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ELECTRONIC DEVICES TO ASSESS DISTRIBUTION, DIVING AND FORAGING BEHAVIOUR OF HECTOR'S DOLPHINS

POP2019-01

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BACKGROUND

- Electronic devices = instruments (tags) that can be attached to dolphins to provide a range of different data
- Tags are now forming an important tool in increasing our understanding of dolphins and contributing to improvements in their conservation and m
- Yet, while tags can provide insightful data about dolphins that have previously been difficult or impossible to collect, tagging does present potential risks to tagged individuals.
- 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.

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PROJECT SCOPE

The project has the following main objectives:

1. Delivery of 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.

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LITERATURE REVIEW METHODS

- Standard literature review using online search engines
- List of all references plus assessments of each available as electronic spreadsheet from CSP.
- Wide range of criteria reviewed including:
  - level of scientific rigor
  - level of proven efficacy (i.e. mm and fish capture rates)
  - caveats and uncertainties in methods
  - impacts of tagging on animal health
  - relevance to Māui and Hector's dolphins
  - costs and benefits.

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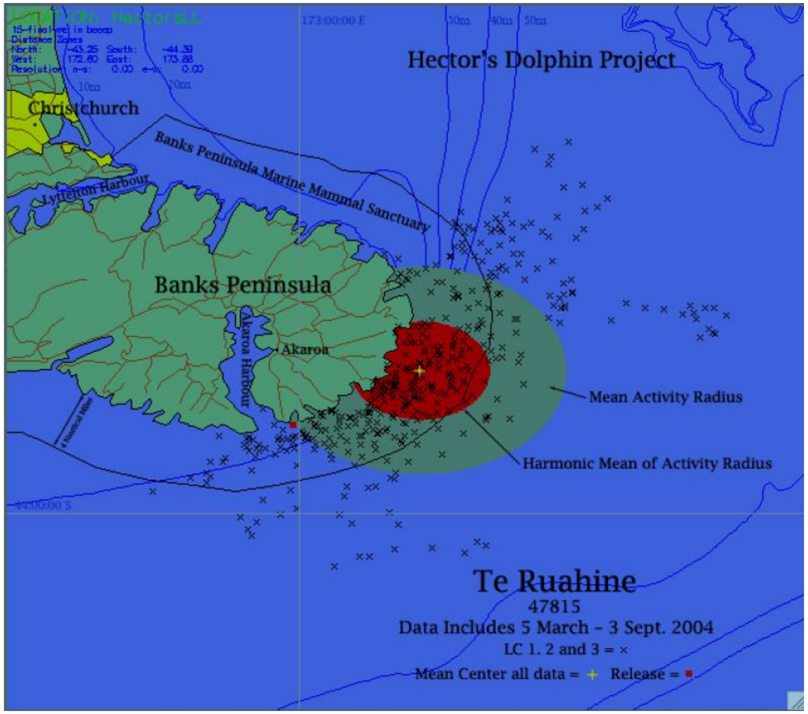
LITERATURE REVIEW RESULTS

- Review identified 36 research papers spanning the period 1972 to 2019 relevant to DDDs. Most (78%) within last 10 years
- Range of material considered: international scientific literature, government agency commissioned reports, conference proceedings, commercial research and results from industry and scientific trials
- Some useful recent review papers identified (e.g. Andrews et al. 2019, McIntyre 2014)



Hector's dolphin satellite tracking data from Stone et al. (2005)

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SCIENTIFIC RIGOR OF STUDIES

- 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.
- 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
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SCIENTIFIC RIGOR OF STUDIES

1. Sample size
2. Sample selection
3. Complex metadata

- Very few of the tagging 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
- McIntyre's (2014) noted a paucity of tagging research with explicit conservation &management implications despite most studies claiming that the research was to actually to address such a need (but failed)
- Given that dolphin tagging is rarely undertaken, any data that come out of a dolphin tagging programme are likely to be novel, new, and publishable regardless of the quality of the research. However, this may have led researchers into complacency

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SUMMARY OF KEY REFERENCES

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	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

REVIEW OF DOLPHIN TAGGING PROJECTS IN NZ

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

A range of other NZ tagging studies reviewed (e.g. whales, seals, etc)

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TYPES OF TAGS – LOCATION DATA

Device	Location derivation	Data transmission	Common applications	Typical battery duration	Approx. Weight (g)	Advantages	Disadvantages
Radio tag	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	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	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	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	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	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	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.

