LARGE WHALE DISENTANGLEMENT TECHNOLOGY WORKSHOP

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A report of a workshop held in Woods Hole on December 14th 2001

The second in a series of workshops on large whale management at sea.
Report for the first workshop is available at www.whoi.edu/science/B/people/mmoore

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Woods Hole, MA 02543

Friday December 14th 2001

Executive Summary/ Action list

This workshop set out to conceive and plan the necessary technology to improve disentanglement of large whales at sea. The overwhelming message from the presentations and discussions included in this report is of the enormity of the problem and risk facing management of severe entanglements. The need for entanglement avoidance screams out from these pages. The workshop profited from people with a broad diversity of engineering and biological backgrounds around the table. We thank them all for their time and energy.

Three focal areas emerged, each of which could be partially served by an attached multipurpose device. It was christened "***Robocyamid***", after the cyamid lice that adorn the callosities, genital slits and any wounds of all right whales.

Assessment

- Need better aerial images with real time assessment.
- Underwater imaging - a towed body, a boat mount or on a whale-mounted robot.
- AUV's (autonomous underwater vehicles) too slow and expensive for this application. Better to use a boat-based pole to attach device to whale or attached gear. A rope-ascending device may be able to image and maybe cut on arrival at obstructions.
- Onboard data collection to assess sedation: pitch, roll and fluke rate is available in the current Johnson/Nowacek dtag (digital recording tag on suction sups). Need heart rate and video. Could be part of Robocyamid concept.

Restraint

- Need better fluke harness - ? suction cup device to attach to back, allowing lines to fall either side, and then join, to form a fluke loop. On the water CCS workshop in early 2002 in Provincetown MA to test extant technology. Needs a whale tail model that flips from horizontal to vertical, and then testing on a free humpback.
- Net gun system developed by Woodward, Univ. of Maine, could be a promising method for attaching fluke harness
- On board serial drug delivery device – remotely triggered – could be part of Robocyamid package.

Cutter deployment

- Better cantilevered pole cutters.
- Attached cutting device – could be part of Robocyamid package.

In summary there are four areas on the to do list:

1. Better aerial and underwater assessment.
2. Better fluke restraint.
3. A Robocyamid package with assessment, sedation and cutting functions.
4. A rope-ascending device to image and maybe cut flipper and rostrum wraps.

It was also agreed that a contingency fund should exist to allow charter of an offshore platform for multi-day attempts without return to port.

Steering Committee: Michael Moore (Chair), Dan Smith, Richard Arthur, Mark Johnson, Doug Nowacek.

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CCS: Center for Coastal Studies
WHOI: Woods Hole Oceanographic Institution
NEAq: New England Aquarium

Thanks to the Northeast Consortium for financial support.

Agenda

0900 – 0930	Michael Moore – Welcome, agenda, right whale anatomy and photos of a recent entanglement necropsy
0930 – 1000	Stormy Mayo/ Bob Bowman - Review of some case histories, an overview of current gear and needs, and issues that might be addressed by an autonomous or semi-autonomous disentanglement device
1030 –1130	Mark Johnson/ Walter Paul. - Experience gained from suction cup devices on the backs of large whales. Rope cutting issues. Options for communication between device and vessel, and power supply issues.
1130 – 1200	David Brunson University of Wisconsin - Review of sedation efforts and potential remote deployment
1200 – 1300	Lunch - Becky Woodward – video of whale tail lasso
1300 - 1420	Three working groups 1) Assessment of entanglements – Chris Roman and Bill Lange 2) Restraint – Bob Bowman and David Brunson 3) Cutter deployment – Stormy Mayo and Todd Keitel
1420 – 1520	Bill Lange/ Bob Bowman/ Todd Keitel - Working Group Reports
1520 - 1540	Doug Nowacek - Other data collection options
1540 – 1600	Richard Arthur/ Michael Moore - Wrap up and future plans

Background

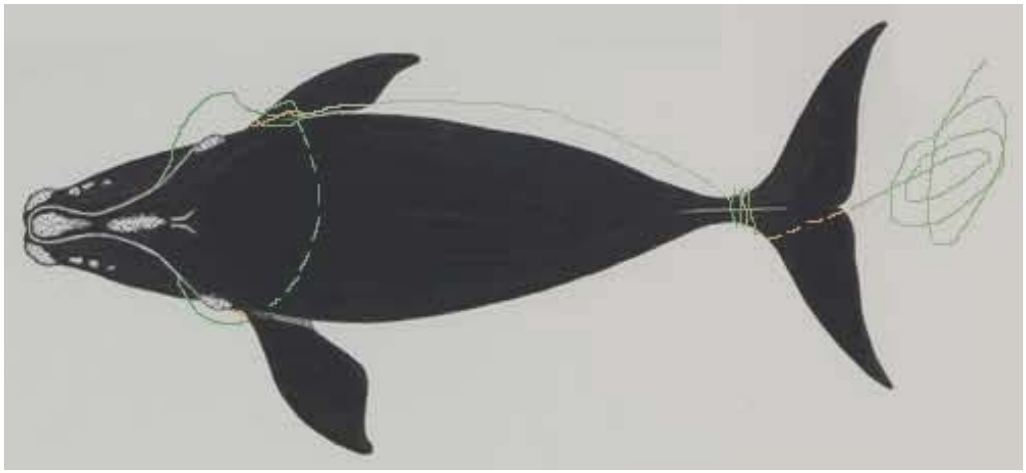
On February 7th 2000 a workshop was held in Woods Hole to discuss the potential for medical intervention in large whales at sea in need of disentanglement. Out of this workshop grew an effort by attendees to develop a sedation system to facilitate refractory disentanglement attempts. The most visible product was the attempts to sedate and disentangle right whale #1102, commonly known as 'Churchill', in the summer of 2001. During these events it became apparent that there was a need for better technology to assess, restrain and release entangled large whales. This current workshop was the result of that need. (Note that 4 digit numbers in this report, such as #1102, refer to right whale ID numbers in the right whale catalog maintained by the New England Aquarium).

