SC/64/O14_Rev - Report of the Symposium and Workshop on Living Whales in the Southern Ocean:
Puerto Varas, Chile 27-29 March 2012

An initiative of the Southern Ocean Research Partnership

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SUMMARY

A Symposium and accompanying workshops were held in Puerto Varas, Chile from 27-29th March 2012, to discuss recent advances in methods for non-lethal research on whales in the Southern Ocean. The first day (27th March) was an open Symposium with invited experts who showcased new non-lethal research methods for whales in the Southern Hemisphere. The Symposium was followed by two days of Workshops that covered specific research areas. The Workshops were each one day in duration and covered the following topics (under the direction of co-chairs):

- Health assessment of live cetaceans (Hall, Perryman);
- Advances in long term Satellite Tagging Techniques for Cetaceans (Gales, Zerbini);
- Population dynamics and environmental variability (Jackson, Leaper; and
- Estimation of diet and consumption rates from non-lethal methods (Freidlaender, Valenzuela).

The Symposium was attended by 124 registered participants from 16 countries (Argentina, Chile, Brazil, Australia, Colombia, Ecuador, France, Germany, Madagascar, Mexico, Norway, Panama, Paraguay, South Africa, UK, USA). The Symposium was also live streamed on the web, allowing an additional 1,553 simultaneous viewers.

Report of the Southern Ocean Research Partnership (SORP) Living Whales Symposium: Advances in methods for non-lethal cetacean research

Puerto Varas, Chile 27-29 March 2012

1. WELCOME AND OPENING COMMENTS

Galletti welcomed participants and introduced the Symposium. She outlined the aims of the Symposium and the importance of non-lethal cetacean research in the Southern Hemisphere. She noted that the Symposium and Workshops are outcomes from the Southern Ocean Research Partnership (SORP). She thanked the sponsors of the Symposium who included the Ministry of Foreign Affairs of Chile, the Directorate of Maritime Territory and Merchant Marine of Chile, the Australian Government, the National Oceanic and Atmospheric Administration of the United States, Oregon State University, the International Fund for Animal Welfare, the South Pacific Research Whale Consortium, Altavoz and Cetacean Conservation Center Chile. The Symposium was primarily held in English with simultaneous translation into Spanish.

Participants were welcomed by Jose Fernandez from the Ministry of Foreign Affairs of Chile who also thanked the Sponsors of the Symposium. CF LT. Rich from the Directorate of Maritime Territory and Merchant Marine of Chile also welcomed the participants and outlined the Chilean Navy responsibilities for cetaceans in Chile, including their protection and conservation.

There were 124 people registered for the symposium from 16 countries (Argentina, Chile, Brazil, Australia, Colombia, Ecuador, France, Germany, Madagascar, Mexico, Norway, Panama, Paraguay, South Africa, UK, USA). The Symposium was also live streamed on the web, allowing an additional 1,553 simultaneous viewers, mostly from USA, Chile, Brazil, Argentina, Australia, Spain, Colombia, UK, Canada, and Germany. A full list of Participants can be found in Appendix 1

The Symposium and accompanying workshops were held in Puerto Varas, Chile from 27-29th March 2012. The first day (27th March) was an open Symposium with invited experts who showcased new non-lethal research methods for whales in the Southern Hemisphere. The Symposium programme is attached as Appendix 2 and a summary of all the presentations is provided below. The Symposium was followed by two days of Workshops that covered specific research areas. The Workshops were each one day in duration and covered the following topics:

- Health assessment of live cetaceans;
- Advances in long term Satellite Tagging Techniques for Cetaceans;
- Population dynamics and environmental variability; and
- Estimation of diet and consumption rates from non-lethal methods.

Galletti was the Conference Organiser and Baker was the Scientific Programme Director. Childerhouse agreed to act as rapporteur.

2. SYMPOSIUM PRESENTATIONS

A summary of each of the presentations from the Living Whales Symposium is provided below. Copies of selected presentations are available at http://www.simposioballenas.cl.

PAST, PRESENT AND FUTURE

History of whaling in the Southern Ocean

Presenters: Phil Clapham, National Marine Mammal Laboratory, Seattle, WA, USA
& Yulia Ivanchenko, School of Environmental Science and Management, Southern Cross University, NSW, Australia

Modern-style whaling in the Southern Ocean began in 1904 when the Norwegian whaler Carl Anton Larsen constructed a whaling station at Grytviken, South Georgia. The first year's catch was 184, but this increased rapidly during the period leading up to World War I. More than 200,000 whales (mostly blue, fin and humpback) were taken at South Georgia and South Shetland from 1904 to 1966, a testament to the extraordinary productivity of the region. The first factory ship was introduced in 1923, freeing whalers from the limited catcher ranges and high taxes that were associated with land station operations. By 1930, there were 38 factory ships and 184 catchers working in the Southern Ocean. In 1931, the first attempt to regulate whaling occurred with the Geneva Convention, but in that same year 29,410 blue whales alone were killed, and more than 150,000 were caught in the 1930's alone. Similarly, the negotiation of the International Agreement for the Regulation of Whaling in 1937 coincided with a peak total catch of 46,039 whales. In 1946, the International Convention for the Regulation of Whaling created the International Whaling Commission (IWC), which remains the body charged with assessing whale populations and setting quotas. Despite these attempts to promote sustainable whaling, disagreement over the status of stocks and overcapitalization in the industry ensured that catches remained high, with more than a quarter million fin whales killed in a single decade (the 1950's).

The evolution of non-lethal whale science and the Southern Ocean Whale Research Partnership

Presenter: Nick Gales, Australian Antarctic Division, Hobart, TAS, Australia

Over the past Century cetacean science has been driven by changing influences. Chronologically these have included commercial whaling in the first half of the nineteenth Century through to post-moratorium/whale recovery science, research that addresses threatening processes (e.g. fisheries and ocean noise) and most recently to ecological studies that can address the role of whales in ecosystems and consequences of climate change. The greatest opportunities for advances in cetacean science have been driven by the rapid expansion of non-lethal research tools. These include our ability to measure and interpret ocean noise (and whale sounds), apply the latest molecular techniques, track whale movements and behaviour with electronic and biologging instruments, handle data with the latest statistical, mathematical and computer visualisation and simulation tools and to view whale habitat with remote sensing technology. Applying these technologies against agreed priority research objectives is challenging and can only effectively be accomplished through large scale, integrated, cross-disciplinary collaborative efforts. Recognising this, Australia led the development of the Southern Ocean Research Partnership (SORP). The Partnership includes over ten IWC members and applies the latest scientific tools to agreed priority research. Six major projects have been commenced and are now being implemented. These include the Living Whales Symposium and five collaborative research projects:

1. Breeding to feeding; habitat utilisation by humpback whales
2. Baleen whales and krill – niche partitioning between minke and humpback whales
3. Ecology of the three Antarctic killer whale ecotypes
4. Acoustic trends in abundance, distribution and seasonal presence of Antarctic blue and fin whales

5. The Antarctic blue whale project.

These ambitious and exciting projects will feed into major multi-disciplinary polar programs including Integrating Climate and Ecosystems Dynamics (ICED) and Southern Ocean Observing Systems (SOOS), as well as providing relevant outputs to IWC, the Scientific Committee for Antarctic Research (SCAR) and the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR). Through this work we have the opportunity of combining historic whaling catch data with contemporary whale science, thus providing a unique century-scale biological signal of changes in the Southern Ocean Ecosystem.

The role of whales in the Southern Ocean ecosystem
Presenter: Lisa Balance, National Marine Fisheries Service, NOAA, USA
Co-authors: R.L. Pitman and R.L. Brownell, Jr.

Whales are large and it matters; this is the macroecological conclusion regarding the role of whales in marine ecosystems in general. A rough calculation indicates that some 15.7 million tons of whale biomass currently exist in the world's oceans. This sheer tonnage implies that whales can play significant roles in marine ecosystems, and a variety of studies confirm this. This overview of the role of whales in the Southern Ocean (that area south of the Polar Front) takes a trophic interactions perspective – of whales as consumers, whales as competitors, and whales as prey. Whales consume krill (all baleen whales), squid (sperm whales, beaked whales, and perhaps, killer whales), fish (some baleen whales, Ross Sea killer whales), penguins (Gerlache killer whales), seals (Pack Ice killer whales), and other whales (Type A killer whales). Obtaining quantitative measures of prey consumption is problematic because such measures rely on estimates of whale abundance, consumption rates, and knowledge of diet composition; all of these estimates are associated with a great degree of uncertainty. Whales also compete for prey with other consumers in the Southern Ocean, most notably for krill. The Krill Surplus Hypothesis, proposed by Laws in 1977 produced a flurry of research documenting growth in penguin populations, purportedly as a result of the removal of whales (krill consumers, and thus, competitors of penguins) by commercial whaling. Although this hypothesis continues to be debated today, there is clear evidence that interspecific competition for krill is occurring. This competition can result in changes in abundance of both predators and prey, and niche partitioning. Finally, whales consume other whales, in the case of killer whales, and this predation has been hypothesized to drive evolutionary responses in behaviour and life history strategies of whale prey. The ecosystem consequences of consuming, competing, and predation can result in top-down forcing in the form of food web restructuring; a number of studies support this idea. Additional research on the degree to which this top-down forcing restructures food webs, especially as whales recover, trophic linkages between whales, their prey, competitors, and predators, and the degree to which whales remain a part of the ecosystem year-around are among the many ecosystem-related topics which should prove fruitful.

MOLECULAR TECHNIQUES

Accessing the molecular archive – wide and deep, past and future
Presenter: C. Scott Baker, Oregon State University and South Pacific Whale Research Consortium

The history of whaling in the Southern Ocean provides an experiment in conservation biology and ecosystem dynamics on a grand, if tragic scale. Molecular ecology provides us with powerful tools to reconstruct the history of this exploitation and to assess the current status of these populations through the collection of small genetic samples from living whales. Until

recently, however, the potential power of these tools has been limited by either the number of samples, or the number of molecular markers that could be applied to each sample. While early studies in molecular ecology were 'narrow and shallow' (i.e. few samples and few markers) the growing archive of samples and the increasing capacity of next-generation sequencing now allow for studies that are both 'wide and deep'. Although no complete genome has yet been published for a whale, several methods for reduced representation genomic sequencing are being applied to whale species and whale populations. One of these, referred to as 'RAD tagging', generates many millions of 'short reads' that can be assembled *de novo* into gene fragments (contigs) suitable for studies of molecular evolution between species or for discovery of Single Nucleotide Polymorphisms (SNPs) within species. A second, referred to as 'genomic amplicon resequencing', generates hundreds of thousands of 'long reads' that can be used to reconstruct entire mitogenomes or to assess allelic diversity in a multiplex of individuals and loci. Finally, next-generation sequencing promises to provide great power in characterizing diversity in pre-whaling populations through 'ancient DNA' archived in bones from early whaling operations, such as South Georgia and Sandwich Islands.

