
Marine Physical Laboratory

The Effects of Ambient Noise Field on the Behavior of Baleen Whales - Pilot Program

Principal Investigator(s) M. D. Stokes

Supported by the
Office of Naval Research
Grant Number: N00014-02-1-0895

Final Report

August 2003

DISTRIBUTION STATEMENT A
Approved for Public Release
Distribution Unlimited

University of California, San Diego
Scripps Institution of Oceanography

20040809 099

REPORT DOCUMENTATION PAGE			<i>Form Approved OMB No 0704-0188</i>
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.			
1. Agency Use Only (Leave Blank).	2. Report Date. August 13, 2003	3. Report Type and Dates Covered. Final Report	
4. Title and Subtitle. The Effects of Ambient Noise Field on the Behavior of Baleen Whales - Pilot Program I		5. Funding Numbes. N00014-02-1-0895	
6. Author(s). M. D. Stokes		Project No. Task No.	
7. Performing Monitoring Agency Name(s) and Address(es). University of California, San Diego Marine Physical Laboratory Scripps Institution of Oceanography 291 Rosecrans Street San Diego, CA 92106		8. Performing Organization Report Number.	
9. Sponsoring/Monitoring Agency Name(s) and Address(es). Office of Naval Research Department of the Navy 800 North Quincy Street Arlington, VA 22217-5660 Atten: Robert Gisiner, ONR 342		10. Sponsoring/Monitoring Agency Report Number.	
11. Supplementary Notes.			
12a. Distribution/Availability Statement. Approved for public release; distribution is unlimited.		12b. Distribution Code.	
13. Abstract (Maximum 200 words). A program of fieldwork was carried out at Peregian Beach, Australia, between 13 September and 26 October. The work was a Pilot Study for a Main Study in 2003 and 2004 concerning the setting to work of a system for passive acoustic and visual tracking of whales, as well as collecting acoustic and remotely observed behavioral data to provide the baseline information of the undisturbed "normal" behavior of the whales during migration along the coast of Australia.			
14. Subject Terms. acoustic, visual tracking, whales, behavioral data		15. Number of Pages. 20	
		16. Price Code.	
17. Security Classification of Report. Unclassified	18. Security Classification of this Page. Unclassified	19. Security Classification of Abstract. Unclassified	20. Limitation of Abstract. None

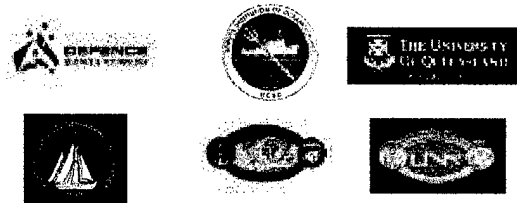
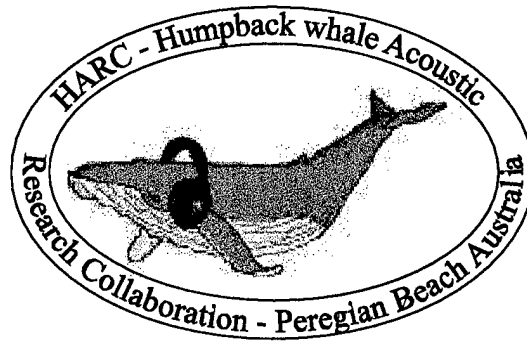
HUMPBACK WHALE ACOUSTIC RESEARCH COLLABORATION (HARC)
PILOT PROJECT

REPORT TO SCRIPPS INSTITUTION OF OCEANOGRAPHY

Michael Noad
Principal Investigator, University of Queensland

Dale Stokes

Principal Investigator, Marine Physical Laboratory, Scripps Institution of Oceanography



1. Executive summary

A program of fieldwork was carried out at Peregian Beach, Australia, between 13 September and 26 October 2002 by the University of Queensland (UQ) as part fulfillment of a subcontract with the Scripps Institution of Oceanography (SIO) funded by the US Office of Naval Research (ONR). Additional funding was provided outside the SIO-UQ sub-contract by the Australia Defence Science and Technology Organisation (DSTO). The work was a Pilot Study for a Main Study in 2003 and 2004. The Pilot Study was concerned with the setting to work of a system for passive acoustic and visual tracking of whales needed for the Main Study, as well as collecting acoustic and remotely observed behavioral data to provide the baseline information of the undisturbed 'normal' behavior of the whales during migration along the east coast of Australia. This built on successful experimental work at the same site by the Australia investigators and involved further development and testing at sea of an array of acoustic buoys, significant further development of software to provide data fusion in almost real time, and development of passive at-sea behavioral data collection techniques. During the course of the 6-week program different sub-projects within the study were incorporated sequentially until the full compliment of data collection techniques was brought on-line successfully. As well as refining techniques, much valuable data was collected: 459 pods were tracked visually (a 34% increase on the number of pods seen during the same period during a similar visual survey in 1997); 81 acoustic recordings were made including 57 using three or more hydrophones; 66 singers were tracked acoustically; eight singers were followed by the boat and five were fluke-photographed. Dr Dale Stoke (co-PI SIO), Dr Doug Cato (PI DSTO), and Dr Eric Kniest (author of *Cyclops*, Univ. of Newcastle) spent a week or so at the fieldwork site. While many technical and logistical problems were identified, these were either remedied in the field or will be before the Main Study. As a result, the Pilot Study has been a crucial and successful action, and will greatly improve the quality of the Main Study which will be the most comprehensive and integrated program of field research conducted on any species of baleen whale.

2. Background to HARC

There has been little rigorous study of **the effects of ambient noise on baleen whale behavior** and the degree to which these animals interact with their acoustic environment. Studies of the impact of anthropogenic noise have been very limited. While a lot has been learnt about baleen whale acoustic repertoire and some about associated behavior, the functions of their vocalizations remain unclear and the acoustic interaction with the environment largely unknown. A much better understanding is required to effectively model the impact of anthropogenic noise.

Unanswered questions include how these animals use vocalizations for communication and maintaining their behavioral repertoire, and how this may be influenced by the ambient noise field. The biological significance of sounds produced by individuals is not well understood and little is known about the context and perception of acoustic signals.

The effects of anthropogenic sound sources on the whales via interaction with the natural ambient noise field are thought to be important, however understanding this requires an understanding of the whales' use of sound under 'normal' (undisturbed) conditions.

