & dives transmitted. Data often patchy due to interrupted transmissions. Location estimates can carry high spatial error. Fine-scale reconstruction of movement not possible. Argos coverage poor in areas closer to equator. |
| GPS relay tags | SMRU GPS SRDL; Wildlife Computers Mk10 SPLASH tag | Fastloc GPS | Argos | individuals in remote locations with non GSM coverage or prospect of device retrieval | 3-6 months | 370 | As Argos relay tag (above). Solar powered option for extended battery life. Fast and accurate location estimates across most of the globe. Can integrate TDR. | Not all locations & dives transmitted. Data often patchy due to interrupted transmissions. Argos coverage poor in areas closer to equator. entering GSM range data are lost. |
| GPS-GSM tags | SMRU GPS Phone tag | Fastloc GPS | GSM (FTP/SMS) | Pinnipeds in non-remote locations (with GSM coverage) | 1-12 months | 370 | Many power options including solar panel. All dives and locations can be transmitted. Fast and accurate location estimates across most of the globe. | Individual must enter GSM range in order to transmit data (time lag in data retrieval). Not useful in remote locations. If tag detached at sea before entering GSM range data are lost. |
| GLS/SPOT tags | Wildlife Computers TDR-Mk9 | Solar geolocation | Archival | Fish, birds, turtles, penguins | 8 years | 5-120 | Very small and with an extremely long battery life. Can log detailed foraging behaviour over long term. Cost effective. | Locational accuracy can be relatively poor. Must be recovered to retrieve data. Doesn't work in places without day/night cycle (i.e. polar regions). Limited data types collected. |
| Pop up tags | Wildlife Computers PAT tags | Geolocation | Archival until tag released when data is transmitted | Fish, turtles | 2 years | 60 | Archives data over long periods which is transmitted when tag is released and floats to surface. Cost effective. | Locational accuracy can be relatively poor. Doesn't work in places without day/night cycle (i.e. polar regions). Limited types of data collected. |

Table 4. Summary of types of tags providing information other than location data reported in the literature.

| Device | Examples | Description of data collected | Common applications | Advantages | Disadvantages |
|---|---|---|---|---|---|
| Time-Depth recorders | Wildlife Computers Mk9, Mk 10; Little Leonardo ORI400-D3GT | Depth (pressure), temperature | Widespread application across a range of marine species for diving studies | Cost effective. Simple. Advanced and robust technology with long development history. Satellite linked models available (but only data summaries available) | Limited covariate data collected. Collection of high quality data can require recapture/recovery of tag. |
| CTD tags | SMRU CTD SRDL | Conductivity, temperature depth, fluorescence | Regularly used on elephant seals for oceanographic research | Long term duration with high quality data. Satellite linked models available (but only data summaries available) | Large units for deployment on large animals only. Collection of high quality data can require recapture/recovery of tag. |
| Magnetometer & Accelerometer tags | Wildlife Computers TDR10; Little Leonardo GPL400-D3GT, ORI400-PD3GTC | Depth, 3D movement data | Fine scale movement data from seals and penguins | High resolution diving and movement data. | Requires recapture/recovery of the unit to access data. Relatively short term (limited by memory) |
| Camera tags | Customised VC-VISS; Little Leonardo DVL1300M-VD3GT | Video, acoustic | Video data from whales, seals, and dolphins to investigate dive & social behaviour, prey | Visual record of behaviour and activity. Can attached with other tags to provide full record of diving. | Can be limited by low light levels (e.g. deep water) or murky water. Moderate term (limited by battery and memory). Generally small field of view and limited range of video. |
| Active acoustic tags | Vemco V16-6x-L | None | Commonly used on teleosts and elasmobranchs to record presence/absence at recording stations) | Low cost (although it is necessary to have receiving stations to collect data). Can integrate with receiving stations from other projects to achieve high levels of coverage. Small units and easy to attach. Long term operations. | No data on movements away from receiving stations. No other data than position. Introduces addition noise into the ocean. Tag may make the animal more detectable by prey and/or predators. |
| Passive acoustic tags | Acousonde 3A; AquaSound AUSOMS-mini | Acoustic | Recording of animal and ambient acoustic data | Full record of sound around the animal including vocalisations, heart rate, and fin beats. Can be used to measure and identify ambient & anthropogenic noise in the ocean. | Can be limited by background noise levels (e.g. water flow noise). Moderate term (limited by memory). |
| Physiological tags | Acousonde 3A; FirstBeat Technologies HR | Range of biologging data: Heart rate, stomach temp, Jaw movement | Monitoring of physiology of seals | Provides insight into physiological of free ranging individuals. Wide range of data possible to be collected. | Can be difficult to attach and keep operational. Can be invasive to an individual. |
| Multi-sensor high-resolution acoustic recording tags (MHARTs) | SMRU DTAG; CATS CAM; UQ Z-tag | Combination of various data identified above | Deployed on larger species for general ecological studies | Can provide integrated data from many sensors in one unit. | Generally larger units that cannot be deployed on smaller animals. Large amount of data and energy drain leads to short deployment times |

### *3.3.2. Tag attachment methods*

A major limitation in the use of biologging instruments on cetaceans has been attachment techniques (Hooker & Baird 2001). The additional difficulties in locating and attaching devices to exclusively aquatic marine mammals (compared with marine mammals that haul out on land) explains the high proportion of tagging studies for seals compared with cetaceans (McIntyre 2014).

Current attachment techniques for cetaceans include the use of stainless steel barbs designed to penetrate the blubber of study animals (e.g. Minimikawa et al. 2007; Andrews et al. 2008) or potentially less-invasive suction-cups for shorter-term deployments (e.g. Amano & Yoshioka 2003; O'Malley Miller et al. 2010). Scientists generally rely on either capturing smaller cetaceans (e.g. Lydersen et al. 2002) or remotely deploying instruments using tagging poles (e.g. Davis et al. 2007), cross-bows (e.g. Mate et al. 2011), firearms (e.g. Tyack et al. 2011) or air guns (Heide-Jørgensen et al. 2001).

