

Attachment for Question 5. (Blue Whale Study Inc. EPBC Permit application 2009)

Description of research

A. research proposal

The following outlines our perceived research priorities and methods for the next three years. The priorities and methods are likely to be relevant for the five-year life of our permit.

1. RESEARCH OBJECTIVES

Our objectives are to:

- Significantly increase our understanding of the population identity, affinities and movements of blue whales in our region, enabling assessment of population status and trends.
- Significantly increase our understanding of blue whale ecology and habitat, and the ways in which blue whales exploit their habitat and prey.
- Assess responses of blue whales to climatic variability including climate change.
- Assess responses of blue whales to human activities so that these activities can be managed optimally with respect to the whales' needs.
- Develop community awareness of blue whales and their habitat through a range of education and participatory monitoring programs.

This research is driven by a number of central questions, detailed below.

1.1. Are blue whales recovering from 20th century whaling exploitation?

Answering this question requires us to establish a population estimate as a starting point to assess growth or decline for whales using the upwelling region. To do this we need to be able to separate actual population change from effects of movement between feeding areas brought about by changes in regional productivity related to large-scale oceanographic variability (e.g. Benson *et al.*, 2002¹). We know from our aerial survey data that blue whales move throughout the large upwelling system between Bass Strait and the Head of the Bight (Gill *et al.*, *in prep.* 1²). The degree of interchange between, or fidelity/residency to individual feeding areas is unknown. It is likely that many blue whales will return to known feeding grounds depending on this regional productivity. Our limited photo-ID mark-recapture data shows that an individual blue whale was resighted in the Bonney Upwelling over a seven-year period, and individuals have been resighted in the same area over periods of weeks, suggesting that if ample food is available whales do not need to move elsewhere (Morrice and Gill, unpublished

¹ Benson, S.R., D.A. Croll, B.B. Marinovic, F.P. Chavez, and J.T. Harvey. 2002. Changes in the cetacean assemblage of a coastal upwelling ecosystem during El Niño 1997-98 and La Niña 1999. *Progress in Oceanography* 54: 279-291.

² Gill P.C., M.G. Morrice, *et al.* In preparation (1). Blue whale distribution patterns and modelling of feeding habitat in a regional upwelling system off south-east Australia, 2002-07 (provisional title).

data; Piatt and Methven, 1992³). At least one blue whale identified in the Perth Canyon was resighted in the Bonney Upwelling, but so far there are no matches in the reverse direction, or with blue whales that move through Geographe Bay south of Perth (Jenner *et al.*, 2008⁴). We also know from our limited satellite tagging data that blue whales move south from the Bonney Upwelling (and from south-west WA) to the STC where Soviet whalers killed many blue whales during the 1960s (Mikhalev, 2000⁵; Gill, 2005⁶). We are developing a project in collaboration with Curt Jenner of the Centre for Whale Research (WA) and Australian Antarctic Division to survey the STC in the next few years using satellite tagging and ecological methods to investigate its probable importance as an alternate feeding ground for 'Australian' blue whales.

Estimating the size of the population and its changing status is extremely difficult without getting a clearer idea of what defines the population genetically and regionally. A preliminary genetic analysis of biopsy samples indicates that pygmy blue whales from the Bonney Upwelling and the Perth Canyon show 'high gene flow', strongly indicating we are dealing with a single genetic 'open' population of pygmy blue whales that forages across southern Australia (LeDuc *et al.* 2008⁷; Attard *et al.*, submitted⁸). Further collaborative work is needed to establish this relationship with more certainty.

We do not know where the blue whales of the Bonney Upwelling breed in winter. They may migrate west across the GAB and up the Western Australian coast to Indonesian waters where our colleague Benjamin Kahn of Apex Environmental studies blue whales in winter. Or they may migrate through Bass Strait and up through the Coral Sea to the Solomon Islands, where many blue whales were sighted in winter 1957 (Ohsumi and Shigemune, 1993⁹), where we conducted an unsuccessful yacht survey in August 2005, but have since received encouraging sightings reports from tourist vessels. Other areas of the south-west Pacific may also be worth investigating. Since blue whales are thought to winter in productive

³ Piatt, J.F. and D.A. Methven. 1992. Threshold foraging behavior of baleen whales. *Marine Ecology Progress Series* 84: 205-210.

