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The Journal of Marine Animals and Their Ecology (JMATE) is an electronic journal focused but not limited to issues related to the preservation of the marine environment, protection, conservation, rescue and rehabilitation of marine life. The unique goal of the journal is to attract a diverse and broad consumer base by having a multi-disciplinary approach to the issues. This will increase interest and readership while facilitating exchange of ideas and knowledge in this rapidly growing field. It is hoped that it will become an equally popular read for the scientist, biologist, rehabilitator, veterinarian or the public. The journal is available to the public free of charge and is electronically published by the Oceanographic Environmental Research Society (OERS) up to 4 times a year: Spring, **Summer**, Fall and **Winter** issues. ISSN#1911-8929

JMATE encourages submissions in the following broad categories:

1. **Original manuscripts** in the following marine animal areas:
    a. **Science** (research etc)
    b. **Techniques** (practical husbandry or other tips)
    c. **Medical Care**
    d. **Environment/Ecology Related**
2. **Reviews and Invited Commentaries**
3. **Brief Communication** - News in Marine Animals
4. **Letters to the Editor**

The instructions to authors are available on website www.oers.ca . Submissions that may not necessarily be formal and complete research projects but may be valuable to inform the community regarding techniques, medical/other care and environment related to marine animals are welcome.

- All submissions must be sent to the Editors at : editor@oers.ca.

Within 24 hours of submission, the corresponding author will be sent an email confirming receipt of the manuscript. The submission will be reviewed by the editors and if deemed appropriate for the journal will be sent to the appropriate reviewer(s) in a blinded fashion. A final decision on any submission will be made and communicated to the corresponding author normally within 3 weeks of the date of submission. In the event the reviewer(s) feel that revisions are required prior to the official acceptance of the submission, the authors will have 2 weeks to revise and resubmit. Once the submission is accepted for publication, a final electronic version will be sent to the corresponding author for final review and approval must be received within 48 hours of receipt of the electronic proof.

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EDITORIAL

The launch of a new journal - how hard can it be?"

Welcome to the Journal of Marine Animals and Their Ecology (JMATE). As the inaugural Editor-in-Chief I can say with some conviction that the launch of this new initiative has been quite the exercise.

JMATE was created in order to provide a non-bias avenue for publication of ideas, research, views and reviews to a broad-ranging readership. We hope that anyone with an interest in marine animals will browse through our journal and find something of interest and value. A diverse range of articles from research, case studies, innovative techniques for everything from data collection to rehabilitation as well as practical animal care ideas can be found within the covers of JMATE. What is also unique with JMATE is that it is run completely by volunteers resulting in no charges or access fees.

Ultimately the goal is to do this in a timely fashion, though I will apologize up front to all who have been waiting for this issue to appear. The birthing pains were beyond anything I would have ever imagined. The system is now set-up and we will strive for an expeditious turnaround time for all submissions. We currently plan for 2 issues a year (June, December), with a possibility of increasing up to monthly as the volume of submissions warrant. I hope that the marine animal community will embrace this journal and that JMATE can occupy a niche, providing a valuable service to the community.

I want to thank all the individuals who made this possible. This ranges from the volunteers who helped with art design, setting up the journal and its guidelines, proof-reading and web organizing it all. In addition it has been very heartwarming to receive the support and patience of all the authors and reviewers throughout the launch process. The internal and external reviewer's willingness to provide peer review for all the papers submitted is critical as none of these works would be the same without their input and suggestions – you know who you are. A list will be published in the next issue (years end) as recognition for the effort and time spent. I encourage anyone willing to review for us to send me an email, we are creating a database so that no one individual will be singled out too often, and would love to add your name and subject area. A fringe benefit for doing all this hard work is a guaranteed venue through JMATE for you to publish your thoughts or work. With that as an incentive I know you all will want to jump on board!!

Some personal acknowledgements are also in order. First to Mr Michael Belanger for his role in conceiving and then pushing this initiative along making it a reality. Specifically his design of the journal cover, his role as Associate Editor, internal reviewer and stepping in as proof reader. As usual JMATE would still be talk without your broad shoulders that carried this to where it is today. Then my Managing Editor, Dr Karim Bandali for masterfully helping set up the guidelines and reference terms for the journal. Finally Mr Danny Quaglietta, our volunteer webmaster and e-publication guru - your commitment, great artistic eye in setting up the manuscript templates and hours of hard work at the keyboard are what makes this journal looks so good.

We want to be responsive to your needs and so please feel free to email us with your thoughts and ideas. There is always room for improvement! With the first issue finally out we are already processing submissions for the next issue. We encourage everyone to send us, as soon as possible, your articles so that we can get them in for the anticipated fall 2008 issue. Seasonal variations will occur with the length of the review process with field work and meetings interrupting the flow, thus the sooner we receive your article the more time it gives us to work around everyone's tight schedules.

With that said, I leave you to peruse volume 1 issue 1 of JMATE. I hope you find it refreshing and thought-provoking. If you feel passionate about an article, there is always a 'letter to the editor' to express your view. This is how marine animal science and medicine moves ahead and we advance our understanding of these unique creatures. I hope to hear from you, either through your submissions or reviews or ideas you might wish to share. Enjoy eh!

Dr Carin Wittnich
Editor-in-Chief, JMATE

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INVITED COMMENTARY

Cost of Rehabilitation - Why Save One Seagull?

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Every year the Oceanographic Environmental Research Society (OERS) receives numerous calls for help from desperate individuals who have found an injured animal and have no one to assist them. The OERS Response Log book is filled with phone calls from caring people who have found an animal that is injured and needs some care. They report that they have called several groups for assistance most of which have refused assistance for a variety of reasons. The most common ones being that they consider the species to be a 'nuisance' or 'common' animal or that they have no money or that there are no volunteers available at the moment to respond. No matter what the species or the number of animals involved, OERS offers assistance. In fact OERS will even respond to calls concerning injured seagulls! But is saving a common animal like a seagull that important? Is it worth pouring time, money and effort into treating and rehabilitating any animal no matter how much it costs? Must an animal be placed on the endangered or threatened list before it becomes 'valuable' so that money or effort can be spent on saving it? Should we save species like snails, frogs, seagulls or coyotes? Not only does it depend on how we evaluate the 'worth' of an animal but also the moral values of society.

Wildlife rehabilitation invokes controversy as there are several points of view, numerous scientific theories and strong emotional reactions when it comes to the care and release back into the wild of injured animals. However, when discussing species that seem to be more intelligent or who create strong emotional feelings within humans, it becomes very controversial and very personal. One species that always creates strong and wide points of view are marine mammals. Some individuals or groups consider them to be intelligent animals who should be saved at all costs while others consider them to be nuisance animals that should be killed or commercially used. The scientific literature is unclear whether marine mammals should be rescued, rehabilitated and released as many factors must be taken into consideration.(1) A fellow OERS director and I were having breakfast with a well known wildlife illustrator and we posed him the following question. If he was faced with the choice of rescuing a pod of Common Bottlenose dolphins, would he do it? His immediate response was that since it was a species that was not endangered or threatened, he would not save any as it would be a waste of money and that it was Nature's way of culling the weak. But if it was an endangered species he would spend as much money as he could to save them. He remained adamant until we pointed out how 'valuable' even a Common Bottlenose could be. We pointed out how much physiological and medical knowledge could be learned working with non-endangered species that could then be transferred to an endangered species. Treatment procedures could be taught or developed using a Common Bottlenose dolphin that could then be applied towards a more threatened species. Veterinarians, animal health technicians, emergency response team members and volunteers could gain 'hands-on' experience handling the Bottlenose dolphin that would become invaluable in the rescue and treatment of a more endangered species. Potential mistakes could be eliminated and learning curves would be lowered using a more 'common' species thereby increasing the odds of success towards a more 'valuable' species. Research could be conducted on a more 'common' species which could then be used to preserve a more endangered species. By the time the pancakes were served, the logic behind our argument had won.

Picture 1. Injured seagull on the mend — 2008. **Reproduced with permission from OERS.**

Mankind's lack of concern about the outcome of our actions is a major factor behind the rapidly changing environments and loss of natural habitats. This results in larger numbers of incidents where animals are injured or the spiraling number of species being placed on the threatened/endangered list every year. Financial cost is often used to justify spending or not spending money saving 'nuisance' wildlife versus threatened/endangered species. Looking at wildlife rehabilitation where animals (small birds and mammals such as squirrels, raccoons, etc) are found abandoned or injured, the costs range from $40 for a Dove to $200 to take care of a raccoon per year in 2007 US dollars.(2) In 1988, 3 Gray whales became trapped in the Arctic ice near Point Barrow, Alaska with the total cost of the media coverage and rescue efforts added up to $5.8 million dollars (1988 US dollars).(3) For a catastrophic event such as

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an oil spill, the costs of caring for oiled marine animals alone is often more intensive, drastic and complicated. Capturing oiled animals, giving them medical treatment, running diagnostic tests and performing intensive rehabilitation care alone can cost thousands of dollars per animal depending on the species. The Exxon Valdez oil spill created numbers that were staggering with reports that the rehabilitation of a single Sea otter cost an estimated $80,000 and that of an oiled sea bird $15,000 in 1989 US dollars!(4) These figures included every possible item spent on oiled wildlife rehabilitation including building 3 operating centers, 1 rehabilitation center for oiled birds, boats, helicopters, wages, etc.

Lets now compare the money spent on some recovery programs for saving endangered/threatened species. Since the early 1930's, the United States and Canada have spent over $200 million (US) trying to preserve the Whooping crane.(5) It has been estimated that between 1999-2004, Canada spent $29 million (CAN) in salaries & expenses alone on the recovery of various threatened/endangered species.(5) However, that may not be the true amounts spent on saving threatened/endangered species. A paper published in 2007 by the U.S. Army Corps of Engineers showed that the actual costs for the conservation of certain threatened/endangered species can be twice the amounts that are actually reported. (6) It is therefore obvious that the rehabilitation of animals or attempting to preserve threatened/endangered species is a huge financial undertaking with no little or no success.

Apart from the financial burden that any animal places on wildlife centers or on conservation programs, there is a moral obligation to protect and preserve those species that are affected by our actions. So is it worth saving one animal? One seagull? OERS believes it is. Just ask any of our staff or volunteers who have helped rescue an animal in the middle of a cold damp night or who spent long exhausting days cleaning, feeding and scrubbing floors and cages if it is worth it. To have a seagull take flight from your hands or watch a squirrel scamper up a tree or see a seal making its way through the surf to return back to its natural habitat after spending days, weeks or months caring for it is indescribable. If you were to ask me I would have to argue that yes it is all worthwhile. And more importantly, it is the right thing to do, no matter what the cost.

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Assessment of bottlenose dolphin (Tursiops aduncus) habitat characteristics in the estuarine waters of the Adelaide Dolphin Sanctuary, South Australia.

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Abstract
The distribution and behaviour of bottlenose dolphins (*Tursiops aduncus*) in the Adelaide Dolphin Sanctuary (ADS), South Australia, was investigated in relation to habitat type and environmental water properties from boat based surveys between May and August 2006. Although the distribution and behaviour of bottlenose dolphins were not related to the physico-chemical properties of the water column or habitat type, this study gives a quantitative assessment of the distribution and behaviour, which is essential when implementing management strategies. [JMATE. 2008;1(1):6-8]

Keywords: Bottlenose dolphin, habitat, conservation, South Australia

Introduction

Bottlenose dolphin (*Tursiops* spp.) habitat has previously been investigated by relating their distribution patterns to a number of environmental factors (4,3,13). However, few studies have quantitatively measured more than one environmental factor, which therefore places some limits on understanding cetacean habitat. Bottlenose dolphins (*Tursiops aduncus)* are found in South Australian coastal waters and Gulfs (8), in particular the Port Adelaide River-Barker Inlet estuary, which supports a population of resident individuals (1). However, this estuary is increasingly impacted and threatened by a variety of anthropogenic activities. As a result, this area has recently been proclaimed the Adelaide Dolphin Sanctuary (ADS), seeking to protect both the resident dolphins and their habitat (16). This stresses the need to develop and implement conservation strategies. Therefore, the objective of the present study was to provide baseline information on the potential relationship between bottlenose dolphins and the space-time structure of their habitat.

The ADS, covering 118km^2 (34°39'S - 138°25'E, 34°51'S - 138°30'E), and ranging in depths from 2 to 16m, is situated on the eastern side of Gulf St. Vincent, South Australia. The northern area of the ADS extends out into the open waters of the gulf and is characterised by the presence of seagrass. In contrast, the southern area of the ADS, consists of sheltered channels that are essentially devoid of vegetation such as seagrass and attached algae and consist predominantly of a bare sandy bottom (7). The potential relationships between *T. aduncus* and the biotic and abiotic properties of their environment were investigated through standard boat based surveys (18), conducted under daylight conditions (07:00 to 15:00) in the austral winter (May - August 2006). This provided even and representative coverage in which to examine the space-time structure of bottlenose dolphin habitat. Group size (defined as being the total number of animals counted within a 100 m radius of each other; (5), behavioural activity (categorized as travelling, milling, resting, feeding and socialising; (15), habitat type (seagrass, bare sand) and GPS location were recorded at the time of a dolphin sighting. Depth, temperature, dissolved oxygen, salinity, turbidity and pH were recorded using a depth sounder and a TPS 90FL-T at 30 minute intervals until the completion of a survey and at the time of a dolphin encounter.

As the environmental parameters were not normally distributed (Kolmogorov-Smirnov test, $p<0.05$), the potential differences in environmental water properties between dates and locations used and not used by dolphins were inferred using the Wilcoxon-Mann-Whitney U-test (19). The space-time structure of the environment used by dolphins was investigated through a principal components analysis (PCA) performed on the observations and the variables (13). These variables were date (julian days), latitude, longitude, depth (m), temperature (°C), dissolved oxygen (mg/L), salinity (ppm), turbidity (NTU), pH and habitat type (seagrass or bare sand). The identification of the components of the multivariate analysis was carried out using the factor loadings of the variable in the PCA analysis since the factor loadings of a given factor could be related to the variance explained by such a factor (11). A subsequent analysis was done introducing in the original PCA additional variables related to the number of dolphins observed at each date and location, together with their behavioural activity.
No statistically significant differences were observed between the environmental water properties measured at dolphin and non-dolphin sites (Table 1; U-test, $p>0.05$). While environmental water properties, in particular temperature and depth (6,18,5) have commonly been identified as factors which influence bottlenose dolphin distribution, this indicates that distribution of *T. aduncus* within the ADS was not related to the physico-chemical properties of the water column. Field observations also suggested a preference in the utilization of

Environmental Property	Dolphin Sites		Non-Dolphin Sites	
	Min	Max	Min	Max
Temperature (C°)	13.4	24.1	13.4	24.1
Depth (m)	1.8	15.4	1.9	14.3
Salinity (ppm)	24.8	44.8	24.3	47
Dissolved Oxygen (mg/L)	8.78	30.14	7.1	20.14
Turbidity (NTU)	1.0	7.4	0.3	4.5
pH	5.49	5.91	5.27	5.64

Table 1: Minimum and maximum values of environmental water properties measured at dolphin and non-dolphin sites.

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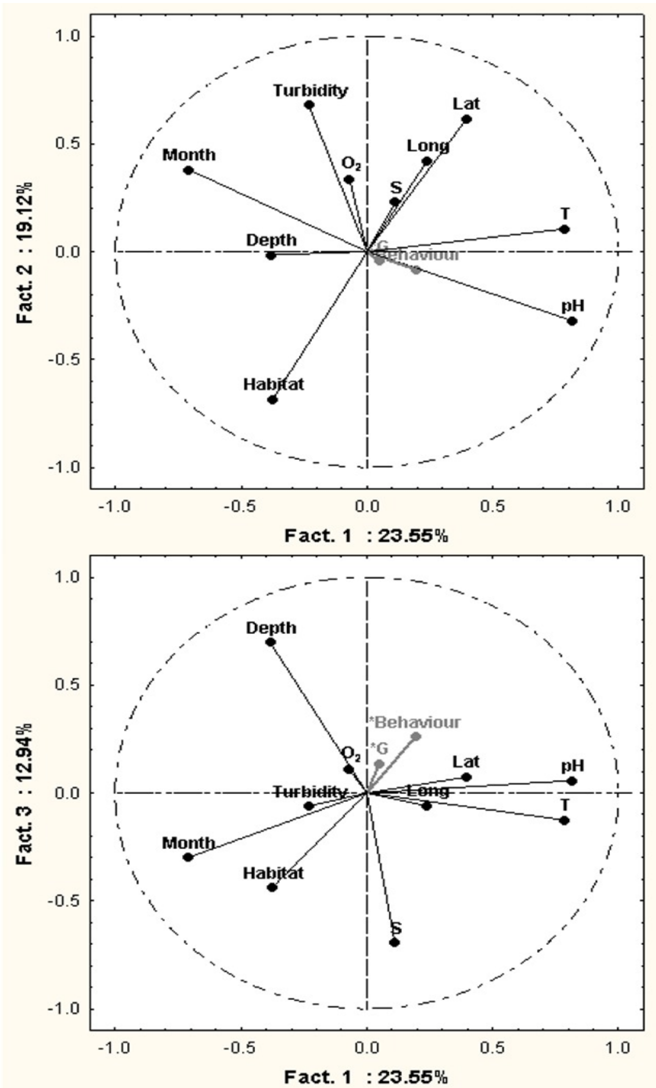

Figure 1.
Principal Component Analysis. Correlation circle showing the position of the initial variables (black dots) and additional variables (grey dots) in the two-dimensional spaces of the three principal components Fact. 1, Fact. 2 and Fact. 3. (G: Group Size; Lat: Latitude; Long: Longitude; T: Temperature; S: Salinity, O2: Oxygen).

one habitat type as all behavioural activities, except resting, were observed over the bare sand habitat within the estuary, whilst only travelling and feeding were observed over seagrass. These observations were specified by the PCA analysis. The first three principal components of the PCA (Fig. 1) explained 55.61% of the total variance. The first component (Fact. 1; 23.55% of the variance), was significantly positively correlated with latitude, longitude, temperature and pH and negatively correlated with depth, habitat type and sampling date (Fig 1). The second component (Fact. 2; 19.12% of the variance), was significantly negatively correlated with habitat type and pH, and positively with sampling date, latitude, longitude, oxygen concentration and turbidity. Finally, the third component (Fact. 3; 12.94% of the variance) was only significantly positively correlated with depth and negatively with salinity. The additional variables relative to the group size and behaviour of the dolphins exhibited patterns in the spatio-temporal space defined by the PCA. Bottlenose dolphins did not exhibit any specific habitat choice (i.e. seagrass or bare sand) in terms of group size (Fig 1.). In contrast, the positive correlation between the behaviour index and the third component suggests that socialising occurs more frequently in deeper water whatever the habitat type. While this may contradict previous studies showing correlations between dolphin behavioural activity and the physical and spatial components of habitat (14), our observation of an increased utilization of deeper waters for socialising may be considered as a first step to identify areas of particular relevance for the ecology, hence, the conservation of local populations of *T. aduncus* (17).