The Humpback whale Acoustic Research Collaboration (HARC) is a collaborative project between researchers at the Scripps Institution of Oceanography (SIO), the Woods Hole Oceanographic Institution (WHOI), Australia's Defence Science and Technology Organisation (DSTO), and the University of Queensland (UQ) to address some of the above issues. This will be accomplished with a study of the behavior of humpback whales, on the east coast of Australia, in the presence and absence of anthropogenic sources (from shipping noise and experimental playback) as well as with variations in a natural ambient noise field, including surf and wave-induced noise, along known migratory pathways. An underlying hypothesis is that the influence of sounds on the whales' behavior can be assessed by detailed observations in the presence and absence of the sound. However to do so requires an accurate assessment of the noise field at the whale's location, an understanding of the physical oceanographic environment and a means of making detailed observations of responses. A variety of instrumentation, including digital-recording animal tags, visual and acoustic tracking, and propagation modeling of the acoustic surroundings will be used.

The Australia investigators have an ongoing research program on humpback whale vocalizations with yearly records of song data extending back 20 years and acoustic and visual tracking with behavioral observations in 1996 and 1997. Other workers in east Australian waters have built up an extensive photo identification catalogues of the stock of migrating humpback whales, and there have been successful biopsy projects on the same stock. These data and expertise would be available for the Main Study. The SIO and WHOI components leverage on the Australian investigators' planned experiments and each other to generate a greater understanding of whale response to noise than could be accomplished by any individual program alone.

East Australian Humpback whales migrate annually between the high latitude summer feeding areas and the low latitude winter breeding and calving areas, within the Great Barrier Reef (Chittleborough, 1965; Dawbin, 1966). During the migration and on the breeding grounds, male humpback whales produce a complex, highly patterned, but stereotyped vocalization known as 'song' as first observed in the northern hemisphere (Payne and McVay, 1971; Winn and Winn, 1978). The song is structured in a hierarchical format composed of 'themes' which, in turn, contain 'phrases' composed of basic sounds or 'units'. Song has been studied since 1979 off east Australia (Cato, 1984, 1991; Dawbin and Eyre, 1991; Jenkins et al., 1995; Helweg et al., 1998; Noad et al., 2000; Noad and Cato, 2001; Cato et al., 2001; Macnight et al., 2001; Noad, 2002) and shows similarly structured evolving song. From 1996 to 1998 a revolutionary change occurred in the song from the other Australian population of humpbacks which winter off the west coast of the continent completely replaced the east coast song, a change previously unobserved in humpback whale song or the cultural tradition of any animal species (Noad et al, 2000). In effect, the song of a few west Australian singers provided a natural play back experiment to the east coast stock. Passive behavioral observations at

the Peregian field site also suggest that females may be using surface-active behaviors to encourage approaches by singers (Noad, 2002). The proposed studies will build on this extensive data set.

3. Aims of the Pilot Study

The 2002 Pilot Project was planned to precede the Main Study which will be undertaken in 2003 and 2004. Generally it was to further develop the passive acoustic and visual tracking instrumentation and experimental procedures for the Main Studies and obtain baseline vocalization and behavioral data of the undisturbed migrating humpback whales.

Specifically, the aims were to:

1. **Refurbish and test at sea 3 existing hydrophone buoys.** These buoys allow acoustic tracking of sources of underwater sound e.g. vocalizing and surface-active humpback whales, vessels.
2. **Build and test at sea 2 new hydrophone buoys** for sufficient redundancy to ensure that 4 buoys will be operational at any time. The use of 4 or 5 buoys will substantially increase the accuracy of acoustic tracking compared with 3 buoys, the minimum number required.
3. **Deploy five moorings** at Peregian capable of holding the buoys in place in all likely weather conditions (to be left *in situ* for the Main Study).
4. **Implement the use of *Ishmael*** (Dr David Mellinger, NOAA – work supported by ONR), new software that allows almost real time acoustic tracking and direct-to-disc multi-channel digital acoustic recording.
5. **Implement the use of *Cyclops*** (Dr Eric Kniest, Univ. of Newcastle), software for real time visual tracking of whales from a land based station using a theodolite.
6. **Further develop *Cyclops*** to include better behavioral recording features and to allow it to be used on more than one computer across a network.
7. **Establish a wireless network link** between the visual observation station and the base station to allow almost real time integration of acoustic and visual tracking data.
8. **Direct a research vessel** to singing whales or other groups of whales of interest.
9. Undertake **boat-based passive visual and acoustic observations** of singers and interactions between singers and other whales, and to collect fluke identification photographs of these whales where close approaches were not necessary.

The Pilot Study also gave Dr Dale Stokes, co-PI SIO, the opportunity to visit the experiment site and participate in the trials.

4. Initial work

Initial work started in March 2002. Funding proposals were developed, permit and animal ethics applications for the Main Study were submitted, software was bench-tested, some

equipment was purchased. In June and July MN spent 4 weeks at Cape Byron, Australia's eastern most point, leveraging on a humpback whale study conducted there annually by the Southern Cross Centre for Whale Research during the northward migration. *Cyclops*, the visual tracking software, was designed for use on this particular project and has been used here successfully for several years. *Cyclops* operates on a notebook computer connected directly to an electronic theodolite. Vertical and horizontal angles to the whales are measured by the theodolite and converted directly to positions by *Cyclops* and displayed in real time on a map of the area.

Eric Kniest, the author of *Cyclops*, was at Cape Byron allowing a first trial integration of acoustic and visual tracking systems in the field. The three existing buoys were deployed (on temporary anchors), *Ishmael* was used to record song on two channels using an ordinary soundcard, and *Cyclops* was able to be displayed on a second computer located next to the acoustics computer over a rudimentary wireless link. *Ishmael* was successfully used to track singers and their positions could be entered manually into *Cyclops* and displayed across the wireless link at the theodolite station. Both *Cyclops* and *Ishmael* proved to be unstable, however, and frequent software crashes occurred.

After the Cape Byron project, Dr Kniest modified *Cyclops* substantially for future use at Peregian Beach including the ability to record behavioral observations not linked to theodolite readings allowing much greater flexibility in data collection. A data acquisition card was also purchased that allowed real time, multi-channel input into *Ishmael* giving true multi-channel recording and almost real time acoustic tracking. An electronic theodolite was purchased for the Peregian project.

A message was placed on *Marmam* inviting people interested in working on the project as volunteers, with food and accommodation provided, to apply. Over 60 applications with CVs were received. These were reviewed and offers of places were made to the best candidates. Many applications were very good and there was no shortage of volunteers with bachelor's degrees and experience working with marine mammals.