⁴ Jenner C., M. Jenner, C. Burton, V. Sturrock, C.S. Kent, M. Morrice, C. Attard, L. Moller and M.C. Double. 2008. Mark recapture analysis of pygmy blue whales from the Perth Canyon, Western Australia 2000-2005. Paper SC/60/SH16 presented to the Scientific Committee of the International Whaling Commission (unpublished).

⁵ Mikhalev, Y.A. 2000. Whaling in the Arabian Sea by the whaling fleets *Slava* and *Sovetskaya Ukraina*. Pp. 141-181 in *Soviet Whaling Data (1949-1979)*, eds A.V. Yablokov and V.A. Zemsky. Center for Russian Environmental Policy, Moscow.

⁶ Gill, P. 2005. Blue whale satellite tagging, Bonney Upwelling, April 2005. Report by Australocetus Research to Department of Environment & Heritage, Canberra.

⁷ LeDuc R.G., A.E. Dizon, M. Goto, L.A. Pastene, H. Kato, S. Nishiwaki, C.A. Leduc and R.L. Brownell. 2008. Patterns of genetic variation in the southern hemisphere blue whales and the use of assignment test to detect mixing on the feeding grounds. *Journal of Cetacean Research and Management* 9: 73-80.

⁸ Attard C., L.B. Beheregaray, C. Jenner, P.C. Gill, N. Kanda, M. Jenner, M. Morrice, J. Bannister, R. LeDuc, L. Möller. Submitted. Genetic structure of blue whales (*Balaenoptera musculus*) in Australian feeding aggregations. *Conservation Genetics*.

⁹ Ohsumi, S. and H. Shigemune. 1993. A sightings survey of larger whales in lower latitudinal waters of the Pacific in austral winter, with special reference to the blue whale. Paper Blue/WP6 presented to the *ad hoc* Steering Group Intersessional Meeting on Research related to Conservation of Large Baleen Whales – Blue Whales – in the Southern Ocean, Tokyo, October (unpublished).

areas where feeding continues through winter, the comparative ecology of these divergent aggregation areas is also of great interest.

Answering these questions can only be possible through continuation of long-term studies, eventually expanding to all the alternate aggregation areas. Our involvement in the Southern Hemisphere Blue Whale Photo-ID Co-operative, established in Cape Town in December 2007 and involving all blue whale researchers in our hemisphere, will allow improved integration of datasets and a better chance of addressing some of these bigger questions.

1.2. What makes good blue whale feeding habitat, and how do blue whales exploit their habitat to maximise feeding success?

The recovery of blue whales is primarily dependent on their ability to secure enough food year-round, and our ability to assess their recovery depends strongly on an understanding of their ecology, both in the upwelling feeding ground and beyond. Blue whales are physically adapted for rapid movement over long distances and their relatively thin blubber suggests that they are heavily reliant not on winter fasting (as do other species with thick blubber), but on constantly replenishing energy stores (Acevedo-Gutiérrez *et al.*, 2002¹⁰). Baleen whales require sufficient 'prey density thresholds' to justify energy expended in foraging and feeding (Piatt and Methven, 1992). This is a delicate balance. If prey thresholds are too low, whales may lose condition and their individual survival, and breeding success including the survival of calves, is compromised. If enough whales are affected the recovery of the species will be compromised.

How do whales know where and when to search for food? What drives their foraging success, and how do we predict good foraging habitat available to the whales? Are some areas of greater overall importance for feeding success, or does this relative importance vary over time? These are questions driving the habitat and foraging ecology aspects of our research. We know that in our region the blue whales move between a range of habitats, such as the Bonney Upwelling front, or the deep waters of the eastern GAB. They also operate at a range of scales to detect and secure their prey (Morrice *et al.*, *in prep.* 1&2^{11,12}). Is our region reliably supporting this population from year to year? Doubts are raised by recent sightings of emaciated and diseased individuals.

Our aerial surveys have shown that the distribution of blue whales changes from day to day, and often from hour to hour. Our small boat work has shown that relative densities of zooplankton in the study area's Central zone vary from day to day at a scale of hundreds of metres (Morrice *et al.*, *in prep.* 1). These are all indicators of how blue whales must follow the 'moveable feast'.