Despite this lack of clear relationships between dolphins and habitat, it is likely that they are responding to other environmental factors. In particular, prey distribution is more likely to affect cetacean distribution than properties of the physical and chemical environment (10,9,2). It is intrinsically difficult to obtain reliable estimates of fish stocks in shallow environments. In particular, in the ADS this limits the ability to make direct links between predator and prey distributions. Further studies should incorporate investigations of dolphin prey space-time dynamics to objectively infer the potential link between dolphins and their habitat. In conclusion, the approach used in this work to quantitatively measure dolphin habitat within an estuarine environment may provide an objective, statistically-sound basis to uncover the complexity of dolphin-habitat interactions in coastal waters. This may also provide assistance to the implementation of further management and conservation plans.

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We wish to thank Flinders University, WDCS, Mike Bossley and Ken Sanderson for providing resources and support, and Peter Cribb for contributing to fieldwork.

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A Hand-held, PDA Based System for Seabird Data Collection During Cetacean Surveys

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Abstract
New methodologies and technologies allow to record an ever-increasing number of complex and accurate field data at sea but information on different species, especially top predators, are rarely collected simultaneously in an effective manner. The concurrent data collection - both in space and time - on birds and cetaceans (especially dolphins) may allow a better understanding of ecological linkages in the marine ecosystem. Herein we describe a new approach involving direct entry of data by seabird observers using a hand-held, pen-based computer or PDA (Personal Digital Assistant), and illustrate a simple database design and its field use for seabird data recording during cetacean surveys. The data - collected through CyberTracker software - have the advantage of being date/time and GPS cross-referenced with cetacean data recorded on other computer platforms available on board (e.g. in our study: Logger software - developed by the International Fund for Animal Welfare - using a PC laptop) or with another PDA. The user-friendly PDA seabird database offers the benefits of: 1) easy adaptation to any other field protocol, 2) reasonable cost, and 3) easy handling in small vessels. [JMATE. 2008;1(1):9-11]

Keywords: computer, birds, marine mammals, technology, database design

Introduction

Real-time and synchronized collection of cetacean and seabird data at the same location at sea is becoming increasingly valuable for a variety of studies aiming to a better understanding of ecological linkages and the role of marine species in an ecosystem. The proposed use of a hand-held PDA allows real-time collection of seabird numeric and descriptive data. The seabird data can be easily cross-referenced with a main database of cetacean data via time and/or GPS thereby avoiding time consuming or postponed data entry with a likely risk of error.

By using PocketPC or PalmOS handheld computers with built-in Bluetooth wireless technology for GPS and CyberTracker software (http://www.cybertracker.co.za/) we were able to create our own data entry template and screen sequence for seabird data collection. CyberTracker was chosen because: 1) it can be downloaded for free, 2) it is easy to use and customize, 3) it gathers large quantities of geo-referenced data for field observations, 4) it uses plain, readable icons, 5) the database is easy to export for data analysis in Excel, Access, etc.

In addition to the handheld computer, CyberTracker software requires the accompanying PDA desktop software and a GPS (Global Positioning System) receiver. First, CyberTracker software must be installed onto a computer with operating system Windows XP or 2000 (in our case the same PC laptop with Windows XP used for cetacean data collection in Logger) and then uploaded to a handheld, pen-based computer. It is also helpful to have the appropriate SD or Compact Flash Memory card for the computer used, to facilitate field back-ups, and removable/rechargeable batteries to ensure data collection throughout the entire survey.

To create a personalized database for seabird data collection any user can utilize or modify a "sample database" available in CyberTracker and simply follow the instructions. The user can create one or more screens (individual page views of the handheld PDA) selecting different choices (called elements) for each screen. Elements are data the user wishes to record in the field. For each screen, it is possible to create text, icons – either importing personalized icons or choosing from the CyberTracker image library - or both; the screen is pen-sensitive making the page scrolling and element choice fast and easy. The screen sequence can be designed in a flexible way depending on the user needs (e.g., different choices may lead to different screens, save screen 3 may bring user back to page 1, etc) and using "navigator" buttons (e.g., *Show Next, Show Back*, *Show GPS,* etc). After the screen sequence is designed, it can be uploaded to the PDA and synchronized. At the end of each cetacean survey, data from the PDA can be synchronized to the main computer and cross-referenced by date/time with cetacean data.

Seabird Data Collection With A PDA During Cetacean Surveys in Southern California

Field data on seabirds in Santa Monica Bay and the Southern California Bight are usually collected by one seabird observer (SBO) during cetacean surveys (Fig. 1). Seabird data are recorded during surveys both in absence and presence of cetaceans utilizing a *strip transect* method. A 300-m strip transect is suggested for concurrent data collection of seabird and cetacean data (2). The method requires recording data on seabirds that are found within a 300-m wide strip as the boat proceeds. There is one critical assumption in strip transect methods: the SBO must detect all seabirds within the sampling zone at any particular time during a chosen interval (for consistency, the interval must be the same used for cetacean sighting; e.g., in our study 5-min samples are used both during cetacean sightings and during the entire course of the survey for seabird data collection). The SBO will continuously monitor and record all birds present within the same 180 degree area relative to the SBO's position on the boat. The possible fields of view are: 1) 180° facing Bow, 2) 180° facing Port 3) 180° facing Stern, 4) 180° facing Starboard. The SBO should preferentially choose to look forward standing or setting in a high position. If there is glare or impaired visibility, he/she should opt for the field of

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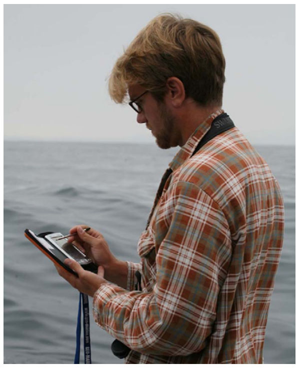

Figure 1: Seabird observer collecting data with a PDA.

view that provides the best viewing conditions.

The number and kind of birds observed are recorded on the PDA by an instantaneous sampling method (1), more recently described for dolphins as point samples (4). The SBO may encounter a situation when the bird abundance is so high that it becomes impossible to count and enter individual birds in real time. In these situations, it is helpful to count birds in blocks (as groups of 10's for example).

During the entire seabird data collection (see SEABIRD DATA COLLECTION DESIGN), the data on sea/weather conditions and cetacean sightings are entered by another database recorder in the software Logger on a laptop computer. For each survey, Logger displays a set of tabbed forms (in our study customized in: *Survey Info form*, *Log form*, *Sighting form*, etc) that are cross-referenced by an index. Logger allows automatic collection and storage of GPS and other NMEA data as well as manual entry of behavioral information on cetaceans, photo-identification data (photo-identification is a technique used to identify individuals in a group), video data, etc. During a dolphin sighting, dolphins are observed for 5-min and data recorded and stored at the end of 5-min intervals when the countdown timer rings throughout the sighting; the first data collection for the *Sighting Form* starts at the end of the first 5-min of observation of a focal group of cetaceans and the data is stored at the end of each 5-min sample (3). The same method is used for seabird data collection. The SBO enters all the seabird data during the chosen time interval (5-min sample) moving back and forth between the different pages, but the GPS position is stored only at the end of each time interval. At the end of a survey, the data from the hand-held PDA are archived by synchronizing the data with the PC computer via USB. This database is then cross-referenced by time and position in the lab to the LOGGER database. All data are stored in a Microsoft Access database.

Seabird Data Collection Design

The Los Angeles Dolphin Project Bird Database was created using the software CyberTracker 3.0 running on a Palm Tungsten E2 handheld with built-in Bluetooth wireless technology for GPS (the database sequence design is available at the Cybertracker website).

The database is comprised of a *Start Menu* screen and six main data entry screens. These are shown in a sequence on the upper part of each page 1-6 and called *Data 1-6* (Fig. 2). Each screen also displays icons on the bottom of the page that help in navigating between screens (*Show Next, Show Back*), viewing the GPS status (*Show GPS*), storing the GPS data at the end of an interval (*Show Major Target*), and viewing the recorded data to edit it in the field (*Show Options*; *all sightings/active sighting*).

The *Start Menu* displays four icons with text representing: *Researcher Name*, *Research Vessel*, *Observation Position* and *Begin Survey.* When all data are entered in the *Start Menu*, the seabird data collection begins at 5-min intervals by selecting *Begin Survey* and clicking on *Show Next* to enter the data acquisition phase of the program.

The *Data 1* screen displays the name of 17 different seabird groups (e.g., gulls, grebes, cormorants, etc) typically found in the study area followed by the number *000*; the SBO can enter the number of specific birds observed for each category throughout the 5-min interval up to *999*. There are also categories for *uncertain* and *other* species in case the SBO is

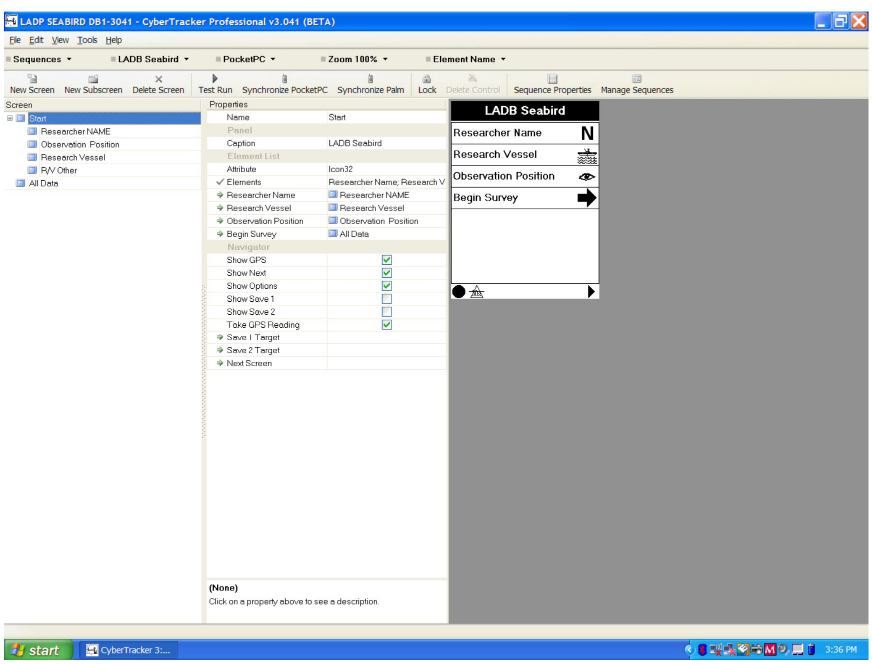

Figure 2: Example of screen for seabird data collection created in CyberTracker.

unable to determine the correct species or needs to write comments (e.g., sighting of a rare species of which the name is known, etc). Comments can be added at any time during the survey in *Data 6* by writing text that is recognized by the PDA. Screens *2 to 5* show a series of checklists where additional information may be entered: estimated distance from vessel to observed birds, age of observed birds (adults, non-adults, uncertain), bird behavior during survey with and without cetacean presence (e.g, passing by, steal fish, approaching cetaceans, etc), type of approach and separation between seabirds and cetacean schools and average distance between birds and cetaceans. During the 5-min interval, the SBO usually works in *Data 1* entering and updating the number of birds observed, but he/she can easily move back and forth between screens checking the appropriate categories and icons or changing the information as required. At the end of the 5-min interval, the SBO clicks on *Show Major Target* to store data and GPS and automatically returns to *Data 1*. At this point, *Data 1* is empty and ready for a new 5-min cycle. If *Researcher Name* or *Observation Position* changes any time during a survey, clicking on *Show Back* from *Data 1* will return to the *Start Menu.*

Authors' Remarks

The Los Angeles Dolphin Project database is not designed for complex data collection on seabirds and, for some of the data recorded, offers only broad-spectrum data estimates on seabirds recorded during a cetacean survey. It is recommended for users in need of general information on seabirds in a study area during cetacean surveys. The Los Angeles Dolphin Project Bird Database, however, can be easily modified.

Acknowledgments

The manuscript was improved through reviews by G. Bearzi and J. Feenstra and Louis Liebenberg. The field research was funded by Ocean Conservation Society and Santa Monica Bay Restoration Commission. Thanks to all the Los Angeles Dolphin Project assistants. Special acknowledgments to CyberTracker for the use of the software and answering our questions, to Maptech for the PC Chart Navigator software, and IFAW for the Logger software. Fieldwork was carried out under the current laws of California and the General Authorization for Scientific Research issued by NOAA (File No. 856-1366).

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Staphylococcal Pyelonephritis and Cystitis in a California Sea Lion (Zalophus Californianus)

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Abstract
An adult, female California sea lion (*Zalophus californianus*) was stranded in Laguna Beach, California (33° 32'43.96"N x 117 ° 47'51.10"W) on January 13, 2007. Clinical signs included marked lethargy, head-bobbing and 'wet-dog shaking'. A presumptive diagnosis of Domoic Acid intoxication was made and supportive therapy including anti-seizure treatment was instituted. About thirty hours later, seizure activity had abated but the animal continued to deteriorate to a semi-comatose state and euthanasia was elected. Postmortem examination revealed severe, bilateral pyelonephitis and cystitis from which a pure culture of *Staphylococcus aureus* was isolated. With the exception of *Leptospira sp* interstitial nephritis, bacterial urinary tract infections are very rare in marine mammals. To the author's knowledge this is the first report of *Staphylococcus aureus* pyleonephritis and cystitis in the California sea lion. [JMATE. 2008;1(1):12-14]

Keywords: California sea lion, bacterial nephritis, *Staphylococcus aureus*

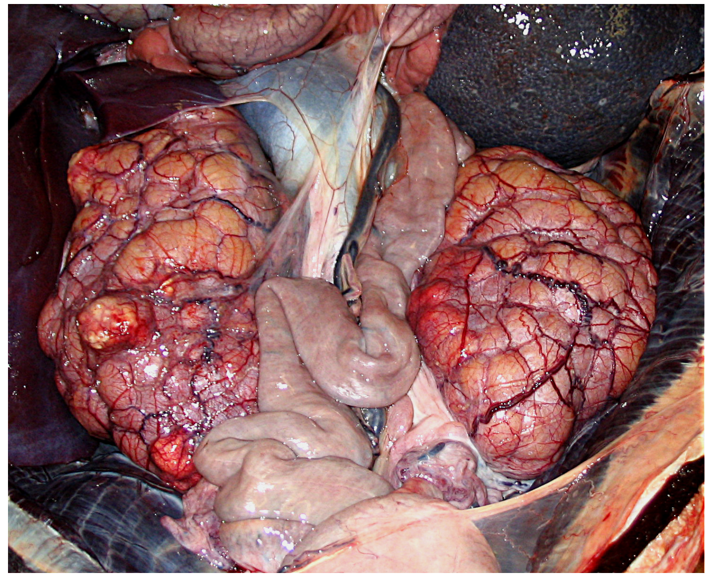

Figure 1a. *Staphylococcus aureus* nephritis in California sea lion. There is a generalized marked, bulging accentuation of the reniculi. A completely abscessed reniculus is noted in the lower right kidney.

Introduction

An adult, female California sea lion (*Zalophus californianus*) stranded on the beach at Shaw's Cove, Laguna Beach, California (33° 32'43.96"N x 117° 47'51.10"W) on the afternoon of January 13, 2007. A rescue team from the Pacific Marine Mammal Center (PMMC) was dispatched to the scene and noted the sea lion to be very lethargic, reluctant to move and exhibiting periodic head-bobbing and generalized 'wet-dog shaking'. Domoic acid (algae toxin) intoxication was suspected and the animal was impounded and transported to PMMC.

