APPENDIX A

Beaked Whale Research

Planning Workshop

REVISED REPORT SUMMARY

Sea Mammal Research Unit, St. Andrews University, 23-24 November 2004

I. INTRODUCTION

This workshop was convened to begin the process of developing a coordinated program of research on beaked whales to address the questions defined at previous international meetings (e.g., the U.S. Marine Mammal Commission meetings: Baltimore, April 2004; and London, Sep 2004). This recognized that:

(i) Some individuals and groups already have advanced research programs on beaked whales;
(ii) One of the reasons for the current poor state of knowledge is that the technology, resources and logistics have not generally been available in sufficient quantity to tackle the difficult issue of studying beaked whales;
(iii) The research community and expertise is fragmented across institutional and national boundaries; and
(iv) There may be a need to pool expertise and resources to achieve the critical mass of researchers and facilities necessary to tackle the problem.

Agenda: followed the titles of the sections summarized herein.

Attendees:

NAME		AFFILIATION
	Richard Bird	RN
	Ian L Boyd (Chair)	SMRU
	Diane Claridge	Bahamas Marine Mammal Survey
	Phil Coles	ORCA
	Jonathan Gordon	SMRU
	Ed Harland	QinetiQ
	John Harwood	SMRU
	Sascha Hooker	SMRU
	Graham Jackson	Dstl
	Vincent Janik	SMRU
	Paul Jepson	IoZ
	Russell Leaper	IFAW
	Colin MacLeod	Univ. Aberdeen
	Kelly MacLeod	SMRU & ORCA
	Simone Panigada	SMRU & Tethys Institute
	Dave Thompson	SMRU
Apologies:	Doug Gillespie	IFAW
	Phil Hammond	SMRU
	Graham Pierce	Univ. Aberdeen
	Peter Tyack	WHIO
	Andy Williams	BDRP

II. REVIEW OF DOCUMENTS

Five background documents were available to the participants:

1. Beaked Whale Research Planning Workshop	I.L. Boyd
2. UK Contribution to conducting CEE with beaked whales: strawman	J Gordon
3. UK Contribution to conducting CEE with beaked whales: Williams submission	A Williams
4. The Bay of Biscay: a target area for beaked whale research?	K Macleod D Walker P Coles
5. Appendix C from MMC Baltimore Workshop	

Dr. Boyd explained that Document 1 was a briefing paper that had been submitted to the Marine Board of the Workshop of the European Science Foundation to inform them of the Workshop and request sponsorship for continuation of the process of building toward an integrated, multi-disciplinary, research proposal. Since then, the ESF Marine Board has approved funding to support further workshops.

The MMC Workshop recommended that there was a need for CEEs; improved understanding of pathology, physiology and anatomy; modelling and experimental studies of diving behaviour; and the significance of current apparent damage at the population level. This would need to include research targeted at CEEs, behaviour, vocalisation, anatomy, physiology and pathology, demography, habitat modelling, acoustic studies, and analyses of historical data.

The current Workshop agreed that there was a need to focus in on priority areas of research and areas in which UK marine mammal scientists could likely make the most useful contribution. CEEs were a particular focus but there was a need to ensure that sufficient basic knowledge, especially of behavior, was available to allow interpretation of the results of CEEs. There was also a need to concentrate on gaining a better understanding of distribution and abundance because one form of mitigation would be for sonar trials only to take place in regions of low predicted beaked whale abundance. Until there was better information about distribution it would be difficult to advise about the form of mitigation. Another priority area is the physiological mechanisms associated with the causes of tissue injury and mass strandings, the understanding of which is central to interpreting CEEs and devising effective mitigation. While population effects are ultimately the most important consideration, the public focus is on the stranding of a small number of animals. Consequently, it was felt that placing large amounts of effort into assessing population size was of less priority than research on mitigation measures that might help solve the problem.

Because CEEs involve intentionally exposing animals to sound, their use has been opposed by some groups in the past. Others believe that they are the most effective way of understanding some aspects of important conservation problems and that properly conducted CEEs present little risk to the target animals and involve the input of negligible additional sound energy in the environment. It will be important to address, and as far as possible reconcile, such differences of opinion during any future program of

CEEs by open discussion with all stakeholders. It was stressed that any program of CEE should be sharply focused on providing practical solutions to conservation and/or welfare problems.

It was also recognized that opportunistic observations made during the course of ongoing activities (Uncontrolled Exposure Observations) could also provide useful information and that many of the techniques required were similar to those required for CEEs. In the past, successful projects to understand the effects of underwater (UW) noise had often employed a combination of both approaches.

With these background comments in mind, the Workshop agreed to concentrate its discussions on three areas:

- Assessment of beaked whale distribution so that sonar trials could be conducted in low risk areas;
- Process for monitoring and mitigation of the effects of sonars on beaked whales; and
- Ways of changing sonars to make them less damaging to cetaceans.

III. TERMS OF REFERENCE

1. Develop an outline of a coordinated program for implementation of research that will address the main knowledge-, technology- and logistics-gaps;
2. Identify current expertise and resources that could be mobilized and included in such a program;
3. Decide on a system of governance of the science process; and
4. Identify the stakeholder groups that need to be informed about research plans.

IV. RESEARCH

1. <u>The report discusses the need for more data/capabilities regarding the following</u>:
    - Beaked whale distribution
    - Beaked whale abundance
    - Modeling techniques: prediction of the temporal and spatial distribution of beaked whales in unsurveyed regions is high priority.
    - Detection: The accuracy of the predictions of beaked whale distribution models would need to be tested through surveys (dedicated or opportunistic). The greatest problem facing such surveys is the poor capacity to detect beaked whales.
        - Beaked whales can be detected visually from suitable platforms when weather conditions allow. However, there is a need to research and develop passive acoustic survey methods. Beaked whales may only vocalise when at depth and they may have a highly direction form of sound transmission. These characteristics restrict the utility of passive acoustic detection of these species but there is a need for much more

research in this area. Areas of ocean overlooked by good land-based vantage points would be ideal.
    - Bottom-mounted hydrophones have recently been adapted for anchorage in deep water. While bottom-mounted static arrays might be useful, these have limitations. They tend to have a relatively narrow frequency range focused at low frequencies and only detect animals that come within a certain range. In order to collate data on distribution within an area, many bottom-mounted systems would need to be deployed. The cost implications of doing this and for the maintenance of the systems might be considerable. However, the use of bottom-mounted hydrophones in conjunction with a towed array could determine whether beaked whale vocalizations can only be detected at depth (i.e., using the bottom-mounted hydrophone) or if surface detection using a towed array is possible.

