Killer Whale / Oil Spill Workshop

Co-Sponsored by NOAA Fisheries and UC Davis Wildlife Health Center's SeaDoc Society

October 11 and 12, 2007
NOAA Sand Point Facility, Seattle, Washington

Background: The objective of this workshop was to provide an opportunity for researchers, oil spill responders and stakeholders to discuss what tools could be effective to deter killer whales from an oiled area and to identify available resources for doing this during a spill. Based on the results of the workshop a plan for dealing with killer whales during an oil spill will be drafted and submitted for inclusion in the Northwest Area Contingency Plan for oil spills.

Meeting Notes

(Prepared by Joseph K. Gaydos)

Thursday October 11, 2007

Welcome and introductions

Lynne Barre: The Proposed Recovery Plan for Southern Resident killer whales identifies oil spills as a primary threat for the endangered Southern Residents. One of the objectives in the recovery plan is to "Maintain protection from oil spills and improve oil spill response techniques for killer whales." To achieve this, it will be important to develop strategies to deter killer whales from entering spilled oil and to develop a killer whale- specific component to the wildlife section of the Northwest Area Contingency Plan. It is for this reason that NOAA and UC Davis Wildlife Health Center' SeaDoc Society are co-organizing this meeting.

Joe Gaydos: The group was asked if anybody objected to taping the meeting so that it could be viewed by people who could not attend. There were no objections and the meeting was taped. Everybody in the room was thanked for participating and asked to identify themselves and the organizations that they represent (see Appendix 1, list of attendees).

Northwest Area Contingency Plan and Marine Mammals

Don Noviello: The "bible" for spill response in the Northwest is the NW Area Contingency Plan, which is now in its 10th edition. The purpose of the plan is to make sure there is effective response in the area. The role and function of the Incident Command Structure (ICS) was discussed and it was pointed out that the Wildlife Branch works under the Operations Section. The Wildlife Branch coordinates all personnel working with wildlife, including federal, state, and local agencies along with commercial and non-profit organizations. This is where any work with Orca or any other marine mammal is going to be coordinated. The duties of the Wildlife Branch are called out in the NW Area Contingency Plan. Basically they are responsible for the implementation of the Northwest Area Wildlife Response Plan. Their goal is to minimize the impact on wildlife by preventing oiling and responding to oiled animals. All of the marine mammals and other wildlife work must be done in accordance with existing laws such as the Marine Mammal Protection act and the Endangered Species Act. Under the Wildlife Branch, there is a Wildlife Reconnaissance Group. It is their job to locate the wildlife being impacted by oil is located and report findings to the Wildlife Branch. Within the Wildlife Branch, under marine mammals there is a Marine Mammal Recovery and Transportation Unit, a Marine Mammal Hazing Unit, and a Marine Mammal Rehabilitation Unit. Regarding Orca, some of the detail missing and questions that still exist include:

- Detail on potential options for using deterrents to keep orca out of a spill
- Currently the Wildlife Branch Director is authorized to handle or haze wildlife, however there currently are no criteria on when and how this should be done. Regarding marine mammals, NOAA has the authority. Should a plan be set up with NOAA before a spill?
- When should hazing be considered? Should a plan be developed or just criteria for hazing?
- What types of hazing should be considered.
- What qualifications are needed by the people who would do this?
- How do we measure success?
- When is enough hazing enough? Who makes that call?
- What safety procedures are required for people who are engaged in those activities?
- How would hazing be addressed under the Endangered Species Act. Will we be hindered by a section 7 consultation during a spill if this is not addressed before a spill?
- What about situations where multiple species could be hazed simultaneously (intentional or not intentional) – does there need to be simultaneous authorization by USFWS and NOAA?

Note: Washington also is currently working on a draft Oiled Sea Otter Response Plan. California already has a species-specific plan for sea otters.

Questions and answers:

1. Under ICS, the environmental unit works with the Wildlife Branch.
2. Currently, there is no list of who the wildlife experts are that would be called in to advise the Wildlife Branch on wildlife issues.
3. Currently there is a Canadian / US structure for working with specific species during an oil spill. This is important because Orca are transboundary in nature.
4. Hazing is the responsibility of the spill responders. Some of the resources for spill response are from the state and some of them are from industry. The details of this are still being worked out.

