

Australian Marine Mammal Centre Grants Program
Final Report
(subclause 9 and Schedule Item 5 of the Funding Agreement)

**Improving the time series of estimates of dugong abundance
and distribution by incorporating revised availability bias
corrections**

Project No. 13/31

TropWATER Report 15/25

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1. Project Summary

The availability of dugongs for detection by aerial observers is influenced by sighting conditions (e.g. turbidity, and sea state), and dugong diving behaviour, which varies with water depth. Availability Correction Factors have recently been greatly improved by analysing dive records collected from satellite-tracked dugongs using new statistical models. This project has used these improved techniques to reanalyse dugong abundance estimates from archival aerial survey data from Queensland to provide more accurate estimates of dugong population size and spatially-explicit models of dugong distribution and relative density to inform dugong management.

2. The Outcomes and Objectives – Key Findings

List the Project Objectives and address each one, noting the degree to which the objective was achieved through the research and issues that may have hampered its success. Describe the key findings as they relate to the objectives and the management questions identified in the initial application.

The main objective of the project was:

To inform dugong management by providing more accurate information on dugong abundance, population status, distribution, and habitat use by reanalysing dugong sighting data collected from aerial surveys conducted in six regions of northern Australia from 2001-2013 using Availability Correction Factors specific to water depth as well as water turbidity and sea state.

This objective has been achieved by undertaking three tasks:

1. Re-analyse information on dugong abundance and trends
2. Re-analyse spatial models on dugong distribution and relative density
3. Compare the results from individual regions with previous estimates

Results are presented in the attached full report (Appendix 1). The major findings follow:

- We improved the usefulness and validity of archival dugong aerial survey data for management by: (1) developing and using revised Availability Correction Factors that incorporate variations in dugong dive behaviour with bathymetry (referred to as the Hagihara method), to reanalyse archival aerial survey data for dugong abundance and distribution, and (2) using improved statistical and spatial modelling techniques.
- Archival data collected since 2002 from five regions in Australia were re-analysed: Moreton Bay, Hervey Bay, the southern Great Barrier Reef region, the northern Great Barrier Reef region and the Gulf of Carpentaria.

- Dugong population size estimations using the previous standard, the Pollock *et al.* (2006) method were compared with the population estimates using the Hagihara method. Estimated relative dugong densities were analysed using a zero-inflated model with a Negative Binomial distribution. Spatially explicit models of dugong relative density and were developed using the method of Grech and Marsh (2007) and Grech *et al.* (2011) with modifications reflecting (1) the results from the Hagihara method, (2) advances in the methodology (Empirical Bayesian Kriging), and (3) improved accuracy of recording aircraft altitude and GPS locations. The sustainable level of human-related mortalities for dugongs per Region was estimated using the Potential Biological Removal (PBR) method developed by Wade (1998).
- While results varied between regions and survey years, the population estimates obtained using the Hagihara method were generally (but not always) lower than those obtained using the Pollock method. The precision of the estimates tends to be similar using the two methodologies. The chief advantage of the Hagihara method over the Pollock method is the increase in the accuracy of the population estimates. Nevertheless, the Hagihara population estimates should be regarded as standardised relative estimates rather than absolute estimates of dugong population size and density. The method is conservative and the estimates are likely underestimates.
- Cross-regional comparisons of dugong population size and area of high and very high density habitat emphasises the importance of the remote regions of the Gulf of Carpentaria and the northern Great Barrier Reef. The Hervey Bay and Moreton Bay dugong populations are clearly of regional significance. The status of the dugong in the southern Great Barrier Reef Region is an ongoing cause for concern.

We conclude that the Hagihara method and the statistical and spatial modelling methods used in this report should be significant improvements over the previous methodologies used to study dugong distribution and because of their improved accuracy and spatial resolution.

Limitations encountered during the project included:

(1) Some of the older aerial surveys (*e.g.*, Moreton Bay in 2000 and Moreton Bay and Hervey Bay in 2001) could not be included in this report. These surveys did not collect information on the sightings conditions (*e.g.*, water turbidity) for individual dugong sightings in a format that allowed re-analysing the dataset with regards to the revised Availability Correction Factors. This limitation only became apparent when working on the individual archived datasets and could not be foreseen at the beginning of the project.