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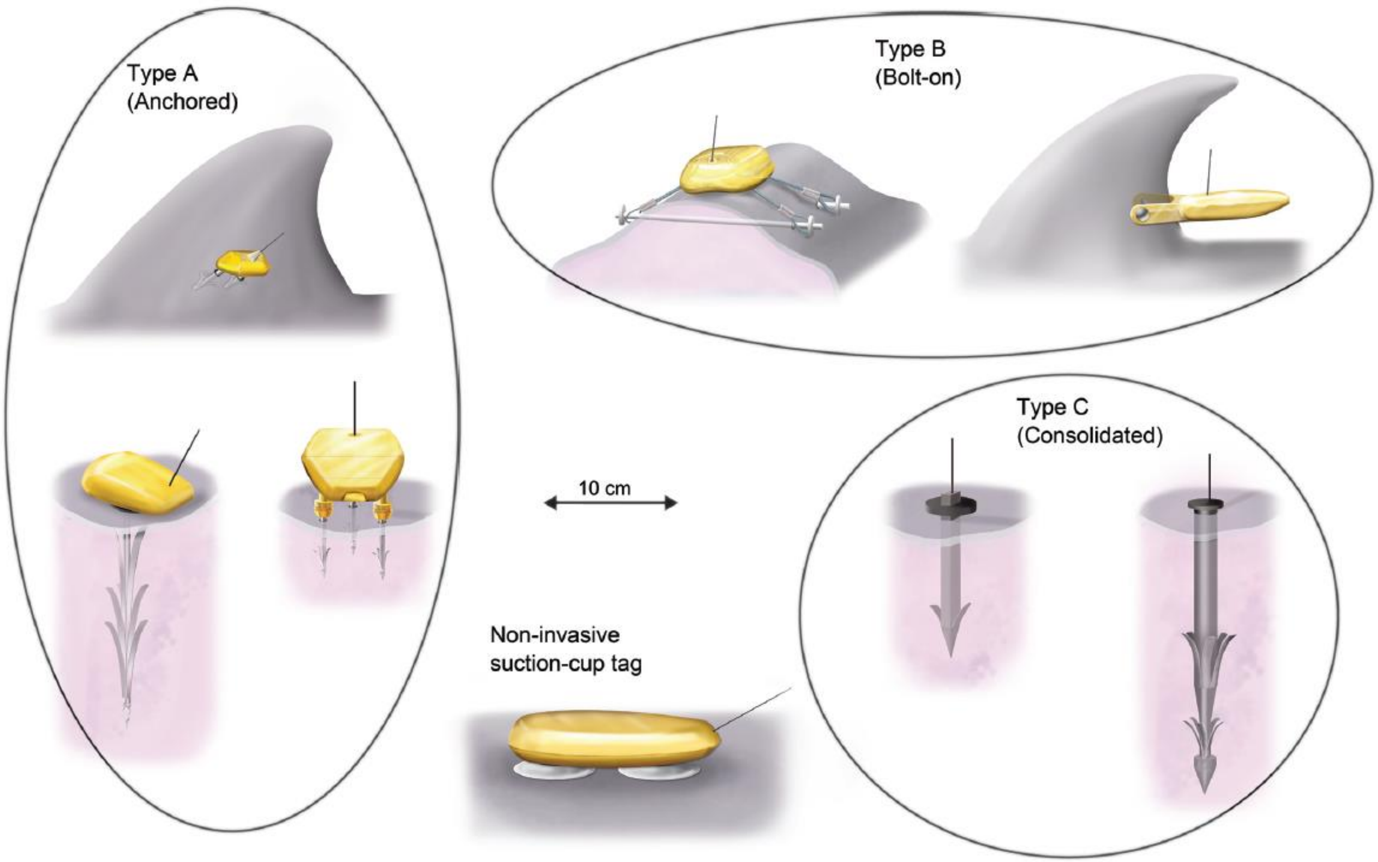
TYPES OF TAGS – DATA OTHER THAN LOCATION



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).