1.3. Can blue whales adapt to climate change?

The upwelling system is subject to natural inter-annual variability in upwelling intensity, shown in Figure 2. This upwelling intensity index (UII) was derived from

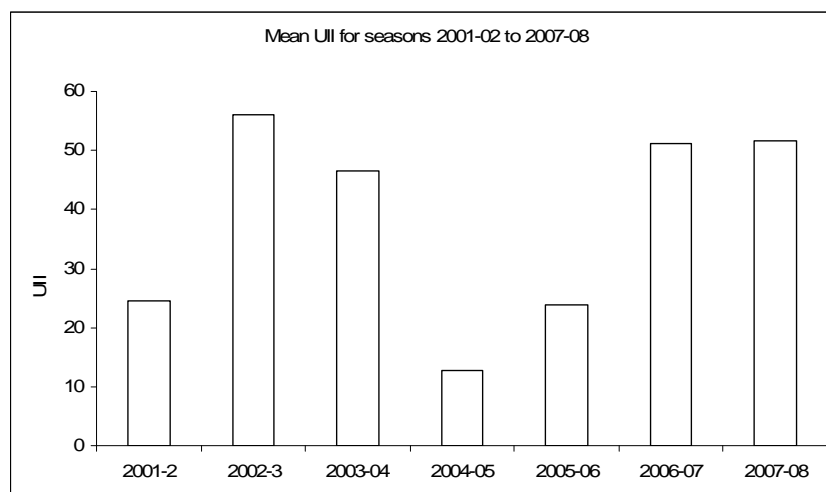
¹⁰ Acevedo-Gutiérrez, A., D. A. Croll and B. R. Tershy. 2002. High feeding costs limit dive time in the largest whales. *The Journal of Experimental Biology* 205: 1747-1753.

¹¹ Morrice, M.G., T. Jarvis, P. Gill. In preparation (1). Blue whale prey patchiness and densities at fine scales off southern Australia.

¹² Morrice, M.G., J. Calambokidis, P. Gill et al. In preparation (2). Foraging behaviour of blue whales in response to a dynamic prey field.

the surface temperature (SST) difference between a cold upwelling centre and a warm offshore reference point (Gill *et al.*, *in prep.* 1). This variability is expected to have significant influences on biological productivity between seasons (see below).

Figure 1. Mean upwelling intensity index (UII) for seven seasons showing variability in upwelling intensity in the Bonney Upwelling (from Gill *et al.*, *in prep.* 1).



Separating effects of climate change from this inherent variability will not be an easy task for oceanographers and biologists, and the degree to which blue whales must adapt to climate change will depend on the nature, extent and rapidity of change. Middleton *et al.* (2007¹³) showed that ENSO events have increased since the early 1980s presumably as a result of climate change, and that these events suppress winter downwelling off southern Australia, promoting enhanced summer upwelling. This suggests that upwelling in the Bonney Upwelling has increased in the last 20-30 years and may be strengthened in future. But as Huntsman and Barber (1977¹⁴) pointed out, strong upwelling off north-west Africa suppressed biological production by not allowing sufficient warm, stable 'relaxation' periods between upwelling events for phytoplankton to bloom. Such a pattern may have occurred in the Bonney Upwelling in the 2006-07 season, with relatively strong upwelling but relatively low numbers of blue whales. So there may be such a thing as 'too much' upwelling, and blue whale numbers may be highest in seasons that have the most favourable balance of upwelling vs relaxation periods (Gill *et al.*, *in prep.* 1).

Long-term datasets are required to unravel these relationships. We are involved in both Victorian and South Australian components of IMOS (a national Integrated Marine Observation Scheme) which aims to address these questions. The combination of temperature loggers and a conductivity/temperature/depth profiler (CTD) is a simple, cheap and effective means of relating climatic variability to thermal stratification patterns in the ocean, giving us valuable insights into upwelling dynamics and contributing to large-scale projects planned by professional oceanographers.

¹³ Middleton, J.F., C. Arthur, P. Van Ruth, T.M. Ward, J. McLean, M. Maltrud, P.Gill, A. Levings and S. Middleton. 2007. El Niño effects and upwelling off South Australia. *Journal of Physical Oceanography* 37(10): 2458-2477.