The attendees all agreed that it was essential to view this workshop in the prior knowledge that the only genuine solution to the entanglement problem is prevention of entanglement, or at least avoidance of severe entanglements, not disentanglement, but that given the ongoing level of entanglements, and the precarious balance of the northern right whale between species survival and extinction, the workshop had merit in the hopefully short term.

1. Right Whale Anatomy – Moore

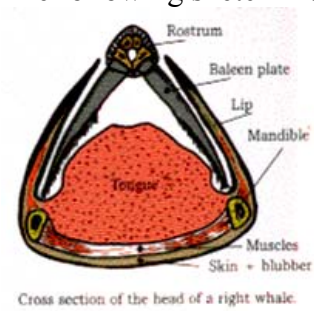
Moore described general right whale surface anatomy and showed slides of entangled right whales, pointing out high risk entanglement sites on the body of right whales: baleen and rostrum, flipper bases, and tail stock. He illustrated the structure of the right whale mouth and blubber coat. He briefly described the cantilevered pole system used for sedation (Mayo et al.), tag deployment (Johnson and Nowacek et al.) and acoustic body condition assessment (Miller and Moore). He then discussed the options to consider in the development of hand-held tools, rope climbers, and possibly AUVs.

The following sketch is of an entangled right whale (#1238) examined dead in the Magdalene Islands, Gulf of St Lawrence November 4th 2001. It illustrates the overall problem with line through the mouth, around flippers and around tail.



Scott Landry – Center for Coastal Studies.

The following sketch illustrates the relevant head anatomy.



Cross section of the head of a right whale.

Sketch, with permission from Pierre-Henry Fontaine, Whales of the North Atlantic 1998, Multimondes, St Foi, QC

The cantilevered pole system laying an acoustic sounder on a right whale

Doug Nowacek - WHOI

2. The Disentanglement Status Quo – Stormy Mayo

Mayo discussed the disentanglement work done at the Center for Coastal Studies, introducing Bob Bowman, Moira Brown and Mark Costa as other members of the rescue team. Assessment is a critical part of rescue efforts, considering not only the present condition of the animal but also the likelihood that the animal may become disentangled over time. Scott Kraus' recent suggestion of building a machine which can assess the condition and state of entanglement of the whales is something which should be seriously considered.

Dave Brunson, Teri Hammar, Teri Rowles and Michael Moore did work on the sedation of Churchill (#1102) about which Stormy was skeptical but the progress was impressive. #1102 was first spotted from the air, East of Cape Cod, 50-60 miles off Nauset Beach. Ropes were seen coming out of his mouth, and a deep cut was noted over the rostrum, which later was found to have a line embedded. His body condition was not emaciated. There was a collaborative effort to disentangle this animal. 9 June 2001 was the first attempt at disentanglement with Bob Bowman's grapple hooks. The best situation is having a trailing line available: cutting this line is not suggested as it leaves nothing to grapple. Two trailing lines were on Churchill. The left side line was the control line and was used throughout the rescue effort. Such a control line may be useful for a grappling/moving/walking robot.

Terry Hammar tested various delivery mechanisms on a carcass that washed up in the summer of 2001. Time is an important consideration and a robot that can go into "sleep mode" may be a good idea – folding arms etc. Telemetry is a great way of tracking these animals and very helpful in the rescue efforts. A single injection system was attempted on #1102, usually with 3 people in the inflatable. Doses are important to consider, Dave Brunson will continue on this topic. Biopsies were taken from #1102, allowing various indicators of health to be examined. The CCS team was able to "wrack back" on the animal to successfully slow it down. Multiple doses with a syringe pressurized with butane, tail harnesses and yokes were also deployed. Attempts at tail harnessing were unsuccessful. By August the animal was emaciated. In spite of these efforts on Sept 16 2001, in 15,000 ft of water, 1102 probably died and sank.

Historical whaling literature states the difficulty of dealing with right whales. Chemical restraint worked surprisingly well and may be a good way to proceed in the future. One of the biggest problems is dealing with the whale itself which usually uses the flukes and causes a very dangerous situation for rescuers – hence the importance of chemical restraint. Characteristics of drugs used so far seem very good.