Genetic bottlenecks and historical population estimates of baleen whales
Presenter: Jenifer Jackson, British Antarctic Survey, Cambridge, UK

Southern Hemisphere baleen whales were killed in their thousands during the whaling campaigns of the 18th and 19th centuries. For many of these species current populations are still a remnant of past abundance. Present day genetic datasets from these populations enable us to gain information about long-term pre-exploitation abundance through analysis of the genetic diversity retained in their DNA. Not only can these 'deep time' estimates tell us about past abundance, but the pattern of divergence of genetic lineages through time can also tell us how abundance changed through the history of the population, using molecular 'skyline' approaches. An example is illustrated with the Southern Hemisphere humpback whale. This genetic diversity can also be informative about the minimum number of animals that survived exploitation, i.e. the extent of the population bottleneck during whaling. It is useful for assessments of current population recovery such as those conducted by the International Whaling Commission. When genetic data are used to estimate minimum bottleneck sizes for southern right whales and Antarctic blue whales, in both cases population dynamics models were found to have estimated lower abundances than those inferred from genetic data. Methods of estimating bottleneck size are still under development and are a promising means of better informing population dynamics models for large whales.

Killer and humpback whale ageing
Presenter: Gina M. Ylitalo, NOAA Fisheries, Seattle, USA
Co-author: D.P. Herman

Information on the age of individual whales is needed to estimate the age distribution of entire whale populations and is fundamental to assessments of status and long-term viability. Until recently, there was no reliable, benign method to determine the specific ages of live animals for remote populations where long-term longitudinal sighting studies are not practical. In two recent studies involving eastern North Pacific killer whales and humpback whales from both Southeast Alaska and western North Atlantic, we described a new method to estimate whale age from measurements of specific endogenous fatty acids (FAs) and FA ratios present in the outer blubber obtained by remote dart biopsy techniques. These studies showed that it is possible to estimate the age of individual whales with better than decadal resolution using this approach. Some new preliminary data suggests that it is also possible to estimate the ages of physically immature Cook Inlet Alaska beluga whales following this

approach based on blubber FA results obtained from capture and release and stranded animals acquired in 2001-2007. Unlike the two previous studies in which exact or minimum known-ages were known and thus served as calibration standards to derive the empirical FA-age models, ages of Cook Inlet belugas were estimated from the von Bertalanffy allometric relationship between body length and teeth growth layer groups derived for this beluga population in the 1990s. The proposed beluga FA ratio – age model should also enable the ages of physically mature adult whales of both sexes to be estimated following this approach.

BIOLOGGING

Overview of existing techniques and future directions
Presenter: Christophe Guinet, Centre d'E´tudes Biologiques de Chize, Villiers-en-Bois, France,

Increased pressure is being placed on wildlife as our global climate changes, habitats are modified and resources are consumed. Understanding the function of species and populations in ecosystems, habitat and resource requirements and their capacity to adapt to a changing environment are essential in the management of ecosystems. Bio-logging, the application of electronic recording devices to animals, is providing such information. Over the last 4 decades considerable progress has been made and a broad range of loggers are now available to investigate the ecology of a broad range of terrestrial and marine species. However within than context, and compared to pinnipeds, whales pose special challenges for long term deployment of loggers due to their large size and challenges associated with gluing the loggers onto the skin. Therefore only short term deployment using suction cups of a broad range of logger (time depth recorders, accelerometer, camera, accelerometer/magnetometer/pressure and hydrophones (D-Tag or acousondes)) have been deployed successfully on a broad range of whale species: humpback, blue whales, northern right whales, killer whales, for example. These loggers, which need to be recovered to retrieve the data, have provided extremely valuable fine scale information, sometimes in 3 dimensions, on behavioural/foraging. However, long term deployment of loggers remains challenging for cetaceans. In recent years satellite data relayed loggers (SRDL) have been successfully deployed on whales, providing the first multi-weeks data sets of continuous diving behaviour and oceanographic data (i.e. temperature mainly and salinity). These SRDL were either bolted or deployed using a crossbow or airgun on whales' dorsal fins using short pins. However, the Argos transmission of these data requires inboard processing. Within an ecological context and in a changing environment, in my view, accelerometer data offers extremely promising perspectives for quantifying foraging efficiency due to the small size of the logger combined with pressure information. Future effort should concentrate on developing inboard algorithms to extract and transmit the most pertinent summarised metrics on foraging effort/success/ and body condition. In future, the existing high resolution data collected by D-Tags deployed on a broad range of whale species will be able to address a range of important scientific questions, including the identification of the most pertinent information to be extracted and to test the efficiency (in processing time and energy consumption) of the optimal inboard processing algorithm.

Fine scale habitat use
Presenter: Ari Friedlaender, Duke University Marine Laboratory, USA
Co-authors: E.L. Hazen, C. Ware, P.N. Halpin, A. Stimpert, R.B. Tyson, and D.P. Nowacek

To date, little information exists to test how cetaceans make decisions regarding where and when to begin feeding. This information is necessary to quantify consumption rates and ecological interactions. Limitations in determining both the location of individual feeding

lunges and the concurrent spatio-temporal availability of prey have limited efforts to examine how foraging decisions are made relative to optimal foraging theory, energetic demands of diving, or a combination of the two. In 2009-2010 we deployed 21 digital recording tags on humpback whales for >350 hours around the Western Antarctic Peninsula and collected concurrent measurements of Antarctic krill distribution and abundance using Simrad EK-60 scientific echosounders. The time, location, and depth of feeding lunges were determined based on published methods using accelerometer data. Prey biomass was determined using volume backscatter and target strengths generated from net samples and krill models. Prey data were then stratified vertically into 10-meter depth bins. We found that the frequency of lunges on a given dive increases with dive depth, supporting an energetic cost of lunging at depth. Throughout night-time hours, the average depth of feeding lunges changed significantly, following a pattern consistent with diel vertical migration observed in the krill. Using a combination of spatially-explicit analytical tools we find that the depth at which lunges occurs correlates to the density of krill, such that deeper dives target denser aggregations of krill. Our results offer insights into the combination of energetic demands of diving and the vertical distribution of prey in determining where and when whales feed.

Large scale habitat use
Presenter: Alex Zerbini, Cascadia Research Collective, USA & NMML, NOAA Fisheries, Seattle, USA
Co-authors: Nick Gales and Mike Double, Artur Andriolo

Large baleen whales typically migrate from winter breeding grounds to summer feeding destinations or between seasonally available foraging habitats. Understanding migratory routes and destinations and habitat use in these regions is important to improve whale conservation. More traditional “tagging” techniques (e.g. Discovery marks, photo-identification and genotype data) have been useful for describing migratory connections between various habitats but provide very limited information about the routes taken during long-range movements and no description of how whales use habitat upon arrival to their destinations. In this presentation we used satellite-monitored Southern Hemisphere humpback whales as an example of the wealth of information telemetry can provide for the study of large-scale movements. Whales were instrumented with satellite transmitters in three primary wintering grounds including Brazil, Eastern Australia, and New Caledonia. For some of these populations, migratory routes and destinations had not been determined until satellite telemetry studies were implemented. These studies allowed for interesting comparisons of the movement behaviour across various populations. For example, Australian whales disperse in various directions and use multiple migratory routes towards feeding destinations near the Antarctic pack ice, whereas whales from Brazil use a relatively narrow migratory corridor en route to feeding destinations located west of South Georgia and the South Sandwich Islands and away from the Antarctic pack ice. Space-state modelling of telemetry data suggests the preferred foraging habitat of Australian and Brazilian whales is associated with the southern boundary of the Antarctic Circumpolar Current. Multi-year tagging of whales from Brazil and New Caledonia indicates remarkable consistency in the routes taken with cases of indistinguishable tracks of different individuals in different years. Tagging of New Caledonian whales revealed a new pattern among humpback whale migration; unlike other populations, these animals visit various seamounts while moving from their primary wintering grounds towards higher latitudes. Satellite telemetry has also allowed us to assess the spatial overlap of humpback whale habitats and areas of interest of a fast-growing oil and gas exploration industry in western Brazil with results that can be used to protect critical habitats. Finally, satellite-monitored whales provide unique opportunities to investigate how these animals navigate with extreme precision through vast areas in our oceans. We conclude that satellite telemetry has become a powerful non-lethal research

method and that future developments should make this technique even more useful for whale conservation.

REMOTE SENSING

Overview of existing techniques and future directions
Presenter: Patrick Halpin, Duke University Marine Lab, Duke University, Durham, NC, USA
Co-author: Jason Roberts

In this presentation we provide an overview of the current state and future directions of remote sensing for the Southern Ocean. This overview is presented in the context of spatial and temporal scales of ecological phenomena and remote sensing products. Three general spatial and temporal scales are explored: Southern Ocean Basin scales, sub-regional scales and in-situ scales. Issues of cloud cover, spatial data aggregation (grain and extent) and temporal return interval are presented as critical issues in the development of consistent remote sensing data products for cetacean research. At the Southern Ocean basin scale common remote sensing products are presented including Sea Surface Temperature (SST), ocean colour/productivity (Chla), ice cover, Sea Surface Height (SSH). In addition dynamic oceanographic products including temperature fronts, eddy detection, kinetic energy climatologies are presented. Finally, data assimilating oceanographic models are presented (HYCOM) to demonstrate additional derived products. At the in-situ scale, active backscatter sonar detection of sub-surface prey (krill) and visual image analysis of local ice cover are presented to demonstrate fine-scale remote sensing data collection methods conducted concurrently with cetacean surveys. The broadest conclusions of this overview is that we have significant development of useful remote sensing data products at the ocean basin scale as well as the local in-situ scale, but have significantly more difficulty developing useful data at the sub-regional scales. This lack of data consistent data at the sub-regional scale is due to the effects of cloud cover, spatial resolution needs and return interval of sensors. The reason that we see differences in our ability to develop remote sensing products at different scales arises because our ability to aggregate data over large areas and long periods of time is possible at the ocean basin scale. At the fine-scale our ability to develop local in-situ data products during cetacean surveys is not limited by atmospheric conditions. But we have difficulties in developing consistently reliable remote sensing products at the sub-regional and within-season space and time scale due to cloud cover and spatial and temporal grain sizes and return intervals. The suggestion is made that to better support cetacean research this intermediate, sub-regional space/time scale should be a high priority for new technological development and innovation in the future.

Passive acoustic monitoring of large whales in the Southern Ocean
Presenter: Kate Stafford, Applied Physics Lab, University of Washington, USA

Sound is the primary sense used by cetaceans; they use sound for navigation, communication and foraging. Frequencies used by cetaceans range from sub-sonic (below human hearing) to ultrasonic (above human hearing). Different species make distinct sounds that can be used to recognize different species. Whales can be heard over much greater distances than they can be seen and their sounds can be detected under ice, in poor weather and in the dark which means they can be studied in a wide range of conditions. There are many tools for recording animals from a simple dipping hydrophone to a cabled acoustic observatory. Most long-term recordings are acquired from hydrophones that are moored underwater for as long as a year. Acoustic recordings can produce many terabytes of data therefore methods have been developed to automatically process sounds much more quickly than real-time. Passive

acoustic monitoring (PAM) can be used to study geographic variation within a species, study broad-scale migration patterns, examine the relative change in populations over time or to find rare species when the density of these animals is too low to make visual surveys feasible. Although PAM is a powerful tool, there are some restrictions to its use. Most importantly, only animals that produce sound can be detected, nothing can be said about silent animals. Large gaps in our knowledge of vocal behaviour for all species remain including knowing what proportion of the population vocalizes, when, and why.