¹⁴ Huntsman S.A. and R.T. Barber. 1977. Primary production off northwest Africa: the relationship to wind and nutrient conditions. *Deep-Sea Research* 24:25-33.

The modeling of our existing habitat, distribution, behaviour and prey data, as well as data from planned research, will allow us to better make predictions about effects of climate change, and to gain insights into the adaptability of whales to spatial and temporal change.

1.4. How sensitive are blue whales to human activities?

Blue whales in our region share their habitat with human industries including shipping, fishing, oil and gas development as well as new players such as wave generator platforms and whale watching. Effects of shipping (e.g. noise, ship strike) are completely unquantified in our region but a major shipping route passes through the feeding ground. The southern rock lobster fishery occupies the mid-shelf zone that blue whales prefer as feeding habitat, and it and other fisheries pose potential for disturbance and entanglement. Increasing numbers of recreational fishers drawn to the region pose disturbance and collision risks. Vessel- and aircraft-based whale watching has also arrived with potential for disturbance.

Natural gas development has occurred in the blue whale feeding ground for decades. There has been considerable discussion between industry, managers and researchers about the most appropriate ways to manage interactions, with preliminary research effort aimed at quantifying impacts on blue whales. Potential risks are physical damage by airgun impulses (regarded as low, although partial deafness remains a risk), masking of normal communication (probably moderate to high), disturbance and displacement from feeding areas (high at times) and disturbance of prey resulting in reduced feeding success (virtually unknown). Management measures include restricted areas or seasons (or combinations thereof), shipboard MMOs, shutdown ranges, and monitoring methods including passive acoustic monitoring (PAM) and aerial surveys.

Estimates of radius of avoidance of seismic by blue whales have varied from 60km or more (Gill and Morrice, 2003¹⁵) to less than 3km (Morrice *et al.*, 2004¹⁶). This discrepancy is not yet explained although PAM work by McCauley (2004) showed that in mid-shelf waters under certain conditions, airgun acoustic energy may be largely absorbed by the substrate at a range of ~5km. But Morrice *et al.* (2004) point out that at times the only available suitably dense krill swarms may occur within a few km of operating seismic vessels, potentially giving hungry whales no alternative but to remain in a highly ensonified zone, with unknown effects on the whales' hearing or other physiological systems. There is much scope for further analysis of work to date and for experimental study into the interactions of whales with seismic (i.e. controlled exposure experiments, CCE's) regarding which we have been in discussion with CMST (Curtin University) and the Centre for Whale Research (WA).

¹⁵ Gill, P.C. and M.G. Morrice. 2003. Cetacean observations, blue whale compliance aerial surveys, Santos Ltd seismic survey program, VIC/P51 and P52, November –December 2002. Report WEG 01/2003, Whale Ecology Group, Deakin University.

¹⁶ Morrice, M.G., P.C. Gill, J. Hughes and A.H. Levings. 2004. Summary of aerial surveys conducted for the Santos Ltd EPP32 seismic survey, 2-13 December 2003. Report # WEG-SO 02/2004, Whale Ecology Group-Southern Ocean, Deakin University.

2. METHODS

2.1. Recovery research

2.1.1. Population modeling

The BWS has accumulated sufficient data over the last 10 years to begin to develop a model of the population of blue whales that use the Bonney Upwelling extended feeding ground. This would include a population estimate with measures of spatial and temporal variability around it, and clear definitions on the limitations of the model (including potential 'missing' individuals and mixed populations). As discussed above this would need to incorporate models of a 'closed' and 'open' population (see Jenner *et al.*, 2008 for WA population model based on photo-ID and genetics, and Bannister *et al.*, 2006¹⁷ for WA aerial survey data). Data that will be drawn on to achieve this includes aerial (1998-2008) and vessel surveys (2003, 2004, 2007), photo-ID and further genetic analysis, historical whaling data, and climate and productivity dynamics to provide inter-annual context. For example models of predicted densities and distributions (e.g. kernel densities), currently being developed by the BWS in collaboration with SARDI (SA), reflect spatial and temporal distribution patterns of whales within the feeding ground. These models would then provide a basis from which to test future survey data, and to continue assessing the status of the population and predictions of where blue whales would be expected to aggregate – vital for effective management planning.