Mayo then showed a video clip from a camera mounted on the helmet of an operator in a small boat behind a whale – illustrating the 6-8 ft amplitude of the fluke movement. The whale always wants to hit the line with its tail. When the line moved underneath the flukes, 1102 starting slashing at it, which indicates intense sensitivity. Right whales are powerful animals and dangerous to rescuers. #1971, a successful disentanglement was very violent with its flukes after it towed a 41 ft gill netter and a drogue for 6 hours during disentanglement. It would be a great advantage to have a good view of the head, like that provided by the pole cam, to determine where the entanglement is occurring. Possible tools: grapples are great for controlling lines and the cantilevered pole has great potential. The Coast Guard has been very helpful and supportive; NOAA too.

Two problem areas – flipper wraps can be fatal as the rope cuts into the bone. Hard to deal with because they occur about 6' under the water and visibility is bad. Hidden/buried line problem needs a solution – when lines cut into the rostrum and along the body, and disappears, how do you get to them? These lines represent serious contributors to morbidity and mortality. Once again, assessment would help to reveal other unseen lines. It is always best to deal with lines when entanglement initially occurs rather than waiting. The solution ultimately is not disentanglement, but non-entanglement. Although this effort (and workshop) is valuable it is only a stop-gap at CCS, it would be best not to have to do this type of work at all.

Questions

Duester: how deep do they dive?
Brown: 600-700 ft
Duester: how much personal space do they have – i.e. how close can you get with a zodiac?
Mayo: depends on the condition and individual.
Moore: pole work, 40ft pole worked best, 20ft exclusion zone in his opinion.
Brown: definitely depends on individual behavior.
Hartley: is it hard to approach animals in social groups e.g. humpbacks?

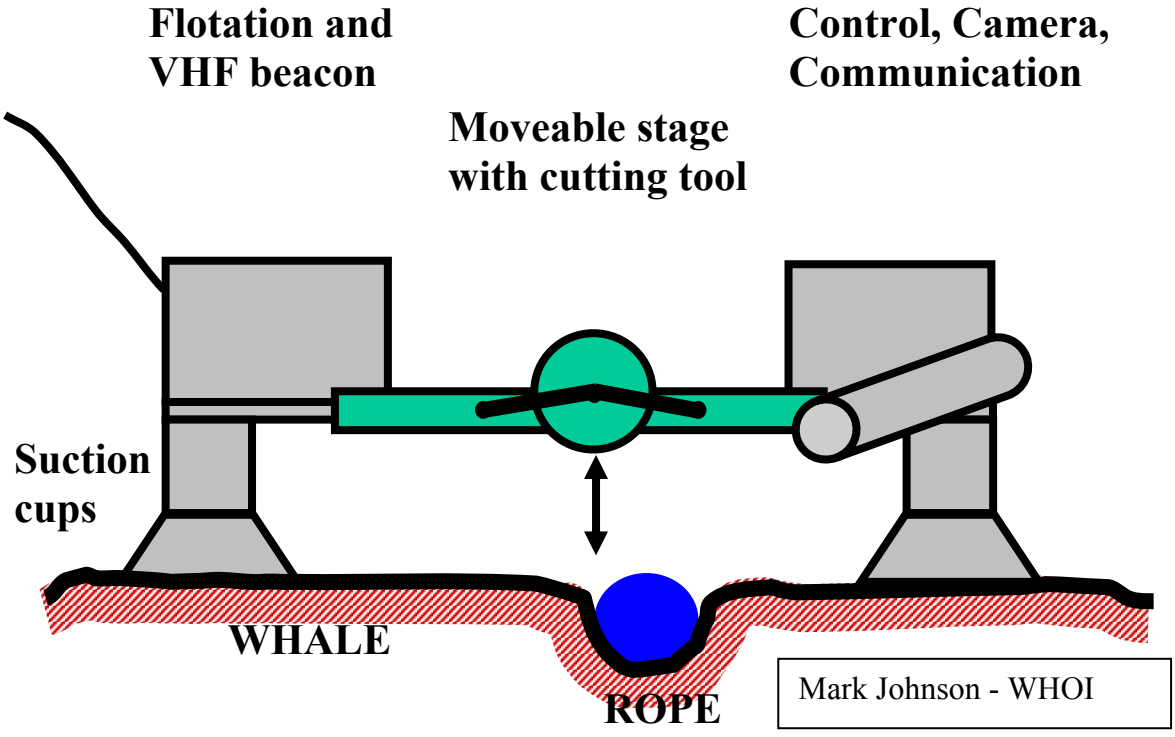
Brown: no way of approaching animals in the middle of socially active groups (SAGS).
Wiley: if animal's let you within 20-30ft before diving a handheld pole may be better than the cantilevered pole as animal is not in a "fluke slap" position.
Mayo: when an animal is recently entangled it is extremely difficult to approach.
Ekstrom: would it help to "blindfold" the animals? Suction cups?
Mayo: is it possible? They watch us.
Moore: Beamish did this once on a tethered humpback in Newfoundland.
Bowman: applying the cups would be almost as hard as any disentanglement.
Mayo: humpback whales are comparatively easy to work with. They are co-operative with much smaller flukes and are easier to disentangle. They could provide a test-bed for some of the techniques to be used on right whales.
Bowman: ethical issues.
Johnson: is it single lines or lines with net that are causing the problems.
Bowman: recently less nets as less nets are out there, more entanglements by horizontal lines – polypropylene, in between trap lines. $3/8^{th}$ to 1 inch line, all synthetic. Some gill nets have been found on entangled whales.
Singh: how many cuts would be needed to cut through?
Mayo: assessment is most important, but 3 cuts are generally what is needed. #2030 – would have needed many more, therefore it depends on the type of entanglement in each individual.
Bowman: Calvin, the entanglement was initially determined to be minimal: it was monitored for two months with a telemetry buoy attached to the entangling gear. The animal eventually freed itself, but the nature of the exact entanglement is still unknown.
Singh: device should stay on whale until it finds the rope to cut. Need to find a rope cutting strategy. The difference between getting a vehicle on the whale and being 100ft away from the animal is a million dollar difference in technology cost!
Roman: is all observation made from the surface?
Mayo: yes it is at present, but the animals that we want to get at are the moving and active animals with sub-surface entanglements.