Oil and Cetaceans: NOAA Manual, toxicity, and pathology

Shawn Johnson: Basic petroleum chemistry was discussed including the size, evaporation, solubility and toxicity of VOCs, medium PAHs, and heavy PAHs. It is difficult to generalize oil toxicity due to the complex mixture of toxic components. Oil exposure can be external, such as epidermal or ocular irritation / ulceration or internal from ingestion or inhalation. Epidermal or ocular irritation can lead to secondary bacterial infections as can gastrointestinal irritation. Volatile compounds have been known to cause pneumonia and emphysema in sea otters after the Exxon *Valdez* oil spill. These types of lesions occur during the first 48hrs after the spill before the highly volatile compounds evaporate. Animals can ingest oil secondary to grooming or nursing or via ingestion of contaminated prey. Once in the GI tract, oil can cause mucosal damage such as ulcers and bleeding leading to secondary maldigestion and malabsorbtion. Oil exposure has been known to cause anemia and immunotoxicosis in some species. Additionally early embryonic death, decreased pup survival and increased pup abandonment has been

documented in sea otters, mink (experimentally) and harbor seals. Population level effects can negligible to severe, including massive declines in abundance, changes in population distributions, age-class shifts, loss of genetic diversity or even extinction.
Research on Cetacean response to oil is limited. Geraci, et al. (1984) showed captive bottlenose dolphins could detect and avoid oil slicks over 6mm thick. The tactile sense was most important for detecting oil in this captive setting. Researchers found that after the 1990 *Mega Borg* Oil Spill in the Gulf of Mexico free-ranging bottlenose dolphins were able to detect slick and mousse oil, but not sheen oil (Smultea and Wursig, 1995). Dolphins near the oil swam closer together, decreased respiration rates, increased dive times and rates of reorientation. Anecdotally, after hurricane Katrina, it appeared that there was no avoidance of spills by free-ranging captive dolphins that escaped during the hurricane.

Cetacean skin is thick and has a high turnover rate (Brown et al., 1983). There is no indication that short-term exposure to oil causes epidermal or dermal pathology in cetaceans. Contact studies with cetaceans showed that acute exposure to gasoline and crude oil showed pale color, but appeared normal grossly within 2 hours. Additionally, oil exposure did not decrease healing of dolphin skin (Geraci and St. Aubin, 1982)

A brief discussion was given regarding response and processing of dead cetaceans during an oil spill. Proper sample collection is vital in order to determine if oil exposure was the cause of mortality. A draft copy of the NOAA Marine Mammal Oil Spill Response Guidelines (Johnson and Ziccardi, 2006) was handed out to all participants and contains details.

Exxon *Valdez* Oil Spill (EVOS) and killer whale mortality
Craig Matkin: Data collected during the 16 years following the grounding of the Exxon *Valdez* in Prince William Sound was discussed. Cetaceans don't necessarily avoid slicks, even during the best of conditions. Both the AB pod and the AT1 groups of whales were exposed to oil during the EVOS. There was a decline in AB pod following the spill. Prior to the spill, it was the most commonly sighted group in Prince William Sound. Post-spill they have been difficult to locate. There were 35 animals in 1984, declining to 31 in 1987 and rebounded to 36 in 1988. In 1985 there were 13 individuals with bullet wounds secondary to interaction with the long-line fishery. Four wounded whales died in 1985-87 and 4 died following the spill, however, unlikely from the wounds they incurred three years previously. Six days after the spill, 7 whales were missing, and the following winter 6 additional whale died (for a remaining population of 23). Deaths included 2 juvenile males, six unsexed juveniles, and 5 reproductively mature females. The number of deaths was 18 times that expected based on the age and sex structure of the pod using life tables for the populations. Carcasses were not necropsied or not found for any of the mortalities. Two males AB2 and AB3 had fins collapse at the time of the spill died in 1994 and 1996. It is hypothesized that a fin going down is a sign of stress or disease. Following the spill, AB pod has been less productive (1.6% increase) as compared to other pods in the area (3.3% increase) and this is thought to be due to losing 5 reproductively mature females. Before the spill, the AT1 transients had several prominent subgroups; the total number of whales was 22 from 1984 to 1989. Their range was limited to Prince William Sound and Kenai Fjords where they feed primarily on harbor seals and Dall's porpoise. In this region, the harbor seal population has been on a 30 year decline. The AT1 population is known to carry high PCB and DDT levels prior to