Physical examination revealed moderate, generalized body wasting and intermittent low-grade tonic-clonic seizure activity with head-bobbing. Heart rate was 86 bpm, respirations ~30/minute and temperature 38°C (100.4°F) . Rehydration was instituted by subcutaneous administration of lactated Ringers. Diazepam (5 mg/ml Benzodiazepine) was given intramuscularly (dosage = 5 mg) to control seizures. Attempts at blood collection via the caudal gluteal and jugular veins were unsuccessful. Twenty four hours later, the sea lion's condition had stabilized with no obvious seizure activity. However, the following morning she had deteriorated to a semi-comatose state with very sluggish to non-existent reflexes and moderate bradycardia and dyspnea. Because of a poor prognosis, euthanasia and postmortem examination was elected. Following euthanasia, blood samples were collected for pick-up and analysis (CBC and serum chemistry) by a local, commercial veterinary laboratory. Unfortunately, the samples were accidentally destroyed in -route to the laboratory.

Postmortem examination revealed a marked generalized muscular wasting and depletion of subcutaneous and visceral adipose stores. Gross and histologic examination of the brain, as well as analysis of blood and cerebrospinal fluid for Domoic acid by a specific ELISA (Dr. Astrid Schnetzer, Caron Laboratory, University of California, Los Angeles) failed to substantiate a diagnosis of Domoic Acid poisoning.

Visceral gross and microscopic pathology was restricted to the urinary system. Kidneys were discolored yellow and exhibited a marked, bulging accentuation of the reniculi (Figure 1a). Transverse sections of kidneys revealed multifocal clusters of multiple, 'ragged' reniculi with scattered, relatively normal reniculi (Figure 1b). Wright's Giemsa and gram-stained impression smears contained necrotic material with intermixed masses of neutrophils and mononuclear phagocytic cells, containing large numbers of gram-positive cocci, singly, as pairs or in clusters (Figure 2).

Histologically, there was moderate to severe, multifocal to diffuse tubuloglomerular necrosis and loss, with moderate to severe, tubulointerstitial neutrophil, macrophage and some lymphoid infiltration. Multifocal, varying sized colonies of gram-positive cocci with surrounding Splendore-Hoeppli material (radiating eosinophilic deposits) were scattered irregularly, throughout the renal parenchyma (Figure 3a). Large masses of degenerating neutrophils and other necrotic debris filled the pelvis of many reniculi (Figure 3b). The bladder was markedly distended with dark-colored urine. A cystocentesis revealed a

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Figure 1b. Transverse sections of formalin fixed right kidney. Multiple foci of contiguous, 'ragged', inflamed renucli are apparent, however several adjacent reniculi are relatively unaffected (medullary pyramid lower right, top section). The large vacuolated portion in the bottom section represents pelvic dilation secondary to corticomedullary loss from necrotizing inflammation.

urine specific gravity 1.2, pH 7.5, moderate to marked levels of blood, ketones, glucose, protein, urobilinogen and bilirubin. The urine sediment contained large numbers of neutrophils, many macrophages containing gram-positive cocci and some plasma cells and lymphocytes. The bladder wall contained moderate to severe, multifocal areas of denuding necrotic urothelium with moderate to marked, submucosal infiltration by moderate to marked numbers of neutrophils and macrophages with occasional scattered colonies of gram-positive cocci.

Swabs of asceptically obtained, clotted blood and the deep parenchyma of the right kidney were taken and submitted to a local veterinary laboratory (IDEXX) for bacterial culturing. No bacteria were cultured from the clotted blood but a pure culture of oxacillin-sensitive *Staphylococcus sp*. was obtained from the kidney. Culture samples were submitted to the University of California at Davis, College of Veterinary Medicine, Clinical Laboratory for speciation. The organism was found to be a coagulase-positive *Staphylococcus,* phenotypically identified as *Staphylococcus aureus.*

Staphylococcus aureus is a gram-positive, coagulase-positive bacterium commonly found as a benign, commensal on the skin and mucous membranes of the respiratory, gastrointestinal and urogenital tracts of wild and domestic mammals and birds. However, when these membrane barriers are compromised by physical trauma and/or immunopathies, *Staphylococci* may gain entry into the tissues, resulting in bacteremia and disseminated inflammatory disease. A classic example in humans and other animal species is lower urinary tract trauma resulting in ascending disease through the bladder and into the kidneys (5). In this case, the fact that *Staphylococcal* bacteremia was not detected from an aseptically collected blood sample gives credence to an ascending disease etiology, i.e. the bacteria probably gained entrance through the vulvar area, up the urethra, into the bladder and finally the kidney.

The normal kidneys of a California sea lion are multilobed or reniculate, being composed of hundreds of lobes or 'reniculi' (LL, Dim., "Little Kidneys"), which are further divided into the standard morphologic subunits of metanephric kidneys, i.e. a distinct layer of cortical tissue completely surrounding a medullary pyramid within a single calyx (1,6,7). Unlike the *Phoca* in which each reniculus is distinctly separated by an external capsule, in *Zalophus*, only a very thin fibrous capsule is noted surrounding the reniculus which allows inflammatory disease to readily spread between reniculi as depicted in this case (Figure 1b) (1).

Howard's 1983 study on the pathobiology of marine mammal diseases noted kidney infections to be "uncommon" in marine mammals, but referenced a case of *Leptospiral* nephritis in a northern fur seal (3). A review of the literature since this time, clearly shows *Leptospira* are now a common etiology for chronic interstitial nephritis in the California sea lion (2,11). However, only a few cases of *Staphylococcus*-associated renal disease have been reported in marine mammals. In a case published in 1973 involving attempts to rehabilitate a newborn Harbour seal stranded in Alaska, pustular dermatitis was noted at 12 days of age, followed by death at 21 days with the post-mortem isolation of a coagulase-positive, S*taphylococcus aureus* from the lung, liver and kidneys (10). In 1974, Ketterer and Rosenfeld reported a *Staphylococcus aureus* subcutaneous abscess in a dolphin (*Trusiops truncatus)*, resulting in fatal septicemia and septic embolic nephritis (4). In 2001 and 2002, *Staphylococcus aureus* septicemia and severe, supparative pyleonephritis was found following postmortem examinations in Harbour porpoises (*Phocoena phocoena*) stranded in the German North and Baltic Seas (8,9). To the authors' knowledge, this case appears to be the first report of urinary tract infection attributed to *Staphylococcus aureus* in the California sea lion.

In conclusion, there are several important points to made and lessons to be learned from this case: 1) Generalized body

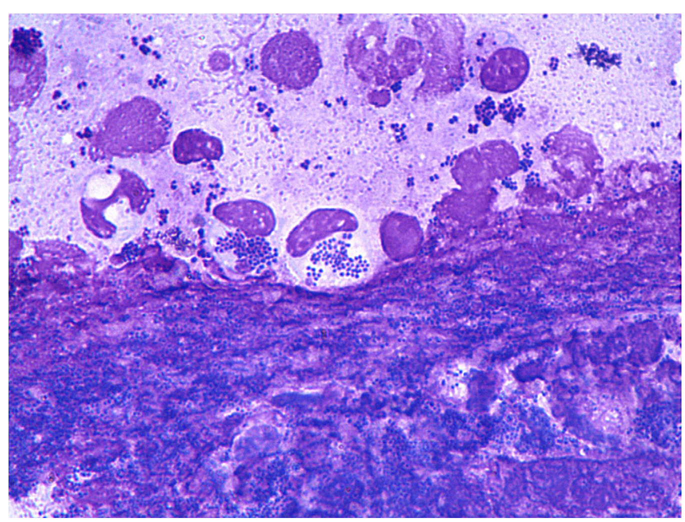

Figure 2. Cut-surface touch impression of right kidney. Note mononuclear, phagocytic cells containing proliferating bacterial cocci arranged in couples or varying sized clusters. Wrights-Giemsa stain, 40x

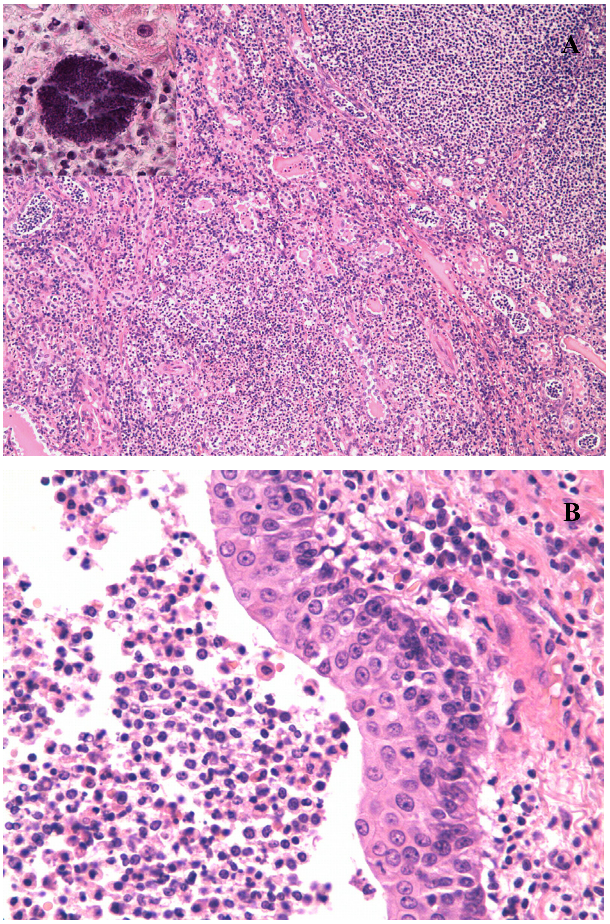

Figure 3. **A,** Obliteration of normal kidney architecture by marked, diffuse tubular necrosis and inflammation. Inset upper left: Gram-positive cocci bacterial colony within interstitium with a surrounding layer of Splendore-Hoeppli material. H & E 4x. **Figure B,** Renicular pelvis with marked infiltration of neutrophils, active macrophages and plasma cells, transitional urothelial hypertrophy and hyperplasia and interstitial mixed inflammatory cell infiltration. H & E 40x

wasting, lethargy and neurologic signs are not etiologic specific findings, but rather they are found in a myriad of subacute to chronic organ-system based diseases, 2) It is necessary to conduct gross postmortem examinations on *all* mortalities occurring in a rehabilitation center. In this case, had such an examination not been done, an erroneous clinical diagnosis of Domoic Acid intoxication might have been made, 3) Cytological examination of tissues is an easily performed, "low tech" procedure that has significant diagnostic utility. In this case, staining of impression smears of grossly abnormal kidneys with a Wright-Giemsa and a Gram's stain, easily revealed a severe, gram-positive coccoid bacterial associated, inflammatory disease process.

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Winter abundance estimates for the common dolphin (Delphinus delphis) in the western approaches of the English Channel and the effect of responsive movement

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Abstract
A survey using line-transect techniques was conducted during two winters providing the first estimates of common dolphin, *Delphinus delphis,* abundance (number of dolphins) on winter pelagic trawl fishing grounds in the English Channel. Independent teams of observers searched with binoculars or naked eye. These methods were intended to allow for the calculation of a correction factor for both animals missed on the trackline and for responsive movement. Results indicated that the naked eye observers missed 7% of the dolphins on the trackline, but that there was a strong responsive movement towards the vessel. Comparing initial locations of animals detected by the two independent teams showed that just using naked eye observations would result in apparent densities that were 1.5 times larger than the dual platform analysis. Using these factors the mean corrected winter density of common dolphins in the study area across both years was 0.74 dolphins/km^2 (CV = 0.39) giving a mean abundance of 3,055 dolphins (95% CI = 1,425-6,544). However, these estimates are most likely positively biased due to responsive movement not being fully accounted for. Nevertheless, the relative index for abundance (number of schools per 100km effort, mean school size 5.1) was the highest recorded from comparable surveys in the North Atlantic and shows that the Channel is a very important winter habitat for common dolphins. [JMATE. 2008;1(1):15-21]

Key Words: *Delphinus delphis*; line-transect survey, mark recapture distance sampling

Introduction

The English Channel constitutes a relatively narrow link between the Atlantic Ocean and North Sea that appears to have had variable use by common dolphins over time (15). Fish stocks in the Channel are heavily exploited here with pelagic fisheries operating during the winter months from October to May. In recent years, several hundred corpses of short-beaked common dolphins (*Delphinus delphis*) have washed ashore in south west England each winter, many clearly diagnosed as having died through capture in fishing nets. In the case of many of the common dolphin corpses, the external damage is consistent with death in small-meshed mobile gear (i.e. trawl netting) (18). The conservation status of the common dolphin has therefore become of great concern (20, 14, 17). In recent years the UK has conducted monitoring of the winter sea bass fishery, which has been found to be responsible for a high rate of cetacean bycatch (6). However, there are still no estimates of total annual bycatch for this species in all fisheries combined (10).

Only a few studies to date have reported the abundance of the short-beaked common dolphin in the NE Atlantic or supplied an estimate or index of density and abundance (8, 5, 4,13). However, these surveys differ in distribution of effort, vessel-type, survey methodology and the season in which they were carried out.

This study utilised a commonly used method for estimating animal abundance, distance sampling, and highlights the consequences of responsive movement of dolphins towards the survey vessel. Line-transect surveys were conducted in two subsequent winters (2004 and 2005) to estimate the first winter abundance of common dolphins in an area of the Western Approaches of the English Channel.

Material and Methods

Survey design

The survey was conducted from the *MV Esperanza*, a 72.3m research vessel which traveled at either a 'fast' average speed of 8.6 knots or a 'slow' average speed of 5.3 knots. All data used for density estimation were collected in 'passing mode', where the vessel did not deviate from the track-line in response to sightings of the target species.

The two surveys were conducted during the winter months, between 21 January and 8 March 2004 and between 17 February and 26 March 2005 in the Western Approaches of the English Channel. The study area was divided into different survey strata and lay between 49°20'N-50°20'N and 3°26'W-6°10'W (Fig. 1). The western stratum (Stratum W) extended to the west and covered 4,743km^2 and the eastern stratum (Stratum E) covered 4,129km^2. Both strata coincided with an area where trawlers operate during winter.

The survey track followed a saw tooth (zig-zag) pattern inside a rectangle (survey stratum). The zig-zags (transects) were designed such that the offshore boundary of the stratum was drawn parallel to the major axis of the coastline. Each point within the specified survey stratum had an equal probability of being on a line. The overall orientation of the transect lines was also designed such that they were placed approximately across likely density contours.

Data collection

To facilitate systematic data collection, the data-logging program *Logger 2000* (developed by IFAW to promote benign, non-invasive research) ran continuously throughout the survey on a laptop computer which was linked to the ship's Global Position System (GPS, a Furuno GP-80 satellite navigation system) through an NMEA (National Marine Electronics Association) interface. This program automatically recorded the ship's location every 15 seconds and provided a continuous visual display of the vessel's track on a map of the area. Data concerning sightings and the environment were entered manually.

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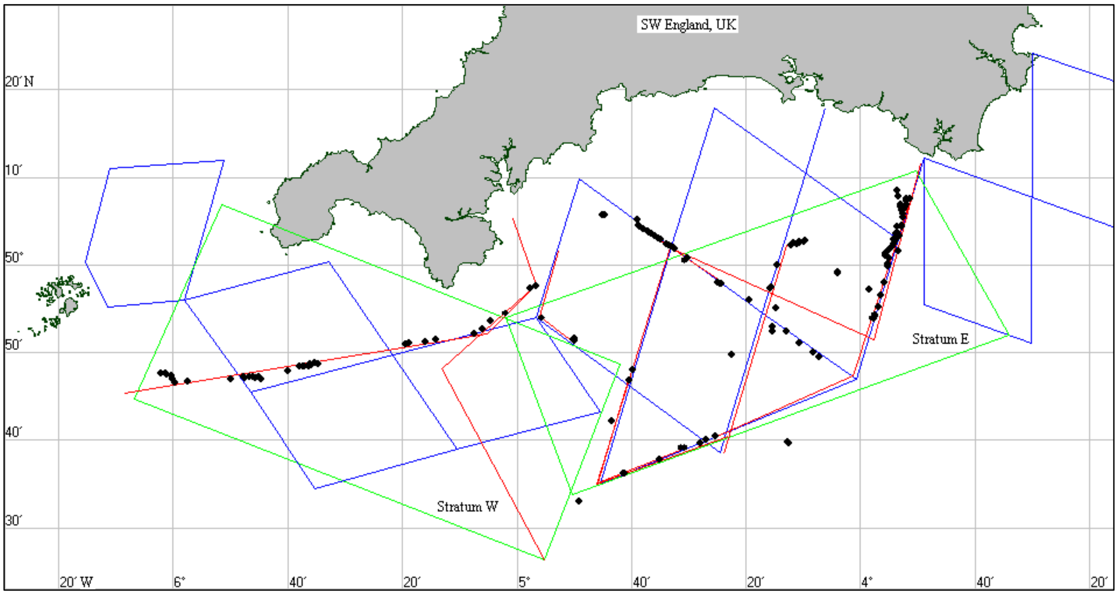


Figure 1. Map showing the transect layout (blue lines) with achieved effort (in red lines) and survey strata (green boxes). Sightings of common dolphins are plotted as black dots.