Photogrammetry and health assessment of gray and blue whales
Presenter: Wayne Perryman, Cetacean Health and Life History Program, La Jolla, USA
Co-authors: Carolyn Miller, Morgan Lynn and Jim Gilpatrick

Over the past decade there have been significant developments in the use of measurements from vertical aerial photographs to assess nutritive and reproductive condition in large cetaceans. The shift from film to digital imaging has resulted in a transition from complex military reconnaissance systems to high-end consumer cameras, making vertical aerial photographic sampling a viable option for a wider range of researchers. We measure lengths and widths of south and northbound gray whales passing southern California and found that we could identify pregnant females and detect changes in shape resulting from the depletion of stored fats during this migration. We found that southbound whales were wider relative to their length than whales returning north and that lactating females were the thinnest whales in our sample. In a time series of length and width data from aerial photographs of southbound gray whales sampled between 1997 and 2003, the mortality event experience by this population in 1999 and 2000 coincided with a drop in population condition, indicated by a reduction in width to length ratios. In a separate study, width measurements from aerial photographs of North Atlantic and Southern right whales were taken at several locations (spaced at intervals equal to 10% of total length). Analysis of these data indicated that the reduction in stored fats by lactating females was most clearly demonstrated in measurements taken at a site 60% of total length back from the rostrum. Examination of measurements of length and width for short tailed blue whales photographed off southern California and in the eastern tropical Pacific also suggest that cows associated with calves differed most clearly from other adults in measurements of width taken about 60% of total length back from the rostrum. The most informative sites for measuring widths from photographs of large cetaceans will likely vary depending on the species sampled and the season (calving/breeding) that the measurements are taken.

LONG TERM NON-LETHAL RESEARCH

Overview of existing techniques and future directions
Presenter: John Calambokidis, Cascadia Research, WA, USA

There has been an increasing tendency for collaborative studies in marine mammal research and this has often gone hand in hand with the increasing number and complexity of methods available. There are a number of advantages and motivations to collaborate including: allowing research not easily conducted by a single person or group, ability to use complex new approaches, conducting work simultaneously in multiple areas, and as a tool to assist in gaining broader scientific and political support for work being done. While collaborations can take many forms, three broad types of collaborations are discussed here with examples of studies that demonstrate how they were beneficial. Broad Geographic collaborations involve multiple research groups using similar methods in different areas to get information from a broader geographic range. The SPLASH study is one example which involved more than 400

researchers from over 50 organizations and 10 countries to gather photo-IDs and samples from humpback whales throughout the North Pacific to determine abundance, stock structure, and human impacts. Participants used similar approaches simultaneously in all known wintering and feeding areas of humpback whales and yielded results for the entire North Pacific basin, something that would not have been possible without such a large collaboration. Multidisciplinary collaborations represent efforts by multiple groups bringing differing expertise to a research effort. The SOCAL Behavioural Response Study represents one example and involved varied expertise including behaviour, photo-ID, use of multiple tag types, passive acoustic monitoring, sound generation, prey relationships, and quantitative analysis to conduct a study that required integration of numerous approaches to examine impact of Navy sonar on cetaceans. Comparative collaborations involve the use of different approaches designed to achieve a similar objective but where contrasting the results obtained provides additional insight. This can involve comparison of results among areas or species but also can be contrasting methods to gain insight. One example of this latter approach was the contrasting of line-transect and mark-recapture methods to estimate blue whale abundance in the eastern North Pacific. While these two approaches initially gave similar results in the 1990s, the results deviated the next decade. Because line transect measures average density or abundance at any one moment in time and mark-recapture estimates population size, comparison of these two results revealed a shift in the geographic distribution and residency of blue whales off the US West Coast that would not have been apparent from either study singly. In order to encourage and succeed at collaborating it is important to recognize some of the concerns including those over addressing publishing rights, credit for work conducted, and future access to data. Overcoming these challenges includes creating mechanisms for broader participation in decisions such as steering groups, assuring proper credit, and allowing levels of autonomy by participants. Ultimately these efforts succeed when the collaboration allows research not achievable otherwise but does not prevent participants from publishing their own results individually as well.

Photo-identification and response to climate change in Peninsula Valdez
Presenter: Victoria J. Rowntree, Instituto de Conservación de Ballenas, Patagonia, Argentina

Individual right whales can be identified from their callosities, which appear as complex patterns of white patches on the black heads of the whales. In 1971, Roger Payne began a program of aerial photo-identification at Península Valdés, Argentina, which is the major calving ground for right whales in the western half of the South Atlantic Ocean. In 2012, this project will complete its 42nd season. Hundreds of females have been recorded with a calf in more than one year, and some have been seen with a calf in as many as ten years. These long reproductive histories have allowed us and our colleagues to accurately estimate the size of the population, its rate of growth, and many other parameters. The normal calving interval is three years. We recently discovered that years of elevated sea-surface temperature (SST) and low krill abundance at South Georgia (a likely feeding destination) tend to be followed by higher than average rates of reproductive failure, as indicated by increased numbers of 2-, 4- and 5-year calving intervals. This suggests that the population may be subject to food limitation, even though it is still far below its historic size. Because krill appear to be sensitive to SST, and to the recession of Antarctic sea-ice, these findings suggest that climate change may pose a serious threat to the population. We are currently using genetics, stable isotopes, and fatty-acid analysis to study where individuals forage and how they respond to yearly variation in foraging conditions, and we are attempting to identify the causes of recently increased rates of calf mortality at the Península.

Distance surveys and mark recapture techniques for abundance and distribution
Presenter: Jay Barlow, SWFSC, NOAA, La Jolla, USA

> Jay Barlow presented a summary of available methods for estimation the abundance and distributions of whales. Such information is valuable, perhaps most importantly, to judge levels of human impacts and to monitor the recovery of species. Although early estimates of whale abundance were based on whaling statistics, more precise methods are now available based on distance sampling methods, shore-based counts of migration whales, and mark-recapture methods from photo-identification or genetic studies. Each method has different advantages and limitations, and choosing the most appropriate method and survey design for a given study is often the most difficult part of abundance estimation. Because most studies of population abundance for whales are so large, development of solid collaborations is also an important first step in any such study. Recent large-scale collaborations, such as the SPLASH project in the North Pacific, have resulted in peer-reviewed abundance estimates of unprecedented precision. We should never have to return to killing of whales to estimate how many (used to) exist.

Following the presentations there was a panel discussion where members of the Symposium could ask questions of the presenters.

3. WORKSHOP REPORTS

A summary report from each of the four workshops is provided below.

Workshop Report on Diet, Consumption Rates, and Ecological Roles of Cetaceans

Living Whales in the Southern Ocean:
Advances in non-lethal research methods and techniques

Southern Ocean Research Partnership
Co-Chairs: Luciano O Valenzuela & Ari Friedlaender

Puerto Varas, Chile
28 March 2012

The goals of this workshop were to organize a group of experts to discuss the current state of knowledge regarding the diet, consumption rates, and ecological roles of cetaceans in the Southern Hemisphere. Presentations were made to highlight traditional and novel methodologies ranging from molecular techniques to tag-derived analysis. Focus groups were then convened to discuss the current state of knowledge, gaps in our understanding of the issues at hand, and to provide recommendations for future work that could be supported by the SORP. Discussions were also based on recommendations made by the IWC Scientific Committee. Below, we present the outcomes of our workshop and recommendations for research. A list of participants is attached as Appendix A.

The first group discussion focused on the ecological role of cetaceans and our ability to determine consumption rates in a quantitative manner. The second group discussion identified molecular methodologies and techniques that are currently being used and that can facilitate our understanding of the ecological role of cetaceans.

***Outcomes and recommendations from Group 1**:*

1. Generating accurate estimates of the consumption rates of whales is hard. Developing bioenergetic models from existing tag data (humpback whales) would help in conducting a sensitivity analysis to identify data gaps and what parameters need to be investigated further.
    - We would like to understand how prey choices are made among species and how these change as local conditions change and the potential for increased interspecific interactions.
    - Relative consumption rates for individual species in discrete locations could be useful to understand differential rates of recovery
2. Southern Right Whales from Peninsula Valdez would be a model species/population to study how reproductive success is linked to feeding success off South Georgia. Tagging studies could inform foraging effort and photogrammetric techniques could inform individual fitness. Steroid-hormone samples (from faeces or biopsy) could also be collected to determine reproductive status and aid in bio-energetic models.
3. Near-shore areas in Chile are prime locations for focused studies on how local oceanographic conditions and prey availability affect the foraging behaviour and distribution of whales (blue and humpback whales).
4. Understanding the amount and types of interspecific interactions in different locations is critical (blue, humpback, and minke whales). Quantifying resource partitioning between species in different locations and with different prey availability will be very useful. This requires tagging studies concurrent to measures of prey abundance, distribution, density, shape, and biomass.

The group recognizes there are a number of species that are not explicitly mentioned in the recommendations. Our **recommendations** represent what we believe to be the most likely species and areas to successfully gain insights.

Given the understanding that generating precise consumption rates for cetaceans will be extremely challenging, our workshop was not able to adequately address conservation and management issues of CCAMLR to understand the absolute consumption of krill in the SO by whales.

If we are able to understand interspecific differences in prey preference (size, density, depth, etc.), we may be able to understand or predict how climate driven changes that affect krill, will ultimately affect whales.

Increasing our knowledge and understanding of the ecology of whales in the coastal regions of Chile will be very useful for making regulations and managing the increasing vessel traffic and whale-watching operations that are likely to become more frequent.

Outcomes and recommendations from Group 2:

The working group recognizes the need to improve our understanding of foraging strategies, prey choices, feeding destinations and overall resource use. In that respect the group evaluated a set of techniques (generally called "dietary tracers") currently being used in a few populations, and diagnosed the knowledge gaps that are preventing their widespread use in other SO species.

Stable isotope analysis (SIA).

1. There is still uncertainty about the temporal information obtained from stable isotope analysis of skin. The isotopic turnover rate of tissues of interests (skin) needs to be evaluated.
    - The group **recommends** that research groups dedicate effort to test the published isotope turnover values and produce new ones for other species. For that, the group **recommends** the use of archived tissue from re-sampled (within a year) animals. The group also **recommends**, whenever possible, the collection of skin samples from the same individual at the beginning and end of the feeding/breeding seasons.