2. <u>Sites for CEEs:</u>
    - The Report provides a graphical presentation of a proposed process for selecting CEE sites that eventually arrives at the following potential locations:
        - Canary Islands
        - Azores
        - Atlantic Frontier (continental shelf off northwest Scotland)
        - Bay of Biscay
        - Alboran Sea
        - Ligurian Sea
        - Ionian Sea
        - Caribbean

3. <u>Databasing</u>: collated marine mammal and oceanographic databases need to be stored and managed. Databasing is crucial to the efficient use and archiving of the datasets. Resources for a database manager will be required.

4. <u>CEE program of research:</u>
    - It was agreed that any program of research should be strongly focused toward a practical solution to the problems caused by the interaction between beaked whales and military sonar. There needs to be a tangible conservation benefit which is compatible with the military need to use sonar, as a realistic endpoint for the research program. The development of methods for CEEs to test the effects of sonars will also have application to methods for assessing the effects of other sound sources in the oceans. CEEs were considered to be useful approaches to answer two related sets of objectives:

        - To test various sound signals to determine whether alternative signals could be found that might affect beaked whale behavior in a less critical fashion than the current sonar designs. Clearly, any alternative sonar signals will have to function effectively in their primary role and any proposed alterations to existing systems will need to be realistic and practical. Discussion involving the military sonar experts in the group revealed that there might be some scope for altering the sonar signals that are currently used, but that some fundamental limitations in flexibility were expected. Any putative new sonar signals would need to be developed in close cooperation with sonar engineers to assure that their military functionality would not be compromised.

- CEEs can make a significant contribution to understanding the behavioural component of mechanisms that cause beaked whales to strand and die in response to sonar. An understanding of the underlying mechanism will inform attempts to mitigate the negative effect that sonars have on beaked whales, and make it easier to test whether alternative sonar signals are likely to be effective in reducing harm to beaked whales. The Marine Mammal Commission meeting clearly identified a potential interaction between behavior and physiology in the events where beaked whales died. Thus, a full exploration of the mechanism will require significant input from animal physiologists both to advise on parameters to measure during CEEs and for interpreting the significance of responses in a CEE.

5. <u>General requirements for conducting CEEs</u>: the report discusses the following scientific, technical and management factors that go into the organization, planning, and execution of CEEs:

- Field sites: The need to establish a number of suitable field sites and a research vessel to carry out the research was a high priority. (See paragraph 4.5 for the rationale for site selection). It will be essential to collaborate with locally based research groups in each location.
- Research vessel: The choice of research vessel and its strengths, shortcomings and costs, has implications for all aspects of the project. The choice of suitable vessel will be influenced by the characteristics of the likely study sites, and the length of time that field teams will need to spend at sea. Given the anticipated need to conduct many replicates and the importance of any program being designed with a realistic expectation of achieving a useful endpoint, research vessel cost were seen as being of considerable importance. It was generally seen as desirable to design the research so that it could be conducted either from shore, or off a relatively small and low-cost vessel capable of remaining overnight in deep water. The vessel should be capable of doing visual observations, acoustic tracking, and VHF tracking, and should be able to launch a small tag-boat for instrument attachment. Small, quiet research vessels are also desirable because they limit their own potential for disturbing subjects and interfering with experiments. While a suitable low-cost vessel is required for the long-term data collected required in this program, larger vessels could also be suitable for the research and could be used if they are available.
- Field teams: The ability to conduct CEEs include a complex set of logistics and tools and requires trained personnel acting as a coordinated team. In order to properly develop these tools and provide adequate training, it was suggested that CEEs could be conducted by the same team using the same facilities, on another

species that was more easily studied than beaked whales. Ideally, the other species should be as similar as possible to beaked whales, and be of some concern in their own right. It might also be advantageous to study another species in the area where beaked whale research was thought likely to take place. While the results of such a CEE would be valuable preparation for CEEs with beaked whales, results from such tests could not be applied directly to beaked whales.

- CEE components, perceived knowledge and technology gaps: the primary steps in a CEE are summarized in the table below:

CEE Component:	**Knowledge Gaps:**	**Technology / Logistic gaps:**
1.) Baseline data and knowledge: to describe unaffected behavior, and to interpret results of CEEs	**Behavior:** movement and diving behavior. **Physiological state:** Are beaked whales susceptible to decompression sickness (DCS) or other traumas	Time-depth recorder (TDR) records are valuable, but few have been obtained; longer-term attachment device not yet available; measuring gas tensions from free-diving animals difficult
2.) Observation of subject during CEE: before, during, and after sound exposure, should relate to baseline data where available	Basic capabilities exist but need refining. A system which includes near real time telemetry of data would be highly desirable for a program of CEE.	**Instrumentation** attached to subject whale should meet design goals*; **other observations** such as visual and acoustic tracking valuable, but may not justify cost
3.) Experimental exposure: playback of sound to the subject to test response	The full characteristics of naval sonars implicated in stranding are not well described. Realistic "alternative" sonar signals need to be developed. Could beaked whales perceive sonars in a biologically important way, such as the sounds of killer whales?	More variants tested require more CEE replicates; Full level (realistic) source requires actual sonar, which is expensive; a lower-level (200dB) source likely to still require specifically outfitted vessel.
4.) Interpretation of results of CEE: How might changes in behavior or physiological state in response to sound affect animal survival. Population-level effects?	Link between behavioral change during CEE and acute damage to whale is not clear. Population characteristics of beaked whales generally unknown.	Insufficient baseline data currently to quantify strength of different effects; no current techniques are available to measure physiological state; long-term effects require long-term research

- Instrumentation: telemetric tagging of a subject whale is likely to be the key field technique, and necessary and desirable data that instrumentation attached to a subject whale should deliver for sufficient time before, during and after the sound playback were discussed. Received sound at the animal (as is provided by the Dtag and the BProbe) is clearly very desirable as it can provide both a measure of the received level of the sound source and an indication of the animal's vocal behavior. However, given the likely variability in responses to different sound levels and the fact that mitigation is likely to be based on distance, it was suggested that this should not been seen as absolutely essential. Most agreed that measured received levels at the whale were highly desirable in order to determine threshold values for the mechanism leading to fatal effects on beaked whales.