Because of the size of HARC and the large amounts of data likely to be collected, we also recruited a PhD student, Joshua Smith, to the project. Mr Smith has much previous marine mammal experience and is primarily interested in the behavioral interactions between singing and non-singing whales. He will be enrolled through UQ.

5. Peregian Beach

The main component of the Pilot Study was 6 weeks of fieldwork at Peregian Beach, 13 September to 26 October 2002. Peregian, the study site used previously by the Australian PIs, lies 140 km north of Brisbane, and consists of a long gently shoaling beach with a 73m high hill, Emu Mt., set 800m back from the beach (Fig.1). Fieldwork was based in a house at Peregian situated 100m or so from the beach. Another house was rented to accommodate the volunteers approximately 400m (a 5min walk) away.

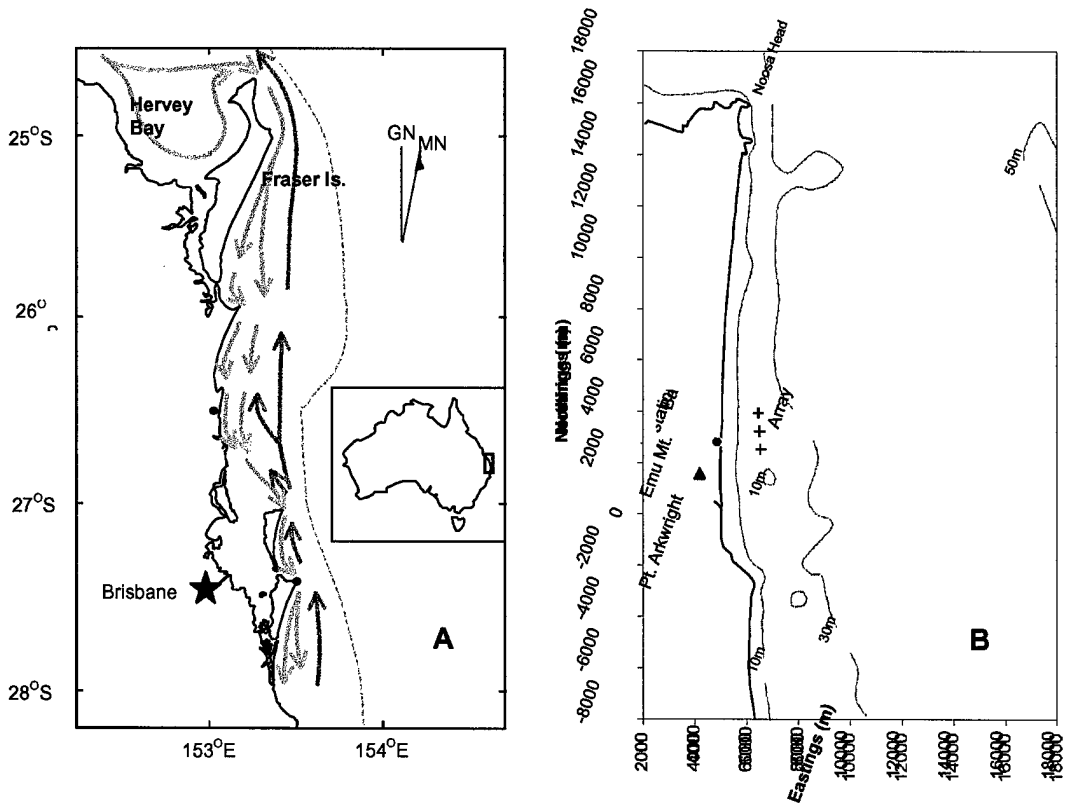


Figure 1. A – southeastern Queensland showing Peregian relative to Brisbane and the migratory routes of the humpbacks. B – detail of the Peregian study site. Only 3 buoys are shown in the array; a further two were deployed in a line east of the middle buoy in this figure.

5.1. Hydrophone buoys and moorings

Each hydrophone buoy consists of a PVC and fiberglass shell that houses a VHF sonobuoy radio transmitter and a 12V gel-cell battery pack (Figs. 2 & 3). A VHF antenna and a light-sensitive strobe light are attached to the top of the buoy. A hydrophone (with preamplifier) hangs beneath the buoy (or is attached to the anchor rope) and is connected to the transmitter inside the buoy. The buoy is anchored or moored in position.

The three existing buoys were built in 1996 by DSTO. All were in reasonably good condition and the original transmitters were used. New antennas were purchased for two of the buoys. Battery packs were checked and faulty cells were replaced.

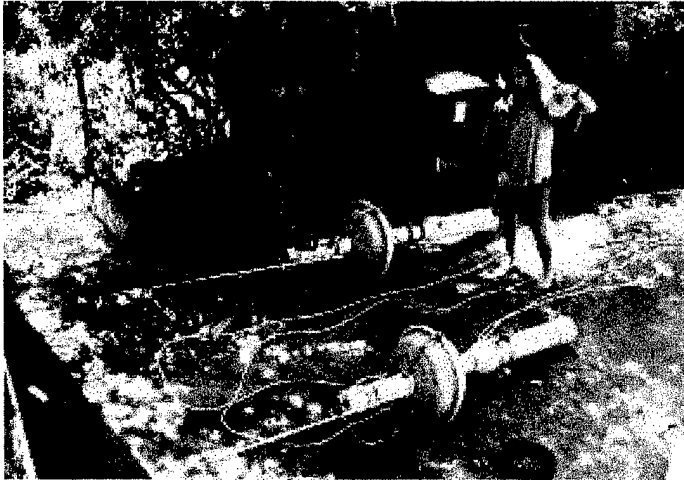


Figure 2. Hydrophone buoys at the base station.

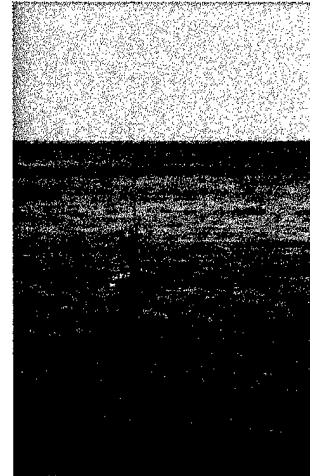


Figure 3. Hydrophone buoy at sea. The back of a whale can be seen behind it.

Two new buoys were built by DSTO and arrived in the field at the beginning of the project. Antennas were purchased and fitted. Some new battery packs were made up. Cables were passed through the shell for connection to the hydrophones.