3. Engineering Issues and Options – Mark Johnson

Issues:
1) what are the rope cutting options?
2) How should diagnostic, medical and camera packages be delivered and attached?
3) Options for communications: moving, cutting, information?
Proposed a remotely operated rope cutter. Johnson and Nowacek have used Moore's 40 ft cantilevered pole concept to deliver suction cup tags on right and sperm whales – a 10lb package could be deployed. Delivering and attaching devices to whales aren't too much of a problem, unless skin condition is poor. Suggested a platform on 4 suction cups delivered on the back and repeat deployment until it intersects with a rope. Questioned a remotely controlled cutter with a running blade and a camera attached. This would not be useful for rostrum entanglements and knots. The robot may not necessarily have to move. Simplicity and practicality would be paramount. Johnson then suggested the concept illustrated on the next page.

Questions
Singh: why limited to stationary cutter?
Johnson: does not want to add more technology than is needed.
Bowman: not good for flipper and rostrum entanglements.
Roman: retention time of suction cups?
Johnson: releases as air and water leaks into the cup, may seal it with a suction/vacuum. Don't want to overdo the pressure – 2 psi are okay on d-tag deployments, but at 5 psi the animal begins to react and does not like anything near the rostrum.
Brown: worst reactions when biopsying from the mid-line on right whales and humpbacks too. They won't tolerate suction cups less than a meter behind the blowhole.
Singh: can you cycle suction cups on and off?
Keitel: Yes, pneumatically. Can you use squid-like solenoids & pressurized suction cups?
Johnson: Yes.
Keitel: Are there natural stimuli e.g. cyamids that would make the whale less responsive?
Johnson: Yes, together with a sedative.
Grasso: octopus type suckers are realizable with existing technologies: they do not require excessive reversible adhesion.
Keitel: keep system as simple as possible: keeping the brain on the boat would be most successful, keep the smarts in the loop. Acoustic coms not practical and antennae are not either, magnetic communications may be an option.

A Remotely-Operated Rope Cutter



Johnson: video over these systems is not possible. A fiberoptic line is not a good idea. A surface float (balloon) attached to something may cause drag on the suction cups.
Roman: how fast do right whales move?
Mayo: right whales move at up to 4-7 knots.
Roman: This is a problem with the AUV community, REMUS is a small submarine, one of the fastest, at with 3-5 knots. First problem is speed. AUV executes its own plan, with very complex content.
Singh: using an AUV is not an option for this, they're expensive, not really as advanced as they need to be. A grappling Crawler with a little camera might do better imaging work. If vehicle is controlled by someone who knows right whale anatomy, they can put the mosaic together and determine very quickly whether the robot is above or below the whale. Relatively easy to do. Some problems, how do you tie the pictures together? Suction, making a mosaic, that is something easily done in a lab setting, independent of biology. Problem with introducing technology across fields, better to keep it with the people who know it. Get the cutter or whatever to a spot where it needs to be, general vicinity is easy – but cutting rope requires dexterity – real-time feed back with images which can make a huge difference. Dollar costs exceeds the average biology budget, this needs to be considered.
Grasso: walker, tracking chemicals in marine environment, maybe have a chemical sensor which can identify wounds that are not detectable otherwise, by seeking chemicals in the boundary layer around the body. Maybe cyamids give off certain chemicals – this could be a diagnostic triage.
Hartley; NMFS tried to diagnose entanglements using thermal imaging, but didn't work. and thermal imaging, but didn't work. However thermal imaging development is progressing quickly. Ann Pabst at the Univ. N. Carolina Wilmington would be a good contact for anyone following up on this issue.
Grasso: chemical sensing may be practical. Can be tuned to particular amino acids and bioactive compounds and will work primarily under water. Can tune it to species specificity.
Bowman: hopefully not working on injured animals, prefer to work on non-injured but initially entangled whales.
Hartley: can it detect bruising?
Grasso: if there are known compounds, it can be worked out.
Moore: cyamids are a potential flag for where the injuries may be occurring – the orange species only spreads from the genital slit in unhealthy or wounded whales.
Bowman: subsurface cyamids, is there an anaerobic environment for these creatures?
Moore: probably not.