the EVOS. AT1s were seen frequently following the spill (likely eating oil-impacted harbor seals) and 9 AT1s disappeared the winter following the spill and deaths included 2 reproductive females and 2 maturing juveniles. Another male (AT11) died in 1990 and female AT12 died in 1991. No additional animals have died between then and 2000 and between 2000 and 2003, 4 more died. It is circumstantial evidence, but both the resident AB pod and the transient AT1 pod had a significant decline after the EVOS.

Robson Bight oil spill and killer whales

Rob Williams gave background information and set a biological context for Robson Bight, killer whale use of Johnstone Strait, and the recent accident that spilled petroleum products in the area. On 20 August 2007, a barge, carrying logging equipment and a diesel fuel truck, tipped over in Johnstone Strait, releasing approximately 20,000L of petroleum products. At the time of the workshop, the equipment was still on the seabed, but it is unknown how much oil remains in the equipment and containers.

Rob outlined a quantitative risk assessment framework that would allow objective identification of high-risk areas: that is, places in which whale density and shipping intensity overlap strongly. Because of physical and biological reasons, a good proportion of the Northern Resident Killer Whale population spends a disproportionately high amount of time in this area. A long-term systematic study evaluating whale usage of Johnstone Strait identified that whales were in the study area on 50-90% of summer days between 1995 and 2002. Additionally, the maximum number of whales present on any given day reached a high of 140, providing the potential for an oil spill in this region to cause dramatic, population-level impacts. When a large proportion of the population is present in an area, whales are very vulnerable to catastrophic events. The Robson Bight study area represents only 0.001% of the NRKW range, but an average of 6.5% of the population was present on any given day of the study. During the 20 August 2007 accident, as many as 60 animals (~25% of the population) are thought to have been exposed to the fuel. Rob proposed a quantitative risk assessment framework for identifying times and places to which particular attention should be paid, and in which to set priorities for prevention and preparedness measures. For example, coast-wide data showed killer whale distribution to overlap most strongly with intense shipping traffic in Johnstone Strait, which is a fairly remote region with few large human settlements. Rural areas that are found to represent such high-risk areas may need particular help in advance in order to be prepared for oil spills.

Marilyn Joyce discussed the incident command structure in Canada and how they responded to the Robson Bight spill. What the spill highlighted for them is that the more work they do ahead of time on their plan, the quicker you can put your plan into action and the less time you spend discussing your plans. Immediately after the spill (within the hour), Marilyn got an email asking for the risk to marine mammal species in the area. A priori risk assessment is important. Also important is having a list of potential protection actions already in place (what can be done). Next, there is a question about what can be done if animals are oiled.

From this event, it is clear that monitoring before, during, and after an incident are important tasks for which protocols, developed in advance, are necessary. Initially, the question is where the whales are, where the oil is, and what the risk is. Tracking during the spill is a crucial task to continually update the risk assessment and plan for any necessary protection activities. Follow up monitoring is also necessary to determine any adverse effects.

It is necessary to keep in mind that all information collected may be relevant to the collection of evidence. Finally, there are scientific questions that may be addressed in a well thought out monitoring protocol that will assist in planning for future spills and understanding the impact of spills on killer whales. The more of this that in place before a spill, more efficient and effective the response.

Highly volatile oil had spilled in an area that was critical for killer whales. However, the spill was restricted to a narrow corridor and being dissipated quickly so they chose not to use whale deterrents during this spill. Although the trajectory of the spill indicted that it was unlikely to hit the rubbing beaches, due to the importance of the rubbing beaches, they decided to do everything they could to protect the rubbing beaches and they did use booms, which would not have been called for in this spill scenario. Whales were monitored by various government and non-government researchers during and after the spill. It is intended that this information will be consolidated to evaluate any chronic long-term consequences. They did not see immediate behavioral changes. It did not come up in this case, but Canada historically has had concern about getting necropsies done and identifying who would pay for it.