The Primary platform

During both the 2004 and 2005 surveys, observations were conducted from a Primary platform. This was located on the outer bridge wings with an approximate eye height of 11.3m and was visually and acoustically independent from the secondary (tracking) platform. The two Primary observers scanned a 90 degrees sector (on port and starboard), forming an approximately 180 degrees combined survey area in front of the ship. Scanning was done with the naked eye. A third person acted as the data recorder, entering sighting information and environmental details. The observers were rotated every hour to avoid fatigue.

Once a sighting was made, Nikon 7X50 marine binoculars with in-built reticule scales were used to measure the vertical angle from the horizon to the sighting in order to estimate distance. The bearing to the sighted animals and the animal(s) headings were determined by using 'angle-boards' which were fixed to the ship's railings. These were aligned parallel to the ship's bow and the alignment checked and corrected throughout the survey.

Sightings data recorded from the Primary platform included the time, GPS position, bearing, distance, species identification (and degree of certainty ranging from definite-100%, probable-75% to possible-50%), presence of calf and/or juveniles, school size (maximum, minimum and best estimate), animal's heading, travel mode, group composition and behaviour.

The following environmental data were collected every hour, and when conditions changed: ship's position, heading and speed; wind speed and direction (using an OBSERMET Wind meter *OMC 939*); cloud coverage and glare conditions (in degrees); visibility; swell height; and sea state. Water depths were obtained using a Furuno Navigational Echosounder (FE-700).

The secondary (Tracker) platform

During the 2005 survey, observations were also conducted from a second platform. This Tracker platform was situated in the ship's crow's-nest, with an approximate eye height of 19.5m, housing one observer ('Tracker'). The crow's nest contained two window frames which interrupted the view but allowed searching an uninterrupted combined area of at least 60 degrees (30 degrees on either side of the trackline with a free view beyond both frames to 120 degrees on either side) using Nikon 7X50 reticule marine binoculars mounted on a tripod. A digital voice recorder with a built-in digital camera (Olympus W-10) was attached to the binoculars and was used to record the following sightings data: time, reticules, heading, species ID and school size. The camera was facing down when photographing the bearing to the sighting to obtain images of reference lines on the deck. These lines were used to calculate the bearing to the sighting relative to the ship's heading using the methods of Leaper and Gordon (12). The Tracker concentrated on searching at ranges beyond 1,000m ahead of the vessel (prioritising sightings >1,500m), trying to detect animals before they had responded to the approaching vessel, and recording re-sightings (tracking) until the animals had passed abeam.

The Tracker platform was not in operation throughout the survey. However, it was used whenever possible and when the ship was going at 'fast' speed and in a straight line.

Data analysis

Only data collected from both platforms during 'fast' speed were used for conventional distance sampling analysis, whereas the Primary platform data collected during slow and fast speeds was used to study the effect of responsive movement.

The line transect method is based on certain assumptions. One of them is that all objects at zero perpendicular distance from the trackline are detected, that is '*g(0)*' equals one, where '*g(y)*' is the probability that an object at a perpendicular distance *y* from the line is detected. In practice, however, this is likely to not be a valid assumption for cetaceans as they can be missed for a number of reasons. This is the main reason why during line-transect surveys two independent data sets are often collected, because it allows for the calculation of a parameter, *g(0),* to account for animals missed on the trackline. If no correction is made for *g(0)* then this is a source of negative bias (3). Another potential problem is that of a 'responsive

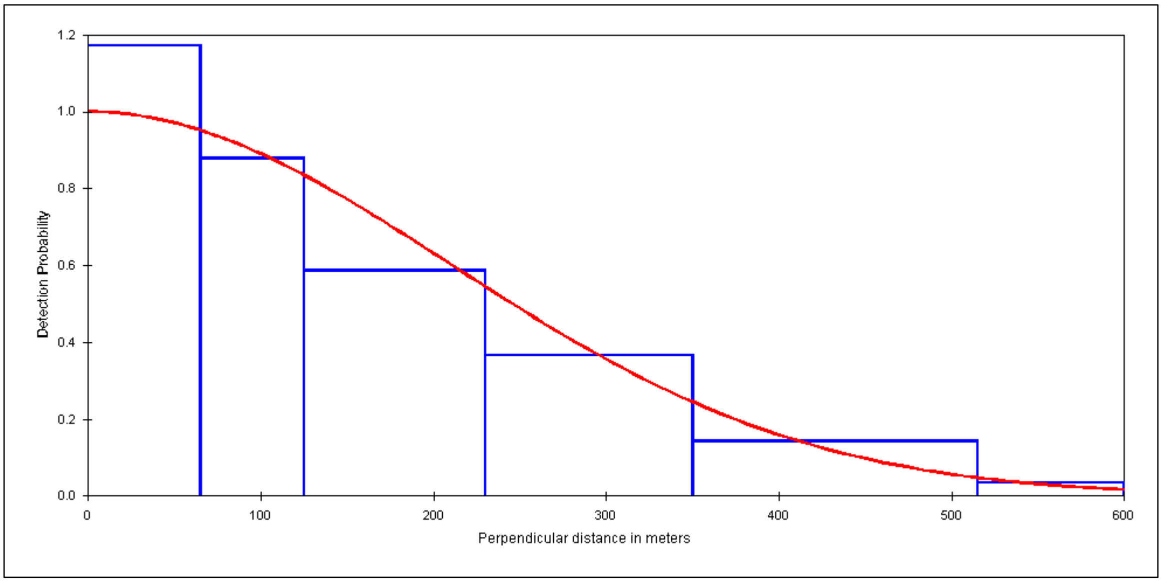


Figure 2. Histogram of perpendicular primary sighting distances and their fitted detection functions for common dolphins (*n*=108).

movement' of the animals to the presence of the survey vessel, since another assumption is that animals do not respond to the surveyor before detection. Common dolphins are known to be strongly attracted to vessels and frequently approach to investigate and 'bow-ride'. If animals approach the vessel before detection, this would positively bias the density estimate.

In the 2005 survey, the methodology followed the Mark Recapture Distance Sampling method first described by Buckland and Turnock (2). This method uses two sets of observation from the independent platforms to estimate a combined correction factor for *g(0)* and the effects of responsive movement. The underlying assumptions are that animals are detected by the Tracker platform before any responsive movement has taken place. In addition, the Tracker needs to search a sufficiently wide sector that animals should not be able to approach to within the field of view of the Primary platform without some chance of being detected by the Tracker.

Data from the Primary platform during double platform effort (predetermined transects and straight lines) were used to estimate the encounter rate (number of detections per km^2), while data from the secondary platform allowed the effective width of search from the Primary platform to be estimated.

Duplicate sightings (sightings seen by both platforms) were identified on the basis of time and sub-sequent resightings, species ID, best school size and heading of the animal(s). The eye-height for each observer was measured in order to convert radial distances calculated from the reticules and bearing data to perpendicular distance (3).

Using the program *Distance 4* (Research Unit for Wildlife Population Assessment, University of St. Andrews, UK) the conventional estimate of density (groups/km^2) was obtained by equating the number of detections from the primary platform (n_p) with the number expected. When assuming *g(0)* equals 1, the equation is:

$$\hat{D}_p = \frac{n_p \hat{f}(0)}{2L} \quad \text{(I)}$$

Where n_p is the number of primary detections, $\hat{f}(x)$ is the probability density of perpendicular distances x recorded from the primary platform and L is the length of transect (km).

The density estimate in (I) is biased if there is responsive movement in response to the platform before detection from the Primary platform or if the probability of detection on the trackline is less than unity. The estimate in the presence of both effects is then:

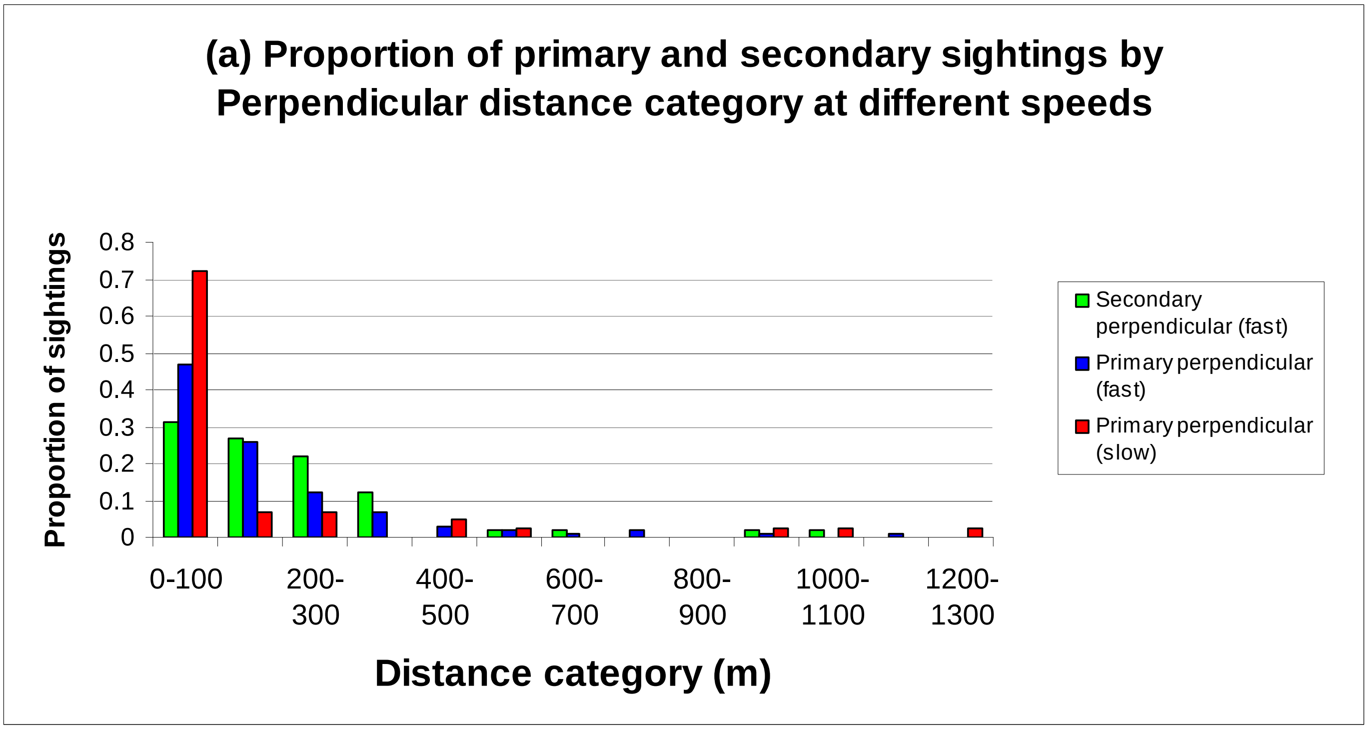
$$\hat{D}_c = \frac{n_p \hat{f}p(0)}{2L\hat{g}p(0)} \quad \text{(II)}$$

Where $\hat{f}p(x)$ is the probability density of perpendicular distances prior to responsive movement, of animals subsequently detected by the Primary platform and where $\hat{g}p(y)$ is the probability that an animal detected from the Tracker platform at perpendicular distance y from the trackline of the Primary platform is subsequently detected from the Primary platform (i.e. the detection function for the Primary platform).

If the Tracker platform is not in continuous operation, the above procedure is carried out on data collected while both platforms were in operation and a correction factor is calculated as:

$$\hat{c} = \frac{\hat{D}_c}{\hat{D}_p} \quad \text{(III)}$$

The density for the entire survey area is then estimated by cD, where D is estimated from the sightings data from the Primary platform for the full survey, calculated assuming $g(0) = 1$ (using *Distance 4*). This estimate does not include any covariates and thus the assumption is that the estimate of *g(0)* for the two platform effort is the same as for Primary platform only. The corrected abundance estimate is calculated by $N_c = c\ D\ A$ and the *CV* of the corrected abundance estimate can be



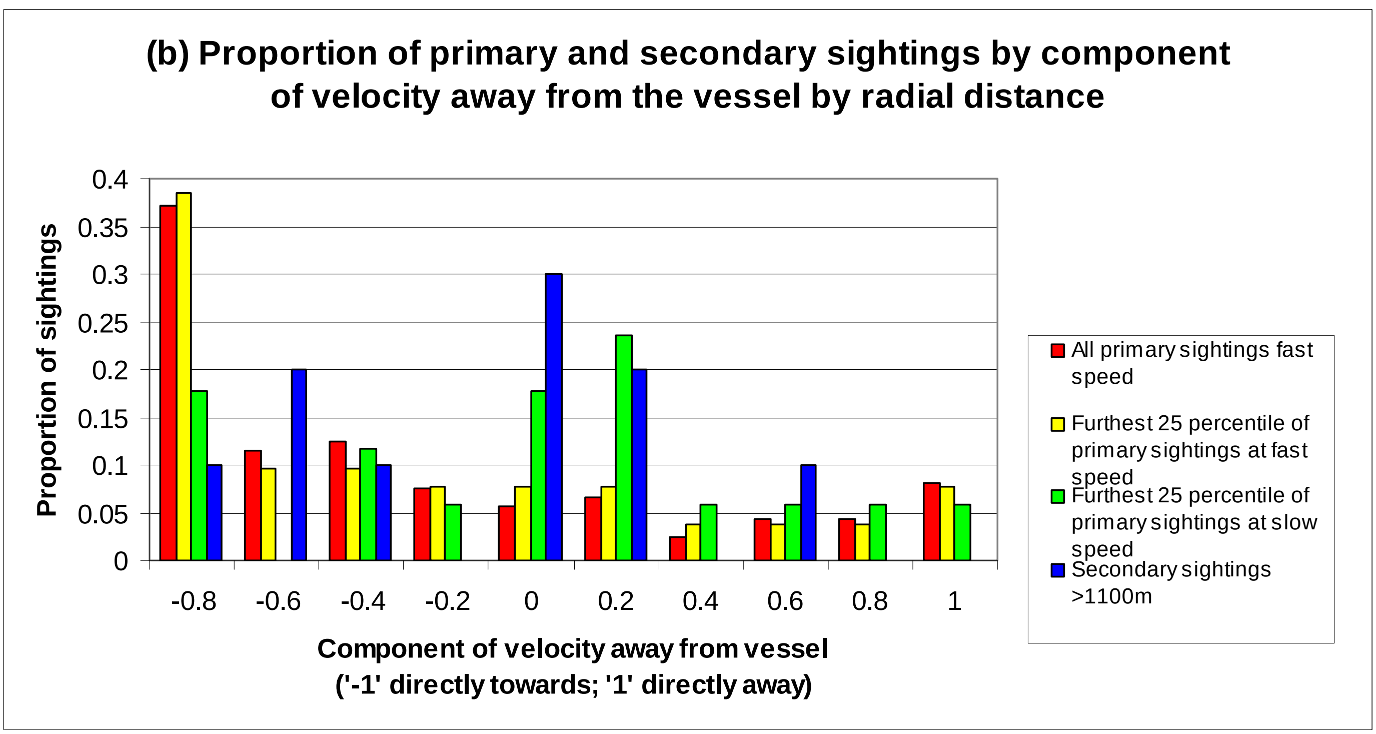


Figure 3. (a) The proportion of primary and secondary sightings by perpendicular distance category (m) at different survey speeds: 'fast' and 'slow' and (b) the proportion of primary and secondary sightings by component of velocity away from the vessel (*i.e.* the cosine of the difference between bearing and heading). Where a value of '1' indicates movement directly away from the survey vessel, '0' perpendicular and '-1' directly towards the vessel.

calculated by equations outlined in Turnock et al. (21). The upper and lower 95% confidence intervals for N_c can be calculated by using the Satterthwaite degrees of freedom procedure outlined in Buckland et al. (3).

Results

Survey effort

The line-transect survey covered 728.5km of transect and the double platform survey covered 514km. A total of 129 sightings of common dolphins of approximately 759 animals were made during the line-transect survey. Other species that were also identified during the survey were: harbour porpoise (*Phocoena phocoena*), bottlenose dolphin (*Tursiops truncatus*), Risso's dolphin (*Grampus griseus*), striped dolphin (*Stenella coeruleoalba*), fin whale (*Balaenoptera physalus*) and minke whale (*Balaenoptera acutorostrata)*.

Density and abundance

Common dolphin sightings first made aft of the beam were excluded. To ensure that only high quality data were used sightings made during Beaufort sea state >3 were removed and sightings beyond 600m were eliminated before *f(0)* estimation. Sightings made by the Primary platform were analysed for 2004, 2005 and pooled across both years.

Using the program *Distance 4*, we fitted detection functions to the perpendicular distance data to estimate the Effective half Strip Width (*ESW*) which is defined as *1/f(0),* for the different survey years. To reduce bias in mean school size estimates due to the potential of a positive relationship between school size and perpendicular distance *(x)*, a regression was performed to investigate the relationship between the probability detection function, *g(x),* and observed school size (3). From this regression, an expected school size was estimated. Akaike's Information Criterion (AIC) was used to select among models fitted to the data. Out of the models tested, the half-normal key with cosine adjustment was found to be the best fit for both surveys. The distribution of perpendicular distances and fitted detection function for sightings data pooled across both years is shown in Fig. 2.