New hydrophones, High Tech MIN-96s with 40 dB pre-amplifier, were supplied by DSTO and MN. The cables had to be extended from the standard 30m to around 75m using three-core microphone cable. Plugs, allowing the hydrophones to be detached from the buoys, were supplied by DSTO and included in the hydrophone cable where they entered the buoys. Anchor ropes were measured and cut, and thimbles spliced. The hydrophone cables were cable-tied to the anchor ropes. The first buoy was deployed on temporary mooring (anchor only) on 16 Sep. The first buoy with permanent mooring was deployed on 21 Sep together with another buoy on a temporary mooring allowing acoustic tracking, to begin. On 24 Sep, two more permanent moorings with buoys were deployed followed by the last two permanent moorings and buoys on 26 Sep and 11 Oct.

One of the buoys was modified to include a 12-to-15V dc-dc converter in an attempt to run the transmitters at optimum voltage. This was successful and improved signal strength and stability with no detectable extra noise. Battery life, however, was halved to around six days necessitating more frequent battery changes at sea. Despite this, the other buoys will be modified in a similar manner for 2003. The use of solar panels mounted on the buoys to extend battery life will be explored.

Problems included the parting of one of the hydrophone cables during rough weather. This was retrieved, the damaged cable replaced, and re-deployed. Another problem was that the fifth buoy, although placed in a position that we assumed would deliver adequate signal strength, was too weak to be used. We substituted its transmitter with the 15V one, but even then signal strength was insufficient to be useful. This low signal strength will be overcome either by using a higher vantage point for the antenna or by moving the buoy closer to shore.

Because the accuracy of the acoustic tracking algorithm depends on the accuracy of determining the position of each hydrophone, permanent, secure moorings rather than anchors were used to hold the buoys. This allowed the hydrophone positions to be accurately determined with the expectation of little movement from these positions during the experiments. Moorings had to be safely deployable by hand from a small boat, large enough to hold the buoys in position in rough weather, and cost effective. The solution we used was to bolt together three or four large (600 x 600 x 50 mm) concrete pavers providing a combined dry weight of approximately 110 kg and a weight in water of approximately 55 kg. The pavers could be thrown overboard by hand and bolted together on the bottom. For added security, anchors were attached to the moorings ensuring limited scope for drag. When buoys were deployed, the anchor line was attached to the mooring and the hydrophone was attached to a small low-water float approximately 2m above the anchor, the point considered least likely to move.

The moorings proved to be easy to handle and deploy. They can also be moved if necessary. They have been left in position with sub-surface marker floats for use in the Main Study.

Summary:

- Existing buoys refurbished
- Two new buoys built and tested successfully
- New hydrophones fitted to all buoys
- Trial 12 – 15V conversion successful
- Modular mooring system successfully deployed and left in position

Actions arising:

- Send hydrophones and transmitters to DSTO Sydney for calibration
- Move one buoy closer to shore or increase height receiving antenna
- Convert all transmitters to 15V power
- Explore possibility of using solar panels on the buoys to extend battery life

5.2. Volunteers

The success of large fieldwork programs relies heavily on the use of volunteers who help collect data. The 13 volunteers (nine at any time) who worked on the Pilot Project were excellent. All had (or were about to complete) bachelor's degrees, two had master's degrees, and all had previous marine mammal project experience. The make up of the team is worth noting: two from Britain, one each from the US, Brazil, Norway (living in Perth), Japan (living in Townsville), and seven from Australia. All overseas participants came to Australia (at their own expense) specifically for the project. All those asked agreed that they would like, circumstances permitting, to come back in 2003. This would obviously be of great benefit to the project and they will be encouraged to do so.

The volunteers worked primarily on Emu Mt collecting visual data (Fig. 4). They learnt to use the theodolite and *Cyclops* quickly, and made several helpful suggestions concerning modifications to *Cyclops* many of which were implemented in the field when Dr Kniest was present. They also helped collect acoustic data and track singers acoustically, as well as taking it in turns to go out in the boat either for buoy maintenance or behavioral observations. They generally proved themselves to be very competent, friendly, easy to deal with, mature, and eager to learn.

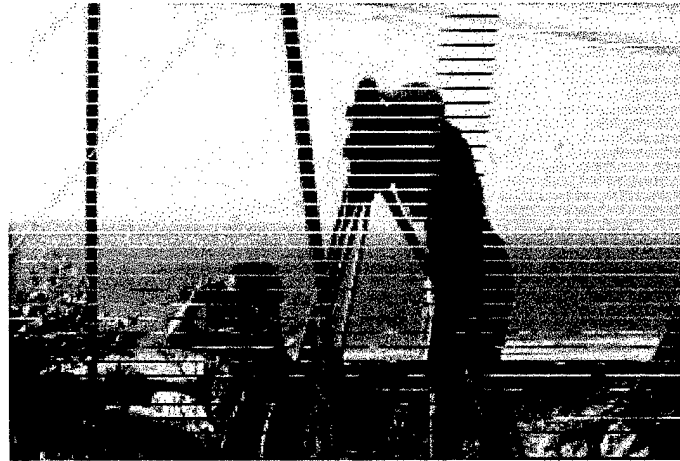


Figure 4. Volunteers on Emu Mt with the theodolite.

The weather was generally good so there was little opportunity project down-time for volunteers to rest. Although we called a couple of days off during the project, in hindsight this was probably insufficient, and some of the volunteers were worn out by its conclusion. Despite this morale was always good. We only had nine volunteers at any one time and this proved to be insufficient at times to cover all the activities necessary for smooth and efficient data collection. It also prevented giving individuals time off on a rotating basis which would have been preferable to calling whole days off. Next year we will aim for 14 volunteers at any time. Dr Stokes suggested that with such numbers (as well as the eight or so scientists likely to be at Peregian during the peak) we might consider a full-time cook – good for morale and allowing more time off for the volunteers.

As well as providing specific technical critiques of *Cyclops*, the volunteers also provided several good suggestions concerning the running of the fieldwork in general which, although generally minor, will be implemented next year. One notable problem was the heavy battery pack that had to be carried up and down Emu Mt each day to power the notebook computer.