Sacramento humpback whales: ICS, methods tried, what worked/didn't work, other issues
Sarah Wilkin discussed the May 2007 incident when two humpback whales entered San Francisco Bay and moved up the Sacramento River. On Wednesday, May 9th, two whales were reported off of Benicia. At first it was believed they were gray whales, but later they were identified as humpback whales. It was thought that they were entangled and concerns were raised when they were initially seen 50 miles from the ocean; they eventually swam all the way to the Port of Sacramento turning basin 90 miles inland. Twenty-two years ago a humpback whale, "Humphrey" swam up the Sacramento River and later did finally leave the area, following the use of many deterrent methods.
Questions that were raised to NMFS as the trustee agency included (1) where did the whales come from (which population or stock did they belong to)? (2) what was their health status? (3) what was the impact of fresh water on these animals? and (4) what options exist for moving the whales back down the river? The whales were identified as a likely California feeding aggregation, but although fluke photographs were obtained for both animals, they were not matched to any photo-ID catalog. Over the first three days that the animals spent in the Port of Sacramento, their health status was visually assessed and whales' behavior monitored. It was quickly determined that both whales had lacerations and were not actually entangled. They attempted to lure whales down river with sounds of humpback whales feeding and sounds from whales mating, which proved unsuccessful. On May 19th, a formal Incident Command Structure (ICS) was set up with NOAA as the Federal On Scene Coordinator. California Department of Fish and Game was the State On Scene Coordinator, and the Local On Scene Coordinator, assigned based on the location of operations, changed as the whales moved. A CDFG employee served as the Public Information Officer, and the US Coast Guard Auxiliary provided an experienced safety officer. Within the operations branch was the "Whale Team." This included at a minimum a team observing the animals on the water as well as any other boats attempting to haze or sample the animals. In this ICS, the Logistics and Finance branches were combined, but

didn't have much to do because there was no budget for this operation. Very important to the ICS was the Joint Information Center set up under the Public Affairs Officer, which included members of most of the participating agencies and partners. The JIC conducted daily press briefings and interviews for the numerous interested media, and took calls and e-mails from the public.

The whales spent several days at two points on their journey: the Turning Basin, and then north of the Rio Vista Bridge. Many different techniques were attempted to haze or direct the whales downstream. Acoustic deterrents included humpback whale sounds meant to attract the animals (played downstream), as well as adverse noises (killer whale calls and alarm sounds) that were played upstream of the animals. An extensive pipe-banging effort with numerous boats was conducted for 3 days. None of these acoustic methods appeared to impact the movements of the whales. Arrangements were made to borrow Low Frequency Active Sonar transducers for the effort, but these were never used. Fireboat hoses sprayed in front of the surfacing whales did cause them to turn 90 degrees, but with only one fireboat, the animals easily maneuvered around it. The animals were successfully biopsied, and a skin scraping was obtained. Due to changes in the whale's skin texture and the deteriorating condition of their wounds, it was decided to attempt to remotely deliver antibiotics. A specialized firearm developed for use in the sedation of entangled whales was borrowed for this purpose. Donated antibiotics were obtained from Pfizer and Bayer, and they were compounded into the necessary concentrations by Grandpa's Compounding Pharmacy. The antibiotic delivery was successfully accomplished, with one 60 cc dart injected into the calf, and 3 darts given to the adult. This occurred on May 27th, the Saturday prior to Memorial Day.

The use of multiple fireboats (as well as a combination of other methods that were individually unsuccessful) was planned for the Tuesday following Memorial Day. However, the whales moved under the Rio Vista Bridge on Sunday, and kept going until they stalled at Benicia Bridge for another 24 hours. However, they were in saltier water; their body condition seemed to improve and they were making deeper dives. They spent a total of 3 days in the northern part of San Francisco Bay, and it is believed that they left under the Golden Gate Bridge at night. They have not been re-sighted since. The media and general public were very interested and full of ideas.