While not strictly related to attachment type, the capture of a dolphin may be required to attach a tag. Although capture-release techniques in general involve greater risk to animals and to people than remote tagging techniques that do not involve restraint and handling, for some cetacean species of smaller body size or whose behaviour does not allow for remote tagging, capture-release may be the more effective option (Andrews et al. 2019). Responses to capture vary by species, and risks must be weighed carefully against the benefits of tagging. One added advantage of capture is that there are additional data that can be collected to provide useful background, context, and information. It goes without saying that these opportunities should be maximised as long as the collection of these data does not unduly extend the length of the capture.

However, there have been some mortalities and injuries from captures reported overseas. Specifically, seven finless porpoises died during captures in China (Wang Ding et al. 2000), one bottlenose dolphin died from 133 captures in the United States (Odell & Asper 1990), one Heaviside's dolphin died from 24 captures in South Africa (Meyer 1997) and there is documented damage to dorsal fins from attachment procedure on bottlenose dolphins in the United States (Mazzarella et al. 2002). While these studies only highlight some of the potential risks from captures, it has not been possible to accurately assess the mortality risk any further as little information is available in the published literature about the number of deaths as a function of sample size.

Whereas the practicality, effectiveness, and safety of available attachment techniques for cetaceans remains a challenge, the increasing number of tagging publications for Odontoceti and Mysticeti suggest that these limitations are being overcome (McIntyre 2014). The range of potential attachment mechanisms are summarised in Table 5. A description of the attachment type is provided as well as a brief summary of advantages and disadvantages of each method. A visual representation of some of the main tag attachment methods is shown in Figure 1.

### *3.3.3. Attachment tag methods on Hector's dolphins*

There have been two Hector's dolphin tagging projects in New Zealand, one of which have used the bolt-on method (Stone et al. 2005) and other used the suction cup method (Stone et al. 1998), respectively. Both these methods have been demonstrated to be effective at attaching tags to Hector's dolphins, albeit with significantly different attachment durations.

In Stone et al. (2005), the authors provide some detailed descriptions and observations about the tagging undertaken using the bolt-on method for three Hector's dolphins. This attachment method would require the capture of dolphins to attach a tag. Stone et al. (2005) concluded that Hector's dolphin was a suitable candidate for satellite telemetry studies and that the risk to this species from capture, handling and tagging seems to be low based on their experience with capturing three Hector's dolphins. Stone et al. (2005) is also a good example of the additional data that can be collected from a dolphin capture, including skin and blood samples for genetic and health testing, ultrasound for assessment of pregnancy and blubber thickness, body measurements, basic physiological information (e.g. heart rate, breathing rate, blood pressure), and bacteria, virus and hormone screening.

The only other attachment method that may be appropriate for Hector's dolphins is the anchored method whereby a tag with short anchors is attached to a Hector's dolphin via a pole or fired from a crossbow. While this method has not been trialled on Hector's dolphins, it has been used on more than 20 other species of cetaceans, including harbour porpoise, which are slightly larger than Hector's dolphins (see Andrews et al. 2015). This method generally supports smaller tag sizes (and therefore fewer electronics) but tag retention sits somewhere between the other two methods at approximately 1 to 3 months.

As discussed previously, the optimal attachment will be a function of the size of instruments required to answer the research question of interest, the longevity of attachment required, and the level of impact that is considered acceptable.



## 3.4. Methods other than tagging

It is important that a range of potential methods are considered when determining the best approach to address a research question as all methods come with various advantages and disadvantages. While the focus of this review has been on electronic tagging, it is useful to briefly consider other methods that may be able to answer the same or similar questions to tagging. There is considerable experience and demonstrated success with the use of line transect surveys by both vessels (Dawson et al. 2004) and aircraft (MacKenzie & Clement 2014) in providing detailed information about Hector's dolphins abundance and distribution. Long-term photo-identification research has also been conducted on Hector's dolphins providing important insights into biologically survival and reproductive rates (Gormley et al. 2014). In addition to these methods, there are also other methods that have the potential to answer research questions about Hector's dolphins. Some of these are discussed briefly in the following sections.

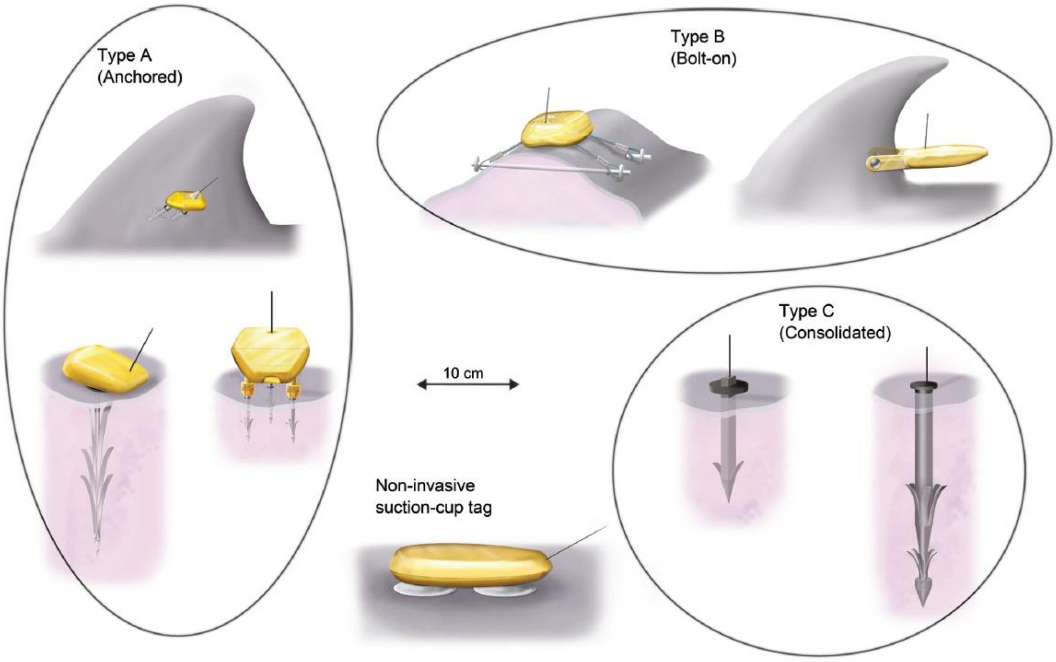


Figure 1. Illustrations of non-invasive (i.e. no break in the skin) and invasive (i.e. break the skin) attachment techniques. Four methods are presented: Anchored, Bolt-on, Consolidated, Suction cup. Reproduced from figure 3 in Andrews et al. (2019).

