REDUCING VESSEL STRIKES OF LARGE WHALES IN CALIFORNIA

REPORT FROM A WORKSHOP HELD IN LONG BEACH, CALIFORNIA; MAY 19-20, 2010

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U.S. Department of Commerce
National Oceanic and Atmospheric Administration
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EXECUTIVE SUMMARY

Collisions with vessels are a threat to a number of marine vertebrate species worldwide, particularly large whales. Reducing the threat of vessel collisions with large whales is a priority issue for the National Oceanic and Atmospheric Administration (NOAA). There are uncertainties about the number of whales seriously injured or killed due to vessel strikes, how this may be affecting their populations, and measures that can be taken to minimize the risk.

This workshop was convened by NOAA's National Marine Fisheries Service (NMFS) Southwest Regional Office (SWR) to improve understanding of the risk of vessel collisions with whales along the California coast and create a foundation for future research and management actions. The goals of the workshop were to: 1) identify current knowledge (including, but not limited to information on species, vessels, and locations; and review information from other areas where minimization measures have been tested/implemented); 2) identify areas where data sets are incomplete, and 3) determine techniques and sources to fill data gaps.

The workshop concluded that the issue of vessel collisions with whales along the West Coast of the United States is complex. Reducing the co-occurrence of whales and vessels is likely one of the only certain means of reducing vessel collisions with whales, but this may not be possible in all areas where collisions occur. Information on whale and ship distribution exists for certain areas along the West Coast, but information is still needed for a broader analysis for the entire West Coast. There are several technologies for detecting whales and ships, but more work is needed to combine the existing data on whale and ship distribution along the West Coast and future research is needed in areas where currently there is little information. Participants identified five recommendations/action items concerning whale data, severity of the threat to whale populations, additional data needs, shipping data, and the proposed Los Angeles Port Access Route Study. The five recommendations are listed under the Workshop Recommendations/Action Items section below.

During the workshop and because of the expertise of workshop participants, NOAA's NMFS SWR requested from those workshop participants with knowledge of whale distribution to provide information about data and data sets pertaining to whale occurrence and distribution. NMFS SWR intends to collect source information on eight species of large whales: blue, Bryde's, fin, gray, humpback, minke, sei, and sperm whales. At the conclusion of the workshop we received contributions from eleven sources, including researchers and the military. The summarized data are reflective of only the whale species and locations studied by the various contributors, thus NMFS SWR intends to expand the number of data sets to include information from others, specifically naturalists and whale watching vessels. This information, combined with expanded source data, will be useful for establishing a baseline of whale presence along the United States West Coast for risk analyses associated with vessel collisions, entanglement in fishing gear, Liquid Natural Gas (LNG) projects, hydrokinetic/renewable energy projects, and a variety of others not listed here.

WORKSHOP RECOMMENDATIONS/ACTION ITEMS

1) **Whale Data:** The Southwest Regional Office (SWR) should officially request that the Southwest Fisheries Science Center (SWFSC) take the lead in organizing and convening a working group in the next 6-12 months to collate available whale distribution data to develop a model, for the purpose of determining whale density in the Santa Barbara Channel, include marine spatial planning principles, and display the results using GIS mapping technology.

2) **Severity of Threat to Whale Populations:** Identify methods to determine potential impacts to whale populations (*i.e.*, significance of threat) along the U.S. West Coast.

3) **Additional Data Needs:** A process for discussions of data gaps and data needs in the immediate- and long-term should be developed. In addition, a process to determine priorities; allocation of money, time, and effort; and methods of collecting data (likely a conference call with participants) should also be developed.

4) **Shipping Data:** NMFS should convene a workshop with those familiar with shipping information to collate available information to combine with information collected in Recommendation 1. It is expected to have cross-participation of certain members from both workshops identified in items 1 and 4.

5) **Port Access Route Study (PARS):** Some, but not all, participants of the workshop expressed their intent to send comments to the U.S. Coast Guard on the proposed PARS study for the Los Angeles area.

LIST OF ACRONYMS

AIS	Automatic Identification System
ARS	Area Restricted Research
ATBA	Area To Be Avoided
AUV	Autonomous Underwater Vehicle
ASV	Autonomous Surface Vehicle
CARB	California Air Resource Board
CINMS	Channel Islands National Marine Sanctuary
CONCEAL	Chronic Ocean Noise: Cetacean Ecology and Acoustic Habitat Loss
CTD	Climate, Temperature, and Depth
DMA	Dynamic Management Area
ESA	Endangered Species Act
GAM	Generalized Additive Model
HARP	High Frequency Recording Package
ICOADS	International Comprehensive Ocean-Atmosphere Data Set
IMO	International Maritime Organization
IWC	International Whaling Commission
LNG	Liquid Natural Gas
MCTS	Marine Communication and Traffic Services
MMPA	Marine Mammal Protection Act
MSR	Mandatory Ship Reporting
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PARS	Port Access Route Study
PBR	Potential Biological Removal
ROMS	Regional Ocean Modeling System
ROV	Remotely Operated Vehicle
TRT	Take Reduction Team
TSS	Traffic Separation Scheme
SAC	Sanctuary Advisory Council
SAMSAP	Sanctuary Aerial Monitoring and Spatial Analysis

SCOOS	Southern California Coastal Ocean System
SMA	Seasonal Management Area
SSSM	Sea Surface Salinity Model
SST	Sea Surface Temperature
SWFSC	Southwest Fisheries Science Center
SWR	Southwest Regional Office
UME	Unusual Mortality Event
USCG	United States Coast Guard

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INTRODUCTION

The Threat of Ship Strikes

Vessel collisions ("ship strikes") are a threat to a number of marine species worldwide. Nearly all large whale species are vulnerable to vessel collisions (Best *et al.* 2001; Knowlton and Kraus 2001; Laist *et al*. 2001; Jensen and Silber 2003; Silber and Bettridge 2009; Vanderlaan and Taggart 2007; Vanderlaan *et al.* 2008; Vanderlaan *et al.* 2009; Van Waerebeek and Leaper 2008), particularly endangered baleen whales such as the northern right whale (*Eubalaena glacialis*), fin whale (*Balaenoptera physalus*), blue whale (*B. musculus*), and humpback whale (*Megaptera novaeangliae*). Virtually all motorized vessel types, sizes, and classes are represented in whale/ship strike records (Jensen and Silber 2003; Laist *et al.* 2001; Van Waerebeek and Leaper 2008). These records of the number of deaths documented in the literature are a minimum, as a substantial number of vessel collisions with whales go undetected or unreported (Laist *et al.* 2001; Panigada *et al*. 2006; Vanderlaan and Taggart 2007). Measures to minimize the risk of ship strikes have included re-routing shipping lanes, creating areas to be avoided, and slowing vessels down in areas where collisions are known to occur. Modifications to vessels and watercraft have also been investigated.

Vessel collisions with large whales are a growing international problem, particularly when endangered or depleted species are involved (Clapham *et al.* 1999). Although collisions are certainly an issue for the individual animal, the problem becomes serious at the population level when the number of deaths from collisions is so great that it affects the population's status (Fujiwara and Caswell 2001). As part of a growing international effort (for example, ACCOBAMS[1]), the International Whaling Commission (IWC) began addressing the problem of ship strikes through its Scientific and Conservation Committees and Ship Strikes Working Group in 2005, and in 2010, developed a standardized global database of collisions between vessels and whales. The Marine Environment Protection Committee of the International Maritime Organization (IMO) included the development of a guidance document on minimizing the risk of ship strikes with cetaceans into its work program in 2008. Measures to regulate shipping, such as modifying shipping lanes or establishing areas to be avoided, are endorsed by the IMO. Several countries have also created ship strike databases, developed national and regional legislation, incorporated rules and action plans to reduce the impact of ship strikes, and raised awareness on this issue through outreach and education programs.