Johnson: two problem areas – flipper and rostrum wraps. Rostrum, animal is very sensitive and it's also the worst possible platform to attach a robot to.
Bowman: a good cantilevered pole would work best for the rostrum, but the flipper wraps are underwater with a bundle of wraps, 4-5 inches of rope, equivalent to cable: this is a big problem.
Mayo: usually a shield of loose stuff, have to be very dexterous to actually get to the tight inside wraps. This kind of flipper wrap is the one we most want to develop on.

Wiley: suggested injecting something into the rope to dissolve it as it cannot realistically be cut.
Unknown: Why do these wraps cause problems? The line, rough polypropylene is put under tons of pressure and it cinches the rope down into the bone. Young animals grow into the rope and it cuts off circulation. Not conceivable to cut this rope – an injection would be great.
Bowman: some kind of physical restraint would be helpful
Mayo: thought about using a dry dock with stranded animals, even so it is difficult to cut these ropes off, chemical disassembly would be best.
Bowman: maybe we can determine whether something is actually hopeless or not.
Moore: According to news reports (http://www.capecodonline.com/cctimes/archives/2001/dec/11/whalezxstale11.htm) CCS rescuers probably will not intervene in the future if an entangled whale appears to be mortally injured. Thus this assessment is vitally important.
Johnson: polypropylene is a very inert plastic
Brunson, D: some of these animals are hopeless: amputations would be futile with flipper wraps. These appendages would basically be rendered useless, so maybe we should focus on less extreme wraps that would be easier to remove.
Johnson: do these wraps have control lines?
Mayo/Bowman: sometimes this is the case.
Johnson: need a camera for assessment and possibly an injection to destroy the line.
Girard, A.: AUV attached to line detects animal slowing down and it surges past and sends pictures back.
Singh: an ascender makes more sense, always driving forward, ascender detects when it has no more room to move and starts snapping pictures.
Lange: two problems, assessment and rope removal. Technology exists to take footage.
Stormy: terrible problems getting in front of the whales – they don't like to have things in front of them.
Lange: outrigger? Camera on whale gives such a small frame of view, something to consider.
Mayo: we can get up level with the head, within 20-30 ft of it, can do it often, not always.
Hartley: always using small vessels?
Mayo: yes?
Singh: think about a remote-controlled helicopter/plane off a small boat, which is cheap and accessible. This would cover the global visibility.
Mayo: difficulty is at the water line, CCS feels good about above surface work with pole cam. Confident in above water assessment.
Hartley: need to look not only at where they are entangling the whale, but also along the entire length of the line. If we had removed a knot at the end of one of 1102's lines, things might have gone differently.
Duester: number of boats?
Mayo: successful in keeping the animal on the surface and then use 3 boats by confusing the animal. If we can get the boat over the nose of the animal, the whale slows down, in that way we can have influence. Need maneuverability: that is why we use inflatables. We want to work on animals which continually want to dive, as other, more co-operative animals in bad condition are probably not recoverable anyway.

Johnson: carrying a camera on suction cups could be good, but near rostrum, is not on. Getting a camera to a flipper area, a rope-crawling device. If the animal is thrashing what is the water visibility like anyway?

Walter Paul – Rope

His experience deals with rope fiber manufacturing and development. Basic need when cutting rope: apply force, have something underneath and then a knife to cut through. 135-155 deg C is the melting point of polypropylene rope.
Lead core rope has lead inside in small pieces – 1 inch long. The rope can be cut in between lead sections. Problem – have to get under the rope as it is on the whale – maybe use 2 fine prongs (whale reaction?) also need an anvil to act as the supporting surface when the knife is activated. To activate the knife you have to decouple the action between the boat and the whale. Higher tension on rope, easier it severs.

Questions

Bowman – we don't use knives with mechanical action.
Paul: Need cutter, float, compliance and activation link. Must be sure to cut right through the rope. Described a cutter with a prong, anvil and piston with an accumulator/pump which is controlled via a pressure hose or cable that is activated from the boat. Mounted on a handle. Requires bench-testing. Handle has to support push, get prongs under rope through blubber, all this without sending the whale into a frenzy and has to allow pull on trigger rope. Speed is essential.
Mayo: never had a problem cutting rope, the problem is actually getting the knives to the right position.
Johnson: the nub of the problem is this point and we should focus on it.
Duester: have you tried a bone saw?
Bowman: No. What about chemical dissolution of rope?
Paul: need to have heat under water and laser would be good if this could happen. Problem with efficiency of lasers.
Brunson, D: need to be precise with laser use.
Ekstrom: focused ultrasound?
Brunson: ultrasound device to measure presence of rope? Did Churchill have rope across his rostrum or was it an old wound?
Ekstrom: used to burn out tumors.
Keitel: need to be tethered.
Moore: Problem for diagnostic ultrasound was cable length: longest available was 12 ft. Our system is only depth sounder, no image. Suggested combining a spinning blade with a video on the tip of the cantilever pole.
Johnson: cannot use pole underwater.
Keitel: preset blade speed and depth.
Wiley: there is a movement away from polypropylene ropes, are there any other materials - poly alcohol dissolves with time and salt water.
Paul: polyprop is cheap and it floats – the floating is the big problem.
Bowman: come up with a new composition?