- Testing the effects of experimental sound sources:
    - Presentation of a sound stimulus in the CEE is technically and economically challenging for more powerful sources. At source levels of roughly 200 dB re 1µPa @1m, a specialized ship would likely be required. Full sonar source levels would likely require even more specialized equipment. Thus, the cost of providing the source could be a significant, if not the major, cost of the overall program.

    - Research would probably start with broadcasts at lower levels from underwater speakers. For this to be realistic, the actual characteristics of sounds transmitted by the sonars implicated in whale strandings should be better characterized to design playback signals. While it was perceived as possible that some aspects of sonar signals used by the Navy (frequency sweep, duration, harmonic content) could be modified, changing other aspects (centre frequency, directionality, source level) may well not be practical. It was suggested that the sonar waveform currently used might be perceived as a killer whale by beaked whales, thus causing such a strong response. Modifications to remove overtones from the sonar might be possible in future, and such an altered sonar signal might be one tested using the CEE approach. Researchers should close the loop with naval sonar engineers to identify changes to the sonar waveform that would not compromise sonar function before testing their possible effect on beaked whales in a CEE.

    - It was generally agreed that CEEs should start with low-level exposure and gradually increase the level over multiple experiments until a response is detected. Many reports have suggested that received levels as low as 170 dB re 1µPa could have caused fatal responses in the Bahamas. It was noted that the actual level to which the animals were exposed is unknown and could have been greater or less that this, so great care should be taken in designing and carrying out exposure levels in CEEs. It was noted, however, that starting at a low-level and ramping up over a series of experiments might remove a "startle" effect that might occur in actual naval operations.

    - One consequence of a cautious research protocol which starts at low levels along with the highly variable nature of many behavioral responses, is that a large number of replicates is required to demonstrate no effect at low levels, before the level is increased and tested again. Beaked whales are recognized as extremely difficult to detect and approach in the field. However, it is imperative to design the project from the outset to be able to collect data at a sufficient rate to achieve its objectives. This points to the importance of using techniques and research approaches which are cost-effective and affordable and to conducting exposures at levels likely to elicit significant responses while being able to quickly cease exposures as soon as those responses are observed. A down-side of moving quickly to high exposure levels is that it might place the subject whale at greater risk.

- Interpretation of the results of CEEs: Interpretation of the results of CEEs is required to understand how changes observed in response to a controlled exposure might affect the subject whale. While all felt it was important to attempt to understand how effects from sonars might affect beaked whales on a population level, it was recognized that this was a secondary issue as public concern is currently with the effects on individual animals. It was noted that any detected change in behavior would be a sign of concern but a proper interpretation of the significance of particular behavioral changes depends on a complete knowledge of the mechanism, which is currently lacking though it is to be hoped that this will improve during the course of a research program. Current hypotheses suggest that changes in diving behavior and surface time should be a focus of interest. To fully describe how changes in behavior might lead to the profound consequences observed in stranded whales, though, baseline physiological data was seen as valuable. Also, any CEE should be conducted with a stranding response capability in place in case of an unexpectedly strong reaction from the subject whale.

V. EXPERTISE AND RESOURCES

The Workshop recognized that the ideas expressed in this report are largely those of the UK-based research community. This community does not have all the expertise required to undertake a program of research on beaked whales as suggested by the draft appendix of the MMC report. The emphasis in the current workshop had been on those areas where, given its field of expertise, the UK community could make the most useful contribution. It also recognized that there were other researchers whose expertise would be vital to the success of a research program. In particular, the Workshop recognized the need to include expertise from the geographical regions in which it was likely that beaked whale research might take place. For the Eastern Atlantic, this includes representative for the Canaries, Azores, Atlantic Frontier, Biscay, Alboran Sea, Ligurian Sea and Ionian Sea

VI. GOVERNANCE

If the process of building a beaked whale research program is to succeed, then it probably needs to be sponsored by an overarching science structure. The Marine Board of the ESF (European Science Foundation) has already shown interest in sponsoring future meetings and approaches will be made to Census of Marine Life (CoML) to have a program incorporated formally into its structure.

VII. COMMUNICATION WITH STAKEHOLDER GROUPS

Dr. Boyd agreed to circulate the report of this meeting to appropriate stakeholder groups, but especially with a view toward obtaining their endorsement of the process of consensus-building within the science community.

APPENDIX B

Recent Advances in the Knowledge of Beaked Whales (Summary)

QinetiQ
December 2005

Recent Advances in the Knowledge of Beaked Whales (summary of draft report)

This report provides information on current activities regarding beaked whale research and other activities over the 18-month period from mid-2004 through 2005. Its primary areas of discussion include:

- Scientific Literature, including grey literature and pertinent Internet sites.
- Conferences, including:
    - ECS 2005 (La Rochelle, France, April 2005): main conference and the Beaked Whale Workshop on "*Ziphiids* and Active Sonar—Research Priorities to Reduce Risk to Beaked Whales From Military Sonar" held the day before the start of the main conference.
    - Lerici 2005: an inter-governmental meeting entitled "The Effects of Sound in the Ocean on Marine Mammals" held 2-5 May 2005 at the NATO Underwater Research Centre (NURC), La Spezia, Italy.
    - Monaco 2005: the Second International Workshop on Detection and Localization of Marine Mammals Using Passive Acoustics" held in Monaco in November 2005.
    - Society for Marine Mammalogy (SMM) 2005: held in San Diego December 2005.