2. No dietary tracer is universal and would provide the needed information for all populations and species. Therefore, there is a need to assess whether isotope ratios are a useful tool to study diet in other species/populations. There is a need to test for the existence of isotopic variability in whales using the SO.
    - The group **recommends** a preliminary assessment of the isotopic variability within and between populations using archived samples. For that, the group **recommends** that a few samples (5 to 10) from each available population be analysed for stable carbon and nitrogen isotope ratios.

Molecular techniques for diet reconstruction.

3. Can we accurately assess the diet of baleen whales using DNA from faeces? There is a need to improve and test molecular techniques to assess diet.
    - The group **recommends** collecting faecal samples for DNA analysis in places where the whales are feeding on known prey species. The group also **recommends** collecting faecal samples from different populations and species across the SO to improve the use of this novel technique.

Combination of techniques.

4. The ability of molecular techniques to allow quantification of dietary items needs to be tested.
    - The group **recommends** collecting and using faeces for DNA analysis and for stable isotope analysis. This would allow for a cross-validation of the techniques, and for a test of the predictions of prey proportions based on DNA analysis.

Fatty acid analysis.

5. Fatty acid analysis is a useful technique to determine the proportion of different prey types in the diet of top predators. However, preserving samples for analyses is challenging (-80°C). New evidence suggests that age determination might be possible using fatty acids present in the top layer of the blubber. Thus, priority should be given to collecting, preserving and analysing samples for fatty acids.
    - The group **recommends** that whenever possible skin and top-layer blubber samples should be collected for dietary analysis and to test the possibility of age determination based on fatty acid proportions. This targeted sampling is of particular importance in populations with long-term photo-ID and individuals of know age.

Effect of population structure on sampling design.

6. Given the body of evidence that whales show site fidelity and genetic structure in feeding areas, there is a need to assess whether there are population genetic structure effects on the interpretation of information obtained from dietary tracers.
    - The group **recommends** that through a combination of techniques (dietary tracers and genetics) researchers evaluate whether structuring of populations in feeding areas exists. For this, the group **recommends** that, whenever possible, the analysis of samples from mothers and their offspring (several years later).

Standardisation of sample collection and use.

7. Sample collection in the SO Ocean is difficult and there is a need to use samples for different research purposes.
    - The group **recommends** that whenever possible researchers use sampling tips that will allow the collection of skin and blubber. The group also **recommends** that research projects be prepared for preserving the sample in different ways (freezing, Ethanol, etc.). The group **recommends** the development of new standard protocols and/or the acceptance of current ones for sample preservation. The group **recommends** that these protocols be made available online.

8. Use of stranded animals.
    - The group **recommends** standardizing the type of sample collected from stranded animals for dietary tracer analysis. Where possible, and at a minimum, researchers should collect skin samples and baleen plates.

Southern Ocean ecosystem change.

9. The SO ecosystem has suffered dramatic changes due to human exploitation of top predators (whales, pinnipeds) and prey species (such as krill). There is a need to assess whether these changes have affected the whales foraging habits, trophic position, and overall ecosystem functioning. Therefore, it is important to "look back in time" using old samples and for dietary tracer analysis and compare them with modern samples.
    - The group **recommends** that a database of available samples (bone, baleen, teeth) from pre- (or during) whaling activities be created. The group **recommends** the start of a research project aimed at assessing ecosystem changes (i.e., trophic level changes) by

conducting stable isotope analysis (carbon and nitrogen of bulk material and individual amino acids) from old (pre/during) and modern (post whaling) samples.

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Workshop Report on Health Assessment of Living Whales

Living Whales in the Southern Ocean:
Advances in non-lethal research methods and techniques

Southern Ocean Research Partnership
Co-Chairs: Wayne Perryman & Ailsa Hall

Puerto Varas, Chile
28 March 2012

The importance of assessing the health of living whales was outlined by Wayne Perryman in his Symposium presentation. The health of a population can be described jointly by its population dynamics and trends and by the degree of mortality and morbidity amongst its individual members. As stressors on populations increase, both anthropogenic and natural, the occurrence of disease, ill-health and physiological dysfunction also increases. The objectives of this workshop were to discuss established and new approaches to monitoring health of living large whales in the Southern Ocean and to make specific recommendations for managers and scientists regarding practical approaches to monitoring these populations

The workshop opened with introduction of the participants (listed below) and was followed by six presentations from the co-chairs and invited participants on various aspects of new approaches to determining the health of living whales. This included advances in photogrammetry (taking measurements from vertical aerial photographs), visual assessments of nutritive condition from oblique photographs, expansion of the application of oblique images to include other indices of health (such as determining the prevalence and severity of skin lesions); what can be determined from the analysis of expired air, exhaled breath condensate and "alveolar" breath from small and large whales and how these different components can be collected; the potential for blow intervals and respiration rates to correlate with body condition in certain species (for example Southern Right Whales at Península Valdés); what can be determined from blubber biopsy and skin samples and how useful faecal samples are in physiological and health assessment studies.

Following discussion of these approaches and their potential biases, two further important aspects of health assessment were highlighted. First, health assessment data and studies should be integrated with population dynamics data, where possible. At the population level the context within which disease and health states are monitored is clearly important, especially where it is feasible to determine, for example age-class specific mortality, fecundity, inter-birth interval, pregnancy rate, age distribution, reproductive success, behaviour etc. Second, integration of live animal health assessment with studies on dead and stranded animals, particularly within the same geographical region, is highly informative and should be a priority.

The participants then endeavoured to highlight some of the major, critical questions that, if addressed, will move the field forward significantly. However, with limited time available and perhaps some lack of expertise in specific areas, the following list serves as a useful starting point for further discussions. It was not the group's intention to attempt to answer these but rather to highlight them as priority areas for future research.

Priority Areas for Further Consideration

Nutritive stress and body condition: What are the early signs of nutritive stress and how can we detect this in living whales? What metrics are we using to determine nutritional status? Various nutritive, body mass and condition indices exist but as yet we do not know what combination of measures are the most reliable and repeatable predictors. For example, studies in deep diving whales and pinnipeds have shown that density estimates from drift or glide dive data collected by speed sensor and accelerometry tags are good indicators of buoyancy and therefore body composition (the more lipid stores the animals have the less dense and more buoyant they are). Could similar buoyancy estimates also be determined from photographs? The condition aspect of health assessment links closely with the need for population models focussed on assessing the impact of environmental variability to also determine body condition and energetic status. As such further, more detailed discussions about condition were held during the Population Dynamics and Environmental Variability Workshop.

Feeding and fasting or starvation state: Can changes in hormone profiles, fatty acids or lipid classes from various matrices such as blow, blubber, skin or faeces be linked to feeding or fasting state? The importance of assessing protein stores as well as fat stores in fasting and starvation was also discussed.

Disease surveillance and baseline data: What aspects should be focused on for establishing baselines and references? The group recognised that diseases fluctuate within populations thus long-term monitoring studies for disease and health states are vital in this context.

Skin lesions: How do we determine the cause of skin lesions in large cetaceans? Can photographs be used to document and understand trends in these lesions?

Stress: How do we measure stress? What are the most appropriate acute and chronic stress indices and how do we standardise our approach?

Emerging issues and exposures: What impact is the transfer of antibiotics from fish farms having on large whales and the development of antibiotic resistance? What is the impact of biotoxins on Southern Ocean whales? How can exposure and responses be detected when animals are experiencing low level exposure?

Standardization of Methodologies: The group then discussed the importance of a standard, generic approach to assessing health in large whales that could be applied to many different species, across ocean basins. They recognised the need for simplicity of approach for comparability, logistics and cost. Thus at the basic level a visual health assessment could be carried out. This would include:

- Photographs of the whole animal (photos need to be taken at random)
- Specific photographs at specified angles
- Visual grading of the animal's overall condition
- Documentation of skin lesions
- Documentation of scars and injuries

Further discussion about the most appropriate photogrammetric body condition measures followed with the conclusion that these need to be developed for each species which might be the subject of a future workshop. Important considerations for this have been discussed previously for specific species at a US NOAA Visual Health Assessment Workshop and future initiatives should refer back to their recommendations for consistency of approach.

- Aerial photos for calibration, where possible

- Behavioural observations to document changes indicative of perturbations in health.

The next level of health assessment should ideally include:

- Collection of a blow expirate sample (for hormones and proteins to determine physiological status and life history stage such as pregnancy although further method development and validation is still required here)
- Collection of faeces (as above and including biotoxin exposure)

Standard protocols for the collection, storage and analysis methods need to be developed.
In addition, ancillary data should be collected to allow confounding and risk factors affecting variability in health results to be determined. These might include sex, animal identification, geographic location, time of day, sea surface temperature or other important environmental data (e.g. occurrence of toxic phytoplankton blooms) and response to strandings (again using where possible, standard necropsy protocols).

The more invasive studies that would provide invaluable information would involve obtaining biopsy samples.

- Blubber (for hormones and proteins as above and including adipocyte hormone assays e.g. leptin, adiponectin, visfatin etc. that may be useful energetic status indicators; percent total lipid; fatty acids for aging and dietary differences; stable isotopes for diet and foraging variability estimation). The group also encouraged mining of stored samples and the use of longer biopsy tips where possible to obtain full blubber thickness samples. Clearly the analysis of these samples would depend on the resources available and the underlying research questions but longer term storage of samples should take into consideration the potential for contaminant and POP analyses in future.
- Skin (for genomics and other 'omics approaches; cytochrome P450 (CYP) enzyme activity to allow baseline biomarkers for polyaromatic hydrocarbon exposure in regions of oil and gas development; stable isotopes for foraging and heavy metals for toxic exposure). The group also encouraged biopsy samples from animals with skin lesions to be collected, particular targeting the edge of the lesion whilst recognising the difficulty of this.

There was discussion of the issues that might be considered by animal ethics committees in approving protocols for repeated sampling the same individual, when a single sample was not sufficiently large for accurate analysis. The group considered that it was vital to determine the degree of intra-individual variation in these parameters. The group considered that repeated sampling of large whales was likely to have little impact if the time between repeat samplings was sufficiently long and would be justified where additional samples improved the precision or accuracy of the parameter measurement. Other "platforms of opportunity" for health assessment included maximising photographic data from aerial surveys and the collection of vertical images for photogrammetry were debated. For example, the use of drones (unmanned aerial systems for photography and blow collection) and a camera mounted on a long pole, which in some situations could allow aerial shots and underwater photos to be collected. Other novel approaches included estimation of respiration rate (blow intervals) but the interpretation and utility of this needs some independent calibration. One of the most important **recommendations** was that an integrated multiple matrix approach was required if possible, where collation of all the different samples from the same individuals together with the ancillary data would be applied. Obviously not all samples could be collected from all animals and faeces would not be available when animals are in their fasting state but correspondence between health estimates using various approaches will ultimately have more power.