Paul: current trends in rope development are unlikely to result in a product that dissolves more easily.
Moore: recent *Eubalaena* award rope disintegration proposal – not practical for the fishing industry.

4. Sedation of Large Whales – David Brunson

Seeking conscious sedation (in contrast to anesthesia: unconsciousness and loss of reflexes) and analgesia.

Sedation: quieting, calming, +/- analgesia. Primary concerns: safety of the drugs both for the whale and for the rescue team, and secondly, the effectiveness of the drugs. Initial obstacles – what drugs? What dose, how to administer, what effect will the drugs have, onset, duration, degree of central nervous system depression? Wanted to deploy drugs first before the whale is excited or harassed. Therefore the drugs have to take effect before any work can be done on the animal. Although sedation is a good tool, it may not provide all day opportunity, but it is repeatable. Midazolam and meperidine have been used in seals, sea lions, killer whales and other marine mammals and produce mild sedation affects. Midazolam: a benzodiazepine (like Valium) at a low dose of 0.025mg/kg for 40,000 kg whale requires 1,000mg. Commercial concentration is 5 mg/ml i.e. 200mls would be needed, so formulated a special concentration 90mg/ml requiring 11ml per dose. Meperidine (Demerol) is an opioid analgesic: dose 0.25 mg/kg i.e. 10,000mg for a 40,000 kg whale. Commercial concentration is 100 mg/ml i.e. 100 ml so formulated a special concentration of 550 mg/ml or 18 ml. Thus a dose of 1 gm medazolam and 10g of meperidine was given to Churchill with special formulation resulting in 29 mls. Midazolam is water soluble and is like valium. Gave this dose 4 times in a 2 hour period with light sedation effects, therefore the dose could probably be doubled in the future. He was confident that the drugs are working and safe at this concentration.. Three different sedation series were administered to Churchill and they did no detectable damage.

The team had to develop a delivery system: a large capacity auto-injecting syringe, special needles, and a cantilever pole system. The syringe had a 40 ml capacity and a 12 inch needle. The drug chamber in front of a standard syringe sealing plug, the pressure chamber behind, with a one way valve to retain pressure. Compressed atmospheric air was used initially, but force was lost as the plunger moved. Liquid butane replaced this and worked very well and is simple to load and use in the field. The butane charge lasted for one day in a bench test. Shape of the syringe can change but the drug has to be delivered at a level of approx 12 inches below skin surface. The cantilevered pole system of delivery was successful. Churchill gave minimal reactions to these injections. Syringes stayed in initially but did fall out eventually.

Measuring the effects of the drugs:
Response to external stimulation – flight distance; pain – test with some type of stimulus.
Heart rate
Respiration rate
Muscle tone/movement

Churchill's behaviour changed after the drugs were administered: surfacing was less forceful, and exhalations began before the blowhole was clear of the water. This was taken as direct evidence that the drugs were taking effect. As time went on his further change in behavior also indicated the drugs' effect wearing off. Respiration rate wasn't a clear indicator.

So the approximate dosage is now known. The dose used was the same as used for captive killer whales, so metabolic scaling doesn't seem to apply here, however environment and stress levels may have been a factor in increasing the required dose. The onset of effects was 20-30 minutes, the duration <2 hours. The level of CNS depression was mild.

Questions
Ekstrom: can an ECG be used with telemetry?
Brunson, D: yes.
Knowlton: what about local anesthesia?
Brunson, D: Local anesthesia may be one of the best tools to decrease the reaction of the animal to any rescue operation procedures.
Moore: really need to know the distribution of the neurosensory receptors on the body of these animals: hopes to do that histologically.

Unknown: can we use spinal or regional anaesthesia – need to inject on the nerve that serves the specific area.
Brunson: we are using a systemic approach.
Bowman: only part of the animal that needs to be restrained is the tail.
Moore: the motor muscles are located above the tail and the nerves are located higher on the spinal cord. Mid-line block could in theory stop the impulses to the muscles and therefore slow down the movement of the flukes. Not a practical approach.

Ekstrom: proposed a non-invasive, different approach to sedation using modulated energy. Acoustics and light. Suggested using a low frequency transducer to project a specific wavelength to match its body length: "tuned acoustic energy". Bathe a whale in 100 cycles/sec of sound and cause full body/internal resonance which may affect the fluke and flipper rate such that the whale will heave to and be sedated. 100 cycles/sec is a typical fundamental calling frequency they use, indicating internal source resonance.
Johnson: Would it deafen them?
Ekstrom: No, use very low amplitudes.

Break for lunch

Becky Woodward - Lassoing right whale flukes.

30-40 ft range, single cartridge 4 barrel net gun, to shoot net over right whale flukes as they enter their terminal dive. 24x18'rectangle lasso. Can buy net guns to mount on the deck of a boat. Can construct lasso out of floating material if desired and different shapes of lassos can be made.

After lunch the workshop reconvened into three subgroups as defined by the morning discussion.