- CEEs: this is the most pertinent information and is provided in more detail here:
    - A number of researchers have proposed that Controlled Exposure Experiments (CEE) be carried out to determine what causes beaked whales to react adversely to sonar sounds. For an introduction to controlled exposure experiments and what they can achieve see the summary paper by Tyack *et al* (Tyack *et al*. 2003).
    - CEE's have been used with a number of other sound sources (Koschinski *et al*. 2003) to determine how animals may react to anthropogenic noise. The use with sonar pulses has attracted adverse publicity and researchers are reluctant to proceed without making sure that the experiments are very well planned and have been vetted by the environmental lobby.
    - Within the UK, no CEE's have been attempted on beaked whales to date, but initial planning meetings are being held to look at a CEE carried out as a joint effort by a number of European organisations, with possible U.S. assistance with tag equipment. There have been a number of CEE experiments involving pinnipeds and harbour porpoise in north-west Europe (Kastelein *et al*. 2001; Kastelein *et al*. 2005a; Kastelein *et al*. 2005b) and these could provide the base expertise leading to a beaked whale CEE. Also in Europe, SACLANTCEN have carried out very limited CEE's as part of the SIRENA series of cruises. Subject animals were tagged fin and sperm whales in the Ligurian Sea. Regrettably this data has yet to be published, although it was mentioned by Bondaryk (Bondaryk 2002) during the ECS workshop on CEE's in 2002.
    - A combined team from WHOI and El Hierro University (Canary Islands) are looking at the possibility of carrying out a CEE off El Hierro in the

Canary Islands (Aguilar *et al*. 2004; Johnson *et al*. 2005; Tyack *et al*. 2005). They have tagged beaked whales during three years of field work and now have a good understanding of their behaviour in the area.

- QinetiQ have proposed the use of Less-Controlled Exposure Experiments (LCEE) as a means of gathering a wider range of data as a low-cost precursor to a full CEE (Harland *et al*. 2005). This makes use of the sounds generated during active sonar trials to study the reactions of animals on the fringes of the sound field. A test was carried out in July 2004 as part of a Sonar S2087 development trial and has shown that such work is feasible (Clements *et al*. 2005). A further potential test opportunity arose in June 2005, but operational constraints meant that the work could not be carried out.

- Conclusions:
  - Despite a number of years of intensive funding of research, we still have a long way to go to understanding these enigmatic animals. The use of advanced tagging technology is at last beginning to increase our knowledge and it is likely that as more animals are tagged then we will begin to understand why there is, under some circumstances, such an adverse reaction to the use of active sonar.
  - The tagging is also revealing much more about the use of acoustics by the two tagged species and this is assisting us in determining how useful passive acoustics will be in detecting the presence of these animals close to an operational sonar. It may also provide additional clues on the interaction between animals and active sonar sounds.
  - In order to get a better understanding of the way animals react to active sonar sounds it will be necessary to carry out CEEs. The present research work is putting in place the necessary groundwork to allow this to happen.
  - The tags have also revealed much information on the diving behaviour and this will be of great use when producing behavioural models for use with environmental impact models such as the UK Environmental Risk Management Capability (ERMC) and the U.S. Acoustic Integration Model© (AIM).
  - The analysis of the stomach contents of stranded animals is also revealing information on the diet of a wider range of beaked whale species. If the behaviour of the prey species is known then it is possible to infer some aspects of the beaked whale behaviour as they hunt for the prey species.
  - Unfortunately, despite the many advances made on a few of the beaked whale species, we still have a very poor understanding of the majority of the species, with some only known from stranded animals and/or a very limited number of sightings.
  - The lack of required information prevents refinement of practical mitigation protocols for sonar operations that can ensure avoidance of impacts to beaked whales.

APPENDIX C

Marine Mammal Observations in Support of NORLANT 04 and NORLANT 05 in the Northwest Approaches to the UK (Summary of 2004 and 2005 Reports)

Marine Mammal Observations in Support of NORLANT 04 and NORLANT 05 in the Northwest Approaches to the UK (summary of 2004 and 2005 reports)

NORLANT 04 Experiment

Experiment Summary:

- Task: detect marine mammals, particularly cetaceans via vocalizations.
- Area: UK Northwest Approaches.
- Time: June 2004.
- Assets: bottom hydrophones and retrievable Autonomous Recording Unit (ARU) hydrophones.

Area Selection:

- Normal UK fleet exercise areas.
- Deep and shallow water regions.
- Pre-exercise review of all data bases (10-day averages over 5 years) to select area and time, particularly blue and fin whales.

Data Collection:

- 17 (ARU) hydrophones distributed between the deep and shallow water areas
- Different whale species can be readily distinguished based on their sounds; the songs of each species has its own unique temporal pattern and time-frequency features (particularly blue, fin, minke and humpback whales)

ARU (Pop-Up Ocean Bottom Recorders):

- Developed by Cornell Bioacoustics Research Program.
- Maximum working depth 4,000 m; weight 105 lb in air.
- Includes microprocessor, hard disks (80 Gb), acoustic communications circuitry, and lithium batteries—all sealed in a 17-inch diameter glass sphere in hardened plastic.
- External hydrophone connected through waterproof connector.
- Recording duration samples: 110 days continuous at 2 kHz sampling; 21 days continuous at 64 kHz sampling.
- Acoustic transponder signal triggers burn wire to release anchor, or can be pre-programmed to release at a specified time.
- Over 20 successful worldwide deployments with this earlier version of ARU; today's newer version is more robust with greater data collection capabilities.

Bottom Hydrophones:

- Used to monitor low frequency mysticete vocalizations.
- Recorded from early May to 19 June.

Data Sets:

- Numerous short-duration pulses noted in higher frequency bands, which may equate to sperm whales that were sighted in the deep water area.
- Other than one series or calls from minke whales hundreds of miles to west of exercise areas, the only baleen whales detected were fin whales—mostly located to southwest of exercise areas—total 338 fin whale calls detected.
- Some fin whale detections were lower in frequency than is usually noted in fin whale songs.