2.1.2. Continuing long-term dataset on recovery status for blue whales through aerial surveys, photo-ID and genetics programs

The above population model will provide further direction for gaps in the data to reduce variability or better explain variability. Aerial surveys are currently the main source of data on numbers and distribution of whales over the extended study area, and also the most consistent long-term dataset from which to assess change since 1998. They also allow the BWS to monitor changes in the context of ecological response to upwelling variability (see Ecological research below), climate change and recovery from effects of whaling. However due to funding constraints we are only able to conduct opportunistic aerial surveys.

While aerial survey effort in the Central and Eastern zones was consistently good over seasons 2001-02 to 2006-07, effort in the Western zone was limited and patchy. The EPP32 seismic monitoring program in December 2003 found 'new' aggregation areas west and south of Kangaroo Island (Morrice *et al.*, 2004). Blue whales were sighted in the same areas in December 2005, but not in extensive surveys in December 2004 or in March 2005 and March 2006, suggesting that the occurrence of blue whales in the GAB is highly variable.

Preliminary analysis of aerial survey encounter rates from 2002-07 shows that peak months are December-March, with February showing highest overall encounter rates. Aerial survey data also shows trends in movement within the

¹⁷ Bannister J., C.L.K. Burton, S.L. Hedley, M.-N. Jenner, K.C.S. Jenner, and V. Sturrock. 2006. Investigation of blue whales in the Perth Canyon, Western Australia, 2006 – aerial surveys. Final Report, 30 November 2006, on work done under the consultancy service agreement between the Commonwealth of Australia and the Western Australian Museum.

feeding ground within seasons. All this data will be presented in Gill *et al.* (*in prep.* 2¹⁸).

In conjunction with aerial surveys, continued sampling of photo-ID and skin for genetics will allow further evidence of population identity, abundance and dispersal to corroborate with aerial survey and satellite tag data. Particularly, increased effort in sampling individuals for both photo-ID mark-recapture and genetics throughout the study area will allow population estimates to be applied to individual whales, including population identity, fidelity to areas, breeding success of females, and long-range movements to other feeding and breeding areas.

2.1.3. Long range movements of individual blue whales

We are planning projects for the next five years that will investigate blue whale migratory movements to alternate aggregation areas. Satellite tagging using ARGOS tags is the most likely option, following up work begun in April 2005 in collaboration with the AAD (Gill, 2005). At that stage the tags only gave short duration data (max 19 days), so that while we obtained very useful movement data within the BU feeding area, and one exciting record of rapid movement from the BU to the STC, we were unable to follow the whales as they migrated north to wintering grounds. We would like to repeat this work in the next 2-3 years as tagging methodology has improved and significantly longer attachments are anticipated. Such tagging studies should give vital clues to distribution in alternate aggregation areas (including wintering grounds) where we hope to carry out ecological work in future.

2.2. Ecological research

Recovery and ecological research are interlinked as ecology explains spatial and temporal patterns of distribution, as well as behavioural patterns that are crucial to understanding population biology. It also enables predictions of where we might expect to find whales at various times of year.

2.2.1. Habitat modeling

We are currently modelling feeding habitat on the broad (ecosystem) scale, using aerial survey data from 2002-07 and a range of habitat parameters (Gill *et al.*, *in prep.* 2). This paper will identify the most significant habitat types over the three ecological zones of the study area. It will also have a predictive capacity best illustrated by density distribution probabilities based on the aerial survey data. A preliminary view of this data suggests that while certain areas appear more important than others, areas of peak density change from year to year, or even from month to month so that it remains difficult to predict blue whale distribution, as climate-oceanographic-prey linkages are themselves unpredictable. We also intend to combine our broad-scale and fine-scale (from Margie's habitat work) results into an integrated habitat modeling paper.

The BWS plans to continue to collect both remote (satellite) and *in situ* (ocean temperature and salinity via moored and profiling loggers, prey via hydroacoustics and direct sampling) habitat data. In particular, since 2001 we have deployed simple temperature logger systems which record temperature at predetermined intervals at set depths, to show temperature-depth stratification

¹⁸ Gill, P.C., M.G. Morrice, and A.H. Levings. In preparation (2). Seasonal variability in upwelling and blue whale occurrence in a coastal feeding ground off south-east Australia, 2002-2007 (provisional title).

patterns which relate directly to upwelling and so temperature 'triggers' for seasonal ecosystem changes. We currently have a logger deployed SW of Cape Nelson and would like to deploy and retrieve two more loggers at other locations east and west, for comparison of upwelling at different locations. This is a highly cost-effective means of recording upwelling dynamics and of contributing to investigation of large-scale climatic effects on upwelling.