Important areas of research include collecting information on whale and vessel distribution; in particular, determining if predictable patterns of whale and vessel distribution exist, developing methods to quantify ship strike mortality, and developing appropriate mitigation measures. For example, information on predictable patterns of whale and vessel distribution was coupled with a risk analysis using long-term distribution data on North Atlantic right whales. This information allowed for a small adjustment to the Traffic Separation Scheme (TSS) servicing Boston, Massachusetts and the TSS in the Bay of Fundy and Scotian Shelf, adding minimal passage time for ships

[1] ACCOBAMS-Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea, and contiguous Atlantic Area. http://www.accobams.org

and achieving a substantial reduction in collision risk (NMFS 2008a; Vanderlaan *et al.* 2008; Vanderlaan *et al.* 2009). Although spatial overlap between ships and whales is not equivalent to collision risk, the spatial overlap between ships and whales is a prerequisite when a ship strike occurs (Williams and O'Hara 2009). As a result of the number of blue whales struck and killed by ships in the fall of 2007, Berman-Kowalewski *et al.* (2010) examined blue whale deaths reported along the California coast from 1988-2007 and determined that a primary factor predisposing the animals to collisions was the spatial and temporal clustering of animals in an area where vessels transit.

While numerous reports have proposed modifications to vessel and watercraft operations to avoid ship strikes (Elvin and Taggart 2008; Kite-Powell *et al.* 2007; Silber *et al.* 2009; U.S. Coast Guard 2006), for some areas there is no practical alternative route for ships, and other solutions need to be considered. There is evidence that ships travelling at restricted speeds may reduce the likelihood of a lethal ship strike (Hazel *et al.* 2007; Laist and Shaw 2006; NMFS 2008a; Pace and Silber 2005; Panigada *et al.* 2006; Vanderlaan and Taggert 2007; Wang *et al.* 2007). In areas where there is a particular concern (due to the species and/or frequency of vessel collisions with whales), vessels have been requested to slow down. Vessel speed restrictions or advisories are widely employed in U.S. waters to reduce the likelihood and severity of large whale ship strikes (*e.g.* Glacier Bay National Park, National Park Service 2003; key port entrances and North Atlantic right whale aggregations, NMFS 2008b). The Channel Islands National Marine Sanctuary (CINMS), National Oceanic Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) Southwest Regional Office (SWR), and United States Coast Guard (USCG) advise ships to travel at 10 knots or less in shipping lanes to the ports of Los Angeles and Long Beach when the threshold of a set number of whales aggregating in/near the shipping lane is met (*e.g.*, an aggregation of 5 or more whales observed within and adjacent to, the TSS).

In 2008, a workshop to identify and assess technologies to reduce ship strikes to large whales (Silber *et al.* 2009) concluded that there are no easy technological fixes; that no technology exists, or is expected to be developed in the foreseeable future that will completely ameliorate, or reduce to zero the chances of ship strikes of large whales; and no single technology will fit all situations. Technologies applicable to reducing ship strikes are limited almost entirely to those that enhance whale detection and could improve the likelihood of providing information and warnings to mariners. However, detection and relaying information may vary among individual mariners and vessels, and substantial distances can be required for vessels underway to avoid, alter course, or even react to an object directly in their path, particularly for very large vessels or vessels traveling at higher speeds.

Evidence of ship strikes comes from either a direct observation from the ship or reports of a whale carcass floating at sea or washed up on the beach (and examined for evidence of collision and confirmed). In some cases, carcasses are found, but because injuries are internal (and circumstances prevent performing a full necropsy) or the carcass is in advanced decomposition, it is not always possible to confirm if ship strike was the cause of death. A dead floating whale may drift a considerable distance from the site of actual impact. In addition, when larger vessels (*e.g.,* container ship) are involved, the mariner may not be aware a strike has occurred and it becomes known only when the vessel arrives at port and carries a dead whale on its bow. In rare cases, the time and location of the impact can be back-calculated to correlate with a previously unexplained decrease in vessel speed. It is very likely that far more collisions have occurred than have been reported (Jensen and Silber 2003).

Collision incidents in U.S. waters are recorded from almost every coastal state (see Jensen and Silber 2003). In California, gray whales (*Eschrichtius robustus*) are the most common baleen whale hit by ships (Heyning and Dalheim 1990; U.S. Department of Commerce 2010 (California Marine Mammal Stranding Database)), followed in order of occurrence, by fin, blue, humpback, and (one) sperm whale(s) (*Physeter macrocephalus*) (U.S. Department of Commerce 2010 (California Marine Mammal Stranding Database)). NMFS declared an Unusual Mortality Event (UME)[2] on October 11, 2007, because of the number of blue whales (four) struck and killed by vessels during the fall of that year. Since the SWR has been keeping stranding records (beginning in 1986), the maximum number of documented blue whale fatalities in a single year was three. Although the 2007 ship strikes caused the mortality of four blue whales, the seriousness of this threat to the population and all large whales along California and the U.S. West Coast could be much larger due to the unknown proportion that goes undocumented.

Workshop Goals and Logistics

The workshop was convened to improve understanding of the risk of vessel collisions with whales along the California coast and create a foundation for future research and management actions. The goals of the workshop were to: 1) identify current knowledge; 2) identify missing data sources and data gaps/needs; and 3) determine techniques and sources to fill data gaps.

The workshop was attended by 35 participants (Appendix 1) from May 19-20, 2010, in Long Beach, California. Four government agencies participated: NMFS, the National Ocean Service, USCG, and U.S. Navy, represented by researchers, biologists, modeling experts, and managers. Representatives from the Maritime Exchange also participated, as did five participants from academic or research organizations.

Presentations occurred on the first day. The group summarized the discussion from day one and highlighted important points at the beginning of day 2 (Appendix 3). The second day also included a “brainstorming” session in which participants were asked to develop a framework to analyze the risk of vessel collisions in two areas, the Santa Barbara Channel area and the San Francisco, California area (Appendix 5). Questions were supplied to stimulate discussion among the participants (Appendix 4). Representatives from each of the four groups presented their discussion points and framework to the larger group. Throughout the presentations, workshop participants provided input and discussion. After reviewing the information presented, the group discussed “next steps” to continue efforts to reduce the threat of vessel collisions and developed workshop recommendations and action items.

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[2] Unusual Mortality Event (UME) is defined under the Marine Mammal Protection Act as: "a stranding that is unexpected; involves a significant die-off of any marine mammal population; and demands immediate response." For more information please go to http://www.nmfs.noaa.gov/pr/health/mmume.

During the workshop and because of the expertise of workshop participants, NMFS SWR requested that those participants with knowledge of whale distribution provide information about data and data sets pertaining to whale occurrence and distribution. NMFS SWR intends to collect source information on eight species of large whales: blue, Bryde's (*B. edeni*), fin, gray, humpback, minke (*B. acutorostrata*), sei, and sperm whales. At the conclusion of the workshop we received contributions from eleven sources, including researchers and the military including: contact information, data type, whale species covered, spatial and temporal coverage, and publication information (Appendix 6). The summarized data are reflective of only of the whale species and locations studied by the various contributors, thus NMFS SWR intends to expand the number of data sets to include information from others, specifically naturalists and whale watching vessels. This information, combined with expanded source data, will be useful for establishing a baseline of whale presence along the United States West Coast for risk analyses associated with vessel collisions, entanglement in fishing gear, Liquid Natural Gas (LNG) projects, hydrokinetic/renewable energy projects, and a variety of others not listed here.

SUMMARY OF THE MINUTES FROM WORKSHOP PRESENTATIONS

May 19, 2010
[13:00-18:00]

CHRIS YATES, NMFS SOUTHWEST REGIONAL OFFICE

Welcome

The primary goal of the workshop is to present current data and knowledge and discuss ideas to minimize whale strikes. The purpose of the workshop is not to brainstorm on management techniques or new technologies as this has already been discussed in other workshops. Our intent is to try and focus on ideas of what can be done with existing information. There will be a sharing of information and discussions on how to proceed in terms of data collection to attain our goals. We hope to develop new collaborations and move forward. Decisions will need to be made in the future and we may not have the luxury of asking for more time or saying we don't have enough data, when it comes time to make those decisions.

MONICA DEANGELIS, NMFS SOUTHWEST REGIONAL OFFICE

Introductions and Agenda

Presented agenda, see Appendix 2 and workshop logistics. Presented a list of questions for participants to think about during the presentations on Day 1: 1) How would you characterize whale/vessel collisions?; 2) Is the assumption: more whales + more ships = more vessel collisions true?; 3) Is current research/management more about understanding why collisions occur or determining ways to minimize the risk?; 4) How do we tackle best available science and best available information?

Presented the list of the following questions that were asked of our speakers to discuss during their presentations: 1) What were/are the challenges with your work?; 2) What were/are the limitations of your work?; 3) What were/are the data gaps revealed from your work?; 4) What were/are other sources of data that could have been useful to refine your work or would have resolved an outstanding issue preventing you from concluding your work?; and, 5) Lessons learned from your work?