Primary successes included protecting whales during their time in the river; the safety of the response participants and public, the public outreach and joint information center, the return of the whales to the Pacific Ocean, the significant on and off-site support including the availability of resources that would not be part of a stranding response under normal circumstances, the interagency cooperation, remote delivery of antibiotics, the gaining of scientific information (as essentially these animals received focal-animal follows for close to 2 weeks), and others. None of the deterrence methods attempted were successful in controlling the behavior of the whales, but we will be assessing the data collected to develop better techniques for use with mysticetes. Undoubtedly, the use of the Incident Command Structure was crucial for the success of this operation, and it should be implemented in future rescue or stranding situations involving many people and partners.

Killer whale hazing tactics

David Bain discussed options for hazing or deterring killer whales from an oil spill. Definitions were given for habituation, fatigue, masking, and middle ear reflex as they pertain to deterrents. Historically, types of hazing devices have been used in a variety of contexts: entrapment, military exercises, collections for public display, fish farms, fishery interactions, playback experiments, and disturbance studies. Things that have worked with cetaceans historically include:

- Oikomi pipes: Oikomi pipes are reverberant metal. Killer whales resolve pulses 10x better than we do. When recordings of a resonating pipe are slowed down 10x so we can perceive them the way killer whales do, they sound like thunder. The sound and timing is variable enough between presentations that killer whales probably won't habituate to them. It is important to use a lot of oikomi pipes and at Barnes Lake fewer than 200 yards were left between boats.
- Mid-frequency sonar: Mid-frequency sonar is the other extreme of the technology spectrum. When the *USS Shoup* was using mid-frequency sonar in Haro Strait, J-pod avoided the noise while it was 22 km away, especially when the sound was not obstructed by islands or shallow banks. Mid-frequency sonar may have dangerous effects if improperly used, including lethal effects on some species.
- Seal bombs (small explosive devices): Seal bombs are explosive, so using them poses the risk of injury to people and to whales. They were not used in the Barnes lake example because people were concerned with pushing whales on shore.
- Airmar acoustic harassment devices: Airmar devices are metal banging metal. When they are slowed down they sound like thunder. Work done around fish pens (Morton and Symonds, 2002) showed they kept killer whales out of an area. Olesiuk et al. (2002) found that they kept 95% of harbor porpoises out for a range of about 3 km (these are fairly useless with pinnipeds). Matkin reported on using them around long-lines in the Prince William Sound sable fishery, but they didn't work well, possibly because there was too strong an attachment to the benefits of being there. Marilyn Joyce commented that these worked in keeping Luna out of a harbor, but were unsuccessful in driving him out if he came into the harbor while they were off.
- Killer whale calls: These devices can be operated off small boats and could be modified to be portable. There have been no rigorous experiments on the use of killer whale calls as deterrents or attractants and this should be better studied. In instances where they have been tried, the sample size is small. Ford found that if you play a whale's own calls back to it, it will basically attack you. In one occasion, calls from other whales in the community played to community members did not seem to result in any consistent movement patterns. In the right circumstances they could be used to attract whales with limited success. Using calls from other whales in different communities, there could be some repulsive values. In conclusion, there would be no predictive value, you could just as easily attract whales as deter them or have no effect at all.

Things that have failed include acoustic deterrent devices (pingers – 132 db), vessel traffic (does change behavior, but won't move them out of an area), gunshots, cracker shells (smaller, safer versions of seal bombs) and fishing nets.

Things that haven't been tried include pulse power deterrents (it is unlikely that these will work), air guns (which have worked or porpoise in seismic surveys and arrays can be even more powerful than mid-frequency sonar), taste aversion and scent deterrents (more for fisheries interactions; won't likely work in an oil spill setting), white noise (is highly disturbing to captive killer whales), low frequency sonar (which is low enough that killer whales won't hear it well and it likely won't be as effective as mid-frequency sonar), acoustic tomography and associated underwater ROV control signals (which have caused some displacement of Dall's porpoise) and industrial noise (pile driving, construction equipment, etc).