2.2.2. Foraging behaviour and interactions with prey

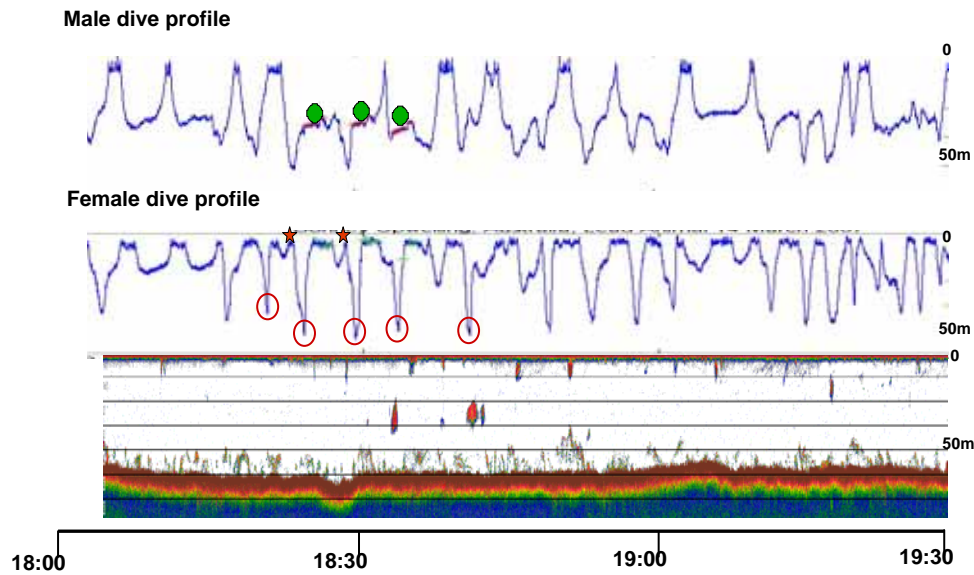
Recent sightings of blue whales in emaciated condition (including in the Bonney Upwelling) raise questions about the vulnerability of the whales to variable (or decreasing) food resources, and the implications of climate change. Given the need to assess longer-term impacts of climate change on diverse ecosystems, a new focus of BWS research will be to compare the plasticity of blue whale foraging and feeding ecology between seasons, and in two geographically widespread feeding grounds, one temperate (the Bonney Upwelling) and the other tropical (the Savu Sea, Indonesia). Given the variability of productivity year to year, and the vastly different oceanographic conditions between feeding regions, the whales' responses to ambient conditions and prey fields may enable predictions about their 'preparedness' for the potential larger effects of climate change.

We have already deployed suction-cup digital tags on seven whales in 2007 in collaboration with Cascadia Research (Morrice *et al.*, 2007¹⁹; Morrice *et al.*, *in prep.* 2). This yielded unique data on fine-scale foraging dive and acoustic behaviour in relation to available swarms of zooplankton detected with real-time hydroacoustic survey, and to concurrent habitat data. Tags deployed on both members of a pair provided the first data worldwide on the coordination of underwater behaviour in blue whale pairs (Figure 4). Acoustic and genetic data has indicated that some of these behaviours and calls were breeding-related. Other data included dive and call types associated with feeding, revealing a relatively low occurrence of feeding dives that may have reflected krill densities below the threshold for successful feeding. This work is currently being analysed and prepared for publication.

We will acquire more of this integrated foraging data using suction-cup-attached dive loggers in the Bonney Upwelling during early 2010 and 2011 to substantially increase our sample size (potentially tagging 20-25 blue whales) across a greater number of individual whales under varying prey and environment conditions. We intend to simultaneously apply satellite tags to gain valuable movement data within the feeding ground at scales comparable to suction-cup tagging data.

¹⁹ Morrice, M.G. and P.C. Gill. 2007. Blue whale aerial surveys for monitoring and mitigation of oil and gas exploration on in the southern margins, southern Australia. Draft report to Santos Ltd.