Cetacean Vocalization Detections Conclusions:

- Although a greater number of fin whale calls were detected than in previous Junes, this is attributed to the use of ancillary signal processing. Each day, subsets of detected calls were logically grouped to represent individual fin whales.
- Very few fin whale songs, or portions of a song, were detected. Detections were mostly less than 1 min duration, low received level and contained only a few pulses. A review of data available from past years confirmed that these fin whale calls were typical for this area in June.
- Few fin whale calls were detected near the exercise areas; over 95 percent of the calls were located to the southwest.
- As expected, no blue or humpback whale calls were detected.
- Coincident to sperm whale observations in area, detailed review of data displayed possible pulsing which, if confirmed during playback, would be the first such detection of odontocetes in this area.

<u>NORLANT 05 Experiment</u>

Objectives:

- Conduct passive acoustic monitoring for the presence of marine mammals and review their acoustic signatures for potential departure from normal behavior during anthropogenic sound transmission events.
- Continue passive acoustic data collection in the vicinity of the same shallow and deep water areas as NORLANT 04, to generate an acoustic database with which behavior and acoustic variability can be measured.
- Use pre-exercise recorded data, passive acoustic data collected during the exercise, and post-exercise recorded data to assess any behavioral reactions to anthropogenic sound transmission events.

Approach:

- Recording acoustic data was accomplished using a Dell Workstation to retain acoustic energy that could potentially provide an indication of marine life behavioral change. The data only offer an opportunity to process low frequency information, but these acoustic data can be gauged against several years of previously archived data and reviewed for variability.
- During the exercise phase, passive acoustic data were collected within hundreds of miles of the deep and shallow water areas. The monitoring consisted of detailed

analysis of all frequencies using an ancillary, state-of-the-art, signal processing methodology.
- The Dell Workstation recorded all available frequencies and logs of marine mammal vocalizations were maintained whenever they were detected. Acoustic data were continuously reviewed for any odontocete and mysticete detections, which were compared to known marine mammal acoustic activity (in the exercise area vicinity) for variation or departure from normal behavioral patterns.
- Passive acoustic monitoring for acoustic behavior data occurred from 29 Jun through 6 July and on 11 July, 2005.

Findings:
- NORLANT 05 data collection efforts expanded the knowledge base of fin whale activity.
- Passive acoustic monitoring of whale vocalizations is more dynamic than is often published in current scientific literature:
    - Fin whales radiate four known call sequences; 20 Hz, Backbeats, Pre-cursor and Schizo signals.
    - The 20 Hz signal is the most detected and has a very high power level of up to 185 dB.
    - Backbeats occur just below 20 Hz pulses and are often masked by the intensity of the 20 Hz pulses.
    - Pre-cursor pulses occur in a band between 128 and 138 Hz. The center of this band is most often near 132 Hz. When present, the Pre-cursor pulses precede the 20 Hz and Backbeat pulse and all three pulses are vocalized in very short time order. Pre-cursors are normally only detected when the fin whale is close to a monitoring system and in northern latitudes. Fin whales have been noted turning the Pre-cursor pulse on and off whilst continuing the common 20 Hz pulse sequences.
    - Schizo calls are the least known and understood of the calls from fin whales. These radiate at lower power than 20 Hz calls, and pulse or cycle up and down in frequency between 20 and 100 Hz. They are normally detected in the 35 to 75 Hz band. Schizo calls are mostly detected independent of the other fin calls, although occasionally a whale will shift back and forth to a 20 Hz sequence during Schizo calling.
    - Call sequence timing is normally visible from the 20 Hz signal as it is low frequency, potentially high output power, and long duration. Fin whales will radiate 20 Hz for many hours in call sequences of 15-25 minutes on, and two to three minutes off. These on/off patterns are often matched across passive acoustic monitoring systems for time-difference fixes. Historical tracks indicate that in most cases the fin is swimming near 2.5 kt or less, when radiating these powerful pulses. Due to their uniqueness and power, they can be detected at many hundreds of miles and positioned with relatively good accuracy.
    - Pre-cursor pulses and Schizo calls are generally only detected in latitudes north of 40 degrees. Fin whales detected south of 40 degrees N are normally detected exhibiting 20 Hz and Backbeats only. The lack of Pre-

cursor pulses and Schizo calls from whales located below 40 degrees N may also be due to greater ranges from monitoring systems and fewer whale detections. On occasion, Backbeat pulses have been detected for up to 30 min in the absence of all other signals. This has also only been observed in northern latitudes.

  - Analysts traditionally search for fin whales using standard signal processing techniques and focus on the 20 Hz signal as it is the most detectable. Results of these searches showed few fin whale detections in the Northwest Approaches during May and June. Searches during this exercise were done using newer, state-of-the-art signal processing and resulted in more fin whale detections than using the traditional standard processing.

Noise:

- Commercial shipping was average for June and July, contributing somewhat to ambient noise.
- Weather was unsettled for some of the days, moderately reducing detection coverage for relatively short time periods.
- The major low frequency ambient noise contributor was two of three seismic profiler vessels operating in the western Atlantic:
  - One of these operated southeast of Newfoundland and provided little increase in low frequency ambient noise levels.
  - The other two profilers were the main contributors to greater low frequency noise levels. Both profilers operated for the bulk of the exercise period.
  - The profiler just east of Newfoundland operated on the shelf and radiated low frequency impulse energy across the basin into the exercise area.
  - The profiler southwest of the tip of Greenland faded in intensity when it moved behind crests of the Mid-Atlantic Ridge.
- Anthropogenic sound transmissions were detected when it was operating at high power and/or in proximity to a passive acoustic monitoring system. Very low frequency (VLF) excitation occurred and the individual pulses could potentially be employed to fix the source position using time-difference-fixing. VLF energy was very detectable and an increase in frequency noted as output power increased.
- A fair amount of earthquake activity was noted in the Mid-Atlantic Ridge area during the exercise.
  - Two low to moderate magnitude swarms originated near the Gibb's Fracture Zone. These small swarms of 11 and 16 earthquakes occurred on 05 and 06 July 2005.
  - Moderate earthquakes in this area were also noted on 30 June and 01 July 2005.