(2) Dugong population sizes were not re-estimated for the Torres Strait surveys. The bathymetry dependent Availability Correction Factors after Hagihara *et al.* (in prep,

see abstract at Appendix 6 of the attached full project report) are based on dive data collected from 16 dugongs in Moreton Bay and Shoalwater Bay. We consider that dugong diving behaviour in those areas may be very different in Torres Strait. The difference in bathymetric features, underwater community structure and distribution of seagrass are likely to result in different dugong diving behaviour, leading to different availability probabilities. The depth distribution of seagrass – primary food of dugongs - in Torres Strait extends to 40 m (Long and Poiner 1997), and ~55,000 km² of seagrass (38% in Western and 49% in Central Torres Strait) occur in water >10 m deep (Taylor and Rasheed 2011). Dugongs in Torres Strait have been frequently sighted in waters 10 to <25 m deep during aerial surveys since 1987 (Marsh and Saalfeld 1990; Marsh and Lawler 1992; Sobtzick et al. 2014). Satellite tracking of six dugongs in Torres Strait also documented their occurrence in waters up to ~15 m deep in Central and Western Torres Strait (Gredzens et al. 2014). In contrast, seagrass in Moreton Bay mostly occurs in water <10 m deep over shallow banks (Phinn et al. 2008; Lyons et al. 2012), and large numbers of dugongs have been consistently sighted on its shallow banks. In the inshore waters of Moreton Bay, 84 to 100% of satellite locations fixes from four tagged dugongs were obtained from water <10 m deep (Hagihara 2015). Thus the probabilities of dugongs being available to aerial observers are likely to be very different in Torres Strait from the coastal environments analysed in this report.

Funding to quantify the heterogeneous availability bias estimates for Torres Strait has been obtained from TSRA and NESP. We are planning to deploy pop-up satellite time-depth recorders to dugongs in Torres Strait. The pop-up unit does not require recovery and increases the chance of data retrieval (via Argos system). When empirical data on dugong diving behaviour becomes available from Torres Strait we will reanalyse the archival aerial survey data collected from 2002. A reassessment of the status of the dugong in Torres Strait using several lines of evidence including a reanalysis of the time series of aerial survey data collected since 1987 using the Marsh and Sinclair (1989) method, the only method for which all the required data were available for the complete time series is at Appendix 4 of the full report.

For a full list of reference, please refer to the attached full project report.

3. Implications for Management

What are the key recommendations for management based on the findings.

This project has increased our capacity to inform dugong management by providing higher quality information on dugong population status, distribution, and habitat use for: (1) long-term analysis of trends in abundance; (2) modelling the sustainability of anthropogenic mortality from Traditional hunting, incidental fishing mortality and vessel strike; (3) spatial risk assessment of threats to dugongs; (4) systematic conservation planning; and (5) EPBC referral guidelines.

4. Other Benefits

How has this project advanced the field of research? (e.g. scientific discoveries, new methodologies)

The revised population estimation methodology (referred to as the Hagihara method) is applicable to many boat- and aerial-based surveys of aquatic wildlife, especially coastal or riverine species. The technique of using a Secchi Disk that mimics the target species to estimate the different detection zones under specific environmental conditions is potentially transferable to other medium-sized aquatic species residing in turbid waters (e.g., manatees, dolphins, turtles, and sharks). We have already extended the technique to marine turtles and used it to obtain an estimate of the marine turtle population in Torres Strait based on the 2013 dugong survey plus data on green turtle diving behaviour obtained external to the survey (Fuentes *et al.* 2015).

The revised spatially-explicit models of relative dugong distribution and abundance developed in this project are more accurate than the models that use the Grech and Marsh (2007) approach as they account for changes in the availability of dugongs to observers with depth. This approach is also transferrable to other studies (e.g. to marine turtles).

5. Problems Encountered (if any)

This project did not encounter any major problems. The limitations of the dataset (i.e. exclusion of some of the older aerial surveys and the Torres Strait surveys) are explained and discussed above (under Point 2).