Summary:

- Recruitment of volunteers successful
- Volunteers were of high quality and ability
- Several from overseas specifically for the project

- High overall effectiveness of volunteers

Actions arising:

- Recruit more volunteers for efficient data collection
- Individuals need more time off
- Explore possibility of full-time cook/caterer
- Reduce the battery size and weight generally of gear to be carried up Emu Mt

5.3. Visual tracking and *Cyclops*

Visual tracking of whales from Emu Mt occurred during the southward migrations in 1996 and 1997. A mechanical theodolite was used and the vertical and horizontal angles written down in a book together with behavioral observations. These were typed into a spreadsheet the next day and only then were the movements of the whales apparent.

During the Pilot Study, an electronic theodolite was connected to a notebook computer running *Cyclops*. The angles were transferred directly to the computer which displayed positions in real time on a map of the area (Figs. 5A & B). *Cyclops* attempts to automatically assign pod identity to new sightings. Errors in the allocation of pod identity are immediately obvious and can be quickly and easily corrected. Vessels can also be entered and are kept track of with different icons to prevent confusion with whales. The research vessel has its own particular identity and the distance from the research vessel to nearby pods is also calculated automatically as are other variables, e.g. pod swim speed.

Due to the importance of *Cyclops* the project, we flew Dr Eric Kniest, the author of *Cyclops*, up to Peregian for a week to provide on-site support. During this time Dr Kniest successfully de-bugged many of the small problems we were having. Many of these stemmed from our need to use *Cyclops* primarily to collect behavioral observations which were not necessarily accompanied by a theodolite shot although *Cyclops* was written originally to be used exclusively for theodolite data. Dr Kniest's presence was therefore extremely valuable. He is now working on improving and re-writing many aspects of *Cyclops* for our visual work.

The wireless networking of *Cyclops* from the notebook computer on Emu Mt to the base station was problematic but ultimately successful. The gear used at Byron over a 100m or so did not work over the 1.5km at Peregian despite having good line of sight. This was overcome later in the season thanks mainly to the efforts of John Noad (recently retired computer expert and father of MN) who arranged and coordinated the installation of a wireless network system (dubbed *PeregiNet*). This consisted of a Netgear Wireless USB Adaptor connected to the notebook computer on the hill, and a Cisco bridge with directional yagi antenna at the base station. Once the wireless connection was established it proved very stable and *Cyclops* ran with few problems at the base station. This allowed the acoustics operators to see in real time the theodolite plots of what was happening at sea. The positions of singers calculated by *Ishmael* could also be entered in

Cyclops at the base station, and these positions would appear on the screen on Emu Mt allowing the observers to search for the singers visually and to be able to direct the boat to pods that were known to contain singers.

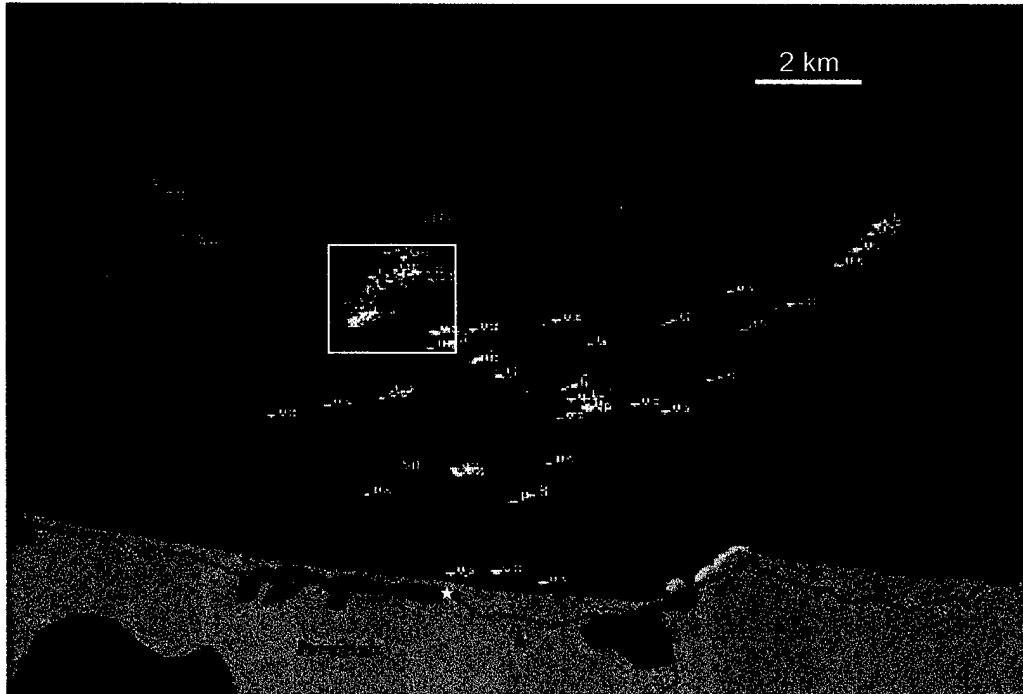


Figure 5A. *Cyclops* output from 22 October. The map is orientated with north to the left. Emu Mt is indicated by the triangle at the bottom of the chart, the base station by a white star, whales by pod letter and behavioral icon, singers by '\$' and circle icon, and the research vessel by a white triangle and 'vs'. Other vessels are not shown for clarity. Details of the singer and vessel movements in the white rectangle are shown in Fig. 5B. (Approximate scale added.)

Cyclops is constantly under development. Ultimately Dr Kniest aims to fully integrate *Cyclops* and *Ishmael* so that that positions generated by *Ishmael* are automatically passed on to *Cyclops* without the intervention of an operator. This would provide an extremely useful package of software that could be made freely available for other projects. To do so, however, Dr Kniest may require some support and we are looking at what might be available to help him continue his invaluable contribution to the project. At the very least, we intend to bring Dr Kniest up to Peregian again for the Main Study in 2003.

Due to the low number of volunteers used during the Pilot Study, most shifts on Emu Mt contained three people – a theodolite operator, a computer operator and a spotter. While this was adequate, two spotters would be better and the volunteers felt that teams of four would be optimal. This concurs with our previous experience in 1997.



Figure 5B. The singer is tracked acoustically as 'SB' before being picked up visually as pod 'G' by EM. The research vessel 'vs' follows the singer at a discreet distance as it heads NNW, turns back ESE, stops singing then heads SW rapidly towards another singer ('\$D' in Fig. 5A). (Approximate scale added).

During the Pilot Study, an old notebook computer was used on Emu Mountain because of the likely wear and tear due to dust, salt and the risk of rain. This proved slow and the screen difficult to see in daylight, so will be replaced by newer model for the Main Experiments.