Having selected a model, we reviewed the options for variance estimation. Bootstrapping was carried out which incorporates uncertainty in model fitting and model selection. Although survey effort was achieved in both strata, some concerns are given to the western stratum (covered only in 2004) where there were large differences between the designed and the realized cruise tracks as a result of heavy shipping traffic in the area (Fig. 1).

For the eastern stratum (Stratum E; 4,129km^2) the designed survey coverage was achieved so the density estimate should not be biased by non-uniform distribution of animals. The combined density estimate for both strata is more sensitive to non-uniform distribution of animals since only a relatively small proportion of the designed survey coverage was achieved in the western stratum due to heavy shipping traffic. The estimate of the density of individuals per km^2 (D) for Stratum E was calculated (Table 1) as outlined in Buckland et al. (3).

Parameter	Value/Estimate
Primary effort (L) in 2004+2005 (km)	573.9
Number of schools (n)	63
n/L	0.109
ESW (km)	0.253
Expected/mean school size (s)	5.063
Density (D) of individuals (ind/km^2)	1.097
%CV(D)	35.94

Table 1: Line-transect *primary* effort and winter density results estimated by *Distance 4* (assuming *g(0)*=1 and no responsive movement) for common dolphins for Stratum E by stratification, where *ESW* =Effective half Strip Width and *CV*=coefficient of variation.

Measuring the effect of responsive movement and survey speed

We pooled data for all initial Primary sightings of common dolphins in sea state ≤3 (to make sure that higher sea states were not affecting the data) for both fast and slow speed modes (transects/straight lines) for the different survey years. The perpendicular distance plots (Fig. 3a) show substantial peaks in the first bin (less than 100m) and this is consistent with responsive movement towards the vessel. We assume that there is no difference in observer behaviour between fast and slow vessel speeds, however, the peak at small perpendicular distances is considerably more pronounced at slow speed than at fast speed suggesting an effect related to the behaviour of the animals.

We explored responsive movement further by examining the estimated swimming directions of dolphins relative to the vessel. Taking the vector component of the dolphin's velocity away from the vessel, the results for the Primary platform are shown in Figure 3b. There is a distinct large peak close to '-1', *i.e.* the majority of sightings are of dolphins approaching the vessel. When only sightings with a distance in the 25 percentile furthest from the boat (>400m) are included in this analysis, there remain significantly more animals with headings towards the vessel than away (χ^2, p=0.001) although this effect is no longer significant for primary sightings made during slow speed mode (χ^2, p=0.8). Results from the Tracker platform also show significantly more animals heading towards the vessel (χ^2, p=0.003). Although the effect is no longer significant for sightings made at distances greater than 1,000m (χ^2, p=0.2), there were nevertheless more than double (n=7) the number of sightings with animals heading towards the vessel than away (n=3). The observed distribution of headings will be affected by the sightability of the animal at different presentation angles (16). The peak we observed was with animals heading directly towards the vessel which would be expected to show a smaller visual target. Thus these observations cannot be explained by presentation angle effects.

Estimating a correction for both g(0) and responsive movement

Using *Distance 4*, we used Tracker platform data to estimate $f_s(0)$; Primary data to estimate *f(0);* and duplicates to estimate $f_{ps}(0)$. The error for the correction factor *c* was estimated by bootstrapping on sightings data from both platforms by transect and applying the estimation procedure to each of 199 bootstrap data sets (Table 2). The *CVs* of corrected density and abundance estimates and the Satterthwaite degrees of freedom (*df*) for the corrected density and abundance estimate confidence intervals were calculated (Table 2).

Parameter	Value/Estimate
Double platform effort, DP (km)	514
Truncation distance, w (km)	0.6
Number of secondary detections, n_s	12
Number of primary detections, n_p	88
Number of primary detections after truncation at 0.600km	86
Number of duplicate detections, n_{ps}	10
ESW of secondary platform, $1/f_s(0)$	1/3.16 = 0.316
ESW for duplicates (km), $1/f_{ps}(0)$	1/3.53 = 0.283
Apparent ESW for primary platform (km), $1/f(0)$	1/5.15 = 0.194
Apparent density estimate, D_p (groups/km^2)	0.431
Corrected density estimate, D_c (groups/km^2)	0.291
Primary detection probability 'near' trackline, $g_p(0)$	0.931
Correction factor, c	0.675
Standard error of c, s.e. (c)	0.113
Provisional density (ind/km^2) for Stratum E in 2004+2005	1.097
Corrected density (ind/km^2) for 2004+2005 survey (Stratum E)	0.74 (CV=39%) 95% CI [0.34-1.59]

Table 2: Summary of variables required for the calculation of a correction for movement and for animals missed on the trackline using the Double Platform Effort data, where *ESW* =Effective half Strip Width and *CV*=coefficient of variation. The corrected density estimate for Stratum E is calculated using the correction factor (*c*).

Distribution

Common dolphins were widely distributed throughout the study area in both winters. It is worth noting that the relative index for abundance (number of schools per 100km effort, mean school size 5.1) of common dolphins sighted (following pre-designed and not pre-designed transect/lines) was much lower in the French part of the Channel (south of the study area, 1.23 schools per 100km) when compared to the study area (14.23 schools per 100km). Areas of few or no sightings included waters to the east of the study area although survey effort was low. Waters to the west of the study area were not systematically surveyed due to unfavourable weather conditions.

Discussion

The obtained estimated corrected density was 0.74 individuals/km^2 (95% CI 0.34-1.59; Table 2) and the corrected abundance estimate for stratum E was 3,055 animals (95% CI=1,425-6,544). There are no other abundance estimates that are directly comparable with these winter estimates for the study area. Other estimates are from ship surveys that took place some years ago and were conducted during the summer months (7, 4, 9) and during autumn (5). The relative index for abundance*,* number of schools per 100km effort (mean school size 5.1), can be compared and was much higher during this winter survey (10.9) than the SCANS 1994 summer survey in the Celtic Sea (Block A: 0.94) (9) and to the NASS 1995 summer survey in the Faeroes and western British Isles (Block E: 1.02) and in the offshore Atlantic (Block W: 7.5) (4). The autumn relative index was also found to be much lower in the western Approaches of the English Channel (2.9) (5).

The double platform survey indicated that Primary observers only missed 7% of the dolphins on the trackline, *g(0)* =0.93, but that a strong responsive movement towards the boat resulted in apparent densities 1.5 times greater than based on the double platform data. Sample sizes for animals first detected at radial distances of greater than 1000m were small (n=10). Although, the number of animals heading towards the vessel was not significantly different from the number heading away, it is possible that some animals were responding to the vessel at greater distances than they were detected. Thus the true correction factor could be much greater than 1.5. In addition, we observed that the *ESW* of the Tracker platform appeared to be rather narrow (316m). It is very likely that animals could approach the vessel from outside the Tracker's view and still be detected by the Primary observers. This means that the strip width for duplicates (ESW_{ps}) will be underestimated and is possibly the reason why the obtained ratio of c^{-1} (1.5) is small. By comparison, Cañadas et al. (4) estimated a correction factor of around six for a similar double platform survey using naked eye and 7x50 binoculars.

This study found that survey speed affected cetacean responsiveness to the survey vessel. In fact, it appeared that there were two effects when comparing the two survey speeds (fast *versus* slow). One is a 'movement' effect and the other is a 'sightability' effect. The perpendicular distance data show a more pronounced effect at slow speed which contrasts with a more pronounced effect at fast speed indicated by the heading data. The heading data for the fast speed mode indicated that there was still significant evidence of responsive movement even for the further 25 percentile of naked eye radial detection distances. For the slow speed data, however, the further 25 percentile of radial distances show no significant responsive movement. We conclude that this is probably due to an availability/detectability effect (*e.g.* surfacing behaviour changes the observer's ability to sight an animal). Indeed, it could well be that dolphins that are approaching a fast moving vessel are more likely to surface in the 'middle class' of distances (around 200-300m).

Conclusion

The winter diversity of the cetacean community in the Western Approaches of the English Channel, with a total of 7 different species seen during both surveys, highlights that the area is an important winter cetacean habitat. The dual platform data suggest that estimates for the winter population of the short-beaked common dolphins in the survey area from the same vessel may have been positively biased by at least a factor of 1.5 as a result of responsive movement. Uncertainties in the level of bias due to responsive movement are a problem for all current estimates of common dolphin abundance. Nevertheless, the observed relative index for abundance is among the highest recorded for common dolphins in the NE Atlantic indicating the importance of the western Channel as a winter habitat for this species.

A bycatch level for small cetaceans of more than 1.7% of the best available estimate of abundance has been deemed in the relevant international forum to be unacceptable (1). Based on our corrected estimate for Stratum E (the area overlapping with the current main fishing grounds) this would equal some 52 (24-111) animals. During the 2003/2004 fishing season, a bycatch of 169 common dolphins was recorded in the area in the UK bass fishery alone, producing an extrapolated total estimated mortality for the UK fishery of 439 animals (19).

Little is known about the overall winter distribution of common dolphins in the NE Atlantic or their seasonal movements. The dolphin abundance estimate for the relatively small survey area in this study is small compared to overall abundance estimates for the NE Atlantic (10). Nevertheless, the high levels of bycatch reported in the Channel area raise both conservation and animal welfare concerns. If this area is only used by a subset of the total Northeast Atlantic population of common dolphins, or if the Northeast Atlantic hosts several different common dolphin populations, there is a risk of depletion within the Channel area. If local depletion were to occur, it is not clear whether common dolphins from further away would then start to exploit and re-populate the Channel area. There is some evidence of population structure within the common dolphins of the NE Atlantic (11, 15).

A more comprehensive and wide-ranging assessment of bycatch, including statistically robust observer programs in both pelagic trawl and also gillnet fisheries is urgently needed. The data from this survey show that the winter population of common dolphins in the English Channel could well become depleted as a result of bycatch.

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The Nature of Humpback Whale (Megaptera novaeangliae) Song

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Abstract
The nature of humpback whale (*Megaptera novaeangliae*) song has long interested both scientists and the general public. Research strongly indicates that humpback whale song is an important component in the social behaviour of breeding humpback whales, with proposals that the song has an intra- and/or inter-sexual selection component. Some scientists, however, have alternate hypotheses, such as song being a means of sonar for detecting females. Song is not the only factor involved in humpback whale breeding behaviour, as groups of males follow and may physically compete for females. Hence, the exact nature of humpback whale song and its relation to their breeding behaviour is unclear. Why does whale song continuously change throughout the breeding season, and why do new songs spread so quickly throughout a population? In many respects, the nature of humpback whale song may resemble and parallel bird song. For example, many bird species that display innovation in the male's song also have increased reproductive fitness, and a similar situation may occur in male humpback whales. To explain why such innovation may be selected for in humpback whales, this paper postulates that sexual selection in humpback whales may have both a physical and cognitive fitness component. [JMATE.2008;1(1):22-31]

"*No one knew why humpbacks sang. Nate had been listening to them, observing them, photographing them, and poking them with sticks for twenty-five years, and still he had no idea why, exactly, they sang*".
From Christopher Moore. *Fluke. Or I know why the winged whale sings*. Harper Collins. 2004.

Introduction

Why do male humpback whales (*Megaptera novaeangliae*) sing? The purpose and nature of the captivating songs of the humpbacks have been an enigma for modern zoologists ever since they were first discovered by scientists (79). Opinions as to the purpose of humpback song varies widely, from the calls being no different to those of herding animals to the idea that they may be a way of transmitting highly complex information, perhaps even being equivalent to language. There is debate as to whether the song is a mating call (vocalisation that contains information about the breeding intentions of the caller), a way of defending an area such as a territory (an area occupied and defended by one or more animals against conspecifics through overt defence or advertisement), a means of co-ordinating co-operation between males, a combination of these functions, or an as yet undetermined function. This theoretical paper seeks to review information on the nature of humpback song and the hypotheses as to its function, and to suggest some new hypotheses.

Humpback whale behaviour

Humpback whales (humpbacks) typically undertake extensive seasonal migration between high latitude summer feeding grounds and low latitude, tropical winter reproductive areas (*c.f.*, Arabian Sea population; 63). On the high latitude feeding grounds, several of them will associate and co-ordinate with each other to produce "bubble nets" that aid in trapping and herding shoaling fish (98). Humpbacks appear to have traditional feeding and breeding grounds as they return to particular local habitats and regional feeding areas, which seems to be a result of early experience and maternal influence. Craig and Herman (26) and Weinrich (101) documented these results through individual return rates and population genetics in the southern Gulf of Maine and on the breeding grounds off the Hawaiian Islands. Research also shows that individuals from various feeding grounds may use one breeding area, presumably to increase their mating opportunities, although humpbacks from one breeding area may also visit several feeding grounds (12,90).

Craig and Herman (26) suggested that not all females completed or even began the migration to Hawaii each year, as they may have become pregnant prior to migrating and returned to, or remained on, their feeding grounds. Some females along eastern Australia also remained in feeding grounds during winter (11). As a result, a biased sex ratio of 2.4 males to 1 female was found in both north- and southbound migrations off eastern Australia by Brown *et al.* (11). This consequently limits the number of females on the winter breeding grounds. As males outnumber females, males have to compete physically for proximity to females (27).

Furthermore, sexual segregation has been observed during the migration from the North Atlantic feeding grounds to the breeding grounds in the West Indies (90). Male humpbacks migrating off eastern Australia, associating together frequently, were found in larger groups than females (10). Males from all feeding grounds also arrive earlier at the breeding area in the West Indies than do females (90).

Finally, comparing females with and without calves during the progression of the breeding season, Craig *et al.* (27) found that males in Hawaii associate preferentially with, and competed more vigorously for, females without a calf (*i.e.*, females with high reproductive potential). This criterion appeared to be less important as the breeding season progressed, presumably as the number of births significantly reduced the availability of calf-less females. These various findings set the scene for very active male competition for breeding females.

Not all humpback populations migrate, however. Mikhalev (63) argued that there is at least one population in the Arabian Sea that remains in these subtropical-tropical waters year-round and noted that this was unusual for the species. As the Arabian Sea is the site of a major oceanic upwelling, productiv-

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ity in this area is high due to abundant nutrients, warm surface waters and abundant sunlight, and so humpbacks in this region may have no need to migrate long distances away from tropical waters to find sufficient food.

The organisation of whale groups on breeding grounds may be more complex than during feeding or migration. Spitz *et al.* (86) examined both the social role of males and group size in humpbacks on winter breeding areas of the Hawaiian Islands in relation to body length. They found that females were larger than males and were rarely found with other females, and also that the sex ratio on the breeding ground was two males to one female. Spitz *et al.* (86) categorised males as principal escort, secondary escort, lone escort with mother-calf pair, male partner and singer. Principal escorts were significantly larger on average than other males except singers. Singers in turn were significantly larger than male partners, but no significant differences in size were found in other pairwise comparisons between the groups. Principal escorts also tended to be the largest or second largest male in their individual competitive group, and their size indicated that they had reached sexual maturity. Interestingly, the other categories of males may not be mature except singers. Group structure may also be a function of other factors, such as time of day, with Hawaiian adults generally being alone in morning and gathered into pods (a group of cetaceans), increasing in size over the day (46). This structure is important, as the breeding grounds are where the majority of male humpbacks are found singing. Male singers off Maui, Hawaii, were joined on occasion by other individual males, where the pair either split up or formed a group (32). Singing also occurs before and after male-male interactions during the breeding season (32). However, singing appears to be a solitary activity and does not necessarily result in immediate physical contact with females or other males.

Evidence suggests that humpbacks have a promiscuous mating system. Individually identified females were resighted with different male associates during at least two breeding seasons off the Gulf of Maine (20). Clapham and Palsboll (20) also found that the offspring of individual females had multiple paternities. This was further reinforced recently by the paternity analyses of Cerchio *et al.* (15), which also indicated a promiscuous mating system. The system was found not to be egalitarian, as some male humpbacks had a slightly greater reproductive success than others. In the sample analysed, most males were not attributed any paternities over the 5-year study, with rates of one or two paternities close to expected values from a random mating system. However, two to three males were assigned three paternities, which was significantly greater than expected (15).

Given the uneven sex ratio on the breeding grounds, a promiscuous mating system would probably produce competition between males for access to females, so there would likely be intra-sexual selection based upon ability to monopolize and defend a female. This competition may be physical, as aggression can occur within groups of males, especially when males are apparently competing for access to a female with or without a calf (8,42,96). Such male aggression can draw blood (8,33) and may possibly, on very rare occasions, be severe enough to result in the death of a male humpback (72).

Competitive behaviour has also been observed away from the breeding grounds in both north- and southbound migrations, although most male-male interactions were not agonistic and some were even co-operative in nature (10). However, physical aggression may not be the only method of competition used by male humpbacks, and song may be a key technique. Here we introduce humpback song and then discuss possible causes and effects of males singing.

Picture 1. Humpback whale breaching - reproduced with permission Allan Whaley/FUNDEMAR

Humpback whale song

The structure of humpback whale song

The sounds produced by humpbacks are low to mid frequency, usually 30 Hz to 8 kHz (23,75,85,93). Peak frequencies are generally around 315Hz and 630Hz (5), although high frequencies of up to 24kHz may sometimes be reached (4,6,7). Although the higher frequency components of their calls would be relatively short range, the low frequency components can travel considerable distances. As a result, humpbacks are able to communicate over tens or hundreds of kilometres and may not need to be in close physical proximity to remain in contact (1).