Figure 3. Dive profiles for the pair of tagged blue whales. The female (lead) is shown here lunging close to the bottom (red circles) and at the surface (red stars) with krill swarms for the same depth and time period. The male called (song sequences = green circles) as the female was feeding.



2.2.3 Temperature logger studies

Since 2001 in collaboration with Andrew Levings we have deployed temperature loggers to record changes in ocean temperature at a range of depths, over extended periods. When upwelling starts in late spring, cool water intrudes under warmer surface water, and the pattern of such temperature stratification is determined by the timing and intensity of upwelling. At the end of the upwelling season in autumn, stratification ends and the water column begins a return to 'mixed' winter conditions. Each season shows variations on this general pattern.

Figure 5. Temperature logger data for the 2005-06 season, for near-surface, midwater and near-bottom. The logger was deployed about 15km to the SW of Cape Nelson.

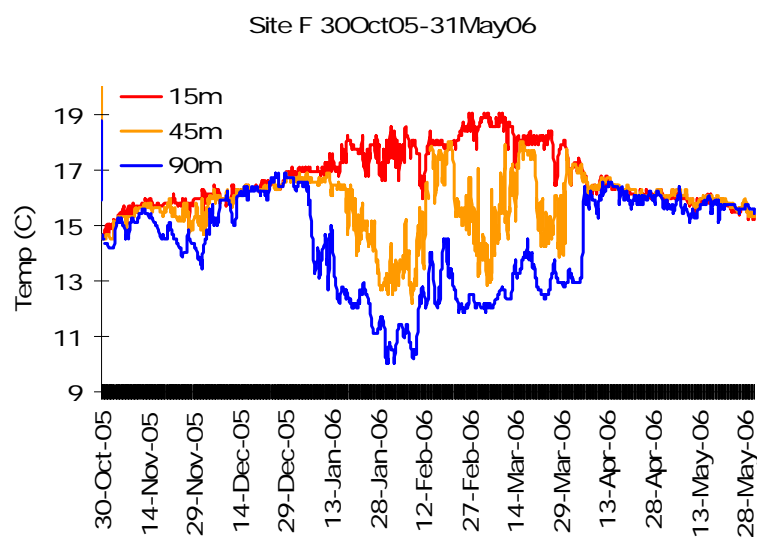


Figure 5 shows logger data for the 2005-06 upwelling season. Upwelling started in November, but south-easterly 'upwelling' winds failed during December so conditions returned to the mixed 'winter' state until upwelling resumed in January

2006 with the resumption of strong south-east winds. This failure of upwelling during an important 'start-up' month probably contributed significantly to the relative weakness of upwelling during that season (see Figure 1). Temperature loggers give us direct insights into such aspects of upwelling dynamics.

2.3. Whale interactions with offshore industry

We have an ongoing interest in blue whales' interactions with offshore industry, particularly seismic surveys, and more recently with the proposed Oceanlinx wave energy project off Cape Grant near Portland.

Our past involvement with Santos and with other operators has given us unique and valuable insights into blue whale-seismic interactions. Aerial surveys have allowed us to monitor distribution patterns and behaviour of blue whales with respect to seismic surveys for the past 5 years (Gill and Morrice, 2003; Morrice *et al.*, 2004; Morrice and Gill, 2007). Further analysis of this data in collaboration with our colleagues John Hughes (John R Hughes Geophysical Pty Ltd) and Andrew Levings (Levings and Associates) and publication in a refereed journal, will allow this information to be widely available and interpreted in the correct context for managers, industry and other scientists working in this field. This data is unique worldwide and will provide a basis for more detailed research to better quantify these interactions, and inform best-practice for operations proposed in the feeding ground.

B. Researchers and institutions involved in or supporting the research

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Other researchers and research assistants may become involved in the research over the next five years as is deemed appropriate.

C. Relationship of the above researchers to the permit applicants and details of funding

With the exception of Peter Gill and Margie Morrice, who are the permit applicants and Directors of the Blue Whale Study Inc., all the researchers listed above are colleagues and collaborators in various aspects of the research.

Since no funding is secured yet for any of the research proposed for the five-year period from April 2009, the funding relationships for various aspects of the research are not yet clear. It is likely that some funding will be sought and provided by ourselves (the Blue Whale Study Inc.) and some will be provided by our colleagues and collaborators.