Case Study Example

The group then discussed a Case Study purely as an example of the application of such a health assessment approach. Three populations of humpbacks in the South Pacific, E and W Australia with a comparative population of humpbacks in Brazil would lend themselves to such a study. And in some of these populations good population dynamics and trend data indicate they are rapidly increasing. This would provide excellent baseline health data, which could then be compared to data collected when the populations reach some asymptote and changes in the health status and increased mortality and morbidity and condition or reduced fecundity would be expected. Samples could be collected from northbound and southbound animals during fasting (thus faeces would not be collected in this example). The basic sampling would include body condition metrics from photogrammetry using for example the scoring system developed in the SPLASH Program. Calibration using aerial vertical photographs might be possible and existing photographs examined to estimate prevalence of skin lesions (recognising there may be biases in data collection). Skin lesions would be documented from more systematically collected photos to determine severity and prevalence.

Blow samples would be collected for pregnancy and other reproductive hormone analysis plus, where possible, analysis of indicators of inflammation (maybe pH) and microbial flora with blow collected or plated out onto appropriate agar or other media. Repeat sampling of same individuals would be **recommended** to determine individual variability.

Biopsy samples for reproductive hormones and other proteins and peptide investigations including the so-called "hunger" hormones such as leptin and adiponectin. Fatty acids and stable isotopes would be assayed and skin samples for CYP activity where oil and gas development was planned (e.g. Brazil). However, POPs and PAHs can both induce CYP activity so data on both inducing compounds are required. In addition, biopsy skin lesion samples for histopathology would be collected if at all possible. Strandings would continue to be monitored and responded to and causes of death established where possible.

Additionally, important baseline data on body density estimates from dive data collected using accelerometer tags would be encouraged, if funds were available. The movement and dive data would also be invaluable in putting the results of the health data into the context of the behaviour and potential environmental exposures of the tagged animals. Ancillary data on age estimation using fatty acid ratios would be determined although this approach in these species needs some known age animals for validation and model building. Sex would be determined using genetic markers from skin and skin would also be stored in RNALater for future transcriptom analysis. Known individual animals with documented reproductive histories would be targeted where possible. The group also recognised the not insubstantial issues relating to obtaining CITES and National permits for sample shipping although some useful protocols are available to share. Finally comprehensive collection, storage and preservation and analysis protocols would be developed for each of the sample types so that consistency and standardisation for future comparisons would not bias the results.

Health Assessment Recommendations

Finally the group outlined a number of broad health assessment recommendations to be taken forward from this workshop.

1. The collection, storage, and analysis of these data must be standardised. And the value of long term storage and appropriate archiving of samples recognised.
2. The workshop **recommended** that health assessment studies build on existing research efforts and integrate with, for example stranding response efforts. Health assessments

(particularly the basic, visual assessments) should be incorporated into studies on large whales, especially where long term studies with good population dynamics data exist. Examples of these include the studies of Southern right whales in Península Valdés; studies of blue whales and other large cetaceans in Chile; studies in Brazil, Australia, Latin America and Tasmania.

3. The workshop **recommended** the establishment of baseline information and data and an assessment of the degree of parameter variability within and between individuals
4. Data sharing opportunities, especially using online open access databases and protocols should be maximised. For example, the blue whale visual health assessment protocol, SPLASH protocol and Patagonian Right Whale necropsy protocol (and other necropsy protocols) should be made available through a large whale health assessment portal (perhaps under the auspices of SORP).
5. The workshop **recommended** the continuation of the method development, validation and interpretation of results (e.g. condition, nutrition, physiology, markers of health and disease, stress indicators etc.). Regular forums for discussion of health issues for large whales in the Southern Ocean and including both ethical and scientific method issues, and exchange of scientists between countries and programs should be encouraged and efforts made to facilitate them.
6. The workshop **recommended** that disease and health surveillance and risk assessment of new and emerging infections and biotoxin exposures be instigated and linked with on-going National Programs for surveillance of these pathogens and toxins.
7. The workshop encouraged integration of veterinary science and input from veterinarians into large whale health assessment studies.
8. There are many gaps in marine mammal health knowledge and skills in the Southern Ocean region and efforts to build capacity and ways that expertise could be accessed by such countries encouraged. For example, the development of a list server, apps and other social media would all enhance global reporting, knowledge exchange and collaboration. For example the group applauded the IWC skin lesion assessment and online expert group initiative that will be available in the near future.

List of Participants

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Workshop Report on Large Whale Population Dynamics and Environmental Variability

Living Whales in the Southern Ocean:
Advances in non-lethal research methods and techniques

Southern Ocean Research Partnership
Co-Chairs: Russell Leaper & Jennifer Jackson

Puerto Varas, Chile
29 March 2012

1. CHAIRS AND RAPPORTEUR

Jackson and Leaper co-chaired the meeting and acted as rapporteurs.

2. BACKGROUND AND INTRODUCTION

Understanding the effects of environmental change on whales is an objective of the Southern Ocean Sanctuary established by the International Whaling Commission in 1994. Two themes of SORP are also post-exploitation whale population structure, health and status and the response of whales to changing atmosphere and oceans. To understand past changes in whale populations and to be able to predict likely future impacts of environmental change requires an understanding of the way that variation in the environment affects whale population dynamics.

Leaper noted that the timing of the workshop was particularly relevant due to a major paradigm shift in thinking about environmental variability and whale population dynamics in the last few years. In the past, population dynamics and environmental variability might have been treated as rather separate subjects. Within traditional population models, variability was seen as a nuisance in terms of the overall goal of estimating rate of increase or the status of the population relative to carrying capacity. More recently there has been a fundamental shift in thinking towards considering variability as an integral part of population dynamics that needs to be explicit within models. For example, since 2007 the Scientific Committee of the IWC has been considering the implications of environmental variability for estimating Maximum Sustainable Yield Rate (MSYR)[1] in large whales.

The workshop recognized the limited number of time series of data for large whales that are long enough to estimate effects of environmental variability on life-history parameters. Not only is it critical that these continue (see section 7) but it is important that all the potentially informative data sets are fully analysed. Insights and theoretical approaches from studies of other taxa may also be informative and were included in a bibliography prepared for the Workshop but were not discussed in detail. Well-studied populations of large herbivores have demonstrated environmental effects on population dynamics and some papers address how these fit with ecological theory. However, further consideration needs to be given to the extent to which inferences for large whales can be drawn from these studies.

The Workshop also noted the large research effort on environmental linkages to krill in the Southern Ocean and the importance of these in contributing to an understanding of effects on large baleen whales. Some of these studies had been considered at the CCAMLR-IWC workshop (IWC, 2009b) and were not discussed in detail at this Workshop but were referred to during discussions.

[1] MSYR is the fraction of a population that can be sustainably extracted on an annual basis when the population is at its optimum population size

The Workshop concentrated on **recommendations** for work that could be implemented in the next few years. These included **recommendations** for analysis of existing data sets and field data that could be collected in the short-term that might supplement and help with analysis of longer-term data sets that already exist. It was noted that there is a need for field biologists to think of the kind of simulation studies that could help optimise the design of monitoring programmes and modellers need to think of realistic data that can be collected in the field that would narrow the uncertainty within models.

3. OUTCOMES OF PREVIOUS WORKSHOPS WITHIN IWC

The IWC has held several workshops relevant to environmental variability and whale population dynamics. The CCAMLR-IWC workshop in 2008 to review input data for Antarctic marine ecosystem models noted the value of further, integrated analyses of existing datasets and series (e.g. CCAMLR 2000, SOWER, GLOBEC) to explore the relationships of predators, prey and environmental correlates. That workshop had also noted the importance of appropriate, coordinated long-term data series of key features of the environment, predators and their prey. The subsequent IWC Climate Change workshop in 2009 suggested three criteria for identifying the most useful datasets (duration, temporal resolution and spatial scale). That workshop noted that the financial and logistical constraints of satisfying the three data criteria could be overcome through collaboration among researchers, institution, and nations, using strategically designed hierarchical or nested sampling protocols. It also recommended emphasis on cetacean studies that allow comparisons between contrasting regions where data on a wide range of ecosystem components are available from ongoing multi-disciplinary projects. The Workshop noted that SORP had been conceived to foster these types of collaborations.

Recommendations from the climate change workshop of particular relevance to the current Workshop were (a) developing models that can integrate the demographic and spatial consequences of climate change; (b) exploring the value of developing ecosystem models that begin with baleen whale dynamics rather than building bottom-up ecosystem models; (c) further correlative studies should be undertaken in order to improve the conceptual understanding of population processes, and hence enable the development of a set of testable hypotheses.

4. MEASUREMENT OF LIFE HISTORY PARAMETERS CONNECTED WITH ENVIRONMENTAL VARIABILITY

Disentangling environmental impacts from natural variability is hard to do. Even if demographic parameters can be reliably measured, the changes that are observed could be due to one, two or several factors, e.g. physiological variability in reproductive rates, methodological bias in data collection, environmental effects on reproduction and survival, cumulative multi-factorial ecosystem effects, and social ecology. If environment and anthropogenic activities negatively impact the population then body condition may be a crucial parameter. Measurable changes in body condition over time may offer the best opportunities for understanding environmental impacts. Interpretation of body condition and collaboration among researchers to look for comparable effects is important as measures can vary greatly between studies.

4.1 Body condition

Hall summarized the outcomes of the SORP Health Assessment workshop. The major challenges are how to detect nutritive stress and defining the best metrics for assessing energy stores in relation to body mass. Possible metrics have included blubber lipids, fatty acid profiles, hunger hormones e.g. leptin, nectin; proteomics, and body density. However no set of metrics has been identified as giving the best indication of nutritive condition.

Some studies have related cetacean health metrics to reproductive success. Analyses of body condition from the North Atlantic right whale photo-id catalogue revealed body condition changes in females across the calving cycle; they were significantly thinner during calving and post-calving years than they were in the year prior to calving (Pettis et al. 2004). In an analysis of pollutant loads in Sarasota Bay bottlenose dolphins, Wells et al. (2005) found that while immature males and females accumulated PCBs to an equal extent, females subsequently transmitted PCBs through lactation to their first born calves, who had high mortality rates.

Rowntree described using focal animal follows to monitor blow intervals of southern right whales that were travelling slowly or resting over 30 minute periods. Blow interval appeared to be correlated with body condition as determined by the height of the fat roll on the neck and also the size of the calf. Mothers with larger calves were estimated to blow at 76 second intervals on average, compared with mothers with newborns, who blew every 110 seconds on average. It was noted that respiratory rate is a widely used measure of animal health by veterinarians. However, it is not clear whether using blow rate as an indicator of body condition will be applicable to whales in other areas, including feeding grounds.

It was noted that blubber thickness had been measured from free-living right whales using ultrasound but also that examination of stranded animals has shown large variation in blubber thickness at different points on the body. There is a need to better understand how blubber changes with physiological states. In studies of starvation in odontocetes it had been found that early in nutritive decline, lipids were utilized first, then proteins, and finally back to lipids (Koopman et al., 2002). This sequence may make photogrammetry more useful in understanding starvation across all stages than an analysis of lipids would be. A combination of blubber thickness, morphometrics and body density may therefore provide a good measure of overall body condition. Stable isotopes from skin biopsies are likely to only detect extreme starvation but it was also noted that when pinnipeds become nutritionally stressed them their diet becomes broader. So any change in the isotopic signature, observed on a population-wide basis could be informative.