A humpback song can be broken down into a number of “themes” (75). In turn, each theme contains a number of repetitions of a phrase. Phrases may last for 20-40 seconds, while entire songs may be longer than 30 minutes. Themes are generally sung in a particular order (75) and the singing whale can take about 10 minutes to come back to the original theme. The structure of the song is complex and hierarchical, consisting of short and long segments with multiple layers of repetition or periodicities that may contain six units or even 400 units (91). The song conveys one bit of information per second, compared to humans with approximately ten bits per second (91).

Light does not travel far underwater, particularly at depth, whereas sound travels faster underwater than through air. This renders vision underwater less effective than hearing as a means of communicating. In broadcasting and receiving sound underwater, there may be strategies that improve this mode further. For example, there would be less interference from the deep scattering layer at certain times of day or night, or with less stratification related to the diurnal vertical migration of plankton. Males may use the sound propagation properties of the top layer of the water. For example, sending a song along a thermocline would allow a broadcast to cover a wider horizontal area. This suggestion is supported by the findings of Au *et al.* (7), whereby the higher frequencies in humpback song, which do not travel as far as lower frequencies, are projected horizontally.

There are also indications of a diurnal pattern in sound pressure levels of whale song, whereby levels were significantly louder at night during the breeding season in Hawaii (5). Sound levels increased during sunset and only decreased at sunrise. It has been suggested that this pattern may reflect song being sexual advertisement as the main male mating strategy at night, while vision may be key to the formation of competitive groups during the day (5). There are several other alternative explanations. For example, many animals rely on sound for communication at night, and the humpbacks may simply be compensating for the increase in ambient noise. Another possibility is that the whales are taking advantage of, or compensating for diurnal changes in oceanographic features, as discussed by Au *et al.* (5).

Song in other whales

Many baleen whales spend a significant percentage of their time producing loud low-frequency sounds (57). Some examples of the frequency of sounds produced can be seen in Table 1.

Many of these sounds are less elaborate than humpback whale vocalisations, with less structure, and are not generally considered to be songs. Even so, fin whales (*Balaenoptera physalus*) produce series of pulsed sounds that are directly associated with the reproductive season and are thought to be produced by the males (100). The same sound sequences are never repeated exactly and are thought to stimulate vocalisation in other fin whales, while the approach of another whale induces a calling animal to cease (100). Fin whale use of these signals suggests a similar function to the songs of humpbacks (100).

Common Name	Scientific Name	Frequency of Sounds Produced
[1]Right	*Balaena glacialis*	Largely below 500 Hz
[2]Minke	*B. acutorostrata*	60 Hz to 6 kHz
[3]Blue	*B. musculus*	12 to 222 Hz
[4]Bowhead	*B. mysticetus*	Largely below 1000 Hz
[5]Fin	*B. physalus*	About 20 Hz

Table 1. Examples of sounds produced by baleen whales
[1]22; [2]60; [3]28,57,83,87,88,89,92; [4]29,30,60; [5]100

The one other whale known to sing is the bowhead. These songs are simpler than those of humpbacks, consisting of many repetitions of a small number of sounds in the same order (54). They are produced during the spring migration (54), on or near the winter breeding grounds and may change from year to year in a similar manner to those of humpbacks. This could be an example of convergence in evolution, or it may indicate that the song predates the speciation of either the bowhead or humpbacks, suggesting that the original reason for the song may be different from the development of its unique complexity in the humpback.

The changing structure of whale song

Another interesting aspect of humpback song is that it is constantly changing over time (75). All the males in a humpback population within a region sing essentially the same song (77,104), which may have segments that overlap with songs belonging to adjacent populations. Humpback song is generally produced on the breeding grounds (17) and rarely produced on feeding grounds. When the males resume their song at the beginning of a new breeding season, the song is the same as at the end of the previous breeding season (75). As the breeding season progresses the songs of each population change in structure (74,75,78). Innovations by individuals are copied and incorporated into their songs by other males in the breeding site, until these changes are apparently adopted by all males (74,75). At the end of the breeding season males tend to cease singing until the following mating season. It has been suggested that song transmission is cultural, as the changes arise spontaneously and are incorporated by others as they arise (39), but there may also be some components of whale song that change independently of cultural exchange (16).

Comparisons with bird and bat song

The use of sound as song is not unique to humpbacks (62). The most studied form of song in animals is bird song, which generally functions as either a means of territorial defence from other males or a method of mate attraction and female selection. For example, song playback experiments have been carried out to show territorial defence in several bird species (*e.g.*, *Pardus major*; 51). Whales and songbirds may have a similar means of communication through convergent evolution. Birdsong is usually exclusive to males, as is the case in humpbacks (33,41,102) and is typically sung during the breeding season, which again is analogous to humpbacks, with a link to seasonal hormonal levels in birds. Although humpback song is sporadically heard in the summer feeding grounds (56,59), it is much more frequent both approaching and in the winter breeding grounds (81,103,104).

We may also be witnessing a two-strategy situation, as appears to occur in the male greater white-lined bats (*Saccopteryx bilineata*) in Trinidad. Males sing songs, while females produce only short calls (36). Males use a particular screech song in what appears to be marking a territory and a longer, more tonal call when interacting with females. Males with more complex songs were found to have more females in their territories, and females were found to be capable of distinguishing male from female ultrasonic sounds.

Song as Sonar to Detect Females

Magnusson and Kasuya (55) developed a probability model for male whale mating strategies, where females grouped in a pod and were receptive only briefly during the breeding season. They suggested a searching strategy for individual males which would be advantageous when: 1) a female is receptive a high percentage of time; and/or 2) a male is expected to locate a high number of pods in a breeding season. They noted that there was limited data available to test the model, but they suggested that sperm whales should benefit from this search strategy. Could the song of a humpback be a component of a search strategy?

In support of the theory that song is a searching mechanism, Frazer and Mercado (40) presented a long-range sonar model for humpback song. The sonar model suggests how singing males might find females, even though females generally ignore or avoid singers (32). It also suggests why males hardly ever sing while in the company of females or while competing with other males for the position of primary escort. They conclude that many cetacean vocalizations must have both a communication and a sonar function.

Au *et al.* (3) questioned a number of the assumptions in this model, considering the noise-limited form of the sonar equation, current understanding of humpback behaviour, and the characteristics of humpback songs. They also argued that evolution should favour a stable signal if sonar is important to mating success by echolocation, but that in reality songs are plastic and change at a variable rate within each season, changing completely within about 5 years (74,75). However, all songs have some stable elements, such as the inclusion of specific frequencies broadcast at certain times and syllables of specific lengths; perhaps these are used as a searching mechanism. Whale song may have originated as a sonar mechanism that evolved, modifying the structure to incorporate other functions. However, a singer has never been observed localizing females (3). Moreover, if whale song is a form of sonar, why do whales not use it to detect conspecifics at all times? For example, on the feeding grounds song is not used when locating other animals to help in herding prey species. There would also be a strong argument for females to sing if it were used as sonar. However, most if not all of the above arguments apply only if sonar is the primary function of the song, not an incidental benefit from a signal used mostly for another reason.

Song as a Sexual Signal

Honest signalling and reproductive fitness

Many sexually-related signals in nature, including calls by vocal vertebrate species, are attempts to reflect fitness honestly by conveying the abilities of the signaller to the receiver (24,37,44,45,106,107,108). This might be an announcement of size or a display of fitness by essentially demonstrating how much of the signalling cost the signaller can absorb. This then allows a female to choose the best male possible to father her offspring or allow males to assess their competition.

The costs of producing a signal, such as a song, can be measured in terms of time and energy; that is, the energetic cost of signal production and the missed opportunities for breathing and foraging. Song production carries a notable energetic cost, through increased metabolic rate and energy consumption, as has been reported in birds (99). Costs may also be measured in terms of increased exposure to predators or advertising the singer's presence to their prey. These latter costs are likely to be negligible for humpbacks, as they rarely feed on the breeding grounds, and adults are not generally subject to predation.

If humpback songs are indeed an honest communication of fitness, the elements likely to indicate their physical fitness would include frequency (potentially linked to the size of the singer) and duration. Humpback songs can last for more than two hours (97,105) and the production of such a loud sound for such long periods of time certainly would be costly and would imply the intrinsic fitness of a singing male. Another option is that the time between breaths might convey size to a female or a competitor (19).

A recent study on swimming rates in male humpbacks suggests that singing during migration has additional costs. Noad and Cato (68) discovered that singing humpbacks, migrating between the Antarctic and Australia, swam much more slowly than non-singing whales (2.5 kmph versus 4 kmph). The slow swim speed may be the result of singing being physically costly, such that the energetic costs of singing preclude fast movement. There may also be an indirect cost of singing, whereby swimming at a slow speed reduces the amount of time males can spend feeding as the result of a prolonged migration to the feeding grounds in the Antarctic. As the value of the song must lie in how well it accomplishes its purpose, thus this behaviour must carry some additional benefit. For example, it might increase the number of females (if they are the targets for the song) exposed to an individual's song (68).

While key information on physical fitness may be conveyed by singing, this does not explain why songs are complex and yet consistent within a population. This suggests that they convey additional information. For example, the ability to remember a complex song might be an indicator of memory capacity and mental fitness.

Potential Benefits of Song

As discussed earlier, males appear to be competing for females: 1) directly through physical aggression or indirectly through male behaviour resulting in ranking in a social hierarchy; 2) indirectly through displays to females; or 3) a combination of both. Consequently, a male may have a number of attributes to bring to this competition, which may be used sequentially or as needed. As discussed above, it is possible that these attributes include vocalisation through song, along with size, strength, and social abilities.

Songs for Females

When singing whales join females, male behaviour thought to be associated with sexual activity is usually observed (95), which suggests that song could function as a sexual attractant. Although somewhat unusual, females have also been observed joining singers (60), further supporting this idea. Perhaps the broadcast of the male's song in a favourable place is important, as in the lek scenario discussed below. For example, a male might position himself at a point in the water column where the long distance transmission of sound is optimal, such as using a thermocline to produce a waveguide. A female receiving the song might be able to determine distance using received frequencies and then judge the male's relative fitness by the power of his song. Chu (19) also argued that indication of physical fitness could be conveyed through song structure correlating with breath-holding ability. This could be tested further, as there are many other characteristics, such as swimming speed, size, age and blood testosterone levels, that could equally be considered as indicative of male fitness and could feasibly be compared to song structure.

Male-Male Competition

Darwin (35) pointed out that courtship displays may also be directed at other males competing for females. That is, fitter males warn less fit males of their presence and that competition with them would ultimately be futile. In the case of humpbacks, this latter function would benefit both the singer, who would not have to exert himself to discourage other males, as well as the less fit males, who could suffer physically in a conflict with a stronger male. Darling and Bérubé (32) suggested that song is indeed for male-male communication or display due to the frequent cessation of song when one male joins another. They also noted that an escort may sing with a female-calf pair, adding further support to this idea.

Fertile females are likely to be a limiting resource for adult male humpbacks. Males may therefore use their song to compete against each other directly in a number of ways. One option is that the song is involved in establishing or indicating a male's position in a dominance hierarchy, as has been suggested by Darling (31) and Darling and Bérubé (32). There is some support for this as males tend to avoid or, on fewer occasions, charge at or approach (the latter term has been suggested as a more appropriate term by Darling) the playback of whale song, the latter presumably in a bid to displace a male perceived to be of lower status (66,94). The results of these playback experiments are suggestive of territorial songs. Although males do not appear to hold physical territories, they may have simply gone unnoticed, as the distances involved could be large if they are maintained acoustically. Alternatively, it is quite possible that they may move their 'territories' if, like several pinnipeds (*e.g.*, northern elephant seal, *Mirounga angustirostris*; 53), they monopolise females rather than control other resources, as female humpbacks would be moving around unlike although female pinnipeds on a rookery.

Male and Female Receivers

If humpback songs appear territorial, but also seem to function as a sexual attractant, the communal display (in this case, singing) suggests that male humpbacks are using an area of water as a lekking arena (65). Leks are aggregations of displaying males to which females are attracted for mating. Jiguet *et al.* (49) define parameters for a lek as: a) no male parental investment occurs beyond sperm; b) males aggregate at specific sites for display; c) the only resource females find on a lek is the male; and d) females can select a mate (although this last parameter is disputed; see discussion in 21). An interesting example of a lekking bird is the only parrot to use such a mating system, the kakapo (*Strigops habroptilus*) (25). In the breeding season, the male settles into a bowl-like depression that he has dug in the ground at a suitable site and then begins a deep, resonant boom sound. In a good location, the boom can be broadcast over 5km. However, to address the lack of rigid spatial structure in the humpbacks 'territories' (or perhaps 'maritories'), Clapham (21) proposed the term 'floating lek'.

In a floating lek, a humpback male would use song to define an area as his 'territory'. Other males that hear the song could approach and attempt to displace the singer holding the area. Females might avoid singers for this reason, expecting and circumventing male-male confrontations by judging male fitness from a distance and remaining in the area if he measures up. Smaller humpbacks would be less able to compete directly and would be more likely to adopt alternative mating strategies, such as attempting to sneak into the 'territory' of an inattentive or otherwise occupied dominant male to mate with a coercible female. Sneaky mating is a strategy used in a wide variety of vertebrates, including various pinnipeds (*e.g.*, northern elephant seal: 53), and this scenario would explain the sizes of males reported by Spitz *et al.* (86). Singers would be trying to establish or maintain 'territories', primary escorts would be engaged in guarding a mate from smaller challengers (21) and the pairing of smaller males could represent a cooperative effort to gain access to a defended female (see below). It would follow that singers would sing more at night, in an effort to deter sneaky males from using darkness to hide their activities, as observed by Au *et al*. (5). It would also explain why more groups are seen later in the day (46), as sneaky males might tend to encroach on a singer's area more when he sings less.

Interestingly, playback experiments have shown that males will approach the social sounds made within a competitive group, more often than they approach song (66,94), which may indicate the use of a tactic reported in northern elephant seals. Less dominant males will often challenge a more dominant male when they have just finished a long fight and are exhausted, increasing the chances that the challenge will be successful (53).

A strategy of sneaking is a relatively inexpensive use of time and energy. Also, by not displaying, the sneaky male does not draw attention to himself from competitors or predators, although adult humpbacks on breeding grounds experience minimal predation pressure. Regardless, it is possible that a singer may receive (incidentally?) some environmental information from echoes produced by a song, such as the presence of other whales, as postulated by Frazer and Mercado (40). As mature females are larger than males, it is also possible that a singer can distinguish between a female, a large male and a smaller male. If females tend to remain at a distance from a singer, a singer might cease singing in order to join a female accompanied by a bold escort that the singer detected, protect his area and take the opportunity to mate.

Male-male cooperation

The majority of singers are lone males and while females are likely to hear the singing, it is generally only males that appear to move towards singers (32). Similarly, a singer usually stops singing when joined by another male (94), suggesting that the singing has either succeeded or failed to achieve its goal. It is thus likely that the goal is either to keep other males away (as discussed above), or to bring specific males closer to form a pair/group. As mentioned above, co-operation between males might be necessary in some cases to control females or force them into mating. It would also be easier for co-operating males to separate a female from her calf to facilitate mating. In primates, infants have been shown to disrupt attempts at mating (43). Gore (43) noted that successful males enticed the female to a position out of sight of the infant to mate with a cooperative female. However, the mother-offspring bond in humpbacks appears to be very strong.

Darling *et al.* (34) also hypothesised that male cooperation in mating could account for the song and singing as collaborative behaviour. They noted that males joining singers appear to behave co-operatively when escorting females. As a result they suggest that song may provide information on male-male associations over time with the changing nature of songs (see below) documenting a changing history of associations. They note that this may help document reciprocity when males assist each other when mating. However, this is not consistent with the agonistic interactions that have been reported by others (8,94).

Moreover, Noad *et al*. (67) reported that a song sung by two immigrant male humpbacks (from the western coast of Australia) was quickly incorporated by all the male singers in the entire eastern Australian population, within the space of a year. If whale song provided information on associations between males at another breeding ground, the rapid incorporation of this information by whales in a different area seems incongruous. Information on whales encountered on their own breeding ground would be more important than a record of male-male interactions where males are unlikely to meet.

The evolution of a complex call might have originally indicated that the singer was capable of a high level of cooperation and/or cognitive ability. Similarly, those who could memorise and reproduce the complex call would have been indicating the same. Thus new songs rapidly learnt/copied might have demonstrated the fitness of the individual males. As the song became more intricate, those less able to cooperate might have been excluded. However, currently singers and primary escorts are generally some of the larger males (86), whereas such co-operative efforts would more likely be necessary among smaller males.

Changes and Novelty

As mentioned above, humpback whales change their song over time, presumably at some cost. Innovative processes take time and attention, as does listening to the songs of others for changes that then need to be learned and mastered. Whether innovating or copying, there should be some value in the alteration to justify the efforts.

Novel song could be the result of immigration (67), mistakes in learning (48), faulty repetition (possibly akin to genetic drift through mutation), or invention. The last example means innovation is conscious and requires directed effort on the whale's part; in this case, copying (imitation) might be less difficult or costly.