Table 5. Summary of attachment types for tags as reported in the literature. Based on data provided in Andrews et al. (2019) and other relevant references.

| Attachment type | Invasive? | Description | Deployment method | Examples | Deployment time | Advantages | Disadvantages |
|---|---|---|---|---|---|---|---|
| Anchored | Invasive | Anchored tags have the electronics package external to the skin, attached by one or more anchors that puncture and terminate below the skin. The anchors, often solid shafts with retention barbs or petals, are designed to terminate in the internal tissue of the dorsal fin or in dermal or hypodermal tissue along the dorsum. | Anchored tags are usually deployed using remote-attachment methods that do not require restraint of the animal, such as projection from a crossbow or air-gun, or placement with a pole. | Commonly used on a wide range of cetaceans including small and large dolphins, killer whales, and large whales . | 1-3+ months | Remotely deployed with relatively high success rate. Well tested on a wide range of cetaceans. Small size limits the electronics that can be included in the tag. | Relatively short tag longevity. Challenging to use with small dolphins due to size and strength of dorsal fin able to hold tag. Increased drag due to external placement. |
| Bolt on | Invasive | Bolt-on tags have external electronics and one or more piercing anchors. An element of the tag is attached to the external end(s) of one or more 'bolts' that pierce tissue, creating a tunnel around the bolt with an entry and exit site (like a human earring or a pinniped flipper tag); e.g., single-point dolphin tags that trail behind a v-shaped piece that is 'bolted' to the dorsal fin, or the three-pin design with the tag bolted on one side and a flat plate held on the opposite side. Another example of a bolt-on design is sometimes called a 'spider-legs' tag, where the tag sits as a saddle over or near the dorsal ridge, connected via cables to piercing pins, rods or bolts. | Creating the hole for the bolt currently requires capture and restraint of the animal, and manual contact with the skin. | Used for small and medium dolphins and beluga. | 6-12+ months | Relatively long transmission time and high success rate once attached. Little movement in tag after release. | Require the capture of an animal to attach the tag. Challenges in identifying optimal location to place pins to avoid blood vessels. Increased drag due to external placement. |
| Consolidated | Invasive | The electronics and retention elements are consolidated into a single implanted anchor. The electronics are typically inside a metal case, usually a cylinder, designed to be partially implanted in the body, with only a small part of the top of the tag and antenna and/or sensors projecting above the skin. Retention barbs, or petals, are connected directly to the implanted package. Puncture of the skin typically occurs on the body or the base of the dorsal fin (not the central part of the dorsal fin), and the distal end of the tag sometimes terminates internally to the muscle/blubber interface. | Application of these tags does not require restraint and they are deployed with remote methods. | Used on large whales with a thick blubber layer. | 3-6+ months | Tag is a single unit that sits internal to the animal with only the aerial external. Low drag and little chance of damage or being knocked off. Remote deployment. | Although most tags with implanted parts are likely to be fully shed within a few months, there are reports of implanted tags or parts of tags that have been retained within the tissue of cetaceans for many years. Possible internal muscle shearing during locomotion leads to injuries and tags sites can show persistent regional swellings or depressions. |
| Harness | Non-invasive | Tags are attached using a harness fitted securely to the animal. The harness generally fits around the body (e.g. the dorsal and/or pectoral fins). | Attaching the harness requires capture and restraint of the animal, and manual contact with the skin. | Not used much anymore on marine mammals except for captive studies. Used in birds and turtles. | 1-3 months | Once individual captured harness easily put out and later removed. Nothing left (e.g. holes or scars) on individual when harness removed. | Harnesses that encircle the body can impose significant drag loads, an increased risk of entanglement and lead to skin chafing. Therefore, the use of harnesses is not recommended with free-ranging cetaceans. |
| Peduncle belts | Non-invasive | A collar is fitted around the peduncle of the tail and the tag is suspended from the collar. The tag is free floating on a long tether and dragged behind the animal so the tag can reach the surface and transmit. | Attaching the harness requires capture and restraint of the animal, and manual contact with the skin. | Only used for dugong and manatees. | 3-6 months | Quick and easy to attach once individual captured. Relatively high transmission rate. | Peduncle belts are still experimental but placing an object on part of the body that moves as much as the caudal peduncle presents obvious challenges that have yet to be resolved, including the potential for altering the biomechanics of swimming and/or skin chafing. Potential risk of entanglement from tether. |

| Attachment type | Invasive? | Description | Deployment method | Examples | Deployment time | Advantages | Disadvantages |
|---|---|---|---|---|---|---|---|
| Suction cups | Non-invasive | While any tag configuration can be used these are generally archival tags with a radio or satellite transmitter to recover the tag. A tag is attached to the animal by either passive or active suction using one or more suction cups on the tag body. The tag can be programmed to release at a certain time so it can be recovered, and the data downloaded. | Suction cup tags are usually deployed using remote-attachment methods that do not require restraint of the animal, such as projection from a crossbow or air-gun, or placement with a pole. | Used on a wide range of cetaceans including small and large dolphins, killer whales, and large whales | Hours to days | Can be remotely deployed and doesn't break the skin. No impact to the animal and nothing left on animal once the tag comes off. Benign attachment mechanism. | excessive vacuum pressure can cause complications such as blistering or hematomas below the cup (Shorter et al., 2014). A suction cup that does not cause significant discomfort is also likely to reduce the possibility that the tagged animal will intentionally remove the tag. relatively high drag from large external tag. |