Our goal is to create a foundation for future research and management action by identifying current knowledge, missing data sources and data gaps/needs, and techniques to fill in these gaps including pros and cons and "non-traditional" data.

MONICA DEANGELIS, NMFS SOUTHWEST REGIONAL OFFICE

Large Whale Ship Strikes in California (1988-2010)

All reports are opportunistic. Reports include a high certainty that a ship strike occurred, but other information is unknown. If a report is received from a vessel at sea or a vessel coming into port with a dead whale on its bow, we generally know the vessel parameters (size, speed, type), we may have some information about the whale, but we rarely know the final outcome (injury/mortality). With strandings, we know a lot about the whale, but little about the vessel. It is rare to know a lot of information about both the vessel and the whale when a vessel collision has occurred.

We have had a total of 79 strikes from 1988- May 2010. The stranding information indicates large incidences of strikes in southern California. Gray whales are struck most often, followed by blue and fin whales, then humpback whales. Reports indicate that the San Francisco area and the southern California area (including Santa Barbara, Los Angeles, and San Diego Counties) have the highest numbers of vessel collisions. Vessel collisions also coincide with seasonal distribution of species; *i.e.*, the majority of gray whales struck coincided with their migration, with the highest numbers in April, when more animals are closer to shore. Data were also plotted by year and revealed an increasing trend with 2007 having the highest total number of animals struck.

B. Mate Comment: 30 of 79 strikes were gray whales which all occurred within the same 5 month time frame from 1988-2010. This could be an area of focus.

ELIZABETH PETRAS, NMFS SOUTHWEST REGIONAL OFFICE

Management Actions

Whales are protected under the Marine Mammal Protection Act (MMPA) and most are listed under the Endangered Species Act (ESA). The SWR is working in various ways to improve its understanding of vessel strikes of large whales, which is integral to helping us make management decisions, including consultations on Federal activities. The SWR's current activities related to vessel strikes include: 1) working in collaboration with Channel Islands National Marine Sanctuary, USCG, Marine Exchange, shipping industry, and scientists; 2) gaining a better understanding of what is going on in the Santa Barbara Channel area and along the West Coast; 3) trying to improve reporting and response; 4) supporting research and monitoring; and 5) reaching out to the Ocean Protection Council, ship operators, and the public, and attending harbor safety committee meetings. The USCG's Port Access Route Study (PARS) is expected in late 2010. The SWR will provide public comments in attempting to get USCG to focus on whales. If changes in the shipping lanes are proposed as a result of the Stock Assessment Reports, the SWR will be doing Section 7 consultations, as required under the ESA.

ALISON AGNESS, NMFS NORTHWEST REGIONAL OFFICE

Evaluating the Risk of Vessel Collisions in ESA Section 7 Consultations

There is a need to evaluate the risk of vessel collisions in ESA Section 7 consultations. There are three proposals to develop Liquid Natural Gas (LNG) terminals in Oregon that if built, will generate new shipping traffic. One proposal estimates 250 one-way trips per year to a terminal, and that number could triple if all three terminals are built. LNG vessels are large and travel at fast speed in the ocean (*i.e.*, vessel characteristics: sea speed of 20 knots; double hull; and 945 feet long). Based on our review of the best available science, collision risk is influenced by vessel size and speed, such that whales are at highest risk of strike from large vessels travelling at fast speed and LNG vessels fit in this category. We have developed an analytical framework to estimate a rate of strike for each whale species based on existing stranding records and a crude understanding of existing vessel traffic across the West Coast. We extrapolate these rates over the lifetime of the LNG terminal project to estimate a number of strikes that may be caused by the new LNG vessel traffic. A better understanding of shipping traffic across the West Coast would improve our estimates, but of greater importance, an overlay of shipping traffic and whale densities across the West Coast could allow us to identify and analyze the effectiveness of mitigation measures. A specified vessel route could minimize the risk of a ship strike if designed to minimize the likelihood of whale exposure to the vessel traffic. As a practical example, one terminal proposed a funnel route as a mitigation measure, but there are no existing tools to evaluate the effectiveness of this measure. We have discussed a number of minimization measures that LNG terminals could incorporate in their terminal use agreements to reduce the risk of strike, and these include: monitoring and strike avoidance measures, speed restrictions (12 knots or less) and route restrictions (avoid high strike areas). However, it remains difficult to evaluate the effectiveness of a route restriction. In summary, we need a spatial and temporal assessment of strike risk across the West Coast, and hand-in-hand, the underlying shipping data and whale distribution data to populate the assessment. Such a task could be taken on and would likely need to be a collaborative process with scientific and management input.

SEAN HASTINGS, CHANNEL ISLANDS NATIONAL MARINE SANCTUARY

Channel Islands National Marine Sanctuary Update

The Sanctuary Advisory Council (SAC) set up a sub-committee to address the ship strike issue. Whales are afforded additional protections under the National Marine Sanctuary Act. An annual prevention and emergency response plan was drafted. The Santa Barbara Channel is a choke point for shipping traffic. Ship strikes are likely occurring in or near the Channel. A data set of whale sightings in the Santa Barbara Channel exists. The rerouting of ships outside of the Channel and the new western approach proposed by the PARS has complicated things and poses two questions: what are the ships doing? and, what is the presence/absence of whales on the back side of the islands? Of the other Sanctuaries on the west coast, the CINMS is the lead in terms of ship strikes as a Sanctuary issue. Research should focus on a better understanding of spatial and temporal distribution of whales in and around the shipping channel and a better understanding of oceanographic conditions and prey/krill distribution/densities. Other research on ship tracking is occurring as are aerial surveys and volunteer observation data from whale watching boats. Although shipping information is available through the Automated Identification System (AIS), gaps in coverage exist around the region. Megan McKenna will be training staff to better understand AIS data and access to AIS. The Bren School students, from the University of California, Santa Barbara, are going to analyze the feasibility of various management alternatives recommended by the SAC. They, too, will participate in McKenna's AIS training.

Paper distributed:

Abramson, L. *et al.* 2009. Reducing the threat of ship strikes on large cetaceans in the Santa Barbara Channel Region and Channel Islands National Marine Sanctuary: Recommendations and Case Studies.

JOHN CALAMBOKIDIS, CASCADIA RESEARCH COLLECTIVE

Blue Whale Behavior In Shipping Lanes And Response To Ships

Long term studies by Cascadia Research of abundance, migration/movement, and behavior, include photo identification and tagging studies of humpback, blue, and gray whales. Abundance estimates of humpback whales based on mark-recapture show a 7.5%/year increase in abundance in the North Pacific, which is expected to taper off at some point. The North Pacific population is estimated at just over 20,000, with about 2,000 feeding off the U.S. West Coast, and is most likely still below pre-whaling numbers off of the U.S. West Coast. There is also evidence of changes in feeding habits from krill in the 1990s to more fish starting in 1999 and continuing until recent years. Blue whales have more ambiguous abundance estimates as they are typically farther offshore and harder to track for mark-recapture abundance assessments. Mark-recapture was fairly consistent until 2000, when the proportion of time blue whales spent in California decreased, resulting in a lower average density. The overall population estimate may be the same but the proportion off of California may have decreased due to distribution shifts– partly due to changing prey availability and oceanographic conditions (as measured by indicators like the Pacific Decadal Oscillation). A slight overall population increase is suggested by the mark-recapture estimates of blue whales in the last few years. Survey data identify overlaps between sightings and shipping lanes (ex. north of the west end of Santa Cruz Island and the continental shelf, the eastern end of the Santa Barbara Channel and the area off of Palos Verdes).   A major area of concentration south of the northwest Channel Islands is of concern because of changes in shipping traffic. The Sanctuary Aerial Monitoring and Spatial Analysis or (SAMSAP) monitoring and sightings database provides 9 years of sightings data.   Satellite tags on blue and fin whales show aggregations south of the northern Channel Islands including off the Los Angeles area. Suction cup tag results on blue whales show dive patterns in relation to day/night and depth. The dive depth increases during the day and the whales go into "non-feeding surface mode" at night. Whales are twice as likely to be at 15 meters or less at night then during the day and may be more susceptible to strikes. Data on close approaches between whales and ships revealed that there is no strong evidence of avoidance behavior by the whales and, in some instances; the whales were approaching the direction of the ship. Surface series after close approaches were dramatically longer than other surface times in dive patterns during two observed close approaches. Most close approaches occur where shipping lanes intersect the continental shelf contour. Whales not only dive differently at night, but are moving differently as well; they could be entering shipping lanes at night even if they aren't feeding there during the day. Surface time and vulnerability are highest at night. The highest number of blue whales ever recorded in the Santa Barbara Channel occurred in September 2007: that same year, NMFS determined the UME for blue whales caused by ship strikes. In 2007, there was a high density of blue whales in the Santa Barbara Channel and they were distributed closer to the shipping lanes. Whale use of the shipping lanes was lower in 2008-2009. Ship strikes on whales in Washington based on stranding records have increased dramatically over the last 30 years.