Summary:

- Data collection on Emu Mt was improved greatly through the use of an electronic theodolite and *Cyclops*
- *Cyclops* has been successfully adapted to the needs of the project with respect to single computer data collection.
- *Cyclops* can currently be operated on two machines (base station and Emu Mt)
- A wireless network was successfully established between Emu Mt and the base station
- Volunteers learnt to use the theodolite and *Cyclops* quickly
- The optimal number of volunteers on Emu Mt is 4 at any time

Actions arising:

- Increase observer numbers from 3 to 4
- Expansion of *Cyclops* to full network capabilities would be useful.
- Get a better computer for use on Emu Mt – faster; brighter screen.

- Full fusion of *Cyclops* with *Ishmael* to provide a seamless and powerful whale tracking package?
- Eric Kniest to continue development of *Cyclops* with regards to use at Peregrine – networking, debugging, etc.
- Invite Dr Kniest to Peregrine again for on site support.
- Explore possible sources of support for Dr Kniest.

5.4. Acoustic tracking and *Ishmael*

Acoustic tracking of underwater sound sources was achieved by measuring time of arrival differences of the same sound arriving at different hydrophones at known positions (Fig. 6). *Ishmael* was recently developed by Dr David Mellinger (NOAA with ONR support) for recording and tracking marine mammal sounds and so was ideal for the project. *Ishmael* was first used at Cape Byron and Dr Mellinger was kind enough to make several changes to *Ishmael* for us during and after this initial test period.

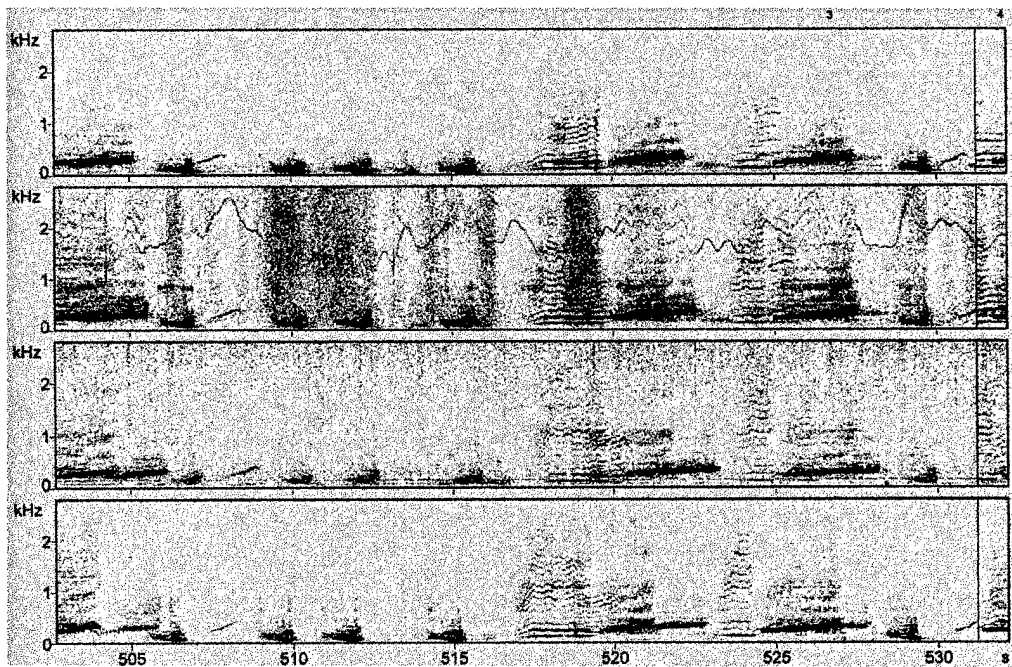


Figure 6. Typical *Ishmael* display with a singer in close proximity to the array, showing outputs of hydrophones 1 to 4 down the page. Differences in background noise levels reflect non-standardised amplification of the signal between the receiver and the DAQ card as well as variations in hydrophone gain. Delays in arrival times of individual sounds can be seen clearly, the singer being closest to hydrophone 4 followed by hydrophones 1,2 and 3.

During the Pilot Study we ran *Ishmael* on a single computer and attempted to both record to the hard disk drive (HDD) and calculate acoustic positions simultaneously. This pushed both hardware and software to their limits and often resulted in both fatal and non-fatal errors. During the Main Study these two tasks will be separated and run on different machines to improve operational stability. Despite these problems, *Ishmael* generally proved to be an excellent tool. Some aspects could be improved, however, and David Mellinger will be approached to make some small changes that could make tracking in particular easier for operators.

HDD space also proved a problem – despite having a 60GB HDD, this filled up in the first couple of weeks and data had to be burnt to CD. Unfortunately this could not be done safely while *Ishmael* was recording and so had to be done during non-recording periods. This proved somewhat tedious and better data storage solutions (e.g. DVDs, external HDDs) will be explored for the Main Study.

Another issue affecting the accuracy of tracking was accurately measuring the positions of the hydrophones after deployment. Ideally this needs to be close to 1m accuracy to give adequate tracking accuracy out to distances of 10 km and proved more difficult than anticipated. In 1997 a diver in the water maintained position directly above the hydrophones which were just visible on the bottom in 20m of water. This year conditions were not as good and visibility was often not adequate to allow the moorings or hydrophones to be seen at 20m, and some were deeper at around 25m. In addition, the second theodolite we used to measure the positions of the buoys from the beach using a laser range finder (EDM) was inadequate for getting distances to the more distant buoys. Theodolite positions taken from Emu Mt, however, proved to be reasonably accurate (estimated +/- 10m) and so were used for much of the time. Also we were conscious of probably having to move some of the moorings before the Main Project when more effort will be put into properly measuring the positions of the hydrophones. In order to overcome theodolite problems, this will probably be done using highly accurate GPS units hired for a short period.

Summary:

- *Ishmael* successfully recorded song and located sound sources although it was unstable due to high data load
- Data recording direct to HDD was successful but storage and backup was problematic
- Positioning hydrophones very accurately was found to be difficult but not necessary for the Pilot Study

Actions arising:

- *Ishmael* to be run on two computers – division of recording and tracking
- Faster, more efficient data backup to be used
- Hydrophones to be very accurately positioned using specialized GPS
- Discuss minor alterations to *Ishmael* with David Mellinger.