A voting exercise was done where people were asked what they felt about which deterrents would be acceptable for use to keep killer whales from an oil spill slick. They were given three votes and asked to vote for the techniques they felt were most practical, while still being acceptable. Results were:

Oikomi Pipes	20	Seal Bombs	6
Mid-frequency sonar	20	Bubble curtains	5
Acoustic harassment devices	12	Vessel traffic	3
Killer whale calls	11	Air guns	2

Friday October 12, 2007

Permits
Sarah Wilkin spoke about permitting required for working with marine mammals during an oil spill. There is a contingency under the Marine Mammal Protection Act that gives a waiver for the "take" of marine mammals by Federal or State employees for the health and safety of the animals or for human safety. There is no such exemption under the Endangered Species Act. Under the ESA a permit is required. The Marine Mammal Health and Stranding Response Program (Dr. Teri Rowles) has a permit in hand for the "take" of marine mammals associated with oil spills. This covers luring or deterring marine mammals from oil spills. In summary, permits are in place, but there needs to be NOAA involvement at the Federal or Regional level.

Risk Assessment for Southern Resident Killer Whales:
Fred Felleman discussed a risk assessment that is underway studying the movement of Southern Resident Killer Whales and vessel traffic through the Strait of Juan de Fuca and the San Juan Islands. This risk exposure is significant and increasing and equipment stockpiles might not be close enough to this high risk area. As we think about responding to a spill and interactions with killer whales, we need to be thinking about this. The base model is finished and complete analysis should be finished in the next year. Mike Ziccardi said that the Pacific States BC task force is completing a risk assessment for oil spill likelihood on the outside of the coast.

Coordination
(Participants: Marilyn Joyce, Matt Newport, Brent Norberg, Don Noviello, Marty Smith, Brad Smith, Sarah Wilkin, Phil Winberry, Ruth Yender, Mike Ziccardi)

This group determined that protocols are in place for the initial call out and notification that an oil spill had occurred and that there is potential wildlife involvement. This includes notification to the Department of Fisheries and Oceans and Environment Canada. Any oil spill-related actions involving orca would be covered under the Marine Mammal Protection Act and the current permit held by NOAA's Marine Mammal Health and Stranding Response Program. Resources are available for wildlife reconnaissance, however orca specific information on how to locate and track orca need to be identified. Specifically, a list or organizations and resources should be made detailing the organizations and people that would help identify and track the location of orca. Additionally, a list of experts who are able to identify individual whales should be compiled. It is important to pre-identify resources and contracts for the potential hazing or deterring of orca from entering a spill long before it is known that orca are heading towards a spill. A list of needed equipment should be prepared, the equipment should be acquired and staged where possible or details should be made on where to obtain the equipment if that is not possible. Furthermore, it will be important to train personnel on how to use the techniques and to ensure that trained experts are up to date on Hazardous Waste Operations and Emergency Response (HAZWOPER) training. Finally, it was decided that the current killer whale necropsy protocol (Raverty and Gaydos, 2004), combined with the NOAA draft manual on oil spills and marine mammals (Johnson and Ziccardi, 2006) contain adequate information on sampling and testing of samples for necropsy, including the prioritization of samples to take if sampling time should be limited (such as for a floatingn carcass). It might be helpful to identify locations where a necropsy could be performed, but usually that is a last minute decision based on the circumstances.

Monitoring
(Participants: Kelley Balcomb-Bartok, Lynne Barre, Candice Emmons, Nic Dedeluk, Frank Holmes, Dyanna Lambourn, Craig Matkin, Dawn Noren, Pete Schroeder, Rob Williams, Gina Ylitalo)

This group identified monitoring needs for pre-spill, during a spill, and post-spill. Before a spill, baseline information gathered on the health status of individual animals as well as the reproductive and contaminant status of the population will permit evaluation of the impact of the spill on the southern resident killer whale population. Baseline data include information on body condition, respiratory rates, contaminant levels, host microbes, background PAH levels, immune status and reproductive status of individuals. Currently, groups that have baseline data (body condition, respiratory rate, etc.) include but are not limited to researchers at the Center for Whale Research, Department of Fisheries and Oceans (Canada), Global Research and Rescue, and NOAA's Northwest Fisheries Science Center.