We plan to continue our work: photo-identification (dedicated surveys and Naturalist Corps), studies on behavior of animals in shipping lanes, distribution and habitat use from sightings and satellite tagging, and participate in the Behavioral Response Study with the U.S. Navy to study reactions of blue whales to sounds—this may possibly tie into behavior around ships.

Audience Question: Is there an availability of oceanographic data i*.e.*, krill distribution?
Calambokidis Answer: Cascadia targets locations of whales, gets other data from Jay Barlow – may be possible to pick up definite patterns with clear bathymetric data.
Audience Question: Is there a hypothesis of why there is a change in distribution?
Calambokidis Answer: This can be answered on three levels: huge geographic movements from California to Alaska, the presence/absence within southern California because of oceanographic and krill distribution, and fine scale movements within the Santa Barbara Channel that determine whether the whales are in or just outside of the shipping lanes.

BRUCE MATE, OREGON STATE UNIVERSITY
Using Satellite-linked Radio Tag Tracks to Reveal the Convergence of Large Whales with Shipping Lanes Off California
Animals have been tagged off of the Farallon Islands in California, near San Francisco Bay and the Santa Barbara Channel area. We've recorded satellite tracks of blue, fin, humpback, and gray whales in the eastern North Pacific and noted their coincidence with several shipping lanes. Blue whales use offshore areas more than humpback and gray whales. When compared, grays are much more commonly found nearer to shore. In

addition to risk exposure during the late spring-summer-early winter feeding season, animals are at risk from ship collision during reasonably consistent north-south migrations in the fall and winter. For blue whales, individuals are at risk off the California coast from June through October, while individual gray whales have shorter exposure to such risks during migrations from January through May. Movements of mother/calf gray whale pairs in April are very close to shore, making them more vulnerable.

MEGAN MCKENNA, SCRIPPS INSTITUTUTION OF OCEANOGRAPHY

Insights on Ship Traffic Patterns, Presence of Baleen Whale Calls, and Behavior of Blue Whales Around Commercial Ships

AIS is a radio signal that ships send and receive to communicate identification information. AIS is a powerful tool to monitor ship behavior in a coastal region; however, improvements in data sharing and storage can be made to make AIS even more useful for management purposes. A number of AIS receiving stations in the region have been set up by the Scripps Whale Acoustic Lab at Scripps Institution of Oceanography to monitor traffic and relate this to acoustic measurements. AIS data collection began in the Santa Barbara Channel in 2006, with improvement in coverage in 2008 and 2010, including a new site on Santa Cruz Island which gives extended coverage south of the northern Channel Islands. The number of AIS transmissions from individual ships in a particular area and on a certain day can provide information on the density of ship traffic in specific areas. Cargo ships comprise 77% of shipping traffic in the Santa Barbara Channel; the AIS category of “cargo ship” includes container ships, vehicle carriers and bulk carriers, and speed varies by vessel type. Recent trends in ship traffic in the Santa Barbara Channel area show a 24% decrease in the number of ships between September 2008 and September 2009. The decrease in traffic appears to parallel the recent economic trends. Additionally, there has been an increase in traffic south of the Channel Islands (from 3 to 10 ships per day). The change in ship routes began July 1, 2009, when the California Air Resources Board rule (CARB) on air emissions went into effect. In response to the new regulations of using cleaner fuel within 24 miles of the coast, most ships opted to remain offshore for a longer period. This change in routes overlaps with an active Navy Range, and has the potential to increase the risk of ship strikes to certain species of baleen whales.

The High Frequency Acoustic Recording Package (HARP) is used for acoustic monitoring in southern California; the instruments measure a broad frequency range and record low frequency baleen whale calls and high frequency dolphin whistles and clicks. Ship noise is also recorded. Analysis of acoustic data from March 2009 to September 2009 showed that calling baleen whales (fin, blue, humpback, Bryde’s, and possibly sei) were present south of the northern Channel Islands (in the Santa Cruz Basin). Fin whales were detected 90% of the time. This information is useful for indicating the presence of animals when sightings data are not available.

WAYNE PERRYMAN, NMFS SOUTHWEST FISHERIES SCIENCE CENTER

Update on Blue and Gray Whales

Blue whales are common between the Santa Barbara Channel and Long Beach, California. We conducted aerial surveys and observed variation between years. The gray whale population is larger than the blue whale population. Gray whales typically migrate inshore. There are approximately 20,000 gray whales transiting through the area. Gray whales are often hit by ships. Carnival Cruise Lines reported 3 strikes off of Baja

California, Mexico, between March and June of 1998; one gray, one large unidentified whale, and one whale shark. Most of the time the collision was undetected until the ship slowed to enter port. The cruise line wanted to avoid ship strikes and wanted information to avoid future ship strikes and worked closely with NMFS. When analyzing the cruise line's tracklines, particularly focusing on winter months, there are likely a lot more gray whale ship strikes than documented. There is also the floating/sinking affect with regard to reporting or documenting a strike. There could also be a bias with northbound whales (skinnier) possibly sinking and thus underreported when compared to southbound whales (fatter) that may float.

J. Calambokidis Comment: I agree with Wayne, there are an unknown proportion of strikes than those that are identified for all species.

JAY BARLOW, NMFS SOUTHWEST FISHERIES SCIENCE CENTER
Fin and Blue Whale Distribution Off the U.S. West Coast (Observed and Predicted). Ship-based marine mammal surveys were conducted off the U.S. West Coast in 1991-2008. Fin whale distribution has not changed much from 1996 through 2008, although abundance has increased from approximately 1800 to 3000 based on the last two surveys. There are seasonal changes in distribution (*i.e.*, more animals observed in the northern California range July-August and more observed in the southern California range mid-October to December). Fin whales are rarely seen in the Santa Barbara Channel, but large densities have been observed outside of this area and around Point Conception, an area of high ship traffic. A large shift in blue whale distribution has been observed, beginning around 2000, when more whales were found more northward, thus shifting from more animals found in the Southern California Bight and central California areas to a more even distribution along the entire West Coast. Survey abundance in the study area has changed from 1900 animals in 1996 to 507 in 2008. Mark/recapture data show that actual population abundance has not decreased, but has shifted out of the survey area. Blue whales are more concentrated in the Southern California Bight early in their feeding season (June-July).

Observed distributions and modeled distributions, how to fit models to actual observed information (habitat data and cetacean surveys).

The plots show average predicted density for blue whales for 6 years and each of the individual survey years were averaged across all years to calculate the average species density. Key predictor variables for blue whales included depth, slope, mixed layer depth, chlorophyll, and salinity. The plots show density predictions for each individual based on environmental conditions. The model predicts a high density of blue whales in the California Current, specifically, in the Southern California Bight. Generalized Additive Model or Generalized Additive Model (GAM) blue whale encounter rate model (depth, slope, sea surface salinity, ln (natural log) chlorophyll, and mixed layer depth) and the GAM blue whale group size model (slope, mixed layer depth, and log chlorophyll) vary with oceanographic conditions. A lot of variance exists and is not explained by the model, but the model can predict distributions to a certain extent. An index of krill abundance (acoustics backscatter) added very little predictive power and, to be useful in predicting current density, would need to be measured in "real-time." In addition, whales require dense patches of krill, so detection of krill by SONAR is not necessarily where you would find whales. Key predictor variables for fin whales included sea surface temperature, mixed layer depth, chlorophyll, and salinity. The plots show average predicted fin whale density; each of the individual survey years was averaged across all years to calculate average species density. The encounter rate model for fin whales included sea surface temperature (SST); encounters were highest in the temperature range of ~14-18 degrees Celsius. Species for which SST is a key predictor allow us to run NOWCASTS and FORECASTS. We've integrated climate products into predictive models, called NOWCAST, and incorporated SST. NOWCASTS are what animals are doing right now, based on SST developed by remote sensing systems (provided in real time). This enables the use of data with models for predictions of where animals are now. The FORECAST Regional Ocean Modeling System (ROMS) can predict what ocean conditions will be like up to 9 months in the future. We use our best models built with the 1991-2005 survey data to predict environmental conditions during 2008. We then used actual effort and sightings from our most recent shipboard survey conducted in 2008 to assess predictive performance of the models. Overall, the average prediction based on historical data does well with the predictions, but there is room for improvement. The NOWCAST data picked up the more subtle differences in distributions at finer scales then the "average" distribution. Predictions using FORECAST ROMS for our example in October 2008 show promise for forecasting at finer temporal resolutions. One of the biggest challenges is getting the data to fit the model. Currently, these models are better for large scale predictions of distributions and are not appropriate for a fine scale (under 50 miles) like the Southern California Bight. Although the models would need to incorporate parameters for fine scale, they are doing a good job of actually predicting where animals are, although not perfect.