### 3.4.1. Acoustic research

Acoustic research is an area of significant growth in marine mammals with the increasing sophistication and decreasing cost of acoustic recorders (Nowachek et al. 2016). A range of acoustic research has been undertaken on Hector's and Māui dolphins over the last 30 years, the majority of which has been reported in the last 10 years (e.g. Dawson 1991;, Rayment et al. 2009, 2010; Tregenza et al. 2016; Leunisson et al. 2019; Nelson & Radford 2019). The major strength of acoustic research is that long-term monitoring can be undertaken relatively cheaply with the placement of acoustic recorders at sites of interest. While the effective detection range of Hector's dolphins is likely to only be a few hundred metres around a recorder, it does allow for the systematic collection of data. For an example of applied acoustic research, Nelson and Radford (2019) estimated the usage patterns of Māui dolphins from acoustic loggers and recorders suggesting that these dolphins are routinely found outside of protected areas on the west coast of the North Island. Some of the limitations of acoustic monitoring are that detection ranges can be limited to very short range, recording instruments can be lost to trawling, or other activities and background noise levels can mask dolphin vocalisations.

### 3.4.2. Unmanned aerial systems

Unmanned aerial systems (UAS or drones) are becoming more commonly used for marine mammal research. From surveys for population assessment (Torres et al. 2005) to the use of aerial systems to observe behaviour (Nowacek et al. 2001) and photogrammetry (Dawson et al. 2017), the benefits of viewing marine mammals from aerial platforms have been reported for many years. Currently most reasonably priced UAS are somewhat limited in flight time, although increasing battery power and rapid advances in charging technology are likely to increase these flight times in the near future. The advantages of UAS are that they can be rapidly deployed and provide an insight into dolphin behaviour without any disturbance. Larger UAS can be used for systematic survey work to investigate distribution and movements. A recent UAS project by MĀUI63 is investigating Māui dolphin distribution using artificial intelligence (AI) techniques to analyse and distinguish video footage of Māui and Hector's dolphins from other species with over 90% accuracy (Farrell 2019; WWF 2019)[3]. If the efficient use of UAS becomes possible, then it reduces the need for manned aerial surveys, which uses considerable resources and also carries inherent human risks.

### 3.4.3. Biopsy research

For several decades now, molecular ecology has been using biopsies or other skin samples to understand and investigate a wide range of marine mammal questions including such things as population structure and size, systematics, diet, individual identification, and kinship. Biopsy samples can be easily collected from free swimming

[3] Article downloaded from: https://www.wwf.org.nz/?16501/INTRODUCING-MISSION-POSSIBLE

Hector's and Māui dolphins with little or no impact. The combined collection of these samples over time allows provides considerable power to detect individual and population level changes. At present, the only way to distinguish a Hector's from a Māui dolphin is through molecular discrimination and therefore it is a fundamental part of research on these species (Hamner et al. 2014a). Perhaps more importantly, genotype capture-recapture estimates are now used as the primary means of estimating the population size of Māui dolphins (Hamner et al. 2014b; Baker et al. 2016). The advantages of biopsy sampling and molecular analysis allows for the long-term monitoring of individuals allowing a range of additional questions to be answered.

#### *3.4.4. eDNA*

Non-lethal genetic sampling for identification of cetaceans at sea can be challenging and resource intensive (Baker et al. 2018). Advances in analyses of environmental (e)DNA now offer an alternative for detection and identification of rare, cryptic, or vulnerable cetacean species. As eDNA is relatively new, the methodology for eDNA sampling is advancing rapidly as the number and range of applications increases. While there are still challenges in replicating lab trials in the field, Baker et al. (2018) confirmed the potential to detect eDNA in the wake of killer whales for up to 2 h, despite movement of the water mass by several kilometres due to tidal currents. eDNA trials are presently being undertaken for Māui dolphin by the University of Auckland (R. Constantine, pers. comm.). The attraction of the technique is that if detection sensitivities can be increased, then it may be possible to detect dolphins from background water samples without the need for biopsy sampling or even seeing them. This could provide a valuable insight into individual movements and home range of particularly rare species, such as Māui dolphins.

## 3.5. Summary of best practice considerations

There were some common themes to those tagging studies that had a moderate or high degree of scientific rigor. In essence, many of these are the polar opposites of the caveats and biases that were identified as poor studies as outlined in Section 3.1.3. Some of the best practice approaches from these more scientifically rigorous studies include the following components:

- clear and transparently defined research questions followed by a comprehensive evaluation of pros and cons of various tagging and other methods to address them. Also, clear articulation of any other relevant issues or standards that must be considered (e.g. animal welfare, iwi input and views). If these two items are clearly and well laid out, then the decision-making process is made more transparent and the methodological outcome justifiable.
- strong experimental design including use of appropriate controls (e.g. quantifying any differences in behaviour between tagged and untagged dolphins)

- identification of how the tagging data will be used including what analytical methods will be used. Evaluation of whether these methods will be able to answer the research questions (e.g. variability in the accuracy of a location fix is greater than size of the area being investigated)
- large sample sizes sufficient to address the research question robustly
- consideration and monitoring of a range of potential explanatory variables, e.g. CTD tags, and fixing variables such as. age, sex, area, behavioural state wherever possible
- formal necropsies of any individuals which died during or after tagging
- ideally, multi-year and multi-regional studies to investigate temporal variation
- calculation of statistical power for results to aid in accurate interpretation of any significant (and non-significant) results
- clear instructions, communication and training provided to all parties involved in the trials to ensure experimental designs are implemented accurately
- inclusion of a detailed and structured follow up study of tagged dolphins to ensure any long-term effects are understood as part of the main study. This is frequently overlooked in tagging studies and should be an integral part of any study and can actually end up costing more than the main tagging programme itself.
- well-funded; tagging programmes are generally expensive to undertake. In addition, there should be a requirement for adequate funding for follow up studies of tagged individuals included in the budget.
- well-developed consultation process with iwi and the public prior to tagging being approved followed by good communication of results. Communication Plan essential.
- improved reporting of "failures" (e.g. tags that didn't transmit or collect data, attachments methods that failed)
- clear agreement for the open sharing of data on tag development limited (e.g. the use of proprietary tags often means experiences (e.g. positive and negative) are not shared with the wider research community)
- genuine independent oversight of tagging operations. Generally, only pro-tagging people are involved which can lead to biased and inaccurate reporting
- capture and tagging operations videoed so process can be shared with different groups (e.g. Animal Ethic Committee, iwi).
- tagging can represent a risk to dolphins and therefore the most experienced research team possible should be brought together including bringing international experts to New Zealand to lead and/or train local personnel.