It was noted that the whole body of the whale may be used for health assessment and therefore it was important for photographs to be as extensive as possible in addition to body locations used for photo-id. Most photogrammetric measurements of body size have been taken from aerial photographs directly above the animal, but aerial and lateral photographs can complement each other. A time series of measurements of size and body shape of known individuals can be particularly informative. It was agreed that girth was generally the most useful size measure related to body condition and body width from directly above is a good proxy for overall girth.

The Workshop noted the value in establishing a baseline set of desirable images (e.g. viewing angle relative to the animal and area of the body included in the image) for examining body condition for each species. The Workshop **recommended** that all planned photo-id and genetic surveys collect information on individual body condition in a standardized way. In particular, there are now several methods that allow quantitative measurements to be made from calibrated images. These include measuring the range to the animal from angle of the dip to the horizon from a platform of known height or using a laser range finder. Other systems use parallel twin lasers to project two dots on to the animal at a known distance apart. The Workshop **recommended** that all photo-id studies attempt to take calibrated images that can allow direct measurements. In addition to measuring body condition, measurements may also be useful in analysing skin lesions, scars from entanglement and propeller injuries.

4.2 Mortality

Rowntree summarized recent discussions regarding the high calf mortality event observed at Península Valdés. No evidence for mass pathogen infection has been found; low prey abundance and/or biotoxins are possible causes. Fatty acid analyses are being conducted to determine what the mothers were feeding on. It was also noted that in a comparison of skin samples of mothers and calves, stable isotopic differences between mothers and calves were much larger in 2003 and 2005 than in 2004, and may be related to higher mortalities observed in 2003 and 2005 than 2004. This may be explained by starving mothers or calves recycling protein as an energy source in those years.

On the subject of contamination related mortality, it was noted that some species can survive high contaminant loads but that this may become problematic when the animal becomes food deprived, e.g. transient killer whales (Krahn et al. 2002). It was observed that survival of male killer whales is lower than that of females and that this may be due to the ability of females to excrete toxins into milk. Pollution 2000+ (IWC 2007) discussed how calf survival might be reduced by contaminant loads transmitted via lactation.

4.3 Reproductive output

One way of relating environmental variability to environmental conditions has been to examine the reproductive output of individual females over time (e.g. Forcada et al., 2008; Leaper et al., 2006). This requires a long time series of known individual life histories. Multi-state mark recapture models have been used to estimate the transition probability between various reproductive states (e.g. calving, receptive, or resting). Cooke et al. (2003) had fitted such a model to the southern right whale population breeding at Península Valdés prior to the years of high observed calf mortalities (see section 4.2). Bannister et al. (2011) describe a similar model for the southern right whale populations breeding in Western Australia and at the Head of the Bight. This study was considered in some detail because the simulation approach was intended to investigate the power of a time series of surveys to estimate changes in life history parameters. The results also revealed different population dynamics between the two adjacent southern right whale populations. The simulations suggested that carefully chosen but intermittent rather than annual surveys may be adequate for estimating numbers and trends but annual surveys were **recommended** for investigating environmental effects. The study also concluded that the time series of 13-15 years was rather short to estimate recruitment variability and to detect poor-breeding years in a population such as the southern right whales, with a strong cohort structure.

Jackson summarised Forcada et al. (2008) which demonstrated how multi-strata models could be used to determine how vital rates contribute to buffering against environmental change. It was observed that with recent advances in age determination of individuals through e.g. fatty acid analysis, stage specific models such as these could be possible for some cetacean populations. However, it was also noted that while such models may be plausible for pinniped populations they are difficult to implement for large whales due to their parameter complexity.

Barlow et al. (2011) simulated humpback whale photo-id data collection in the North Pacific in the same manner as that collected by SPLASH, by building 'virtual' humpback populations of various sizes which moved seasonally between multiple breeding and feeding grounds (SimSPLASH). Through simulation they tested the impact of different sample collection biases on closed population abundance estimates over the 2-year collection period of the SPLASH project. Significant identified biases included measurements taken only from breeding or feeding grounds, exclusion of calves from the dataset, missed photo-id matches, and population changes through birth and death that were not accommodated in the closed model. This simulation study highlights that breeding area only studies may be strongly biased as they only capture animals close to study sites. When feeding

area samples are collected, these can effectively correct for capture heterogeneity on the breeding ground. Barlow noted that while this simulation approach incorporates information about adult survival rates, it is likely that calf and juvenile survival rates will respond more rapidly to environmental changes. The SimSPLASH model could incorporate changes in other life history parameters if sufficient information were available to estimate them.

It was noted that the response of the cetacean social system to major perturbations is not often considered; for example humpbacks in Fiji show slow recovery that may be a function of loss of cultural memory (Gibbs et al. 2006 SC/A06/HW34). Examination of individual life histories can also overcome some of the complications caused by immigration and emigration when estimating population dynamics.

The Workshop re-iterated the need for continuation of long time series of data for examining environmental effects. The Workshop also **recommended** the use of simulations to demonstrate whether time series of data are likely to be able to detect such effects and to help optimize data collection in the field. Such simulations may be very useful in demonstrating the value of long term studies to funding agencies.

Body condition metric	Measurement type	Information provided	Example where done	Storage guidelines for collection
Non-invasive methods				
Photo ID	Lateral body image	Whale fatness and skin condition	Humpbacks, gray whales, right whales	N/A
Photo ID with lasers or stereo camera	Calibrated size measurements; body width as a proxy for girth from aerial images	Whale size and body condition	Some photogrammetry for most large whales. Dual lasers used for Hector's dolphin.	N/A
Ultrasound	Underwater measurement of body shape	Whale size and shape	North Atlantic right whales	N/A
Breath collection	Collect with vacuum or similar. Measure CO_2 and pathogen load	Respiratory health, pathogen load	Fin and humpback whales, Baja	
Wheezing blow noise	Focal follows	Respiratory health	Southern right whales, Península Valdés	
Invasive methods				
Stable isotopes	Carbon, nitrogen, sulphur	Foraging location, prey	Southern right whales, Península Valdés, South Africa	Frozen or dehydrated. OK in ethanol.
	Fatty acid profiles	Prey type, age	Killer whales, humpbacks	Samples need to be kept frozen. Ideally -80^{o}C but -20^{o}C acceptable
	Persistent organic pollutants	Foraging location	Eastern and western gray whales, NP and NA humpbacks	
	Progesterone, testosterone, cortisol	Pregnancy state	North Atlantic right whales	
	Compound specific analysis- lipids, amino acids, esters	Trophic level of animal and how it varies within a sub-group		

Trace elements	Could provide longitudinal localization	North Atlantic fin whales
Fat hormones	Leptin and nectin, resistin and visfatin	
Heavy elements	Mercury, lead	

Table 1. **Draft table of metrics which could be used to determine individual condition, reproductive state or foraging location**

The Workshop **recommended** that biopsy sampling from individuals be routinely used to analyse geochemical tracers (e.g. stable isotopes) and other 'eco-markers', as well as DNA, since this approach can help us identify foraging locations of populations. It was noted that for this to be most useful, 'isoscape' characterization (spatial prediction of isotope values) of the Southern Ocean was important, as presently this information is patchy.

5. INCORPORATING ENVIRONMENTAL VARIABILITY INTO POPULATION MODELS

The effects of environmental variability on whale population dynamics can be substantial and need to be taken into account within population dynamics models. Simulation studies (Cooke, 2007) have shown that the fitting of deterministic population models to data from whale populations in the presence of such variability can yield misleading inferences with the potential for significant management consequences, including overestimation of sustainable yield. Cooke (2007) developed a theoretical framework that extends the standard Pella-Tomlinson model for baleen whale population dynamics to include environmental variability. This framework predicted that population growth rates would become more variable as populations increase towards their carrying capacity, and that even when the relationship between mean growth rates and population size is nearly linear or only gently curved, individual population trajectories are likely to exhibit abrupt changes and reversals in trends after periods of apparently steady growth. It provides a simple and widely applicable means to incorporate environmental variability into the individual parameters of life-history-based population models.

Life history models fitted to longitudinal data on individuals tracked over time, such as from photo-id studies, appear to offer the best prospect of detecting and estimating variability in parameters, but variations in some parameters, such as calving intervals, are easier to detect than variations in others, such as survival rates. Patterns of calving intervals of the southern right whale population wintering off Península Valdés Argentina show variability which has been correlated with oceanographic factors, and with the reproductive success of other krill predators based around South Georgia, a known summer feeding ground of the right whale population (Leaper et al., 2006).
Brandon and Punt (2009) describe another approach to incorporate environmental variability into a population model for eastern gray whales. In their model, deviations from expected birth and survival rates were allowed to be a function of sea-ice variability in the Bering Sea based on the hypothesis that the amount of sea-ice in the Bering Sea early during the feeding season may be related to variability in calf production the following year (Perryman et al., 2002).

6. EXISTING LONG-TERM DATA SETS

The workshop reviewed tables of whale time series data from the IWC climate change workshop in 2009 (IWC, 2009a) and the MSYR workshop in 2010 (IWC, 2010). IWC (2010) had identified data sets on southern hemisphere right and humpback whales and summarized data available on breeding grounds, feeding grounds and migratory routes. The Workshop noted that the data sets on southern right whales breeding at Peninsula Valdes, in South Africa and in Australia did allow estimation of demographic parameters from individual life histories. There is also some more recent data on the

New Zealand population. However, there is limited data on the feeding grounds for these populations. The Workshop **recommended** studies on the feeding grounds where these are known and further efforts to identify other feeding areas.

Although there are large photo-id catalogues for some southern hemisphere humpback whale populations these have not been fully investigated for individual life history data. The larger population sizes and lower resight rates make this much more challenging than for southern right whales. The Workshop **recommended** examining humpback whale photo-ID catalogues to assess the resight rate and the feasibility of fitting appropriate models to estimate individual life history parameters as has been done for southern right whales.

The Workshop also considered data tables compiled for the IWC Scientific Committee review of MSYR (Punt, 2010), which contained data sets where there was a time series of data which may allow population increase rates for depleted populations to be estimated. These time series had been used to investigate the potential for environmental variability to bias estimates of MSYR. Bayesian meta-analyses of these data sets had been used to investigate the process variance and serial correlation coefficient for calving rates and intervals (Punt, 2010; Cooke, 2011). These estimates are important for understanding the likely magnitude of historical environmental variability on population growth rates.

In addition to the time series listed in tables in Punt (2010), the Workshop noted that time series of data on humpback whales from New Caledonia, Ecuador and Brazil, pygmy blue whales from south Australia and southern right whales from New Zealand may also be of value in investigating environmental variability and population dynamics. Ongoing data collection in these areas is continuing to extend the time series.