Some songbirds have been shown to invent or improvise song components (50,52), and a similar situation could be occurring in humpbacks. Analogies to the continuous evolution of whale song can also be found in birds. For example, the passerine saddleback (*Philesturnus carunculatus*) lives in semi-isolated populations with males preferring to settle in non-natal areas. Each population has its own song dialect. The dialects overlap, with some song themes shared by adjacent populations (48).

Nottebohm and Selander (70) suggest that dialects in birds reduce the gene flow between populations, but cross-breeding does occur. In fact, males that move into a new territory typically copy the songs sung by their new neighbours. In return, the established males copy aspects of the newcomer's song. This phenomenon is termed 'song-matching'. Song matching is known to occur in several other species, with the songs of immigrant birds being copied by endemic males (58).

Mutual copying seems to be limited in humpbacks, however. The arrival of singers from another population to the east Australian breeding population did not lead to a hybrid song, but to the population-wide adoption of the unfamiliar tune (67). Thus the situation in whales appears to involve other factors not encountered in bird species.

There are a number of outstanding questions regarding song-matching in humpbacks: why does the song change; why do changes spread throughout the whole breeding population until all are once again singing the same song; how do songs change; and by what mechanism do the changes spread? It is possible that males in different populations behave differently. The Arabian Sea population is thought to be non-migratory (63). A comparison of behaviour between this population and one that migrates would be a valuable test of this hypothesis.

Payne (77) suggested that by matching an established male's song, a younger male might disguise his presence and take advantage of the protection afforded to an established male. Thus a male keeping abreast of changes in a song might: 1) create an opportunity for sneaky mating; and/or 2) keep up with the competition. It seems unlikely that a sneaky male would want to advertise his position to the local established male at all. However, it is possible that song-matching reduces the competitive edge that larger animals have over smaller ones. To explore this fully, we would need to know who changes a song and if changing a song confers an advantage.

Cerchio *et al.* (16) alluded to the possibility that males producing innovative song have a selective advantage with respect to female mate choice. However, they did not offer a mechanism by which females would gain an adaptive advantage through mating with a male with an innovative song. Innovative song would have to be tied to a heritable trait that conferred survival or reproductive advantage for it to be a driving force behind mate selection. This would be the case if females assess male fitness through song in a way that is not reliant upon physical abilities, but through cognitive awareness. Alternatively, it is entirely possible that female mate choice based on song is self-supporting. That is, male offspring that display a particular trait are more likely to have numerous offspring of their own because females have a preference for it. This is known as Fisherian self-reinforcing selection (2).

If females are indeed assessing mental fitness they may prefer males who have newer songs, and perhaps the ability to innovate, or adopt innovations, is a trait that has value. Innovative song, or quick adoption of innovative song, may be an honest indicator of the ability for rapid cognitive response or initiation. However, the complex structure of the song and an ability to remember the constantly changing structure might also be an honest indicator of humpback memory. Memory must be an important contributor to a male's fitness, considering the long migratory routes of humpbacks. A recent study has observed unusual cortical architecture in humpbacks (compared to that of a fin whale, *Balaenoptera physalus*, and several odontocetes), which has previously been found only in hominids and the great apes, and is thought to be involved in processing complex behaviours (47).

Any female preference for males with a slightly different song structure may be selecting for a mate from outside the local population. For example, female European warblers (*Acrocephalus* spp.) prefer males who have more elaborate and unusual song structures (13,14). This could also be the case in humpbacks, with females being more receptive to males signalling elaborations of the normal song structure. Humpbacks have a relatively low reproductive rate and may be somewhat isolated, which could lead to inbreeding depression (18). Outsiders would have a substantially different genotype from the local males and inbreeding depression could be avoided if a female were to choose a mate with an unusual song to father her offspring. However, humpbacks found around the Pacific Ocean (Mexico, Hawaii and Japan) all share a similar song type, despite distinct genetic differences between whales from the various breeding populations (9). Furthermore, such selection would be complicated by innovation within a population.

It is also important to note that 'different' and 'novel' are not necessarily the same. The scenario above suggests that females value difference and not necessarily novelty. In that situation, some males would be expected to keep the original song or develop their own, as either would differ from the current song. However, it is possible that the true value of the songs does not lie in the fact that they are merely different. Consequently, novel song could be an important criterion in sexual selection. For example, in village indigo birds (*Vidua chalybeata*), males that spontaneously change songs, and are then imitated by other males, are more reproductively successful (76,77).

Mechanisms for change in song

The mechanism for change in humpback songs is unknown. As mentioned earlier, change in song could be a result of conscious effort or a random process. If it is a random process, the song could be considered a cultural version of a gene, known as a meme (38). Memes evolve more quickly than genes, which could allow songs to become almost unrecognisable within 5-10 years (74,75), even though humpback songs change only during breeding seasons.

Any innovation, from whatever source, that provides additional advantage would spread quickly through a population with the ability to imitate. Each innovation represents a mutation in the structure of the meme, which then spreads through the population like a successful gene, but at a much faster rate. Genetic mutation is limited and will only modify the phenotypes that were present, with large changes taking many mutations. If meme mutation functions in the same way, only small changes would be possible, but these would be additive and become large differences quite quickly. Quicker change still would be expected if new memetic 'alleles' (*i.e.*, song elements) were introduced into the population.

This might have occurred when the vagrant whales first turned up in eastern Australia (67). If the memetic evolution in western Australia had taken a different path, conveying greater benefits, then the eastern whales with their ability to imitate may have recognised these benefits and switched memes. The more successful meme then spread throughout the population at the expense of the original one. This might explain why the western Australian whales did not simply begin singing the local song to fit in. Had they done this, it would mean that the value of a song is not in its novelty, but more likely within its elements or complexity. However, the fact that the eastern Australian whales adopted the song of the immigrants does not confirm selection for novelty or difference, as they may also have simply adopted an inherently better song for achieving whatever purpose it is for.

Random memetic mutations could arise from errors on the part of a whale resulting in the irreversibility and constantly changing structure of humpback song. One possible source of error could be rapid decay, reformation and rearrangement of memory-associated neurones in the brains of humpbacks. This is the case in canaries (*Serinus canaria*), which have a limited memory capacity and a need to constantly relearn mating song structure with a new song, replacing the old one in the memory neurones (69). With a song being constantly replaced, it would be inevitable that some learning errors would occur, leading to a change in song structure. However, there is little change in the form of humpback songs between the end of one breeding season and the beginning of the next, implying that the whales do not have a limited memory capacity.

These memetic changes could also be the result of a more active process, such as through active trial and error, with the members of the population (including the innovating whale) consciously or subconsciously assessing the worth of the variant and either adopting it, or abandoning it accordingly. An intriguing alternative to trial-and-error is intelligent innovation, with a whale pre-determining what could be a good adaptation to the song in terms of effective broadcast or female preference.

One other interesting possibility arises from the tendency of an animal to acclimate to signals to which it is repeatedly exposed. Acclimation to a signal potentially associated with a stressor involves a reduction of the physiological response to that signal, which often leads to increased physiological responses to novel signals (see 84). A similar heightened response would confer an advantage to whales seeking responses to their songs. Even if a physiological response isn't involved, it is likely that a new song would still be noticed more readily, as the possibility remains for females to 'tune out' signals (songs) to which they are repeatedly exposed.

Environmental Conditions and Song

Another option is that humpback males change their song in response to environmental conditions. Several species of animals change signals and displays to compensate for background noise in the environment. For example, two species of lizard (*Anolis cristatellus* and *A. gundlachi*) increase the speed of body movements used in visually 'noisy' environments (71). Short-term environmental variation is known to be a factor in temporary changes in humpback song. For example, humpbacks have modified their songs during exposure to low frequency sonar transmissions (64). Thus it is possible that song changes are the result of other short-term events, and leaves open the possibility that variability in environmental conditions throughout a season may lead to concurrent changes in songs.

Perhaps humpbacks arrive at the breeding ground and test the previous year's song in the current oceanographic conditions. In response to changing environmental factors, such as ambient sounds, eddies, temperature or salinity differences, or volcanic activity, the male humpbacks may modify their song in some way to improve detectability by increasing the signal-to-noise ratio, repeating certain features, or changing the frequencies involved. Many environmental features can persist over weeks or even months and thus the costs of modifying their song could be offset by the benefits to the males in broadcasting song.

Arms Races, Fashion and Relics

As discussed above, it could be that males in a population try to copy novel or better songs as quickly as possible to avoid being out-competed. This would result in a vocal arms race to produce a population-wide song structure that rapidly evolves throughout the breeding season. If this were the case, it would also be expected that when a male singing a novel or in some way better song enters a population (through immigration or innovation), other males would immediately start imitating this song to offset whatever advantage it conveys, as was reported by Noad *et al.* (67). Perhaps then the male song is equivalent to a vocal form of clothing; with most whales following the current trends in fashion, rather than expending energy resources on novelty.

It should be noted that it is also possible that the original driving force behind changing songs, as well as the reason that the males sing in the first place, may be an evolutionary relic. For example, if selection pressure was great enough, it may be that all whales that could not produce a complex song, or keep up with changes in that song, were unable to breed and are thus no longer represented within the population. This would mean that all males currently in the population now meet these original selection criteria. Despite the fact the physiological and behavioural mechanisms producing change could remain in place regardless, female choice or male competition must now involve more subtle differences between the songs, such as precise peak frequencies related to the size of the whale. For instance, the key of C played on a guitar and a banjo would have the same pitch but different overtones, which are subsidiary frequencies acting together. The result is differences in the quality of sound. It may also be that in their studies, researchers are missing such subtle differences between songs, possibly through the type of frequency filters that they use in their measurements.

Other hypotheses

Cetaceans are thought to have high cognitive awareness and culture (73,82) that might lead to the argument that singing is for pleasure, either of the male himself or for the female. Songs may still be a part of the male's mating strategy, but if it is pleasurable as well, this might increase the rate at which novel elements are produced or lead to the males singing more often. Song might also be carrying news that is updated by all singing males in increments, or even a collective current oral history. Information of this kind in the song might be valuable for survival (34). Alternatively, the primary function of the choral singing could be to synchronise oestrus in females (8).

Summary

There are numerous hypotheses concerning the nature of humpback song, many of which are not mutually exclusive. The logistical difficulties of studying the behaviour of humpbacks in comparison to songbirds render it challenging, although not impossible. In the meantime, it is a nice thought that, perhaps, humpback whales really are attracted to their mates for their minds.

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Contaminant Levels in Sirenians and Recommendations For Future Research and Conservation Strategies

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Abstract
World wide marine contamination is of greater concern especially as developing countries become more industrialized, yet have few if any regulations controlling their production of contaminants, especially those which may affect the various species that live in marine habitats. This may also affect humans who live on or near these bodies of water and who still hunt species such as sirenians. However, controversy exists as to whether the levels of contaminants in sirenians (dugongs and manatees) is of concern to the survival of these species or whether these levels might be detrimental to the humans consuming them. To better understand the present levels of contaminants in the Order Sirenia, we reviewed the literature to quantify these levels and to see if contaminant levels had increased over time. The possible role these contaminants may play in future research and conservation initiatives is also discussed. Although it is thought by some that marine species such as sirenians may be able to detoxify or neutralize many contaminants, levels must be identified, measured and monitored to prove if detoxification does occur. This important physiological process must be verified if any conservation plan to save these species is to be successful and maintain viable populations. As well, certain human populations might be at risk from consuming these animals and therefore measuring these contaminants is necessary to protect these vulnerable communities from contaminant related health issues. [JMATE. 2008;1(1):32-39]
Keywords: Dugong, Manatee, Contaminant Levels, Research Strategies

Introduction

Research into world wide marine pollution has experienced a surge of interest in recent years as developing countries have become more industrialized and are producing more contaminants which are released into the lakes, rivers, streams and oceans (33, 30, 29). These contaminants may become a concern to not only the various animal species that live in these ocean habitats but to humans that live on or near these bodies of water as well (29). Many of these marine species filter out or bioaccumulate these contaminants that can be potentially dangerous for those other animal species who consume them and to humans as well. A large section of the population of developing countries still hunt many of these animal species (marine mammals, fish, etc) which forms a key source of their protein (25). There is ongoing controversy as to whether the hunting of sirenians, especially dugongs, still exists. Some scientists and government officials believe that dugongs are not being hunted for food or hides and therefore hunting does not pose a threat to their existence. However, there are many re-

Picture 1. Free ranging Florida manatee Tricechus manatus latirostis. **Reproduced with permission from OERS.**

cent publications proving that this activity is still being practiced in many developing countries today and that hunting still poses a serious threat to the survival of dugongs (12, 23, 24).

Dugongs are the only surviving members of the family Dugongidae and can be found from eastern Africa to the Philippines and Palau, and between Australia and Okinawa (26). Within the manatees, there are three species- West African (*Trichechus senegalensis*), Amazonian (*Trichechus inunguis*), and West Indian (*Trichechus manatus*). These species can be found in or along the Atlantic tropical and subtropical rivers, estuaries and coastlines usually located in less developed countries (22). Sirenians are usually long living and either stay in specific seasonal areas or move along coastlines which make them ideal study species for long term, geographical studies (6). As herbivores, sirenians must eat large volumes of vegetation daily and this vegetation absorbs or filters contaminants through the soil or water in which they thrive. It is therefore important to look at how sirenians accumulate and store the increasing amounts of contaminants that are being released into their environment. In addition, pollution in these various aquatic habitats, especially those found in developing countries, is actually subject to worsening contamination which is expected to continue for many decades.

Materials and Methods

The scientific literature was reviewed for levels of various contaminants such as elements (arsenic, copper, lead and mercury) and organochlorines (polychlorinated biphenyls- PCBs, dichlorodiphenyltrichloroethane-DDT, Dieldrin) from 1976 to 2000, a timeline where data was available for sirenians. All

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values were converted to reflect the same units (mg/kg wet weight) and blubber and liver samples were used for consistency of reporting.

Information gathered through reports, books, and various publications from various government departments (Australia), non government organizations (Oceanographic Environmental Research Society) and official agencies (United Nations, Marine Mammal Commission) was used to evaluate the present status of research strategies and conservation actions. The contaminant levels that were garnered from the review, was used to discuss the implications and success of future research strategies or conservation actions to preserve the manatee and dugong.

Discussion

Present Levels

There is limited information concerning contaminants in marine mammals such as sirenians for numerous reasons. It is logistically and financially very difficult to study them in their natural habitat. This is due in part to the political apathy as no government is willing to assume a leadership role or funding responsibilities for such studies. Funding for long term projects to study the effects of pollutants on these species is proving to be difficult to secure (27). Ideally, research should validate the exact amounts or types of contaminants being released, what possible effect each type of contaminant can have individually or in combination with each other, the temporal and spatial changes over long periods of time, the possible effects of other environmental stressors combined with contaminants, and what possible pathological effects these contaminants can have in sirenians (19, 27). Contaminants are not only toxic themselves but their metabolites also can be of concern and it would require the analysis of over 300,000 compounds to monitor these synthetic organic chemicals and their possible detrimental effects which are currently in use (28).

Element and Heavy Metal Contaminants

In marine mammals it is very difficult to directly correlate specific levels of contaminants to a specific effect (33, 5). The research that has been done in harbor seals and dolphins has established contaminant levels that seem to cause a detrimental effect on these species (29, 5). However, these results were produced under artificial conditions in captive animals which makes it hard to correlate the corresponding detrimental effects that wild animals would experience who are exposed to various other stress factors including the huge number of contaminants in their habitat.

It is generally accepted that manatees have low levels of contaminants compared to other marine mammal species and that these low levels are not a threat for the future of these species (6). However the research literature seems to indicate that organochlorines have a greater effect on sirenians when compared to heavy metals. It has been reported that dugongs seem to be susceptible to organochlorines such as polychlorinated dibenzo-*p*-dioxins (PCDDs) and that PCDDs may have an adverse effect on their health and therefore may be a risk to present and for future generations of dugongs (10). In the literature, it has been reported that heavy metals such as mercury can affect the neurological development of the young of certain mammalian species (rats, monkeys and humans) but as yet no direct link has been established in any marine mammal (5, 33). In the past 30 years, much of the sirenian research has focused on measuring the levels of contaminants in small geographical regions, with little research on establishing what effects these contaminants may have on the various organs of this species, or on the possible effects on the development of their young or what the lethal levels might be for them (12).

Dugongs

The data available on elements and heavy metal contaminants in the tissue of dugongs shows an increase over time (Table 1). Arsenic maximum levels in dugong livers between 1982 to 2000 have shown increases from 1.25 to 7.7 mg/kg wet weight and copper maximum levels have ranged from 425 to 303 mg/kg wet weight between 1978 to 2000. Concurrently, lead and mercury maximum levels have also risen from 0.10 to 3.08 and 0.05 to 1.11 mg/kg wet weight between 1978 to 2000. Other heavy metals such as iron, magnesium and nickel have shown similar increases. Although it has not yet been established that these levels of elements and heavy metals may have reached levels that can have detrimental effects on dugongs, it is clear that levels are rising.

Manatee

Manatee research has focused on levels of persistent organic pollutants with less emphasis on elements and heavy metals. Studies looking at these contaminants (elements and heavy metals) date from 1984 and 1991, precluding any comments on today's levels. New research needs to be done to reflect the current levels of these contaminants (Table 2). The few heavy metal studies published that focused on sirenians are mostly found in Florida manatees and were over a relatively short 5 year time interval (1977 to 1982). These studies showed that copper maximum levels had decreased (840 < 39.76 mg/kg wet weight), lead remained the same (3.08 > 3.57 mg/kg wet weight) and mercury had increased (0.14 > 0.38 mg/kg wet weight).