Conclusions:

- No variation from normal behavior patterns for fin or blue whales due to anthropogenic sound transmissions was noted.

- Monitoring the NORLANT 05 exercise via passive acoustics was challenging and rewarding. More whale vocalizations were noted than initially anticipated.

- As expected, an increase in whale vocalization activity was noted from 29 June to 11 July 2005. Exercises to be conducted later in the calling season and other geographic areas would allow for increasing the data take and, hence the statistical significance, of the current database.

APPENDIX D

Effects of SURTASS Low Frequency Active Sonar on Fish

Presented at the Acoustical Society of America (ASA) Meeting in Vancouver, Canada

May, 2005

Effects of SURTASS Low Frequency Active Sonar on Fish

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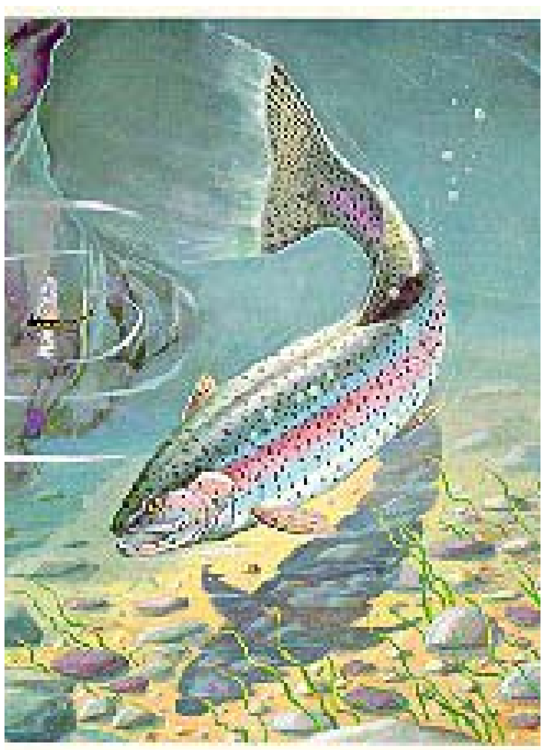
OBJECTIVES

- **Examine effects of SURTASS LFA on fish including:**
  - **mortality**
  - **changes in hearing capabilities**
  - **auditory anatomy**
  - **non-auditory systems**
- **Sound very similar to SURTASS LFA**
- **Sound levels similar to those to which fish might be exposed**
- **Effects on fishes with structural differences in auditory system**

Methods

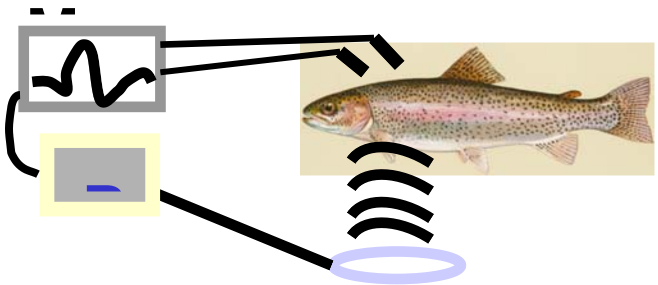
Experimental animals

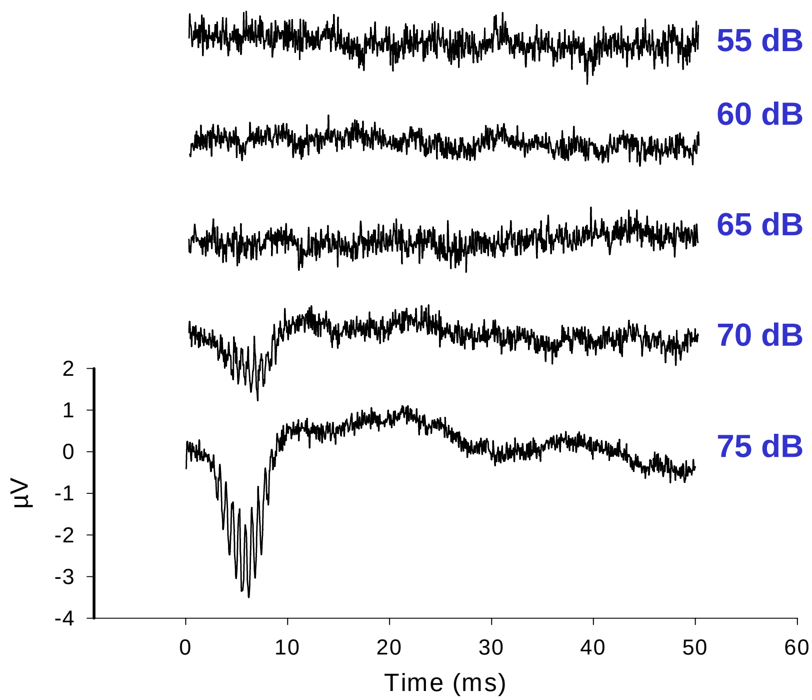
- **Fish of concern are endangered salmon (genus *Oncorhynchus*) -- not available for experiments**
- **Using a "surrogate" salmonid indigenous to Seneca Lake, rainbow trout (*Oncorhynchus mykiss*)**
- **Ears and other systems of rainbow similar to salmon (hearing generalist)**
- **Channel catfish represents hearing specialists**



Physiological determination of fish hearing

- **Measure auditory brainstem response (ABR)**
- **Give signal that reflects sounds detected by the ear, but measured in the brain**