There are also some best practice guidelines and standards that should be carefully considered in addition to New Zealand regulatory requirements (e.g. Marine Mammal Protection Act permit, Animal Ethics Approval):

- The Society for Marine Mammalogy has published the Guidelines for the Treatment of Marine Mammals in Field Research (Gales et al. 2009) that scientists contemplating tagging of cetaceans should follow.
- Two recent documents have provided best practice recommendations for the use of tags with pinnipeds; one for implanted tags (Horning et al. 2017) and one for external tags (Horning et al. 2019). While these are for pinnipeds, many of the issues are the same for dolphin tagging.
- Andrews et al. (2019) produced the Best Practice Guidelines for Cetacean Tagging, which represent an excellent guide from tagging practitioners. They also provide a suggested approach to guide decision process for those considering a cetacean tagging study (Figure 2).

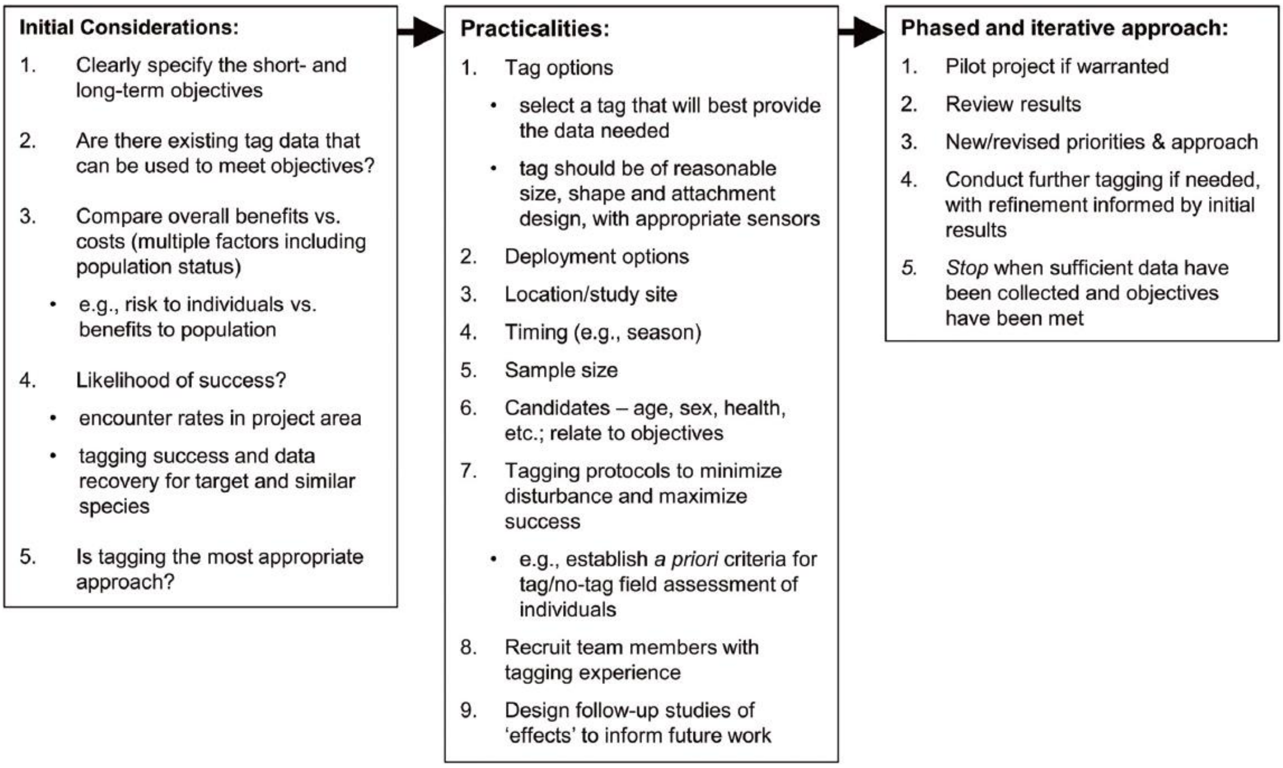


Figure 2. Recommended approach to guide decision process for those considering a cetacean tagging study. Reproduced from figure 2 in Andrews et al. (2019).

## 3.6. Research costings

It is extremely difficult to provide reliable costings for tagging projects given the considerable variation in the scope, nature, and extent of a trial. However, it is possible to summarise what was found in the literature review although many references did not provide costings and so it was necessary to estimate them.

As a general rule, robust tagging studies are likely to be very expensive (e.g. 47% of studies were between NZD$100,000 and NZD$1,000,000) due to the large sample sizes that are likely to be required to achieve robust, statistically significant results. In general, the majority of costs in such a study are split between (i) tag purchase and satellite time and (ii) field research costs including vessel time and personnel. There are some tagging projects that were estimated to cost less than NZD$100,000 but these are generally projects with very low sample sizes.