6. Communication

How will results be communicated to management

Key stakeholders that were engaged during this project include the Torres Strait Regional Authority (**TSRA**); the North Australian Indigenous Land and Sea Management Alliance (**NAILSMA**); the Department of Parks and Wildlife (**DPAW**) in Western Australia; the Department of Land Resource Management (**DLRM**) in the Northern Territory; the Great Barrier Reef Marine Park Authority (**GBRMPA**); and the Commonwealth Scientific and Industrial Research Organisation (**CSIRO**).

The planned peer-reviewed publications will be circulated to relevant stakeholders via mailing lists and announcements on wider platforms, such as *The Conversation* and the MARMAM list. Communication of the results will also be conducted via face to face briefings, presentations and seminars.

We shall arrange to brief GBRMPA, TSRA and the Qld EPA as soon as possible.

Publications (other than theses and dissertations)

Results from this project were used in the following papers:

Publication:

- (1) Fuentes M.M.P.B., Bell I., Hagihara R., Hamann M., Hazel J., Huth A., Seminoff J.A., Soltzick S., and Marsh H. (2015) Improving in-water estimates of marine turtle abundance by adjusting aerial survey counts for perception and availability biases. *Journal of Experimental Marine Biology and Ecology* **471**: 77–83

Papers close to submission and included as appendices to the main report:

- (2) Marsh, H., Grayson, J., Grech, A., Hagihara, R., and Soltzick, S. Re-evaluation of the sustainability of an Indigenous marine mammal harvest using several lines of evidence. *Biological Conservation*
- (3) Fuentes, MPB, Delean, S., Grayson, J., Lavender, S., Logna, M., and Marsh, H. Spatial and temporal variation in the effects of climatic variables on dugong calf production and neonatal survivorship. *PLOS 1*

Further planned publications:

- (4) Hagihara, R., S. Soltzick, R.E. Jones, L. M. Marsh & H. Marsh. Improving dugong population estimates by accounting for heterogeneous availability bias. *Marine Mammal Science*. (Abstract appended to main report)
- (5) Marsh, H., Soltzick, S., Grech, A., Hagihara, R., and Jones, R. Re-evaluation of the status of dugongs in coastal Queensland waters using improved methodologies. Target journal *Wildlife Research*

7. Project Outputs

A list of the actual outputs of the research including milestones, progress reports and data products such as models etc.	Proposed date of completion	Actual date of completion
Produce progress report	09/14	09/14
Reanalyse information on dugong abundance and trends	02/15	03/15
Reanalyse spatial models on dugong distribution and relative density	03/15	04/15
Compare the results from 6 regions with previous estimates	03/15	04/15
Produce final report	05/15	05/15
Produce and submit publication to high impact Journal(s)	07/15	Two papers are close to submission, the other two will be ready for submission by 07/15

8. Financial Account of the Activity

Include reasons for any variation to the budget, underspends and difficulties	
<p>A financial statement has been forwarded to the AMMC by JCU DTES Grants.</p> <p>Minor variations in the budget include:</p> <p>(1) Revised salary commitments: Salary commitments outlined in the proposal were estimates based on a realistic assessment of the availability of CIs Sobotzick and Hagihara. However, as the project progressed, it became apparent that other Research Assistants (Fuentes, Preston and Kim-Kiatoski) had to be engaged to ensure a timely completion of the project.</p> <p>(2) Revised publication costs: Publication costs for the target high impact journals will be due at the time the paper proofs are received and approved. Although one of the four planned publications is accepted and another is very close to submission, the consultation and reviewing process is expected to potentially exceed the project end date (07/15). Publication costs will therefore be covered with funds outside this project and have been added to the budget as an in-kind contribution.</p>	
Signature of Chief Investigator	
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Date	31 May 2015
Signature of Organisation Representative	
Name	Jasper Taylor
Date	1 June 2015

Please forward 1 hard copy, and one electronic Word document of this report to:

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Appendix 1 – Full project report

‘Improving the time series of estimates of dugong abundance and distribution by incorporating revised availability bias corrections’

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