During a spill it will be critical to pinpoint the location and movement direction of whales. This can be done using existing visual monitoring networks including Orca sighting network, The Whale Museum hotline, public sightings, and the whale watch operators' network. Additionally, there are acoustic arrays that can identify the presence of killer whales. Real time reconnaissance can be done by media helicopters and wildlife reconnaissance groups and it should be ensured ahead of time that these people are capable of correctly distinguishing between Dall's porpoise and killer whales. If whales are moving through an oil spill, it will be critical to identify individual animals either visually or acoustically. To do this, it will be important to have a list of people that are adept at the individual identification of whales and assure these people are HAZWOPER trained. Killer whales that are not behaving normally or have physical signs suggesting disease should be investigated and tagged if possible so that they can be followed. Regional stranding networks should be alerted to look for stranded animals (killer whales and other marine mammals).

Protocols and techniques for nighttime tracking should be developed, including, but not limited to sona buoy arrays and infrared photography. NASA technology may have some applications to tracking whales and the oil slick or sheen 24 hours a day and these should be explored.

After a spill, it will be critical to continue to monitor killer whales to determine the impact of the spill on the population. Post-spill monitoring of whales should include annual census, evaluation of changes in post-spill movement patterns, impact of the spill on regional fish stocks of importance (salmon and herring), as well as changes in fecundity for the population. As during a spill, sick animals should be tracked and complete postmortem evaluation should occur for any animals that die. The potential for increased mortality surveillance beyond the current passive surveillance for carcasses was discussed.

Life saving displacement (hazing)
(Participants: David Bain, Marilyn Dahlheim, Fred Felleman, Jeff Foster, Joe Gaydos, Peter Hamilton, Brad Hanson, Shawn Johnson, Jodi Salinsky, Doug Sandilands, Heather Trim, Marla Holt)

All discussions of deterrent techniques were prefaced by the concept that techniques were only effective if used correctly. The correct use of deterrents should incorporate the element of surprise, while minimizing the potential for habituation.

Oikomi Pipes: have been used and are very effective. The noise resonates better with a handle on the pipe, a cap on the top and cone on the end of the pipe. Five foot pipes are great for a zodiac but need to be longer for bigger boats. This has been effective when boats are less than 200 yards apart. The key is to get the animals on the surface and keep them moving forward. This is not effective if the boats are not coordinated and moving in a unified fashion. Also, having two lines of boats is more effective than one line. This technique would be most effective for herding of animals and might not be as efficacious for keeping animals out of a very large area (such as in the middle of Juan de Fuca Strait). It would be effective over several hundred meters and could be dangerous at night or during poor sea conditions. This technique would work well on other odontocetes (Dall's and harbor porpoise).

Mid-frequency sonar: This has caused deterrence in killer whales in Haro Strait during the *USS Shoup* transit episode in 2003 at a source level of approximately 235 dB (exact level is classified) and frequency is 2.6-3.3 kHz over 1-2 second signals emitted every 28 seconds (US Navy, Pacific Fleet, 2004). There are probably a very limited number of boats that have this capability. This could be effective for over 25 km (important in a large spill, but excessive for a small spill). The problem with this incident is nobody knows the received levels that were effective in causing a response, though this might be estimated fairly accurately with Navy cooperation. Concerns with using this are that harbor porpoises and Minke whales apparently do not tolerate this as well as killer whales. The advantages are that this can operate at night and it has a potentially very large range. Concerns include what would be the close range impacts on harbor porpoise, Minke whales, Steller sea lion and other species as well as other unknowns, and potential difficulty in controlling its use.

Acoustic Harassment Devices: These produce noise loud enough that they are likely to cause pain in animals at a certain range (acoustic deterrent devices are not loud enough to cause pain, but can be heard; often called net pingers). Airmar devices have a source level of 195 dB re 1 μPa_{RMS} and their peak energy at 10kHz with higher harmonics. There are many of these at Ballard Locks and might be more in Washington. These have been banned in BC where they were designed to deter pinnipeds but did not have any impact on them while they did have an impact on cetaceans. These could be moved at low speed from small boats or could be hull mounted on boats to allow faster movement. They are designed with 4 transducers that alternate transmission. They can be battery operated, but need a continuous power source for long-term use. It would not take too long to train people to use them. They may deter killer whales 3 km away. The received levels needed to cause deterrence without acoustic trauma are unknown. Based on work with AHD's, oikomi pipes, white noise, and vessel engines, it is thought that killer whales react strongly at the 135 dB re 1 μPa_{RMS} received level. At Ballard Locks, California sea lions that had never fed there before avoided them, but some sea lions familiar with feeding at the locks did get acclimated and ignored them over time. Although some are at Ballard locks, it might be good to pre-position them. This would have higher acceptability than mid-frequency sonar because its estimated injury level would be very close (<10 meters). The 195 dB model is omni-directional. Also, there is a directional unit that has a slightly higher source level that could be heard at a greater distance. A line of these could potentially be deployed at the sight of the spill or near whales to move them away.