Subgroups and chairs

Assessment - Chris Roman and Bill Lange
Restraint - Bob Bowman
Cutter Deployment - Stormy Mayo

Assessment subgroup

Chairman: Chris Roman and Bill Lange
Nowacek
Knowlton
Grasso
Girard, A
Girard, P
Baldi
Partan
Smith
Singh
Dwyer
Duester
Moore (partial)

Assessment Subgroup

Lange described a priority to improve aerial photography to help make initial assessment of the animal. He suggested the need for a system to provide real-time analysis of images to relay information to coordinators on water/land-
help to focus their attention on specific areas of the whale. A second issue concerned areas of the whale under the water, in particular, the flippers and belly. There is a need for a system to provide wide shots of whale to avoid the need to create a mosaic. The third issue was monitoring of the animal on a real-time basis, specifically heart-rate in terms of sedation response. The final issue was to define terminology better – such as 'mortal wound'.

The discussion began with some general comments and questions about right whales including reactions to boats/other animals, natural history, etc.

1. Aerial photography
Lange suggests the use of high-definition video mounted in/on the survey plane to provide high quality digital images (30 frames/second) with the ability to zoom in/out to specific areas of the body. The system would also allow observers to view the images in real-time to relay information to the necessary team members. The equipment to test the system is available - already tested briefly in Iceland on killer whales.
2. Underwater imagery
Lange suggested the use of a towed body- system available in the WHOI warehouse that will be repaired and loaned to Stormy for testing (use two boats, one trying to avoid the other to simulate the whale's reaction). The system could be mounted on a rigid inflatable off to the side of the boat. The camera tow body would have controllable fins to provide better visualization. There could be a pan and tilt zoom function internal to the housing. Lange suggested traveling around the animal: towing camera to achieve images underneath and along all aspects. Maybe can avoid head on approach to obtain necessary images. Could vary the length of the towed body to allow greater flexibility in distance to the whale.

Nowacek: heart rate data derivation is in the process of development, not easily obtainable at the moment.
Hartley: heart rate data important for sedation info.
Bowman: life expectancy of tag?
Lange: a few hours to a few weeks. More extensive optical surveys are going to require more land-based/laboratory interpretation. Data collection needs to be concise and focused to avoid substantial processing.
Bowman: what is the time span to deploy better imaging?
Lange: warehouse has towed camera body parts, need to be put together and tested. Baldi and Lange want to work on the visual quality, and will work with Brown and Cole (NMFS) to deploy.
Moore: We need to better define a mortal entanglement?
Knowlton: Heather Pettis looked at whether you can assess the fatness of a whale photographically. She found 10 severely emaciated animals that haven't been seen since (n=8) or were subsequently seen dead (n=2). (Churchill is included in the 10). Of these 10 animals, six were entangled and one was ship-struck. White flippers also indicate a poor prognosis.
Moore: need to have side view photos of the front half of whales as part of initial assessment. D-tag should have data available real time to be of use during a disentanglement.
Johnson: that is possible and a test model may be available.
Moore: pitch and roll data from the d-tag is relevant now and should be deployed but further development is certainly recommended.

Singh: suggested the use of a suction cup camera attached to the whale by a suction cup- the camera itself would be on a "fishing line". Once attached the line would let loose

(amount of line out would be controlled by observer) and the camera would drop underneath the whale. Would have to look into hydrodynamics of the camera, specifically when the whale was swimming, and development of special fins for the camera which could be remotely operated.

Restraint subgroup

Chairman: Bob Bowman
Brunson, D
Brunson, A
Woodward
Brown
Wiley
Miller

Bob Bowman reported back on physical and chemical restraint. He spoke about existing models. Two extant systems need the animal to have an existing control line on it. Other models involve a lasso on a cantilevered pole system. Discussed Becky Woodward's system – maybe requiring stronger material and different lines etc. He described a planned practical workshop in Provincetown in Spring 2002 with a working model of a right whale fluke. Will help prepare operators for training and point out weaknesses. Bob Bowman and Marc Costa will come up with a longer pole.
Johnson: suggested there may be a benefit of a drug delivery system attached to the four suction cup system suggested earlier by him. Thus, multiple doses of the drug and if needed, the antidote, could be administered remotely. This would be a huge improvement to the current delivery method. The dose would be on a radio link which needs to be worked on. At the moment we should try to work with the existing cantilevered pole system. Sedation drops the fluke and the harnesses need to be designed considering this fact.
Mayo:Churchill's head was up and this may have caused the "fluke drop". Suggested running a remotely-inflated tail collar down the control line, to keep the tail up and reduce the amplitude of the flukes, and therefore reduce the weight required to restrain the whale. The primary objective is to stop the whale from creating dangerous situations with its fluke.

Cutter deployment subgroup

Chairman: Mayo

Hammar
Costa
Paul
Arthur
Keitel
Reeb

Cutter/deployment summary – Todd Keitel

Two problems: How to cut the rope and how to deliver the cutting device. Two types of ropes: 1) loose and accessible to tools, and 2) tightly embedded ropes. Tool doesn't have to do everything, but taking a few parameters into consideration, we thought that the device could carry almost any blade and would probably be able to work for almost all the entanglements. Reciprocating blade works well in some situations, circular blade has dimension limitations. Standard blade would probably work best as long as needed degrees of freedom and visibility are met.