5.5. Boat-based observations

In previous projects at Peregian, a boat was only used to maintain the array. During the Main Project a boat will be used to make behavioral observations at sea and will attempt to collect photo-IDs and biopsy samples. During the Pilot Study the boat was directed to surface-active pods by the observers on Emu Mt and singers by the acoustic analysts on 15 days. Some difficulties were found putting the boat on to distant (> 5 km) singers due to errors in accuracy mostly likely due to inaccurate hydrophone positions, however, the boat, itself equipped with a hydrophone, was able to approach and find eight singers. These were observed and photos were taken from a discreet distance using a 450 mm telephoto lens (300 mm optical with 1.5x magnification due to digitization) (Fig. 7). Two of the singers were escorting other whales and six were lone whales. Other non-singing pods were also approached and observed passively as we developed boat-based techniques and protocols.

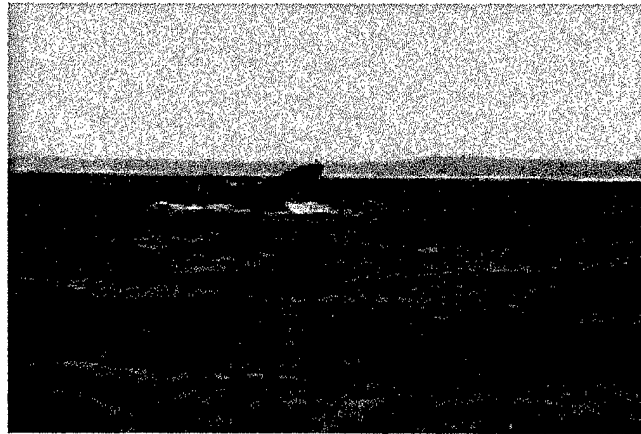


Figure 7. The fluke of a singer with part of the trailing edge missing. This easily identifiable fluke has already been matched with a sighting from 1986 showing that this singer is a mature animal.

A Canon D60 digital SLR camera was purchased for the photo-ID work. Although the cost of this was greater than originally anticipated for an ordinary SLR, the recent consensus among the marine mammal research community is that these cameras are now more cost-effective than ordinary SLRs over time because there are no film or processing costs, their images are of very high quality, and there are huge savings in labor and time by being able to download images quickly and directly to computer rather than waiting for processing and then scanning individual images. Our experiences so far with the camera agree with these endorsements. There will also be animal welfare benefits during close-approach photo-ID work where the photographer will be able to ascertain with certainty when a suitable photo has been obtained allowing us to break from the pod at the soonest possible time.

Although finding and following singers was successfully achieved, it was more difficult than originally anticipated. Windier than normal weather did not help, making lightly-blowing singers difficult to see either from the boat or Emu Mt. To counter this, it will be necessary in the Main Study to spend as much time as possible at sea. Also finding singers did become easier with practice, again demonstrating the importance of a Pilot Study, and should be easier next year.

It should be noted that all Australian governmental permits and UQ animal ethics approvals for the close-approach photo-ID and biopsy work in the Main Project (2003 and 2004) have been obtained.

The help and expertise of the boat owner and operator, David Paton, should be recognized. Mr Paton runs the Cape Byron research project and his skills at spotting and following whales as well as a photographer were of great benefit to the project. As a holder of a coxswains certificate and a commercial diving ticket, he was also meets UQ's Occupational Health and Safety requirements concerning the use of boats at sea and diving for the placement of moorings and hydrophones. He doubles as the supplier and operator of the boat, and as a very competent field worker. He should be considered an integral part of the project.

Summary:

- Singers were successfully approached and behaviours recorded
- Some identification photographs were collected
- Canon D60 digital SLR camera proved an excellent research tool with many advantages over conventional models
- Obtaining boat-based data may be more difficult than previously anticipated requiring a greater on-water effort
- David Paton's experience and skills make him an integral part of the project
- All Australian permits are in place for photo-ID and biopsy work

Actions arising:

- More on-water effort than originally anticipated will be required to collect adequate sample sizes
- Increased on-water effort will require greater coordination between UQ, SIO and WHOI to avoid conflicts
- At least 2, possibly 3, boats will need to be used at times
- Ethics approval needs to be finalized from DoD and SIO to allow close-approach photo-ID and biopsy components of ONR/SIO funded work

5.6. Visiting investigators

Dr Dale Stokes (co-PI SIO) visited the field site 22 – 28 September. His visit was very welcome and he mucked in immediately, despite jet-lag, to help ready the buoys for deployment. Several planning sessions were very productive from both UQ/DSTO and SIO perspectives. Dr Stoke's visit coincided with that of Dr Kniest and their meeting was

also very productive particularly with regards to networking and the importance of integrating the inputs of all teams as fully as possible.

Dr Eric Kniest (Uni. Newcastle), as mentioned above, was at Peregrine 19 – 28 September. His considerable contributions have been already been outlined.

Dr Doug Cato (PI DSTO) visited the site 17 – 23 October. Dr Cato was already familiar with the site from MN's previous projects there. It should also be noted that Dr Cato visited the Byron field project in July. Planning sessions involving Dr Cato were held and made considerable progress identifying managerial and scientific issues for the Main Study next year.

The overwhelming consensus from all parties was that the Pilot Study was successful in achieving its aims and had been a vital shake-down before the Main Study that would greatly enhance the effectiveness of the Main Study.

6. Data collected

Acoustic recordings were separated into 'selected recordings' and automated 'samples'. Selected recordings were made when there was something worth recording (usually one or more singers) while automated sample recordings were made for 2min every 15min around the clock to collect a comprehensive record of the acoustic environment. Eighty-one selected recordings were made with a total duration of 180h (range 0.1 – 9.2h, mean 2.2h), including 57 with at least three buoys operating, the minimum required for tracking. Approximately 3000 sample recordings were collected.

At least 66 singers were tracked acoustically. Further analysis is required to better determine how many passed through the study site as some singers were recorded but not tracked, and some singers within 10km were sampled only. On any given day the numbers of singers that passed during daylight hours ranged from 0 to 8.

Three hundred and thirty one hours of observations were made from Emu Mt. including 26 full days and 10 part days. Four hundred and fifty nine pods were seen (daily range 0 – 31).