Organochlorine Compounds

In general, there is limited knowledge on the accumulation of persistent organic pollutants or POPs in sirenians and their possible effects. Since 1994 there have been a total of 5 major papers dealing specifically with organochlorines or organohalogen contaminants (14, 1, 32, 15, 12). Three of these publications dealt with dugongs in Australia, one looked at dugongs in Thailand and one in manatees within Florida. These studies only studied organochlorine pesticides such as dioxins and polychlorinated biphenyls (PCBs) and the Haynes publication studied these contaminants from samples that were taken between 1996 to 2000 (12). In 1998, the Marine Mammal Commission sponsored a workshop "to review what is known, and what needs to be learned, about the possible effects of persistent ocean contaminants on marine mammals" (18). The scope of this workshop was ambitious and its objectives ranged from reviewing the literature, looking at any potential effects, identifying the importance of, outlining research and monitoring programs, and expanding present research/monitoring programs of harmful persistent contaminants or organochlorines in marine mammals. This workshop concluded that "there is good reason to be concerned that survival and reproduction in certain marine mammal populations may have been affected, and are being affected, by persistent contaminants, particularly organochlorines" (18). It must be taken into consideration that most of the information used to publish the proceedings of this workshop was published prior to 1998.

Dugongs

Heavy Metal Year (Reference)	Amount (mg/kg wet weight)		Location
	Minimum	**Maximum**	
ARSENIC			
1996 to 2000 (13)	0.45	7.7	Queensland, Australia
1996 (13)	1.54	2.17	Great Barrier Reef, Australia
1992 (12)	0.18	0.40	Torres Strait, Australia
1982 (17)	no value	1.25	Okinawa, Japan
COPPER			
1996 to 2000 (13)	9.5	303	Queensland, Australia
1996 (13)	53.9	117.8	Great Barrier Reef, Australia
1992 (12)	22	370	Torres Strait, Australia
1992 (13)	6.0	19.6	Northern Territory, Australia
1991-1993 (13)	58.1	984.2	Torres Straight, Australia
1984 (13)	15.3	74.9	Northern Territory, Australia
1974-1978 (7)	6.4	425.6	Queensland, Australia
LEAD			
1996 to 2000 (13)	<0.08	3.08	Queensland, Australia
1992 (12)	0.05	0.10	Torres Strait, Australia
1974-1978 (7)	Not Detectable		N Queensland, Australia
MERCURY			
1996 to 2000 (13)	0.05	1.11	Queensland, Australia
1992 (12)	0.02	0.04	Torres Strait, Australia
1977- 1980 (12)	0.01	0.05	Cleveland Bay, NE Australia

Table 1. Toxic Element Levels in Dugong Livers (12, 13, 17, 7)

Heavy Metal Year (Reference)	Amount (mg/kg wet weight)		Location
	Minimum	**Maximum**	
COPPER			
1982 (21)	15.26	39.76	South Western Florida
1977-81 (20)	3.08	840	Throughout Florida
LEAD			
1982 (21)	0.31	3.57	South Western Florida
1977-81 (20)	1.26	3.08	Throughout Florida
MERCURY			
1982 (21)	Not Detectable	0.38	South Western Florida
1977-81 (20)	Not Detectable	0.14	Throughout Florida

Table 2: Toxic Element Levels in Manatee Livers (20,21)

Haynes et al. in 1999 reported that levels of POPs in dugongs were equivalent to those found in carnivorous marine mammals (12). The accumulation of POPS and PCBs within marine mammal populations found in the Northern Hemisphere have been related to reproductive, nervous and immunological abnormalities (12). What is known of POPs in sirenians has been reported using small numbers of animals and were done in very specific geographical locations.(Table 3) Kemper et al. in 1994 published a review of organochlorine levels in the blubber of marine mammals found in Australian waters (14). In 2 dugongs, the authors found that there were non- detectable levels of PCBs and DDTs. In 1996, Ames et al. published levels of DDT (0.087 and 0.356 µg/g wet weight), HCB (0.085 µg/g wet weight) and DDD (0.672 µg/g wet weight) in the livers of Florida manatees(n=19) (1). In 2001, Vetter et al. published **blubber** levels in 3 Australian dugongs showing PCB levels between 89 to 209 (µg/kg lipid weight) and DTT levels between 15 to 173 (µg/kg lipid weight) (32). Haynes et al. in 2005 published that concentrations of organocompounds such as dieldrin (1-43 µg/kg lipid weight) and DDT (2.8 - 66 µg/kg lipid weight) were present in low concentrations in dugong **blubber** samples(n=52) taken between 1996 to 2000 and that their dieldrin levels (0.4 - 9.2 µg/kg wet weight) were similar to those that were measured in the livers of dugongs taken from the same region (0.32 - 1.02 µg/kg wet weight) (12). However, Gaus et al. in 2004 reported that dugongs (n=17) from Queensland, Australia had higher PCDD/F (polychlorinated dibenzodioxin) levels (80 - 2000 pg/g lipid) than dugongs from Thailand or other trophic marine mammals found in remote, low industrial areas such as the Arctic or New Zealand, but similar to that of orcas found in waters off the British Columbia coast (1250 - 2400 pg/g lipid) (10). The potential immediate risks of organochlorine compounds to dugongs is unknown and what effects they may have on the long term conservation efforts to save them is undetermined.

Manatee

As in the dugong, information concerning organochlorine contaminants and their effects in manatees is limited. The few papers published looking into organic contaminants in the manatee mostly looked at tissue from the Florida manatee (*Trichechus manatus*) (Table 4) (9, 20, 21, 1). The Ames paper published in 1996 actually was reporting organochlorine levels in tissue from the Florida manatee taken between 1990-1993 (1). There has been no published data on organochlorine levels in tissue from the Florida manatee since 1993, so the current status is unknown. Total PCB levels in both blubber and liver of manatees reveals that from 1977 to 1993 there has been non detectable to low maximum levels (4.6 mg/kg wet weight). Total DDT levels in manatee **blubber** reveals a similar trend between 1974 to 1993, from <1.0 to non-detectable levels (mg/kg wet weight) respectively. Dieldrin levels reveal the same trend of non-detectable levels from 1974 to 1993.

When studying contaminants in the tissues of any species or within their environment one must realize that present and future levels will constantly be in flux for many decades or even centuries as contaminants are still being released into the air, ground and water. These enter into the marine environment either directly or indirectly. For instance, despite the fact that PCB use and production was halted in the 1970s, 35% is still being used, 30% is located in dump sites and an astounding 34% is unaccounted for (28). The levels of many contaminants still seem to be increasing in the various tissues of numerous species despite measures to control or reduce them (33). The immediate or long term effects of these contaminants on the various species found along the food chain is presently unknown or can only be speculated. Extensive research proposals and long term conservation strategies, especially in developing countries where these contaminants are being released, need to be implemented.

Organochlorine & Year (Reference)	Tissue	Amount (mg/kg wet weight)		Location
		Minimum	**Maximum**	
∑PCBs				
1996-1999 (32)	Blubber (10 congeners)	Not Quantified	209 (lipid)	Queensland, Australia
1996 (13)	Liver (17 congeners)	Not Detectable		Great Barrier Reef, Australia
∑DDT				
1996-2000(13)	Blubber	0.5	59	Queensland, Australia
1996-1999 (32)	Blubber	Not Quantified	6.5	Queensland, Australia
1996 (13)	Liver	Not Detectable		Great Barrier Reef, Australia
Dieldrin				
1996-2000(13)	Blubber	Not Detectable		Queensland, Australia
1996-1999 (32)	Blubber	Not Quantified	14	Queensland, Australia
1996 (13)	Liver	Not Detectable	0.5	Great Barrier Reef, Australia

Table 3: Organochlorine Levels in Various Tissues of Dugongs (13,32)

Organochlorine & Year (Reference)	Tissue	Amount (mg/kg wet weight)		Location
		Minimum	Maximum	
∑PCBs				
1990-1993 (1)	Blubber	Not Detectable		Throughout Florida
1982 (21)	Blubber	Not Detectable		South western Florida
1977-81(20)	Blubber	Not Detectable	4.6	Throughout Florida
1974 (9)	Blubber	<1.0	<1.0	North eastern Florida
1990-1993 (9)	Liver	Not Detectable		Throughout Florida
1974 (9)	Liver	<1.0	<1.0	North eastern Florida
∑DDT				
1990-1993 (1)	Blubber	Not Detectable		Throughout Florida
1982 (21)	Blubber	Not Detectable	0.25	South western Florida
1977-81(20)	Blubber	Not Detectable	0.28	Throughout Florida
1974 (9)	Blubber	<1.0	<1.0	North eastern Florida
Dieldrin				
1990-1993 (1)	Blubber	Not Detectable		Throughout Florida
1977-81(20)	Blubber	Not Detectable	0.36	Throughout Florida
1974 (9)	Blubber	Not Detectable		North eastern Florida

Table 4: Organochlorine Levels in Various Tissues of Florida Manatees (1,9,20,21)

Research Strategies and Conservation Actions

The immediate and long term goal for research strategies or conservation actions obviously include ensuring the preservation of current species thereby creating biodiversity. Establishing biodiversity will allow for the prospering of individual species thereby increasing the number of species and ensuring healthy and flourishing ecosystems. In return, these ecosystems would allow for the future sustainable harvest of multiple species of animals that will be necessary to feed the continually expanding human population. However, these ecosystems are facing various stressors that are preventing these species of animals to reproduce and maintain healthy populations. The world's rivers and oceans have been and continue to be used as sites for the disposal of contaminants. Many species of key fish stocks have been over-fished beyond possible recovery. Important habitats, necessary to insure the survivability of many species, have been changed and key species have become extinct. The effects of climate change have created disturbances that have happened so quickly that many species have not been able to adapt quickly enough thereby causing massive die offs of local populations. Recently, the introduction of new stresses such as noise is causing behavioral changes and even the possible death of marine mammals. Drastic and innovative research strategies and conservation actions are required to be able to save as many species as possible, several of which are presently endangered or threatened, in order to maintain natural ecosystems and preserve biodiversity. Being a key species and a possible sentinel of how healthy the marine environment can be, sirenians require research strategies that are focused and conservation actions that are strong and vigorous to ensure its protection.

A review of the research literature reveals that since 1954 there have been 163 published research articles concerning the dugong and 319 for manatees. Most of these articles looked at sirenians and their preferred habitat, types of seagrasses eaten, population numbers and impact of indigenous fishing and anthropomorphic influences such as boats and tourism. Only recently has interest focused on contaminants within their environment or tissues. In 2002, Marsh et al. published an assessment report and action plan for developing countries in which dugongs were found (17). Under chemical pollutants, Marsh wrote that high levels of heavy metals were found in older dugongs and that there was no evidence that these heavy metal pollutants were harmful. However, certain tissue levels were at levels reported potentially harmful to humans. Information on pesticides was very limited and low compared to other marine mammals found elsewhere in the world. It was suggested that chemical pollution should be looked at in the dugong's range that had higher population numbers as opposed to looking at small isolated numbers. The report went on to describe threatening processes and research initiatives for the survival of dugongs (Table 5). The majority of threats and research work examined in dugongs has been reserved to mostly looking at determining abundance, habitat mapping, mortality rates and causes and anthropogenic impacts. No comprehensive environmental study exist that measures the amounts of contaminants found within dugongs or assessing levels that may be potential harmful to this species and be a potential threat to humans who hunt these animals for sustenance. The only country that has studied contaminant levels

Country	Threatening Processes	Existing Research Initiatives
East Africa/Red Sea/Arabian Coast	Habitat loss/Degradation, Fishing pressure/Hunting	Determining abundance/Habitat mapping/ Habitat use/Impact of oil spills
India/Sri Lanka	Habitat loss/Fishing pressure/ Hunting	Determining abundance/Habitat mapping/ Habitat use/Mortality Source
East and Southeast Asia	Habitat loss/Fishing pressure/ Hunting	Determining abundance/Habitat use
Taiwan	Habitat loss	Determining abundance/Habitat mapping
China	Habitat loss/Fishing /Hunting/ Ecotourism	None
Philippines	Habitat loss/Fishing pressure/ Hunting/Boat impacts	Determining abundance/Habitat mapping/ Habitat use/Impact of fisheries/Anthropogenic impacts
Thailand/Cambodia/ Vietnam	Habitat loss/Degradation, Fishing pressure/Hunting	Determining abundance/Habitat mapping/ Habitat use/Mortality rates & causes/prepare conservation strategy
Malaysia/Singapore/ Brunei	Habitat loss/Fishing pressure/ Hunting/Boat impacts	Determining abundance/Habitat mapping/ Habitat use/Mortality rates & causes/Prepare conservation strategy/Anthropogenic impacts
Indonesia	Habitat loss/Fishing pressure/ Hunting/Boat impacts	Determining abundance/Habitat mapping/ Habitat use
Pacific Islands	Habitat loss/ Hunting/Ecotourism	Determining abundance/Poaching & hunting activities
Papua New Guinea// Solomon Islands/New Caledonia/Vanuatu	Habitat loss/Fishing pressure/ Hunting/Ecotourism/Boat impacts	Little or no recent research
Australia	Habitat loss/Fishing pressure/ Hunting/Ecotourism/Boat impacts	Determining abundance/Habitat mapping/ Habitat use/Mortality rates & causes/ Conservation strategy/ Anthropogenic impacts/Chemical pollution

Table 5: Dugong Threats And Existing Research (17)

intensively in dugongs has been Australia and most of these have been with small numbers or within a small geographical area.

Conceivably, to be successful any research strategy concerning sirenians should:

- be well funded
- be logistically organized between a large number of countries and over large geographical regions
- be centrally coordinated and managed by scientific committees composed of scientists, biologists, technicians and experienced field personnel (rangers, local fishermen, etc)
- have a central research facility that would store and maintain a tissue bank so that tissue and information could be shared between regions and countries to reduce the repetition of studies and maximize the information produced
- be composed of a well conceived research strategy that effectively looks at contaminants and their effects on sirenians by studying the following 3 major components:

  i) the accumulation of contaminants over time
  ii) the accumulation of contaminants in various small and large geographical locations
  iii) the effect of these contaminants on the various physiological systems.

Although it would seem that although sirenians and numerous other marine mammals may have physiological methods to detoxify many contaminants, this does not negate the importance of identifying toxic levels of these contaminants if any conservation plan is to be successful. In summary to be successful, research strategies must include adequate financial investments, technical assets and human resources in a systemic plan that looks at every member of a species as being critical to maintain a viable population.

Conservation Actions

As in human medicine, to be truly successful, conservation action ideally should be geared to prevention and not reaction. For example, in Japan hundreds of people died and several thousands more suffered as a result of mercury poisoning in the 1950's and '60's. Despite this, meat from several marine mammals are still being offered for consumption in today's Japanese markets even though that they contain high mercury levels (8). In the Arctic, many wild species in that region, have very high contaminant levels and thus pose a similar and serious hazard to the many communities who are still dependent upon hunting these species as their source of protein (33). These indigenous people continue to eat meat which may be hazardous to their lives, most likely because no direct correlation has been confirmed between these contaminants in marine species and their causing sickness or disease.

When looking at sirenians, conservation actions must be instigated with the idea to predict problems ahead of time thereby preventing the introduction of these contaminants into the environment which might affect their reproduction or survival. For instance, it is known that an increase in rainfall leads to greater amounts of runoff which kills the seagrasses that dugongs eat (4) and increases contaminants reaching the waterways. As a result, dugongs die either from starvation or other non-specific causes including possible contaminants or move to another region which can cause competition between animals. If proper clear cutting or farming practices would be introduced to prevent the increase of runoff during the rainy seasons, this would minimize the effect on the dugongs by preventing deaths and lowering the amount of contaminants into the environment. In the manatee, numbers of death have been lowered from collisions with speeding water craft by changing legislation and promoting public awareness, but new threats such as hypothermia or the higher number of deaths within perinatal young have prevented an increase the manatee population (2). The immediate cost of reacting to cleaning up contaminants in terms of money, equipment and human resources are extremely high and result in damage to our environment that requires decades to restore or repair (3). To successfully conserve sirenians in the many countries in which they geographically range, all conservation plans must be proactive and co-operative in preventing the introduction of contaminants into their environment.

As our human population continues to grow, the demand for more sources of protein will increase. As proof, McNiven et al. concluded that "pre-colonial hunting rates of 300 dugongs a likely minimum for the Strait (Torres) and 500 dugongs per year (the current mean catch rate) plausible" (18). So more dugongs are now being hunted than in pre-colonial times thereby increasing the likelihood of a human health issue. This review provides the realization that little progress has been made since the publication of the Marine Mammal Commission's workshop in 1999 that concluded "there remains great uncertainty about specific effects of contaminants in marine mammals" and that "closing of these knowledge gaps will make science better able to guide policy, management, and regulatory decisions related to contaminant impacts on marine mammals (23). When specifically looking at sirenians, the workshop also stated that "Because sirenians feed near the bottom in coastal and inland waterways and are herbivores, their exposure to contaminants may include less widely recognized chemicals…". So it would seem that since 1999, little has been done to explore the levels of contaminants or their effects within sirenians.

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