DANIEL PALACIOS, NMFS SOUTHWEST FISHERIES SCIENCE CENTER
Habitat Models for the Northeast Pacific Blue Whale From Satellite Tracking and Remote Sensing.
We are concerned with two questions: Can we predict movement behavior based on environmental variables? and What can we learn about the ecological niche of blue whales in the Northeast Pacific? We used satellite information with Bayesian state-space models to generate improved location information and can classify locations based on transiting or foraging (area restricted search- ARS). The validity of the two behavior modes (*i.e.,* related to traveling or feeding) has been tested in other studies. The state-space approach has been proposed as a powerful tool for modeling animal movement data because of its ability to deal simultaneously with potentially large measurement errors and variability in the dynamics of movement. Blue whale tagging from Bruce Mate included 128 transmitting tags, only 92 of which transmitted for longer than 7 days (between 1993 and 2007). Most of the whales were tagged in Santa Barbara Channel, the Gulf of California, and the Gulf of Farallones. Blue whales migrate to an offshore oceanographic feature in the eastern tropical Pacific known as the Costa Rica Dome. The Dome is not a static feature; it is seasonally variable. Travel speeds during transit were significantly faster than during ARS movements (mean = 3.7 km/h and 1.05 km/h or 2.0 knots and 0.6 knots, respectively). However, with only one location/day we're grossly underestimating the actual route (and thus speed). The blue whale tracks revealed that foraging activity occurs all along the coasts of Washington, Oregon, and California; in the Gulf of California; and west of the Costa Rica Dome. The Sea Surface Salinity Model (SSSM) generally distinguished well between transiting (27% of locations) and ARS (43%) behavioral modes, with 30% of locations remaining as uncertain. We ask the question: Are these behaviors associated with the environmental conditions experienced by the animals along the tracklines? Relevant environmental variables such as sea surface height, eddy kinetic energy, Ekman upwelling, SST and gradient, chlorophyll, primary productivity, etc., were obtained at each whale location. Physiographic variables

include distance to shelf, distance to the coast, depth, and slope. We modeled the presence or absence of ARS behavior at various locations. Behavior is a function of the environment and response is the presence/absence of ARS. The predictors are environmental variables and the framework is a GAM and nonparametric multiplicative regression analysis.

ARS behavior is most probable with cool SST (although a secondary peak also occurs at warmer temperature); highest ARS behavior occurs in areas with a high frequency of fronts. High productivity and low slopes (closer to shore) indicate high probability of ARS behavior. SSSM revealed persistent areas of ARS behavior throughout the migratory cycle, further evidence that blue whales feed year-round. Migratory movements of blue whales may be described as commuting between regions with optimal food supply. In summary, long-term satellite tagging allowed description of multi- year and month movement and migratory cycle of the northeast Pacific blue whale population along the west margin of North America in summer-fall and to the Costa Rica Dome in winter-spring. General issues with models include inferences to population (assumptions; habitat models require a lot of assumptions) and autocorrelation of whale tracks. The objective differentiation between foraging and transiting/migratory behavior allows us to begin testing hypotheses about how the environment affects movement.

ROB WILLIAMS, UNIVERSITY OF BRITISH COLUMBIA

Whales and Ships in Coastal Waters of British Columbia

We conducted small-boat line-transect surveys and density surface modeling using GAMs to describe whale density as a function of environmental and spatial variables to predict whale density throughout coastal waters of British Columbia. Most British Columbians live in the southern half of the province, and there is comparatively poor observer coverage in the north to detect human-caused mortality. British Columbia is developing a dedicated marine mammal stranding response network, and our intent was to assist those efforts by identifying areas where capacity-building for that stranding network may be needed. The estimates of whale abundance and distribution were derived from a systematic survey design. The objective was a spatial analysis, so only static variables (latitude, longitude and depth) were used, but the methods are easily expandable to include dynamic variables. This choice reflects the fact that we were primarily interested in where whales were, on average, rather than why they were there. The SWFSC survey data and analytical capacity are world-class; given the institutional interest and capacity to conduct predictive models, inclusion of dynamic environmental covariates would be appropriate. In the British Columbia study area, we are dealing with a lot of geographic complexity introduced by fjords and islands. The British Columbia ship traffic intensity data were compiled by Patrick O'Hara, using logs kept by Marine Communications and Traffic Services (MCTS) of the Canadian Coast Guard. MCTS monitors ship traffic using radio contact, radar detection and satellite tracking. The MCTS data are less precise than the now-standard AIS data; AIS coverage remains poor along much of the British Columbia coast. The analyses revealed that some parts of the coast are rarely visited by large cargo ships. A relative index of "ship strike risk" was approximated by simply multiplying the number of whales predicted to occur in any grid cell by the number of ships that pass through that cell in a typical summer. Of course, spatial overlap does not imply ship strike, but it is a necessary precursor for it. Given the cryptic nature of ship strikes in remote areas, the index provides a coarse filter and rapid snapshot of places where we should pay close attention. The analyses revealed that areas where ships and whales are most likely to co-occur are remote from urban areas.

Consequently, spatially biased observer coverage could easily result in carcasses being missed in these remote areas and substantial underestimation of ship-strike mortality. This metric of co-occurrence of whales and ships may also serve as a proxy for vulnerability to oil spill risk. Using northern resident killer whales (*Orcinus orca*) as an example, we found that narrow Johnstone Strait (designated critical habitat) was the highest risk area, possibly due to a "bottleneck effect." This type of analysis is a useful approach for priority setting, response planning and oil spill preparedness. Fin whales, on the other hand, have less of a bottleneck effect than killer whales, but their highest-risk areas are in a section of Hecate Strait where very little whale research occurs. Fin whale studies would benefit from good transboundary cooperation among Canada, the U.S., and Mexico. Robust spatial modeling methods are being developed that work well on sparse data and geographically complex regions, especially the SPLINTR models (spatial modeling of line transect data) being developed by Mark Bravington and Sharon Hedley. Parenthetically, this simple spatial overlap analysis may also provide a useful starting point to identify areas where whale habitat may be degraded acoustically by shipping noise. Our new project, CONCEAL (Chronic Ocean Noise: Cetacean Ecology and Acoustic Habitat Loss), is a collaborative study with Chris Clark (Cornell University) that aims to quantify the amount of acoustic space that whales lose due to shipping noise. In the British Columbia study, the sites with the highest ambient noise happened to be found in critical habitat for resident killer whales. There may be a link between shipping noise and ship strikes. If acoustic masking elevates risk of a ship strike, then whales will receive less "advance warning" of an approaching ship when they are in geographically complex waters than in the open ocean where sound propagates farther. It would be worth exploring whether sound propagation in the Santa Barbara Channel causes similar issues in geographic bottlenecks or sites where ships make sharp course adjustments. Ultimately, we have found integration of acoustic information with shipping traffic information (whether through MCTS or AIS) via spatial modeling to be beneficial. Given the cryptic nature of the problem, however, we must be cautious when concluding that known ship strike mortality is low relative to mortality limits calculated by the Potential Biological Removal (PBR). The PBR framework assumes that you have a good estimate of mortality – in the case of ship strikes, a priority topic is to estimate the proportion of mortality that goes undetected.

Audience Question: Is there distribution of risk between large and moderately sized vessels?
Williams Response: In British Columbia, the bulk of known injuries in killer whales come from smaller boats. Scarring emphasizes survivors of ship strikes, however. For large whales, it is easier to filter AIS data by vessel type or speed than in the British Columbia database.
J. Calambokidis Comment: In Washington, mortalities most often come from larger boats.