Also, while the costs of the field programme are normally the focus of the budget, it is also important to consider and include the development costs of the research programme. There is likely to be considerable costs associate with pre-field work planning, analysis, permitting public consultation and stakeholder engagement prior to the project even being approved. If this is a government-led process, then these costs may be able to be absorbed by the agency leading the work but if it is being led privately, then these costs should be factored in. While same costs are likely to relevant to any research project, it is likely that a Hector's dolphin tagging programme will generate more than normal levels of work given the public profile of these dolphins.

It is unhelpful to speculate about what a tagging programme may cost without knowing the research question under consideration. However, what is clear is that there are range of research projects that range in scale from small strictly experimental projects to large scale projects with a multi-year and multi-regional focus. While there were some small scale field experiments which were undertaken for less than $100,000 and which provided useful data, these were generally limited in their applicability due to small sample sizes.

## 3.7. Other considerations

### *3.7.1. Cultural and social science considerations*

The use of electronic tagging (e.g. acoustic, archival and satellite telemetry) to study the behaviour and ecology of marine animals has increased dramatically over the past decade. As scientists continue to use these tools, it is inevitable that other researchers and the public will either encounter animals carrying such tags or become aware about them through media and/or social media with increasing frequency. If the animals appear adversely affected or injured by the tag (e.g. showing signs of trauma), then this information has the potential to generate conflict with various wildlife stakeholders (e.g. tourists/operators, divers, fishers, hunters) that can negatively affect existing and future research efforts and potentially undermine conservation work. Yet, the sharing of this information also presents an excellent opportunity to advance the field of biotelemetry by improving animal welfare, tagging technology and practices, while also gaining the trust and support of stakeholders through effective communication about the tagging research (Hammerschlag et al. 2014).

Māui and Hector's dolphins have an extremely high public profile in New Zealand and are routinely the subject of media attention. There are various stakeholder groups that regularly use Māui and Hector's dolphins in conservation advertising campaigns raising the profile further. In addition, Māui and Hector's dolphins are taonga species for many iwi, hapu and other New Zealanders. They are also formally listed in the Ngai Tahu Deed of Settlement. Formal and open consultation with iwi partners of the Crown will form a key part of any discussions around future research programmes for this species and in particular, the use of dolphin tagging methods.

Social science considerations are important with any research but are particularly relevant to studies that involve potential injury or mortality of animals. While the public would welcome any new data that contributes to the improved conservation and management of Hector's dolphins, a reasonable proportion are likely to be opposed to any research project that could or does lead to injuries or death of dolphins. While the different tagging and attachment systems pose different risks to dolphins, each system will need to be assessed on its relative merits with any decisions, in part, coming down to value judgements rather than strictly empirical factors. This may be a challenging process and therefore it is important that the assessment process evaluating any proposed tagging project must have a strong and up-front component of not only technical decisions but also public and iwi consultation. Furthermore, any experiments or research projects will require permits (e.g. Marine Mammal Research Permit) and approvals (e.g. Animal Ethics) of which public input is a key component further highlighting that a social license to operate will be essential.

Careful consideration of the potential implications from any tagging projects will be necessary to ensure stakeholders, the public and iwi are all aware of the proposals and implications. Given the potential for possible injuries or mortalities, it underpins the strong need for a structured approach to any evaluation process with a thorough consideration of risks and benefits prior to any decision being made. Finally, there will need to be a media and consultation plan in place to support any trials, although the existing DOC CSP and / or FNZ AWEG process may be appropriate processes to consult about any trials, noting that this focus of these groups is primarily technical.



#### *3.7.2. Animal welfare considerations*

While there can be significant scientific and conservation benefits of tagging cetaceans, there can also be negative effects on individuals. Therefore, prior to any decision to use tags, researchers should weigh the positive and negative factors to determine if tagging is scientifically and ethically justified (Andrews et al. 2019). All methods available to address identified research questions (including thorough examination of existing data) should be evaluated prior to the decision to use tags to ensure that the data required can best be provided by these instruments. Andrews et al. (2019) provide a guide that can be used when considering a cetacean tagging project with a flow chart of an example decision process (Figure 2).

While there are regulatory requirements for animal welfare in New Zealand (e.g. Animal Welfare Act 1999) that cover tagging projects, there are also a range of other ethical and welfare issues that, while not necessarily being regulated for, are important to consider. Andrews et al. (2019) provide some excellent recommendations for evaluating ethical and legal considerations for tagging projects that are outlined below: Through following these steps, it will be possible to robustly assess the risks and benefits of a tagging programme and reach a sound decision.

1. Determine if tagging is appropriate
    a. Consider alternative methods for addressing research questions
    b. Review relevant existing data for the species and area of consideration
    c. Ensure that there is a scientific or conservation justification for obtaining new data and that those data are best provided by tags
2. Follow best practices of research design
    a. Develop the research plan with animal welfare as a high priority.
    b. Evaluate equipment options and choose the instrument and attachment that provide the data needed
    c. As much as possible, ascertain required samples sizes and statistical approaches in advance, obtaining expert advice if needed
    d. Tag the fewest number of individuals necessary in the least invasive and unimpactful manner possible to achieve the project goals
3. Prepare adequately for field work
    a. Conduct a thorough risk assessment in advance
    b. Prepare for unexpected risks to the safety of animals and humans.
    c. Ensure the capture/tagging team is trained in the safe and proper procedures for boat approaches (and capture-release techniques if required) and use of tagging equipment
4. Comply with all applicable local, national, and international legal requirements
5. Obtain review and approval by an animal ethics committee, even if not locally required
6. Reach out to stakeholders, including those with subsistence, cultural and economic interests in the study subjects, by:
    a. sharing research goals and soliciting input
    b. coordinating during planning
    c. communicating results throughout and at the completion of the study