Location of project:
Seneca Lake, New York

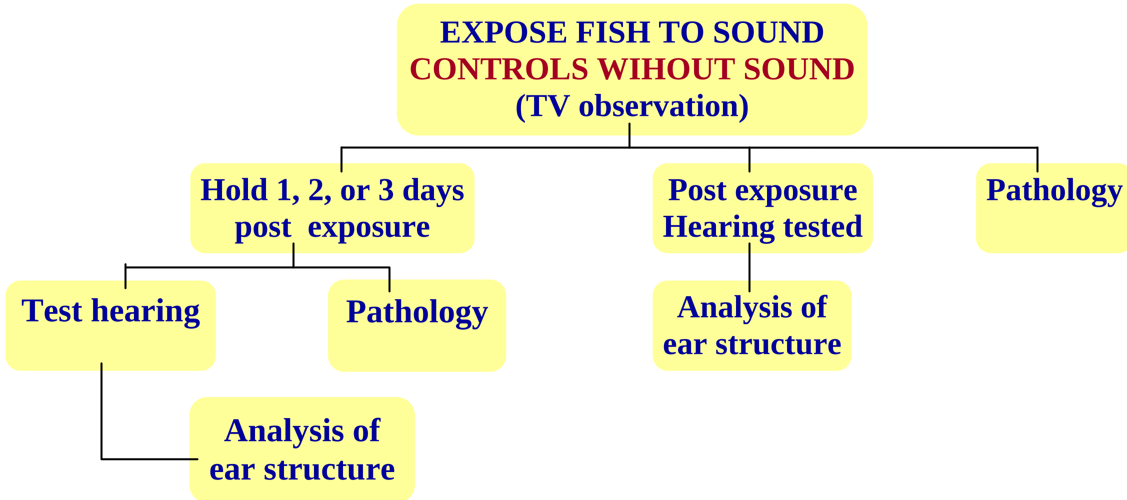
Seneca Lake SONAR TEST FACILITY

- **Navy Sonar Test Facility**
- **Navy has an extensive acoustic facility**

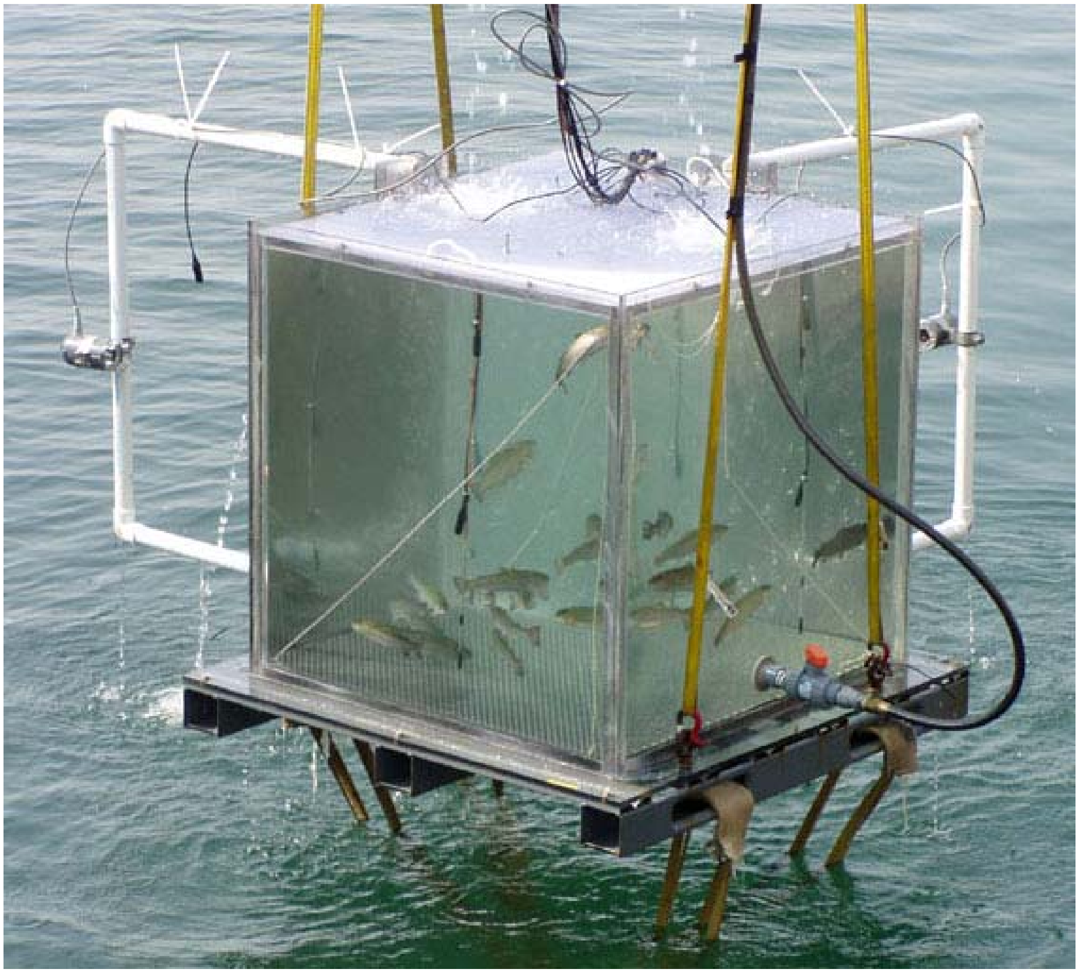
Work done on test barge

- Barge in middle of Seneca Lake
- Excellent shore facilities for physiological and anatomical work
- Strong support staff on barge for acoustic experiments

Experimental overview



- **About 20 fish placed in 1 cubic meter Lexan® test cage**
- **Cage lowered slowly to about 50**
- **Six hydrophones in cage**
- **Two video cameras to observe & record behavior**