Seal Bombs (seal control devices): these are explosive devices that put out a pulse of noise that were used effectively to drive whales during the live captures in Puget Sound. They worked from about 1 mile away. There could be concerns about using these explosive devices where highly volatile oil was located. These were used in Alaska for the long-line sable fishery, but found to be ineffective. The difference in these two is that with the fishery, there was high motivation for killer whales to be in the area. There was limited motivation in the live whale capture. These can be purchased and stockpiled, however there is no known stockpile at this point. They are not very expensive. These might be more dangerous to fish at a very close range than some of the other acoustic techniques.

Killer Whale Calls: There has been no rigorous experimentation on the use of killer whale calls as deterrents or attractants and this should be better studied. Occasionally the playback of calls can cause them to approach a speaker or avoid a speaker, but context in which they are used is very important. On several occasions, calls of a specific pod were played underwater to the pod itself and the pods did approach the boat. In natural settings, the natural calls of killer whales from different communities have caused whales from other communities to separate. For example, transient calls could repel residents from an area or vice versa. This seems to be a low risk and low cost option for attracting or repelling killer whales at close range, but it has not been well studied. It is likely that animals could habituate to this relatively quickly. The impacts to other species in the area are not known.

Bubble curtains: With Keiko, a bubble curtain was used as a barrier from other acoustics. It turned out to buffer sound, but really served as more of an enrichment device than a deterrent. Logistically, this could be very difficult at a large scale and probably not very effective.

Air guns: This is a mechanical device that uses air that expands and contracts to give a strong pulse under water to map earthquake faults or for oil exploration. They are frequently used in arrays to give a higher source level. Depending on the size, the peak energy can be from 10 Hz to 1 kHz, but they produce broadband pulses with energy at frequencies ranging to over 100 kHz. The higher frequencies are less intense and attenuate faster. Harbor porpoise have been seen moving away from them at 70 km so they could have impacts at great distances. Because mysticetes hear low frequencies better, there is more concern with their use around mysticetes than odontocetes. There are no data on effectiveness in deterring killer whales. These are generally a towed array that is deployed behind a ship like the UW's *R/V Thomas Thompson*. There is concern about acoustic impacts to killer whales and other species including fish.

Vessel Traffic: Boats have very little value in long-range displacement killer whales, especially the highly conditioned southern resident killer whales. It might be possible to use mailboxes, that fold over the prop of boats and push prop wash directly down. This would be an acoustic and physical deterrent at close range, but it has never been studied.

Aircraft: Helicopters can generate a fair amount of noise and wave movement at close range and could produce a startle or avoidance response. It might be very effective initially because whales are not used to it as they are boats, but they would likely habituate quickly. The other advantage to this is that it could be quickly mobilized, would provide real time tracking and could be used to deploy something like seal bombs.

Strobelights: Theoretically, under a neutral stimulus, this could perhaps prevent killer whales from surfacing in a spill. The difficulty is that light will not penetrate water very far.

Fire hoses: at extremely close range, these could be used on whales at the surface as a physical deterrent. There are no data on this.

Booms or Lines on the water: These have been used to displace small odontocetes from stranding in Hawaii and might have some benefit for keeping whales out of an area, but are likely to be less effective with Southern Residents due to their familiarity with fish nets and poor visibility in Puget Sound compared to Hawaii.

Doing nothing: There have been instances where killer whales have swum through oil spills before (AK Pod in Prince William Sound, Transients outside of Dutch Harbor, Northern Residents in Robson Bight – verdict on impact is still out). Depending on the type and size of spill, doing nothing might be an option.

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