Fifteen days of boat time were dedicated to on-water observations. The main aim was for acoustics operators and Emu Mt observers to direct the boat to pods of singing and non-singing whales and, once there, for the boat team to collect behavioral information on the pods and take opportunistic identification photos. Forty pods, containing 89 whales, were observed from the boat:

- 6 non-singing lone adults
- 6 lone singing adults
- 4 pods of 2 adults of unknown sex/status
- 10 female – calf pairs

- 4 pods of 3 adults of unknown sex/status
- 4 female, calf, escort trios
- 1 female, calf, singer trio
- 2 pods of 4 adults of unknown sex/status
- 1 female, calf, escort, singer quartet
- 2 pods of 5 adults of unknown sex/status

The average time observing each pod was 1.0h. Several short recordings were made of singers within 500m of the vessel. Five of the eight singers were successfully photographed.

7. Actions and Planning for the Main Study

The Main Study will consist of eight to ten weeks of fieldwork during the southward migration in 2003 and six weeks of fieldwork during the northward migration in 2004. In addition to the tools developed and used in the Pilot Study, the main study will also include:

- close range photography of whales
- biopsy sampling of whales
- playback experiments
- deployment of D-Tags

While the Pilot Study was successful, much work remains to be done before the next field season:

1. Detailed research planning by and among all teams to integrate and leverage all studies as much as possible – DC, DS, MJ, MN.
2. Detailed logistical planning by and among all teams to prevent logistical bottlenecks – DC, DS, MJ, MN, JN, DP.
3. Develop field network for efficient and rapid real-time information exchange – JN, MN, EK.
4. Further develop *Cyclops* – specific project needs; network operation – EK, JN, MN.
5. Recruit volunteers – MN.
6. Organize field accommodation including base station – MN, JN.
7. Calibrate, repair, and modify hydrophone buoys and explore alternative power options – DC, MN.
8. Calibrate receiver and explore alternative receiver options – DC.
9. Organize a playback system – J11 transducer with amplifier – DC.
10. Observations of whales at Peregian during northward migration 2003 as feasibility study for 2004 fieldwork – MN, DC, EK.

Currently, SIO, WHOI, DSTO and UQ are in the preliminary stages of joint advanced planning. The major action at this stage is to produce specific and detailed research plans with clearly formulated aims and objectives for each team as well as a manual detailing

logistical and technical information about each project. The UQ/DSTO manual will be written with the volunteers in mind, and include clear data collection priorities as well as detailed instructions on how to operate all relevant equipment and contingency plans should any piece of equipment fail.

8. Conclusion

HARC is an ambitious research program involving a comprehensive set of observations and experiments on humpback whales. The Pilot Project at Peregrine was successful in that it fulfilled its aims and paves the way for a large and comprehensive program of work starting in 2003. With careful planning, we are confident that the project will be very successful with significant leverage of individual studies an important goal.

Appendix I - List of names and initials of participants

SIO

Dr Dale Stokes	DS
Dr Grant Deane	GD

WHOI

Dr Mark Johnson	MJ
-----------------	----

DSTO

Dr Doug Cato	DC
--------------	----

UQ

Dr Michael Noad	MN
Mr Josh Smith	JS

Associates

Dr Eric Kniest	EK
Mr John Noad	JN
Mr David Paton	DP

References

- Cato, D.H. 1984. Recording Humpback Whale sounds off Stradbroke Island. In: Focus on Stradbroke, R.J. Coleman, J. Covacevich & P. Davie (eds.) Boolarong Publications: Brisbane. Pp.285-290.
- Cato, D.H. 1991. Songs of humpback whales: the Australian perspective. Mem. Queensland Mus. 30(2):277-290.

- Cato, D.H., Paterson, R.A., & Paterson, P. 2001. Vocalisation rates of migrating humpback whales over 14 years. *Mem. Queensland Mus.* 47(2):482-489.
- Chittleborough, R.G. 1965. Dynamics of two populations of the humpback whale, *Megaptera novaeangliae* (Borowski). *Aust. J. Mar. Freshwater Res.* 16:33-128.
- Dawbin, W.H. 1966. The seasonal migratory cycle of Humpback whales. In: *Whales, Dolphins and Porpoises*, K.S. Norris (ed) University of California Press: Berkeley and Los Angeles. Pp.145-170.
- Dawbin, W.H. & Eyre, E.J. 1991. Humpback whale songs along the coast of Western Australia and some comparison with east coast songs. *Mem. Queensland Mus.* 30(2):255-257.
- Helweg, D.A., Cato, D.H., Jenkins, P.F., Garrigue, C., & McCauley, R.D. 1998. Geographic variation in South Pacific humpback whale songs. *Behaviour* 135:1-27.
- Jenkins, P.F., Helweg, D.A., & Cato, D.H. 1995. Humpback whale song in Tonga: Preliminary results. In: *Sensory Systems of Aquatic Mammals*, R.A. Kastelein, J.A. Thomas & P.E. Nachtigall (eds.) De Spiel Publishers: Woerden, The Netherlands. Pp.335-348.
- Macknight, F.L., Cato, D.H., Noad, M.J., & Grigg, G.C. 2001. Qualitative and quantitative analyses of the song of the east Australian population of humpback whales. *Mem. Queensland Mus.* 47(2):525-537.
- Noad, M.J., Cato, D.H., Bryden, M.M., Jenner, M-N., & Jenner, K.C.S. 2000. Cultural revolution in whale songs. *Nature* 408:537.
- Noad, M.J. & Cato, D.H. 2001. A combined acoustic and visual survey of humpback whales off southeast Queensland. *Mem. Queensland Mus.* 47(2):507-523.
- Noad, M.J. 2002. The use of song by humpback whales (*Megaptera novaeangliae*) during migration off the east coast of Australia. Ph.D. thesis, Uni. Sydney. 299pp.+xvi.
- Payne, R.S. & McVay, S. 1971. Songs of humpback whales. *Science* 173:585-597.
- Winn, H.E. & Winn, L.K. 1978. The song of the humpback whale (*Megaptera novaeangliae*) in the West Indies. *Mar. Biol. (Berl.)* 47:97-114.

ONR/MPL REPORT DISTRIBUTION

Office of Naval Research (3)
Department of the Navy
Ballston Tower One
800 North Quincy Street
Arlington, VA 22217-5660
Attn: Robert Gisiner, ONR 342t

Regional Director (1)
ONR Detachment
San Diego Regional Office
4520 Executive Drive, Suite 300
San Diego, CA 92121-3019

Commanding Officer (1)
Naval Research Laboratory
4555 Overlook Avenue, S.W.
Attn: Code 2627
Washington, D.C. 20375-5320

Defense Technical Information Center (4)
8725 John J. Kingman Road
Suite 0944
Ft. Belvoir, VA 22060-6218