7. CONTINUING LONG-TERM DATA SETS

Some group members expressed the view that whaling in the Southern Ocean by Japan would likely end within a few years and that this could result in less interest in whale research within the region, particularly by European countries. The annual IDCR/SOWER circumpolar surveys conducted by the IWC using vessels donated by Japan had already been discontinued.

The Workshop agreed that it was important that all national Antarctic research programmes should include a whale component into their research work, preferably within multi-disciplinary co-operative projects such as SORP. CCAMLR will also require data on abundance and prey consumption by whales to fulfil its mandate of setting fisheries catch limits that take into account the needs of predators.

Many of the long-term datasets on whales that feed within the Southern Ocean come from studies on the breeding grounds. These may not be as easy to incorporate into long term Antarctic monitoring within national capabilities and are constantly seeking funding. Grant funds often require these long-term studies to be also relevant to short-term interests and concerns. This will require incorporating new and innovative research within long-term projects such that the overall time series is not compromised but there are still new findings to report and publish.

A better understanding of the effects of environmental variability on whale population dynamics is critical for predicting effects of climate change. Climate change remains a key issue for many funding bodies which may be receptive to projects that demonstrate how studying whales may also help a better understanding of effects on the wider ecosystem. The high level of public interest in whales may also present funding opportunities from individuals and private organizations.

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9. WORKSHOP PARTICIPANTS

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Workshop Report on Advances in Long-Term Satellite Tagging Techniques for Cetaceans and their Application to Address Research Questions in the Southern Ocean

Living Whales in the Southern Ocean:
Advances in non-lethal research methods and techniques

Southern Ocean Research Partnership
Co-Chairs: Alex Zerbini & Nick Gales

Puerto Varas, Chile
29 March 2012

The workshop was held on 29 March 2012 at the Imperial Room, Hotel Los Alerces, Puerto Varas, Chile with 23 participants. The list of participants in Annex A.

Zerbini and Gales welcomed the participants to the Workshop. They thanked the organizers of the Symposium Living Whales in the Southern Ocean: Advances in Methods for Non-Lethal Cetacean Research for their assistance in preparations for the meeting. After a brief introduction from participants, Zerbini presented a brief history on satellite tagging techniques for cetaceans and a description of the most current methods. He also explained the meeting discussions would focus on attachment methods for remotely deployed long-term body-penetrating (tag Type I, ONR, 2009) and dorsal fin-penetrating (tag Type II, ONR, 2009) satellite transmitters (Fig. 1). Zerbini also detailed the practical arrangements of the meeting. Morning sessions would be dedicated to presentations that would provide background information for the workshop participants to discuss future tag development, including latest developments on satellite tag attachment methods and follow-up studies to assess potential physical and physiological effects of body/dorsal fin penetrating tags. Discussion of the various topics presented in the morning would occur in the afternoon.

Fig 1. - Examples of a body-penetrating (Type I, ONR, 2009) (top) and a dorsal fin-penetrating (LIMPET, Type II, ONR, 2009) satellite transmitters.

Gales presented information on development of body-penetrating tags (tag Type I, ONR, 2009) by the Australian Antarctic Division. The primary goal of this work was to improve tag duration and to minimize potential welfare issues to the animals. In early stages of development, attempts were made to use blubber-penetrating tags, but relatively short durations suggested that anchoring on the blubber alone would not provide optimal tag attachments. New designs included longer tags (up to 29cm in length) designed to penetrate beneath the skin and hypodermis and anchor the tag within the variable muscle and connective tissue matrix that underlies the blubber (Gales et al.,

2009). The front 8cm of the tag detaches from the back section of the tag post-deployment; a flexible 0.5cm multi-braided stainless steel wire maintains a coupling between the two parts. Retention of the tag is maintained through two actively sprung plates, and a circle of passively deployed 'petals'. All external components of the tag are built from stainless steel and the tag is surgically sterilised prior to deployment. Transmitters are deployed with the use of a compressed air gun (modified Air Rocket Transmitter System, Heide-Jørgensen et al., 2001) set at pressure of between 7.5 and 10bar. A projectile carrier is attached to the rear of the tag by some retention teeth and is fired at the whale from the bow-sprit of a 5.8m rigid-hulled inflatable boat at a range of 3-8m. The rapid deceleration of the tag and carrier as they strike the whale leads to the withdrawal of the retention teeth that hold the tag to the projectile carrier and their subsequent disengagement. This type of tag is designed to penetrate the body of the whale up to a stainless steel stopper located at the distal end of the transmitter. Only a connectivity switch and an antenna, located above the stopper, are exposed after deployment.

Andrews described the evolution of minimally invasive satellite transmitters leading to the design of the current dorsal fin-penetrating "Low Impact Minimally Percutaneous External-electronics Transmitter" (LIMPET, Andrews et al., 2008; tag Type II, ONR, 2009). Development of this type of tag was motivated by the need for longer tracking duration than possible with suction cup tags, where capture of the target animals was not an option. Tags and deployment methods were originally developed for killer whales as an attempt to understand their role as predators of other marine mammals in the North Pacific Ocean. Tags were intended to be small, remotely deployed, low-drag, location-only satellite transmitter packages that could be attached to the dorsal fin of these animals and that could provide at least one month of tracking data. After many design and testing iterations, the LIMPET tag resulted in a barnacle-type tag (with electronics on the outside of the animal and small implants as attachments) with two surgical-quality barbed titanium darts that penetrated approximately 6.5cm into the dorsal fin of the target animals. Tags are deployed using a crossbow or low-powered pneumatic rifle at distances between 3 and 20 meters. Initial applications of the location-only LIMPET tag on killer whales (*Orcinus orca*) in Alaska provided transmissions ranging from one day to nearly three months, with a median of about one month. The success of the LIMPET tag has led to its use on 19 species of cetaceans, many of which had never before been tracked via satellite. However, there have been some unanticipated problems, such as tags or darts that broke upon impact, which have led to injuries that are slower to heal. Therefore, we have devoted a great deal of effort to improve the LIMPET tagging system, including redesigned tag packages and improved retention darts.

Noad presented the new Zebedee or Z-tag. While not a long-term satellite tag, this instrument has the potential to fill the gap between shorter-term tags (e.g. a D-tag) and long-term transmitters. The Z-tag is under development as a medium term (one to several days) tag for measuring accurate and frequent position and high-resolution dive profiles. It combines a fast-loc GPS Argos transmitter, TDR, VHF transponder and strobe light in a syntactic foam disc. This instrument package is attached to a base with three barbed spikes, which penetrate the skin and blubber. The tag is currently deployed using a pneumatic gun. A corrodible link allows the instrument package to detach from the base plate after the desired attachment period. A sprung disc hangs beneath the detached instrument package to act as ballast, ensuring floatation in the correct orientation at the surface. The tag has been deployed successfully four times off the Australian east coast in October 2011 as part of the Behavioural Responses of Australian Humpback whales to Seismic Surveys (BRAHSS) program. More flexible attachment mechanisms are currently under consideration. The design of the instrumentation package allows the easy addition of other instruments including accelerometers and acoustic recording systems. This tag has the potential to provide high-resolution behavioural data similar to that of D-tags but with accurate position data and over substantially longer periods.

Presentations on tag development were followed by a series of presentations on follow-up studies dedicated to address possible physical and physiological effects of satellite tags on cetaceans. Results from these types of studies can assist with further tag development. Calambokidis summarised a National Oceanic Partnership Program (NOPP) funded study to examine the long term consequences of suction cup and body-penetrating tags on blue, humpback, and gray whales in the eastern North Pacific. This will include collaboration with the Oregon State University (OSU) on their deployments of implant tags and documenting long term follow-up of these animals. The project includes efforts to reconcile tagged animal photo-identifications with the long-term catalogues and sightings histories of these species. Using long term identifications and re-sightings of these individuals will allow comparison of survival and visual health assessment criteria including body condition to be compared between tagged and non-tagged animals post tagging. Assessment of tag sight healing and condition will also be conducted.

Andrews presented information on a case study of a severely entangled North Atlantic right whale which swam away from a disentanglement procedure with a 7mm diameter antibiotic delivery needle buried approximately 10cm into muscle, below the muscle blubber interface. The whale subsequently died, likely due to complications from the rope entanglement, and details of the necropsy findings and implications have been summarised in a manuscript in review at the journal Marine Mammal Science (Moore et al., in review). The retained needle was bent at an 80-degree angle at the muscle-blubber interface. The bend was apparently caused by epaxial muscle movement relative to the overlying blubber, and led to necrosis and a large area of cavitation of underlying muscle. This observation raises the question of whether rigid, implanted devices that span the cetacean blubber muscle interface, where the muscle moves relative to the blubber, could have secondary health impacts.

Andrews summarized results from NOPP-funded follow-up study conducted after deployment of LIMPET tags, primarily in studies done in collaboration with Robin Baird, Greg Schorr and Daniel McSweeney, in Hawaii. Preliminary results from Forward Looking Infra-Red (FLIR) cameras confirm that LIMPET tagging does not compromise the ability of the fin vasculature to radiate heat. Analyses of re-sighting rates for short-finned pilot (*Globicephala macrorhynchus*) and false killer whales (*Pseudorca crassidens*) take into account long-term social groupings. Thirty of the 38 short-finned pilot whales tagged off the island of Hawaii prior to Oct. 2011 have been re-sighted. The social groups of the remaining 8 whales have not yet been re-encountered, so there was no opportunity to re-sight the tagged whales in those groups. For false killer whales, 18 tags have been deployed on 16 individuals from one social cluster. Of those, all individuals have been re-sighted with re-sightings post-tagging for 17 of the 18 tag deployments. Such high re-sighting rates suggest that LIMPET tagging has little or no effect on survival for several years post-tagging. Assessing reproduction for females post-tagging is limited by small sample sizes, long inter-calf intervals, and unknown sex of some individuals, but both Cuvier's and Blainville's beaked whales have been documented with calves born after tagging.

Zerbini presented preliminary results from another NOPP project carried out as a partnership among the Provincetown Center for Coastal Studies, the National Marine Mammal Laboratory-NOAA, Cascadia Research Collective, the Australian Antarctic Division, and the Marine Mammal Centre. The primary goals of this study are (1) to characterize the range of physical and physiological responses to foreign body penetration through the measurement of physical and physiological parameters, (2) to provide data to optimize tag performance, as well as minimize tag loss and impact, and (3) to quantify the effect of tagging on individuals and to attempt to correlate that to sex, age class, reproductive condition, and tagging site. The research is carried out with humpback whales (*Megaptera novaeangliae*) in the Gulf of Maine. This population was chosen because it has been subject of long term (>30 years) longitudinal studies resulting in detailed knowledge of sighting,

reproductive and health history of individual whales. In addition, many individuals show very high within-year and between-years re-sighting rates, providing ideal conditions for fine temporal scale follow-up studies. In 2011, 19 body-penetrating satellite tags (Type I, ONR, 2009) with articulated anchoring systems (Gales et al., 2009) were deployed on individual humpback whales. Average and maximum tags durations were 25 and 99 days, respectively. Ten whales showed localized or pronounced regional swelling, which were documented while the tag was still attached to the animal's body, and, in some cases, after tag rejection. Physical/physiological responses to tagging appear to be correlated with the location where the transmitter was placed on the body, with more severe reactions being observed when tags were placed lower on the body and minimal reactions for tags placed next to the dorsal fin. It was hypothesized whether swelling was caused by tissue damage (e.g. due to shearing) at the blubber-muscle interface as suggested by the entangled right whale example described above. This study also showed evidence that the articulated head of the anchoring systems was damaged in at least some of the deployments, resulting in separation of the head of the anchor and the body of the transmitter. Physical/physiological reactions can be confounded by possible breakage of the head, resulting in more severe foreign body reactions than expected in typical attachments.