ANGELIA VANDERLAAN, FISHERIES AND OCEANS CANADA
Determining Optimum Conservation Initiatives for the Endangered North Atlantic Right Whale and the Efficacy of a Voluntary Area To Be Avoided.
In order to estimate risk, we must answer the following three questions (the set of "triplets" for estimating risk): 1) What can happen or go wrong? A vessel can strike a whale. The most frequently reported species are fin, humpback, right, and gray whales. Of the necropsied right whales, 53% of deaths are attributed to vessel strikes and right whale deaths attributable to vessel strikes could be as high as 10 individuals in any given

year; 2) How likely is it that it will happen? This depends on a vessel and whale being at the same point in time and space. A high probability of whales and vessels= a high probability of a vessel encountering a whale; and, 3) If a strike does occur, what are the consequences? The probability of a lethal injury is a function of vessel speed at the time of collision. There are two ways to reduce the risk of a vessel strike: reduce vessel speed or reroute vessels away from the whales. Eastern Canada study areas include the Bay of Fundy and Roseway Basin, each are a critical summer feeding habitat for right whales. Voluntary conservation measures (*i.e.,* avoid the area and/or slow down) are associated with the Right Whale Conservation Areas found in both these critical habitats. In the Roseway Basin study area, it is 26 times more likely, on average, to observe a right whale within the Conservation Area than outside of the Conservation Area. Vessels are twice as likely to transit north of the Conservation Area as through it; however, there is an emergent diagonal traffic "lane" directly through the Conservation Area. Typically, vessels transit the Conservation Area at 13-15 knots. However, even though the highest risk occurs within the Conservation Area (*i.e.,* 68 times higher, on average, within the Conservation Area than outside of it), there has been very little evidence of voluntary compliance in the Right Whale Conservation Area. AIS is required on all vessels of 300 gross tonnage on international voyages, cargo ships of 500 gross tonnage, and all passenger ships. AIS provides vessel location and speed data. We collected one full year of vessel traffic data recorded prior to the implementation of an Area to Be Avoided (ATBA). The ATBA was designed to encompass the majority of the right whale sightings and the area of highest risk of vessel strikes on Roseway Basin. The ATBA was approved by the IMO and implemented by Canada in June 2008. Although recommended by the IMO, this is a voluntary seasonal ATBA in effect June 1st through December 31st. Compliance was measured semi-monthly in 2008 and weekly in 2009. There was 57% compliance within the first 2 weeks of ATBA; it has stabilized at ~71% after the first year of implementation. In addition, the vessels that continued to travel through ATBA were doing so at slower speed and the probability of a lethal injury, should a vessel strike a whale, decreased from 0.87 to 0.79. Overall, voluntary compliance with ATBA resulted in a reduction in risk of 82%. This study demonstrates that the shipping industry was able and willing to voluntarily alter course, and adoption of ATBA by IMO increased compliance. In summary, we were able to quantify risk from a threat to wildlife by using marine spatial analysis, take the results of the risk analysis and develop policy, and then quantify the effectiveness of those policies.

Details of the above summarized research are found in:

Vanderlaan, A.S.M. and C.T. Taggart. 2007. Vessel collisions with whales: the probability of lethal injury based on vessel speed. *Marine Mammal Science.* 23: 144-156.

Vanderlaan, A.S.M., C.T. Taggart, A.R. Serdynska, R.D. Kenney and M.W. Brown. 2008. Reducing the risk of lethal encounters: vessels and right whales in the Bay of Fundy and on the Scotian Shelf. *Endangered Species Research.* 4: 283-297

Vanderlaan, A.S.M. and C.T. Taggart. 2009. Efficacy of a voluntary area to be avoided to reduce risk of lethal vessel strikes to endangered whales. *Conservation Biology.* 23(6): 1467-1474.

GREG SILBER, NMFS OFFICE OF PROTECTED RESOURCES

Reducing Ship Collisions with Large Whales.

Over 750 collisions with whales have been documented between 1800 and 2007, but many go undetected or unreported. All types of ships and all species of large whale are involved. To develop effective means to reduce ship strikes with whales, two things are needed: 1) data on whale distribution and 2) data on vessel distribution. Several approaches might be used to reduce ship strikes, including: education/mariner awareness, whale detection technologies, reduction in the co-occurrence of vessels and whales (vessel routing measures), or vessel speed restrictions.

Technology for detecting and alerting moving whales has also been investigated including: alarms to alert whales, observers, tagging, active acoustic (sonar), enhanced optics, predictive modeling, and passive acoustics. Improved detection of whales does not necessarily ensure mariners will be motivated, or have the capacity, to adequately avoid whales. Similarly, all whales may not be detected on a ship's path and it is difficult to slow or turn large vessels in response to whale detection. Nonetheless, several approaches, including predictive modeling to determine where whales might occur based on known oceanographic conditions and passive acoustic detections, are among the most cost effective. There are significant pros and cons to any technological approach pursued.

North Atlantic right whale strikes occur throughout the range of the species, and yet, we have an extensive data set available on their distribution. NOAA developed an overall strategy to reduce ship strikes of right whales, and considered the conservation value and economic impact of hundreds of options. The strategy has five elements consisting of: continuing ongoing efforts (mariner outreach, including aerial surveys, and mariner notification of sight whale locations, studies of technologies); enhancing education and outreach programs; federal agency consultations under ESA; new vessel operational measures (routing measures and speed restrictions); and negotiation of a bi-lateral conservation agreement with Canada.

In 1999, NOAA established Mandatory Ship Reporting (MSR) systems in two locations. Under the Systems, ships 300 gross ton and greater, are required to report to a shore-based station when entering these areas. In return, reporting ships receive an automatic message about ways to reduce ship strikes and recent sighting information about right whales. Incoming reports have provided a means to assess vessel traffic in these areas. Such approaches systems may not be applicable in Southern California because certain aspects have been supplanted by use of vessel AIS.

For routing measures, NOAA established recommended routes in certain areas. Although voluntary, use of the routes appears to be high and may be attributable to their being printed on NOAA nautical charts. Working with the USCG, NOAA also approached the IMO to establish an ATBA (established in July 2009) and to modify the TSS servicing Boston, MA. Again, although voluntary, compliance with both appears to be good. The IMO review and endorsement of the ATBA took approximately 18 months. An additional measure, vessel speed restrictions of 10 knots or less, was established in key right whale aggregation areas (or "Seasonal Management Areas, SMA), including 20 nm "bubbles" around key ports along the mid-Atlantic and apply to vessels >65ft. Sovereign and state enforcement vessels are exempt and exceptions can be applied in inclement weather. The rule expires in 5 years and includes a requirement to monitor effectiveness of the regulation. A program was established to monitor adherence to the restrictions using AIS, and to date, compliance has been low. Analysis of AIS data indicate that: most traffic is that of cargo vessels and tankers; most vessels are foreign flagged (62% vs. 38% domestic); and domestic vessels are more likely to comply than foreign-flagged vessels. It is not clear why compliance is low, but is likely linked to poor early enforcement or that SMAs were not noted on nautical charts. NOAA also created voluntary dynamic management areas (DMA), which are based on sightings of greater than 3 whales; thereby being reactive to whale presence. These DMAs are temporary (15 days) and voluntary, asking that mariners route around the area or traverse through it a 10 knots or less.

Measures described here are likely among the handful of management steps that can be taken to reduce ship strikes, and some may have application in California waters. However, right whale distribution is known, and generally predictable along the coast. Large whale occurrence and distribution in California waters is less predictable.

Papers Distributed:

Silber, G.K., and S. Bettridge. 2010. Vessel operations in right whale protected areas in 2009. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, NOAA-Tech. Memo NMFS-OPR-44, July 2010. 44 pp.

Garrison, L.P. (Unpublished). Applying a spatial model to evaluate the risk of interactions between vessels and Right Whales in the southeast United States critical habitat. October 14, 2005.