One of the key conclusions of the literature review that is echoed by other work (i.e. McIntyre 2014; Andrews et al. 2019) is that there were very few research projects that included explicit aims to address instrument and/or instrument deployment influences on the study animals and/or the marine environment. The need for more studies assessing device impacts has also been recognised by other authors (Wilson and McMahon 2006; Hart and Hyrenbach 2009; McMahon et al. 2011). Godfrey and Bryan (2003) reported, from an analysis of radio-tracking papers of various taxa, that only 4.5% of mammal studies (including terrestrial mammals) explicitly assessed tag effects on study animals. Interestingly, 61% of these studies reported substantial tagging effects, thereby further illustrating the need for more information on potential tagging impacts. McMahon et al. (2011) summarised potential negative effects of biologging devices either in association with capture (e.g. stress, anaesthesia side-effects, etc.), device types (e.g. inducing drag, attracting predators, etc.), attachment method (e.g. generation of excessive heat by glues) or timing / duration of attachment (which may have an influence during breeding seasons, etc.). Nevertheless, whereas some assessments have shown no consequences of instrument attachment in terms of long-term survival (e.g. McMahon et al. 2008), the results of this review illustrate a paucity of studies quantifying the influences of biologging devices on the energetics, fitness and survival of free-ranging animals that are used to carry instruments. This field of investigation, therefore, apparently remains an important one that requires more focus in order to ensure the ethical use of biologging instruments.

It is also worth mentioning that most[4] of the tagging studies considered had approved animal welfare/ethic permits which means they must have had some degree of independent consideration of animal welfare. While, animal ethic committees are deemed to be independent, they are generally only provided with information from the applicants (e.g. presumably pro-tagging researchers) and therefore rely on the balanced presentation of information. There are examples of when this has not been the case. A potential indication of this is the Godfrey and Bryan (2003) study, where only 4.5% of studies explicitly assessed tag effects on study animals. This suggests that ethics committees were convinced that the tags wouldn't have any significant effects on animals and therefore didn't require investigation of tag effects. Despite Godfrey and Bryan (2003) finding that 61% of studies that investigated tagging effects found substantial tagging impacts. An improvement in the evaluation of potential controversial tagging programmes, would be if animal ethics committees were able to receive advice independent of the applicant which may aid in the thorough investigation of applications.

Finally, while animal welfare is defined under the Animal Welfare Act 1999, it is important to be aware that welfare (and animal suffering) is not strictly an objective measure and that any assessment will include a high degree of personal opinion and subjectivity. There are also likely to be a range of differing cultural values that need to be considered. In essence, while animal welfare considerations may seem simple to address and, in fact researchers may be convinced that they have addressed them, it is important to consider the wider picture and ensure that all perspectives have at least been considered.



[4] not all studies stated whether they had one or not

## 3.8. Pros and cons of tagging

Table 3, Table 4, and Table 5 all identify specific advantages and disadvantages of the different types of tags and attachment methods. While there are various pros and cons of the many possible combinations, the relative importance of each pro or con is directly related to the research question under consideration. For example, the benefits of sub-dermal anchors and suction cups are to a large degree dependent on the type and length data of interest (i.e. daily behaviours vs seasonal distribution movements). Specifically, anchors have a longer attachment time but a potential for higher impact on the animal. Suction cups have a shorter attachment time but with a lower impact for some species. Obviously these two issues are rarely considered in isolation of each other (and other considerations). Therefore, it is essential that any study clearly articulates the project objectives so that informed decisions can be made about how to balance and weigh potentially competing issues.

## 3.9. Risk assessment

A risk assessment should form part of the assessment and evaluation process undertaken for any potential tagging project. As with animal welfare considerations, any risk assessment needs to be undertaken within the context of a research question so risks can be quantified and assessed relative to the project needs. Without a research question, it is not useful to assess risk other than at the highest level, which is unlikely to be useful given the large trade offs in relative between issues (e.g. tag retention vs. animal welfare vs. sample size vs. cost).

# 4. SYNTHESIS AND CONCLUSIONS

Previous tagging research programmes of Hector's dolphins have demonstrated that tagging can aid in investigating important aspects of their biology and ecology (Stone et al. 1998, 2005), which is also supported by many international tagging programmes on other cetacean species. While both these New Zealand studies had relatively small sample sizes, the researchers concluded that Hector's dolphin were a suitable candidate for satellite telemetry studies and that the risk to this species from capture, handling and tagging seems to be low. Unfortunately, neither of these projects included a comprehensive follow-up research programme and so there was little information available from which to assess any potential short or longer term impacts on the tagged animals.

## 4.1. Research areas that can be addressed by tagging

As outlined in Table 3 and Table 4, there are a wide range of data types that can be collected from tagging projects. Given the range of data types, there is an equally diverse range of research questions that could be investigated. Table 6 identifies several general research areas related to fine-scale distribution, diving and foraging behaviour of Hector's dolphins and provides recommendations of the tagging methods that can best address these research areas.

It is important that the research areas identified in Table 6 are carefully evaluated against specific research questions. While the tagging methods identified can provide useful data in addressing these research areas, the development and specification of any research programme is extremely complex. As previously discussed, it will be necessary to consider a wide range of issues well prior to confirming that the method can deliver against a specific research question. These include issues such as sample size, animal welfare, cost, and considerations of accuracy and precision but, just as important, is the consideration of the public and iwi views.

Notwithstanding these issues, tagging has the potential to address a wide range of important Hector's dolphin conservation and management related questions.

## 4.2. Conclusions

There are a wide variety of tag types and attachment methods, all of which have different advantages and disadvantages, and can be used to answer a diverse range of potential research questions. While Table 6 provides recommendations about the best tagging method to address each area of research, it is not possible to determine the optimal tagging programme unless there is a specific research question and the relative weighting of potential competing considerations (e.g. tag retention vs. animal welfare vs. sample size vs. cost) are stated. Nevertheless, as a general rule, the more invasive (e.g. higher impact on an individual) a tag is, the higher quality and quantity of data that it produces.

The assessment of any proposed tagging programme should follow a strict evaluation process. This process should follow international best practice which is the decision-making approach described in Andrews et al. (2019). This will ensure that any tagging programme is carefully assessed against issues such as welfare considerations, likelihood of delivering a robust result for the research question of interest, stakeholder and iwi consultation and consideration of alternative methods.

