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

- **Project No**. – (not known)
- **Title** - Broad-scale habitat interactions of pygmy blue whales off southern Australia.
- **Chief Investigator** – Dr Peter Gill
- **Co-Investigators –** Dr Rebecca Pirzl, Dr Margie Morrice, Dr Maria Garcia, Dr Andrew Levings, Dr Paul van Ruth
- **Organisation** – Blue Whale Study Inc.

Table of contents

1. Project Summary

A clear, plain English summary of approximately 500 words outlining the work undertaken and any significant findings (for publication on the Department's web site). Include what was done, why and the key findings resulting in recommendations summarised from the sections below.

We examined upwelling variability in the Bonney Upwelling during upwelling seasons 2001-02 to 2011-12, to investigate patterns at both within-season and across-season temporal scales. We focused on two indices of upwelling: alongshore wind stress or *Intensity* (the upwelling forcing factor); and chlorophyll-*a* (chl-*a*; the biological response of the ocean). We then modelled measures of relative abundance of pygmy blue whales from aerial surveys 2002-14 against upwelling indices, to investigate potential relationships between blue whale occurrence and patterns of upwelling.

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 single stated project objective was: To relate inter-annual abundance of pygmy blue whales to weather and upwelling variability off southern Australia.

Upwelling variability: We were able to describe variability between months and seasons over 11 years, 2001-02 to 2011-12. The 'upwelling season' was defined as November-April. February and to a lesser extent March were peak months for upwelling-favourable forcing events, and also showed the lowest incidence of non-

upwelling-favourable forcing events. Overall, only 37% of wind forcing *Intensity* (cumulative wind forcing per a given period) was upwelling-favourable, with the remainder causing downwelling or relaxation events. There was considerable variability between upwelling seasons, with higher levels of upwelling *Intensity* observed in 2001-02, 2002-03, 2006-07, 2007-08, and 2011-12, with 2006-07 and 2007-08 showing the highest values. The 2005-06 upwelling season showed the lowest *Intensity*, largely due to an anomalous lack of upwelling winds in December 2005. Long events (6+ days) accounted for 58% of overall upwelling *Intensity.*

Chl-*a* by month for upwelling events showed strong peaks in February-March, coinciding with peak intensity. The highest chl-*a* values by month were during non-upwelling events in March. Between years, there were outstanding chl-*a* peaks in 2002-03, 2007-08 and 2009-10. These peaks all occurred within relatively strong upwelling seasons, but showed no direct relationship to upwelling intensity of individual upwelling seasons.

Blue whale relative abundance:

Blue whale encounter rate was highly variable between years. GAMs were used to investigate relationships between encounter rates and the primary upwelling indices above, as well as other variables including SAM and SOI. The relationship between blue whale occurrence and upwelling intensity in our study was not linear, supporting the hypothesis that optimal levels of wind stress (combining upwelling and relaxation events) may maximise biological production. However, a reasonably strong upwelling within a season was positively correlated with blue whale occurrence.

The most significant variables in explaining blue whale occurrence were chlorophyll-*a* (within-season), and the Southern Annular Mode or SAM as well as chl-*a* (between seasons). There were also apparent differences in blue whale occurrence east and west of Portland, reflecting known physiographic differences in shelf and upwelling characteristics, with surface chl-*a* more likely to occur in the west, where blue whales are more likely to feed at the surface.

A major hindrance to understanding of blue whale ecology is the lack of knowledge of *Nyctiphanes australis'* ecology in relation to the upwelling. Using proxies (e.g. chl-*a*) is useful in the absence of krill abundance and distribution data, but future biological oceanographic surveys in the region are necessary to properly understand what is driving blue whale occurrence.

3. Implications for Management

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

The key finding of our work is that blue whale relative abundance, and upwelling variability, are highly variable and unpredictable, given current knowledge. We have shown correlations between upwelling variability (notably chl-*a* and SAM) and blue whale occurrence, but these are complicated by temporal lags in upwelling-related productivity linked to large-scale atmospheric perturbations such as SAM, with an indication that blue whale occurrence may be at least partly determined by the strength of SAM during the previous season. This uncertainty is further complicated by the fact that we are dealing with an open population of blue whales. This means

that the occurrence of blue whales in the Bonney Upwelling is likely to be strongly influenced not only by oceanographic conditions directly affecting the Upwelling, but by conditions across alternative summer aggregation areas (e.g. the Sub-Tropical Convergence, the Perth Canyon or beyond) that may prove more or less attractive to the whales during a given season. The degree of interchange between the BU and the STC, already seen in preliminary tagging work, is evidence of the dynamic and variable nature of blue whale foraging strategies in the region such as this.

4. Other Benefits

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

This project has advanced our understanding of upwelling variability in the region by building on and extending physical oceanographic research conducted previously by others. It has also enabled a comprehensive analysis of blue whale occurrence in the BU over more than a decade. For the first time it has related the occurrence patterns of blue whales to the variability in forcing factors responsible for their presence off southern Australia.

5. Problems Encountered (if any)

Describe any major problems encountered during the Activity and how they were addressed.

The analysis was highly complex, due to the nature of climatic events and climate-ocean coupling, and because the Bonney Upwelling is not a closed ecosystem, with likely frequent movement of blue whales between there and alternate feeding grounds such as the Sub-Tropical Convergence and Perth Canyon. There were also modelling complexities due to spatial and temporal unevenness in blue whale survey data over many years. While these were not problems per se, they made the analysis difficult and time-consuming.

6. Communication

How will results be communicated to management

By this report, and by the publication of our paper.

Stakeholder engagement feedback (plain English for feedback to stakeholders)

We will circulate this publication to as many interested parties as possible.

Students supported (if any)

None

PhD Theses and dissertations (if any)

None

Publications (other than theses and dissertations)

Yes

Planned publications

Blue whale encounter rates related to variability in a coastal upwelling system, submitted to *PlosOne*.

Presentations

Some of the research findings from this project will be presented in a Sprigg Lecture

by PG at the South Australian Museum on 2 June 2015. Findings will also be presented at future scientific conferences.

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
Planning and structuring manuscript	07/14	08/14
Remote sensed data download	08/14	09/14
Calculation of habitat indices	10/14	01/15
Whale distribution analyses and mapping	11/14	02/15
Empirical modelling	01/15	03/15
Draft paper and submission	03/15	05/15
Prepare and upload aerial survey data to OBIS or similar national repository	04/15	05/15
Write Final Report	04/15	05/15

8. Financial Account of the Activity

Include reasons for any variation to the budget, underspends and difficulties
There were no variations to the budget. The financial details of the project are currently being audited by BWS' auditor and will be presented to AMMC when they are available.

Signature of Chief Investigator	
Name	Dr Peter Gill
Date	30 May 2015
Signature of Organisation Representative	
Name	Susie Lyons [NB: Margie Morrice is no longer with BWS, Susie Lyons is BWS Deputy Director and is authorised to sign]
Date	30 May 2015

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