Position and orientation of delivery system onto the whale. Many options discussed but the cantilevered pole is probably the best. Optimal placement is probably not going to be achieved using suction cups. Described a design with a circle or retractable hooks. Push up and they stick in, push down and they release. Video feed back would be in place, a second deployment of a buoy anchor will act as a tether between boat and whale walker. Fail safe is imperative, springs to engage hooks are power-charged and loss of power would result in the hooks releasing.
Mayo: hooks into whales may result in bad reactions and that is a serious concern and needs to be checked and tested for acclimation. Can have different lengths of hooks and differing pressures would engage different hooks for walking, clamping etc…
Hartley: could each step forward inject a dose of a topical analgesic (Lidocaine)?
Keitel: This was discussed in the subgroup. Telemetry is possible but it has power limitations, but by using the tethered system, the batteries can be in the buoy. The buoy may also be able to stay in the boat.
Moore: cost?
Keitel: high power, low accuracy and therefore favorable cost-wise, most parts are off the shelf things.
Mayo: integrate with assessment side of things, pack more "gadgets" on it. DSP processor is required and could be remotely controlled (by Stormy on his couch!).
Moore: this concept sounds like a 'Robocyamid', but (added at editing stage) I suspect that basing the device on suction cups rather than hooks is advisable for reasons of pain and permit-ability.

Monitoring Technology – Doug Nowacek

What do we want to know during disentanglement efforts? Between disentanglement efforts, after successful or unsuccessful attempts?
How do we assess the health of the animal visually: we should include Pettis' work at NEAq. Body wounds, blubber thickness etc may help assess whether entanglements are mortal or not. Biopsy to use various assay techniques. Respiration, electromyogram (EMG), ECG rates are known, but between disentanglement efforts are so far unmeasured. Need to have a high data density archival tag: fluke stroke rate, velocity and heart rate? Satellite-linked time depth recorder (TDR) would provide real time dive behavior and if the animal is noted in one area for a sufficient time, that allows opportunities for disentanglement efforts. Johnson can comment on changing memory set up of tag to allow long duration application.
Bowman: possibly add this to the buoy that is already being deployed by CCS. Can add 10 more pounds to the buoy.

Monitoring the whale after disentanglement whether gear is taken off or not. What can we learn from this animal?
Hartley: collecting blood and wound biopsies. Tail restraint and a lift bag under the tail would be a good set up.
Bowman: time restrictions make this improbable. He thinks next season may mirror the entanglements of this season.
Nowacek: to have an overnight team would be ideal.
Moore: having money to charter the right vessel to stay on station for more than a single period of daylight?
Hartley: NMFS have spoken about this option.

Wrap up

Arthur – Assessment is important and using current tools/technology is always the first choice. Tools already in your toolbox. Funding limitations need to be considered and therefore further system contemplation is required.

Moore – suggestions as to where to from here? To have a method to physically restrain a whale is necessary for all disentanglement and rescue operations. Assessment is equally important. Don't think we can currently fund, fabricate and present the walker Keitel and the subgroup proposed. A remotely controlled sedation system would be a great advantage and may be the best immediate advance. He then asked what is the most urgent need for the "workshop on the water"?
Bowman: right whale tail model to test tail harnesses and development of better tail harnesses.
Duester: fuel tank bladder concept could be modified to allow an inflatable tail collar. Would affixing the bladder assist in restraining a whale?
Mayo: not a practical option, size and attachment-wise.

Brunson: attachment to the correct positions is critical and one of the hardest things to accomplish.
Mayo: reasonably healthy animal, can we get enough sedative effect to allow us to get to where we need to go? Physical and chemical systems are intimately linked. Better chemical delivery system and new physical restraint system. This is the primary priority according to CCS.
Smith: Singh mentioned a fishing spool to run out. Smith asked whether it would be possible to attach a package to the whale's back and deploy two separate lines around the peduncle which would attach to each other?
Mayo: interesting idea, not mentioned before.
Brunson: engineers need to help with the harness. Engineers could help with developing electric screws, spring, pump could be developed to engage the plunger in the drug delivery device, but the engineering of the tail harness is most important.
Woodward (added in report edit stage): need tail harness design criteria (what elements are essential: quick release, stops to prevent cinching too tightly, etc) and critical dimensions of the fluke and peduncle.

Bowman: need input on existing CCS tools. Need to solicit other designs from outside people and test the designs in the harbor.
Knowlton: would it be possible to test Woodward's gun on a non-entangled humpback whale in Cape Cod Bay this winter?
Hartley: permits are an issue and need to be applied for asap.

Moore: thanked all participants. The sedation work done by Dave Brunson, WHOI, NMFS and CCS has roused tremendous amounts of interest in the veterinary profession as well as from the public. More awareness in the Mid-west as a result of this work. A lot has been accomplished since the meeting two years ago.

Conclusion: disentanglement is not the solution, we are only treating the symptom, it's the cause that needs attention and solutions.

Mayo/Bowman: concerned that the focus is not where it should be.
Brunson: bring the gear development people into these meetings so that the focus is always maintained i.e. gear entanglements need to be prevented, not solved.
Wiley: there is a NMFS gear development meeting 13-15 February 2002 in RI, more people from this meeting should try to attend.

Meeting adjourned 1600.