Websites:

http://www.nmfs.noaa.gov/pr/shipstrike/
http://iwcoffice.org/sci_com/shipstrikes.htm

PHILIP MCGILLIVARY, US COAST GUARD PACAREA

Technologies and Ideas

The USCG has a vested interest in vessel collisions with whales. In Alaska, there has been a spike in animal mortality from harmful algal blooms in the Bering Strait and an issue with ships colliding with dead whales ("floaters") has resulted. Oil exploration off the North Slope has resulted in a variety of new technologies used by oil companies to reduce collisions with whales (generated by Eskimo whaling community concerns). Environmentally adaptive vessel routing could include variations in ice and animal migrations. AIS is old technology, but we could improve its capabilities (*i.e.,* get a larger bandwidth system with more capabilities for a two-way system which could enable us to send out whale information to vessels) and improve whale-ship avoidance. However, there are limitations to AIS; there are security risks with mariners knowing where whales are located (*i.e.,* can't transmit information using satellite technology). Space Quest is a commercial system of shipping data that provides worldwide real-time data. Shipping is increasing at roughly 3%/annum. Shipping routes are changing to affect more prime whale habitat and high speed ferries are increasing in number worldwide; thus, there are increasing collision risks. Whale detection capabilities have been proven using both fixed hydrophone moorings, and hydrophones on AUVs and ASVs (autonomous underwater and autonomous surface vessels). We could use monitoring hydrophones to follow whales and use inexpensive autonomous vehicles to provide a moving 'fence' around populations in critical areas. Another potential technology is delay and disruption (using wave energy to power) tolerant wireless networking using an acoustic underwater modem that should be available soon [see http://www.dtnrg.org]; this would increase the bandwidth of hydrophones. WaveGlider (real-time control) can be developed to track whales with hydrophones and can an act as communication nodes for underwater Remotely Operated Vehicles (ROVs) [see www.liuidr.com]. RoboKayaks are typically used in threes for whale monitoring via hydrophones; they are equipped with a CTD (to measure the Conductivity, Temperature, and Depth) and can profile the water column. There is also the Southern California Coastal Ocean Observing System (SCCOOS) which is an open source of data on surface current mapping data using 12 gliders and surface vessels for monitoring [http://www.sccoos.org]. In summary, we can use the technology with systems already in place to get better data on what the whales are doing.

Paper distributed:

Gervaise, C. and M. Andre. 2008. Theorie de l'estimation appliqué a l'etude de performances d'un system d'anti-collision entre cachalots et navires. [Theory of estimation applied to the study of performance of an anti-collision system between ships and whales].

Websites presented:

http://www.listenforwhales.org
http://www.dtnrg.org
http://www.sccoos.org

SUMMARY AND CONCLUSIONS

Following the break-out group discussions, workshop participants concluded that the ship strike issue is complex and that reducing the co-occurrence of whales and vessels is likely one of the only certain means of reducing vessel collisions with whales. However, participants noted that this may not always be feasible in all areas where co-occurrence occurs. Although information on whale and ship distribution exists for certain areas along the West Coast of the U.S., more information is needed for a broader analysis. More work is needed to combine existing data and future research is needed in areas where currently there is little information on whale and ship distribution. Participants identified five workshop recommendations/action items listed below:

1) **Whale Data:** The Southwest Regional Office (SWR) should officially request that the Southwest Fisheries Science Center (SWFSC) take the lead in organizing and convening a working group in the next 6-12 months to collate available whale distribution data to develop a model, for the purpose of determining whale density in the Santa Barbara Channel, include marine spatial planning principles, and display the results using GIS mapping technology.

2) **Severity of Threat to Whale Populations:** Identify methods to determine potential impacts to whale populations (*i.e.*, significance of threat) along the U.S. West Coast.

3) **Additional Data Needs:** A process for discussions of data gaps and data needs in the immediate- and long-term should be developed. In addition, a process to determine priorities; allocation of money, time, and effort; and methods of collecting data (likely a conference call with participants) should also be developed.

4) **Shipping Data:** NMFS should convene a workshop with those familiar with shipping information to collate available information to combine with information collected in Recommendation 1. It is expected to have cross-participation of certain members from both workshops identified in items 1 and 4.

5) **Port Access Route Study (PARS):** Some, but not all, participants of the workshop expressed their intent to send comments to the U.S. Coast Guard on the proposed PARS study for the Los Angeles area.

APPENDIX 1: List of Participants

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APPENDIX 2: Final Agenda

Day 1
Presentations will focus on improving the understanding of the risk of vessel collisions with large whales, with an emphasis on those that occur along the U.S. West Coast. This will provide an opportunity for participants to share their work, discuss their methods and the challenges/limitations faced with conducting their work. Throughout the presentations, NMFS will be creating a database to synthesize all currently available information to share with the group on Day 2.

13:00 – 13:30: Welcome and introductions
13:30 – 14:00: Workshop framework; Vessel collision stranding information from the U.S. West Coast; Current management activities (DeAngelis, Wilkin, Petras, CINMS, Agness)
14:00 - 16:00: Whale distribution
Focus on current efforts to understand large whale distribution with an emphasis on the U.S. West Coast (Calambokidis, Mate, McKenna, Perryman, Barlow, Palacios)

14:30-14:45 Break
16:00-16:15 Break

16:15 – 18:00: Whales and vessels
Focus on modeling, vessel information, and management (Williams, Vanderlaan, Silber, USCG)

18:00: Day 1: Wrap-up and Review

Day 2
Discussions will occur as a forum to promote the exchange of ideas. Goals are to synthesize available data sources, identify data needs, discuss how to fill data gaps, and create a foundation for future scientific research and management actions for reducing the risk of vessel collisions with large whales.

9:00 – 10:00: Plenary session – Review of compiled/synthesized data from NMFS database (Day 1) with input from group (Southwest Regional Office)
10:00 – 12:00: Break-out groups with focused questions (All)
12:00 – 13:00 Lunch (on your own)
13:00 – 15:30: Group discussion on data needs, data gaps, how to move forward, revisit NMFS database, etc. (All)

14:15-14:30 Break

15:30 – 16:00: Workshop wrap-up, products, and next steps (Southwest Regional Office)

APPENDIX 3: Summary of Day 1

May 20, 2010
[9:00-10:00]

The group summarized the discussions from Day 1 at the beginning of Day 2 and discussed important points from Day 1. Those are presented below.

- Probably more collisions than we know
- Vessel routes—not necessarily well known—but might gain some insight through projects
- Archived shipping data (to our knowledge not looked into on the West Coast)
- Might be other possible methods to get ship information
- Have seasonal whale data for certain years, places, and scale
- Variety of options for modeling—use what we have, fine-tune, or possibly develop new ones
- GAM information and encounter rate models
- Possibility to predict encounters, but are we missing too much?
- Every vessel could be involved in a collision
- Every species could be involved in a collision
- Baseline information is available and need to coordinate to evaluate effectiveness of any future action to minimize risk (*i.e.*, outreach, alter routes, etc.)
- Do have trends in shipping traffic and insight on vessel presence (*i.e.*, peak times of transit)
- Impacts CARB or economy may have on vessel traffic: Shipping may resume in Santa Barbara Channel or current routes may remain and actually continue to develop outside Santa Barbara Channel
- There are a variety of techniques available to survey (whales/vessels) and we may be able to modify current techniques to gain more information or incorporate novel techniques
- Insight on whale behavior including diurnal prey/feeding
- Need to consider oceanographic information
- Need to consider environmental variables
- Need to consider physiographic variables
- There have been proactive successes—*i.e.*, cruise lines
- Insight into behavioral response of whales post- close encounters
- Quantitative approaches to assessments have been used
- Clear differences/similarities between West Coast and other areas where ATBA has been accepted
- Pre/Post- ATBA, including voluntary, produced quantitative differences
- We don’t have a good handle on outreach, but opportunities exist
- Might be able to get real-time information
- Might want to consider a means to synthesize data
- No central coordination on West Coast (research, outreach, etc.)
- PARS study may give chance to analyze these issues further and get ship strike issue into analysis
- USCG interested in systematic approaches into measures in the Pacific that are not similar to what has been done in other places

- Marine Spatial Planning process may be important new initiative where this issue could be incorporated into organized framework
- Economics and economics of enforcement must be part of any analysis of any measures or spatial planning effort
- Spatial planning gravitates to more data rich applications than data poor applications
- Coastwide versus local effort? Focus on certain areas initially may be more appropriate and then will lead to a larger effort

APPENDIX 4: Questions for break-out groups

20 May 2010
[10-12:00, 13:00-15:00]

These questions were distributed to the 4 break-out groups to stimulate discussions. Results from break-out group discussions are presented in Appendix 5.

Available Data

1) What information do we have?
2) Do we know where the whales are?
3) Do we know where the ships are?
4) What is the best method to accomplish answering the above questions?
5) Is the assumption that More Whales+More Ships=More Vessel Collisions? What supports this assumption? Are there examples where this isn't the case?