After the presentations, the workshop focused on research needed to further improve tag designs. Effort could be directed to minimize the size and diameter of body-penetrating satellite tags in order to possibly minimize trauma of implant and water ingress. The retention/holding petals in body-penetrating tags could be made of more flexible material than metal as long as they are robust enough to sustain the forces at the level tags are implanted. Petals could also be multi-articulated. The position of the row(s) of petals is also likely to be important. It should provide more effective anchoring if it/they are located below the blubber/muscle interface. In articulated anchors, petals will provide better tag retention if located in the transmitter side in cases where the articulation breaks and the head separates from the tag body. It was suggested that textured surface could possibly improve retention if the tissue adjacent to the body of the tag is necrotic due to the presence of salt water. The sensitivity of the exposed aerial was noted and the amount exposed may be critical. In humpback whales, only two out of 204 Discovery marks that were classified as protruding were recovered (0.98% recovery rate) and the two recoveries occurred only within 2 days of mark deployment. In contrast, 6% of fully implanted marks were recovered an average of 727 days after deployment (D. Paton, pers. comm). Full implantation may result in longer durations, but this is difficult to achieve with current technology because the aerial portion of the tag needs to be exposed for proper transmission. Closure of the penetration wound would potentially minimize salt water ingress and tissue necrosis, possibly resulting in improved tag durations. This may be explored through the use of tissue glue or by developing a modified stopper such as a shielded base of antenna with a wet/dry sensor on top of the shield.

As an alternative to body-penetrating tags, new designs with external electronics and a long anchoring system (e.g. a modified version of the LIMPET tag) were proposed. These tags could be designed to promote negative hydrodynamic lift to press tags against the whale's body to reduce the rate at which the tag migrates out. The workshop also noted that electronic sensors along the body of the tag would provide insights into depth of penetration (e.g. whether the tag reaches the muscle layer) and at what level there is water ingress.

The workshop agreed that new designs for cetacean tags ought to be developed and **recommended** that these designs optimize shape and minimize implanted volume and, whenever possible, cutting surfaces. For body-penetrating tags, the workshop **recommended** further studies to assess whether deep penetration is needed. For tags penetrating the muscle/blubber interface, the workshop **recommended** developing mechanisms (e.g. flexible anchoring systems) to minimize tissue trauma caused by shear forces. The workshop also agreed that an increase in sensors for satellite tags is

desirable and **recommended** that priority is given to accelerometer and dive/surface interval data and to the development of algorithms that can compress data for transmission via Argos. The workshop also encouraged the use of commercially available flexible platforms such as the Z-tag, where existing instruments can be incorporated in the platform. Predictable release mechanisms are advantageous for these types of tags. Finally, the workshop also **recommended** continued collaboration among taggers to optimize rate of progress in advancement of tag designs.

The workshop noted that body-penetrating tag duration is likely correlated with position on the body, tissue structure and movement of the muscle relative to blubber (shearing) at the sites tags are deployed. Mobility of the blubber/muscle interface will likely vary at different sites along the body. Tag deployments further forward on the body (e.g. forward to the dorsal fin) may be more stable because there is less movement, which may minimize tissue trauma in the presence of shearing and may facilitate healing. In addition, tissue density is different over the body and tissue changes (e.g. thickness of the blubber layer) occur with seasons; full penetration may not be achieved in sites where muscle is denser and blubber is thinner. Photogrammetric data may provide insights into areas along the body where blubber changes are most profound. Activity of whales at time of deployment may also be an important factor in tag penetration and retention. For example, the ease with which a tag will penetrate muscle tissue may depend on whether the target animal is actively contracting its muscle, so penetration may be better in a relaxed, stationary whale. The workshop **recommended** that studies on carcasses derived from incidental mortality be conducted to investigate variability in tissue structure across species and seasons to guide further work on tag deployment locations. Because fresh animals are needed for these types of studies, the workshop also **recommended** that research protocols be developed and made widely available to researchers around the world to maximize chances of collecting pertinent samples.

The workshop discussed the relevance of the North Atlantic right whale needle case for muscle-penetrating tags. It was noted that the needle was in a very flexible part of the animal (caudal of the dorsal ridge, nearly 70% back from the anterior tip of the animal) and that substantial tissue movement in this region (the peduncle) would have contributed to the scale of the wound. It was suggested that large doses of antibiotics in a single site could have been an irritant, but would likely not explain the scale of the lesion. Despite the small sample size (n=1), the workshop agreed that the right whale needle case showed that (1) rigid objects that go across the blubber/muscle barrier clearly have the potential to cause considerable tissue damage, (2) substantial shear forces are consistent with the breakage of articulated heads of anchoring systems as seen in the Gulf of Maine study, (3) shear at the blubber/muscle interface is likely to vary across the extension of the animal's body, and (4) scientists have generally underestimated the scale of these forces. The workshop noted that it would be possible to use a temporary tag to measure shear forces and that scientists would likely obtain permits for this type of study. Measuring other parameters (e.g. temperature, pH) with such tags would also be possible but tag development would likely be expensive. It was also noted that ultrasound studies on captive animals would also provide insights into shear. The workshop **recommended** the utilization of various methodologies to investigate the issue of shear across tissue interfaces and that future design of tags should take shearing into account.

The workshop reiterated previous recommendations (e.g. Weller, 2008; ONR, 2009) that the development of new tag designs and deployment techniques should be accompanied by carefully planned follow-up studies. If tagging targets a rare species/population, follow-up studies should be conducted using surrogates species first. For example, tagging of endangered western gray whales (*Eschrichtius robustus*) was preceded by follow-up studies with the more abundant eastern gray whale population (Mate, 2009). The workshop also recognized that follow-up studies are likely impossible for some species. In discussing appropriate sample sizes for tagging, the workshop agreed that most studies will be well below sample sizes needed for population level conclusions and that

the idea of cumulative deployments is appropriate. The workshop **recommended** that tagged animals should be identified by photo-identification techniques, and, where possible, biopsy samples should be collected.

The workshop recognized that major skills required for tagging are boat driving, approach techniques and tag deployment and agreed that deployments conducted by trained driver/taggers would likely result in improved tag duration and would minimize risks to the animals. Previous experience in biopsy sampling would probably be useful for those engaged in tagging operations. The workshop **recommended** that only trained people should deploy tags and that networking to support training efforts should be enhanced.

The workshop agreed that communication to local communities, regulatory agencies and the general public prior to tagging projects is important and **recommended** developing proactive mechanisms to explain why whales are being tagged, and what are the risks and the benefits for the animals and for science. The workshop also **recommended** the development of best practice guidelines for tagging that would, among others, deal with issues related to training, tag deployment, and safety for both humans and animals.

Other topics in the agenda were not covered in more detail because of time constraints. The workshop ended at 5:30pm. The chairs thanked the participants for their participation and inputs into such an interesting non-lethal research topic.

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Annex A – List of Participants

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APPENDIX 1 – LIST OF PARTICIPANTS SYMPOSIUM LIVING WHALES IN THE SOUTHERN OCEAN

First Name	Last Name	Country	First Name	Last Name	Country
Kylie	Owen	Australia	C. Scott	Baker	USA
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Michael	Noad	Australia	Yulia	Ivashchenko	USA
Val	Veirs	Usa	Jay	Barlow	USA
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Pamela	Olmedo	Chile	Russell	Leaper	UK
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Helena	Feindt-Herr	Germany	Laurène	Trudelle	France
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Susannah	Buchan	Chile	Sofía	Martínez Véjar	Chile
Natashja	Haddow Brown	Chile	Fábia	Luna	Brazil
Luciano	Valenzuela	USA	Maritza	Sepulveda	Chile
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Elsa	Cabrera	Chile
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Guillermo	Canales	Chile
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Sylvana	Espindola	Chile
Ken	Findlay	South Africa
María José	Pérez Alvarez	Chile
Alejandro	Cammareri	Argentina

APPENDIX 2 – SYMPOSIUM PROGRAMME

27 March – SYMPOSIUM			
Star	**End**	**Introduction**	**Presenter**
8:00	9:00	Registration	
9:00	9:05	Welcome and Initial remarks	Mr. Jose Fernandez
9:05	9:20	Cetacean Sighting Network	CF LT. Alex Rich
		Session 1:Past, Present and Future	
9:20	9:40	History of whaling in the Southern Ocean	P. Clapham and Y. Ivaschenko
9:40	10:00	The evolution of non-lethal whale science and the Southern Ocean Research Partnership (SORP)	Nick Gales
10:00	10:10	The role of whales in the Southern Ocean ecosystem	Lisa Ballance
10:20	10:50	**Coffee break**	
		Session 2: Molecular techniques	
10:50	11:10	Accessing the molecular archive – wide and deep, past and future	Scott Baker
11:10	11:30	Genetic bottlenecks and historical population estimates of baleen whales	Jen Jackson
11:30	11:50	Killer whales and humpback whales ageing	Gina Ylitalo
		Session 3: Biologging	
11:50	12:10	Overview of existing techniques and future directions	Christophe Guinet
12:10	12:30	Fine scale habitat use	Ari Friedlander
12:30	12:50	Large scale migration and satellite tagging	Alex Zerbini
12:50	14:30	**Lunch time**	
		Session 4: Remote sensing	
14:30	14:50	Overview of existing techniques and future directions	Pat Halpin
14:50	15:10	Passive acoustic monitoring of whales in the Southern Ocean	Kate Stafford
15:10	15:30	Photogrammetry and health assessment on gray and blue whales	Wayne Perryman
		Session 5: Long term non-lethal research	
15:30	15:50	Overview of existing techniques and future directions	John Calambokidis
15:50	16:10	Photo ID and response to climate change in southern right whales in Peninsula Valdes	Vicky Rowntree
16:10	16:30	Distance surveys and mark-recapture techniques for abundance and distribution	Jay Barlow
16.30	17.00	**Coffee break**	
17:00	18:20	Panel discussion with all speakers and questions from the floor	
18:20	18:30	Closing remarks and thanks	
End of Symposium - 18:30 – 20:30 Drinks and Poster Session			