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TYPES OF TAGS – ATTACHMENT TYPE

Attachment type	Invasive?	Deployment method	Examples	Deployment time	Advantages	Disadvantages
Anchored	Invasive	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	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	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	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	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.
Suction cups	Non-invasive	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.

METHODS OTHER THAN TAGGING

Brief summaries of methods other than tagging that could be used to collect behavioural data on Hector's dolphins:

- Acoustic research (Dawson 1991; Rayment et al. 2009, 2010; Tregenza et al. 2016; Leunisson et al. 2019; Nelson & Radford 2019)
- Unmanned aerial vehicles (Farrell 2019; WWF 2019)
- Biopsy research (Hamner et al. 2014a, b)
- eDNA (Baker et al. 2018)

It would be useful to include the potential evaluation of these techniques for research questions related to fine-scale distribution, diving and foraging behaviour of Hector's dolphins

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BEST PRACTICE CONSIDERATIONS FOR TAGGING I

1. clear and transparently defined research questions
2. comprehensive evaluation of pros and cons of various tagging and other methods to address research question
3. clear articulation of any other relevant issues or standards that must be considered (e.g. animal welfare, iwi input and views)
4. strong experimental design including use of appropriate controls (e.g. differences in behaviour between tagged and untagged dolphins)
5. identification of how the tagging data will be used including what analytical methods will be used.
6. 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)
7. improved reporting of “failures” (e.g. tags that didn’t transmit or collect data, attachments methods that failed)

BEST PRACTICE CONSIDERATIONS FOR TAGGING II

8. appropriate sample sizes sufficient to address the research question robustly
9. 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
10. formal necropsies of any individuals which died during or after tagging
11. ideally, multi-year and multi-regional studies to investigate temporal variation
12. calculation of statistical power for results to aid experimental design (a priori), and to provide robust interpretation of significant (and non-significant) results (ad-hoc)
13. clear instructions, communication and training provided to all parties involved in the trials to ensure experimental designs are implemented accurately

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BEST PRACTICE CONSIDERATIONS FOR TAGGING III

14. 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
15. well-funded
16. well-developed consultation process with iwi and the public prior to tagging being approved followed by good communication of results. Communication Plan essential
17. clear agreement for the open sharing of data on tag development limited
18. genuine independent oversight of tagging operations
19. capture and tagging operations videoed so process can be shared with different groups (e.g. Animal Ethic Committee, iwi)
20. 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

BEST PRACTICE CONSIDERATIONS FOR TAGGING IV

- 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 (e.g. Figure 2 of the Draft Report).

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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.
- 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 and these were generally limited in their applicability.

CULTURAL AND SOCIAL SCIENCE CONSIDERATIONS

- Māui and Hector's dolphins have an extremely high public profile in New Zealand and are routinely the subject of media attention
- 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.

CULTURAL AND SOCIAL SCIENCE CONSIDERATIONS

- 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.

ANIMAL WELFARE CONSIDERATIONS I

- 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) provide a guide that can be used when considering a cetacean tagging project with a flow chart of an example decision process (e.g. Figure 2 of the DRAFT Report). In addition, Andrews et al. (2019) provide some excellent recommendations for evaluating ethical and legal considerations for tagging projects (e.g. Section 3.7.2 of the DRAFT Report)
- 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

ANIMAL WELFARE CONSIDERATIONS II

- One of the key conclusions 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.
- 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.
- Most of the tagging studies considered had approved animal welfare/ethic permits. 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.

ANIMAL WELFARE CONSIDERATIONS III

- 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.
- 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.

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RESEARCH THAT COULD BE ADDRESSED BY TAGGING

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. GPS tags provide a much higher level of location accuracy than Argos tags and are therefore preferred but can have shorter battery life. Active acoustic tags could also be used but would require setting up receiving stations in key locations.	Aerial (aircraft or drone) or vessel surveys. Acoustic monitoring stations. 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. Physiological tags are likely to require additional sensors (e.g. jaw, head, heart) to the main tag. Multi-sensor tags could be used which could integrate various tag types into a single tag to collect a range of this data. 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. 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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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.
- 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).