Augmenting Data Set

6) If we modify a component of currently practiced research/information gathering can we obtain more data? Suggestions?
7) Formal research collection versus other data sources? Is there a way to combine so we have considered all of the available information? Can formal research be modified to mimic the collection of these other data sources that would allow for a smoother analysis of all available data sources? Suggestions?
8) Regulatory Tool—can we ask project applicants to conduct surveys as part of monitoring requirements for their project? If so, what information would we ask to be collected and how?
9) Is current research more about understanding why vessel collisions occur or determining ways to minimize risk? Can we do the latter without the former?

Analysis

10) Can we do anything with the information we currently have?
11) Is there anything that we know that is a potential "dead stop" from moving forward?
12) Provide feedback on analysis of best available science versus best available information and how each could influence decisions (i.e. criteria to publish or make a management decision). Is there a limit to how "imperfect" data can be in order to make a decision?

Risk Assessment

13) Are vessel collisions a threat to the recovery of cetaceans? If so, are there certain species that are more vulnerable?
14) Are there areas of higher risk? If so, why?
15) Can we identify areas or criteria (perhaps based on whale or vessel behavior) where there is a risk of potential encounters between whales/vessels?

Behavior

16) Are there characteristics about whales that make them more likely to be involved in a vessel collision? Or put whales at a higher risk? Is the collection of oceanographic/habitat information important regarding detection of animals in an area?

17) Are there certain characteristics about certain vessel-types that could cause them to be involved in vessel collisions with whales? Are there characteristics about the vessel that are more likely to cause an injury versus mortality?

Reporting/Detection

18) Detection once a vessel collision occurs—Which species might be more detectable (float)? Are there areas where, if hit (based on currents, etc.) there is a higher likelihood or lack of detection (i.e. where could they go)? Is the collection of oceanographic information important regarding detection?
19) Reporting of vessel collisions with whales. Based on your experience, what do you suggest would be an effective method for reporting (i.e. think of different scenarios—you are out at sea or in a plane—so internet limited; cell phone coverage may be spotty; do you wait until you return to land, etc.). What is the lowest standard for reporting information?

General

20) If you had X funding, what would you spend it on?
21) In general, how would you characterize the vessel collision/whale issue? If it is a concern (for whatever reason) what would you do to solve this issue or alleviate the concern? If you don't think this is a concern, why not?

Real-World Example:

What are the critical elements to develop a framework to evaluate risk of vessel/whale collision? No need to analyze the areas, per se, or come up with a conclusion.

The intent is to apply this framework anywhere, but we picked the following two locations in California.

Location 1: Santa Barbara Channel
Location 2: Entrance into the Port of San Francisco

APPENDIX 5: Summary of Break-Out Group Discussions

20 May 2010
[10-12:00, 13:00-15:00]

See Appendix 4 for list of questions presented to each of the 4 groups for discussion. Groups discussed developing a framework to analyze the risk of vessel collisions in two areas, the Santa Barbara Channel and San Francisco Bay area, California. The questions were used to trigger discussion among the participants. In the afternoon, each group presented the results of their discussion. They are summarized below.

GROUP 1

1) Put together information: What information exists; What information do we have, is it sufficient?; Identify data gaps, identify means to fill those gaps, synthesize data.
2) Assess the level of threats.
3) Examine overlap between whales and ships; "Is there a problem?" May not have been looked at in San Francisco Bay area like it has in the Santa Barbara Channel
4) Possibly set up "no ship areas;" discrete areas for species.
5) Options – ATBA, TSS shifts.
6) Combine DMA and ATBAs.
7) Need compliance. Need to be able to support the areas chosen and quantify (economic impacts, etc.).

GROUP 2

1) Modeling work from other places could be applicable, but components need to be in common currency (density models, data sets, scale, etc.). Begin quantifying the seriousness of the risk. Conduct sensitivity analysis to characterize what you know and what you don't know. Perhaps a species-specific analysis across the range (looking at species status), by season, etc. Determine ways to estimate what the real number of strikes are based on limited reports.
2) Identify absolute risk areas, model the highest risk areas, etc.
3) Continue documentation of whale behavior near ships (is ship spacing important?)
4) Begin modeling the ability to reduce risks via proposed scenarios, Modeling effort should including shipping intensity for the region of interest, AIS data or other sources (*i.e.*, Marview), and whale response behavior.
5) More effort into necropsy of stranded animals. Increase stranding network response.
6) Look at vessel strikes similarly to fishery bycatch analysis (*i.e.*, strikes are the bycatch of the shipping industry).
7) Compare vessel strike risk to other threats.

GROUP 3

1) The idea is to minimize risks (rule out things that may add to the problem). Focus on animals that we know more about, closer to the coast.
2) Outreach/education, enforcement, compliance, and monitoring are critical.
3) Minimize large vessel traffic on the continental shelf; Focus efforts on great circle route vessels.

4) Incentives – Slowing down near the coast provides incentive if a vessel is allowed to go full speed off the coast.
5) Analyze cost to determine economic impact of vessels staying 40 miles off the coast.
6) Data are available to analyze ship traffic.
7) Consider large areas of speed restriction and hotspots.

GROUP 4

1) Whale data
    a. Sighting and effort data need to be reported
    b. Behavioral responses to vessels (slow vs. fast, noisy vs. quiet) by species, age, and sex need to be further documented.
    c. The area south of the Santa Barbara Channel is a datum gap
2) Ship data
    a. Recognize the importance of AIS data and the archival/accessibility of other sources, including resolution of data and effort
        i. Use International Comprehensive Ocean-Atmosphere Data Set (ICOADS) for areas outside the Santa Barbara Channel and for determining pre-AIS historical patterns.
    b. Use current technology to try and figure out how many strikes go unreported, using strike incidents from certain types to estimate others.
    c. Use existing data/interviews to predict future patterns to better understand the logic of the shipping industry, so that we can make better predictions.
    d. Create a virtual observer program to detect strikes.
        i. Unreported strikes
        ii. Compare per mile travel by Navy ships vs. industry ships and reported strikes, to determine discrepancies between the two.
3) Analysis/Integration
    a. Create a uniform database (Whale/AIS) to encompass sightings/effort and AIS data.
    b. Create a density surface/spatial model/habitat model that includes fixed variables (*i.e.*, bathymetry).
    c. Create a probability model for strikes – putting together ships and whales
        i. At varying spatial scales
        ii. Using physical habitat in areas of poor data
    d. Back analysis of 2007 Unusual Mortality Event data to help predict future risk – can we identify some predictors or common factors from that year?
4) Management
    a. Coordination of data/analysis/modeling by NOAA
    b. Take Reduction Team (TRT)-type process to reduce ship strike mortality (TRT used in fisheries).
        i. Use existing Southern California Bight data for PARS immediate action

APPENDIX 6: Summary of Whale Source Data Collection

During the workshop, SWR requested that those workshop participants with whale distribution information fill out a form to turn in at the conclusion of the workshop to document their sources and information including: contact information, data type, whale species covered, spatial and temporal coverage, and publication information. We aimed to collect source information on eight species of large whales: blue, Bryde's, fin, gray, humpback, minke, sei, and sperm whales. At the conclusion of the workshop we received contributions from 11 sources, including scientists, researchers, and the military. The summarized data are reflective of only those that contributed their information, thus we intend to expand the source data to include information from others, specifically naturalists and whale watching vessels. Source data records include eight data types: aerial surveys, models, passive acoustics, pop-up tags, satellite tracking, stranding networks, vessel observations, and vessel surveys.

The geographic coverage is for the entire West Coast of the United States, from Washington to California. However, the full spatial coverage is not consistent throughout the year. SWFSC research cruises provide an excellent look at distribution for almost all species, but data are limited to the summer/fall months. Satellite tags are also good indicators of long term whale movement but are limited in numbers and species. The data sources that were shared have concentrations in southern California and Washington. Once again, this is a reflection of the workshop participants.

This information, combined with expanded source data, will be useful for establishing a baseline of whale presence along the U.S. West Coast. It will be a useful tool for the participants of the workshop described in Workshop Recommendation/Action Item 1 for mapping whale presence and distribution. The data can then be used in comparison with ship traffic or risk analysis associated with vessel collisions. Wider application of these data may include risk analyses of whale entanglement in fishing gear, LNG projects, hydrokinetic/renewable energy projects, and a variety of others not listed here.

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