Table 6. Summary of Hector's dolphin research questions that could be addressed by electronic tags.

| **Potential research areas** | **Recommended tag types** | **Tagging comments** | **Other possible methods** |
|---|---|---|---|
| ***Distribution*** | | | |
| Individual dolphin movement & home range | Satellite - Argos or GPS | Depending on the desired data resolution, tagging could use bolt-on (long term) or suction cup (short term) attachment techniques.<br><br>GPS tags provide a much higher level of location accuracy than Argos tags and are therefore preferred but can have shorter battery life.<br><br>Active acoustic tags could also be used but would require setting up receiving stations in key locations. | Aerial (aircraft or drone) or vessel surveys.<br><br>Acoustic monitoring stations.<br><br>Photo-identification or biopsy sampling for tracking of individual dolphins |
| Seasonal & regional differences in home range | | | |
| Offshore distribution | | | |
| Proportion of time spent outside protected areas | | | |
| Use of harbours | | | |
| Spatial and temporal overlap with fishing | | | |
| ***Diving & foraging*** | | | |
| Characterising dive behaviour (e.g. depth, time, velocity) | TDR | Depending on the desired data resolution, tagging could use bolt-on (long term) or suction cup (short term) attachment techniques.<br><br>Physiological tags are likely to require additional sensors (e.g. jaw, head, heart) to the main tag.<br><br>Multi-sensor tags could be used which could integrate various tag types into a single tag to collect a range of this data.<br><br>Tags could be archival (data logging) in which case they would need to be recovered or transmitting where data summaries are remotely broadcast. | Behavioural focal follows from drones, boats or nearshore elevated cliffs.<br><br>Various diet study methods on tissue, faeces and / or stomach samples |
| 3D dive behaviour | Magnetometer/Accelerometer | | |
| Identification of prey & feeding | Camera | | |
| Diving physiology (e.g. heart rate, energetics) | Physiological tags | | |
| Characterising marine foraging environment | CTD tags | | |

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# 7. APPENDICES

Appendix 1. Details of Hector's dolphin tagging research undertaken between 1978 and 1984 by Dr. A Baker.

Details of Alan Baker's Hector's dolphin tagging programme conducted between 1978 and 1984 with quotes from an email sent to Simon Childerhouse dated 17 December 2003.

*The study area was Cloudy Bay Marlborough, and my base was Whekenui in Tory Channel. I had a skipper and 2 crew. The route was down the coast to Fighting Bay, and from there a grid search across Cloudy bay to the White Bluffs. I worked from January 1978 to April 1984, mostly in spring/summer/autumn. I did make a few trips in mid-winter, but basically the weather was not with me. I operated under a permit from the Minister of Fisheries.*

*Between 1978 and 1982, I caught 27 Hector's and tagged 23. Of the remaining 4, 3 had natural markings which I considered OK for resighting purposes, and 1 dolphin was released untagged because I was unhappy about the way it was behaving alongside the boat.*

*The dolphins were caught from the bow using a rubber padded stainless steel tail grab on a long detachable pole (the boat also had a bow pulpit). The grab was designed by Rod Abel, former manager of Marineland of NZ at Napier, and by then Director of Ocean Park at Hong Kong. Rod's son Grant came as crew on several occasions and instructed me in the use of the grab. There is a knack to it, and it was not necessary to use much force to apply the grab as it was quite sensitive. We had our share of misses though. The grab was attached to a rope which included a bungee spring, the length of which was the exact distance from the bowsprit to the cockpit.*

*When a dolphin presented its tail appropriately while bow wave-riding, the grab was placed over the tailstock and a trigger at the base of the grab was activated closing it around the tailstock. The boat accelerated forward and to port as the dolphin swam off to starboard pulling on the bungee and swinging around towards the boat's stern. Within a few seconds the dolphin was in position alongside the cockpit and the boat was stopped and two crew reached over and stroked the animal and spoke to it while a canvass cradle was being manoeuvred underneath. Once this was in place, a derrick was attached to the cradle and the dolphin lifted out and placed athwart ships across the cockpit (see photo on p118 of the 1983 edition of my guide book - the one with right whale and calf on the cover). There it was examined, photographed, measured, weighed, and an Allfex tag applied to the posterior part of the dorsal fin. The tags were about the size of a 10 cent coin, colour-coded and stamped with a number. The tagging gun needle was sterilized in alcohol, and an antibacterial* *ointment was applied. I also tried freeze branding, but the Argon I used was not cold enough for the dolphin skin - it bleached my fingertips though!*

*With the one exception noted above, the dolphins settled down very quickly, usually once they had been handled while still in the water. There was no struggling once the animal had been lifted out - they just sat there in the cradle quietly while we went about our business - about 3-4 minutes worth. One crew was responsible for keeping the dolphin wet and talking to it (that made us feel good anyway!). Once the work was completed, the cradle was up-ended on the port side and the dolphin simply slid off into the sea. Most often the animal took off at high speed circling the boat, but we were amazed to find that once the boat got underway, the tagged dolphins often reappeared at the bow with their mates!*

*Nine tagged dolphins were resighted on following trips, all but one in the general area where they were tagged. The resighting times mostly ranged from 1-3 months, although there was one at 2 years and another almost 5 years later (which was a surprise), and most animals were identified to individuals through the colour code on the tag. One tagged dolphin was sighted from the Fisheries research vessel W.J. Scott in Pegasus Bay. One of the naturally marked dolphins was resighted by me in Queen Charlotte Sound about 60 km away.*

*The tail grab was very carefully engineered, and it went through a number of versions before we felt it was suitable. There were 2 grabs, and I believe they are still extant, in the care of the Perano family in either Blenheim or Picton. If DOC was wanting to see a grab, or even use it, I think I could contact the right people to arrange that. I would not feel confident about using a tail grab after all this time (and my back would not stand it!), so if this programme goes ahead, I would suggest that DOC contract Grant Abel - did you meet him in Japan? I have his address. I would be happy to consult in some form or other of course!*