**Location of cage
vs. source**

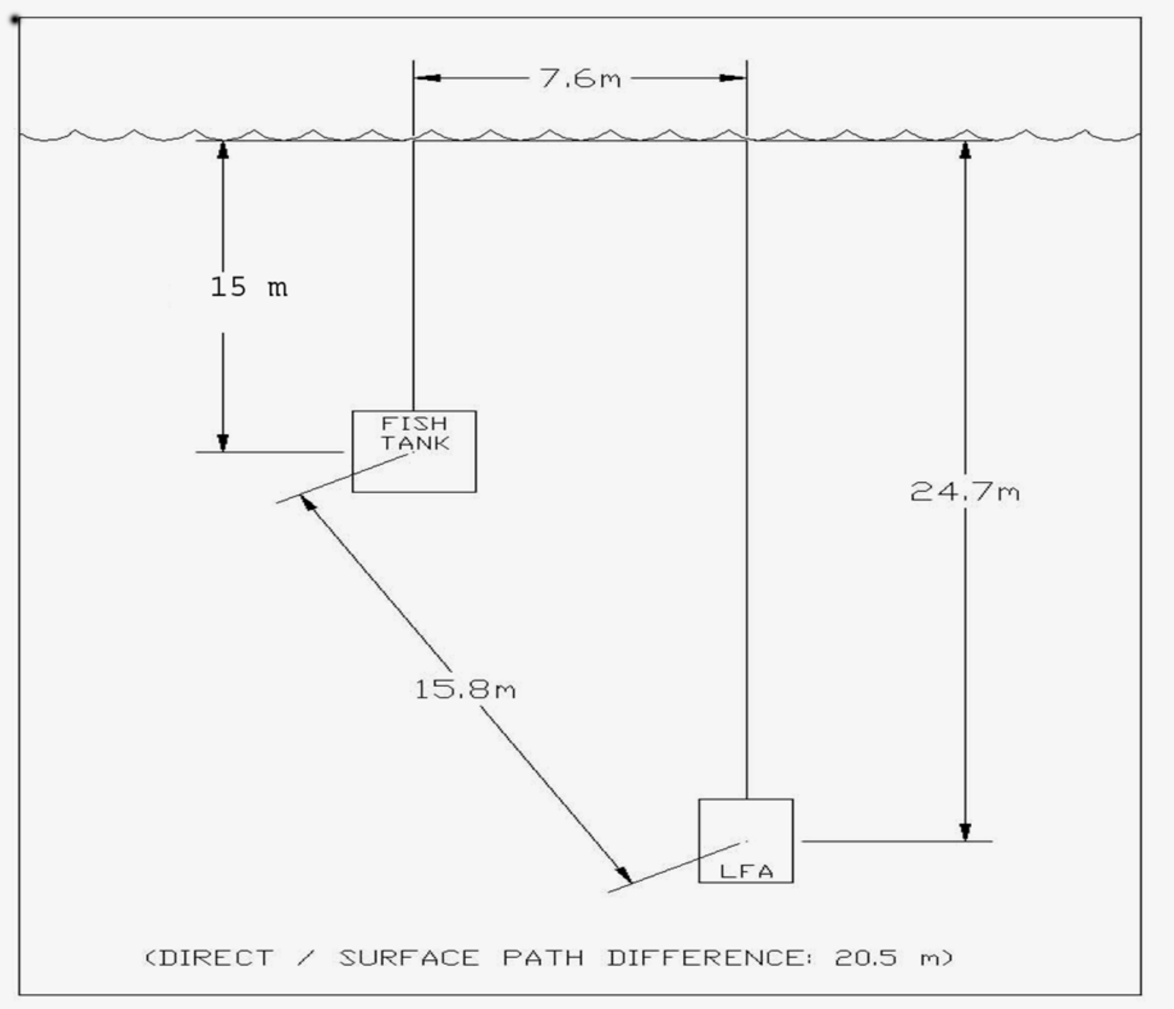
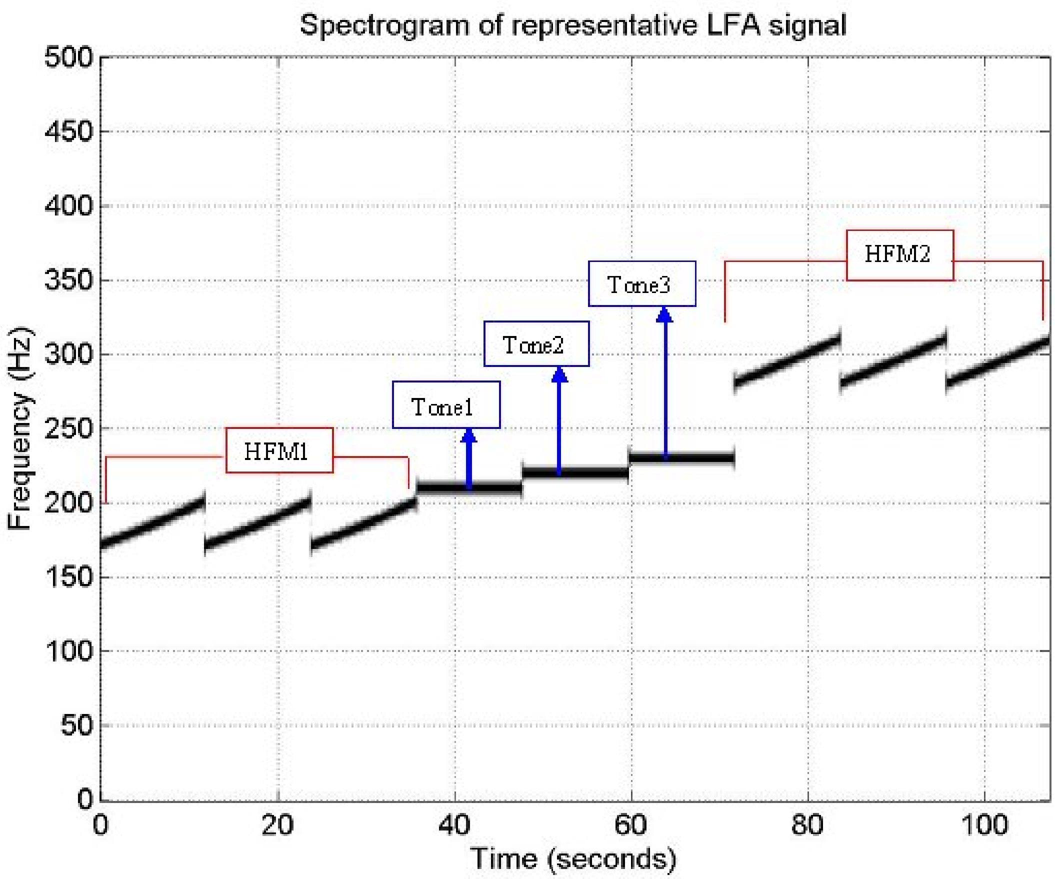


Figure 1. Fish Tank Test Geometry.

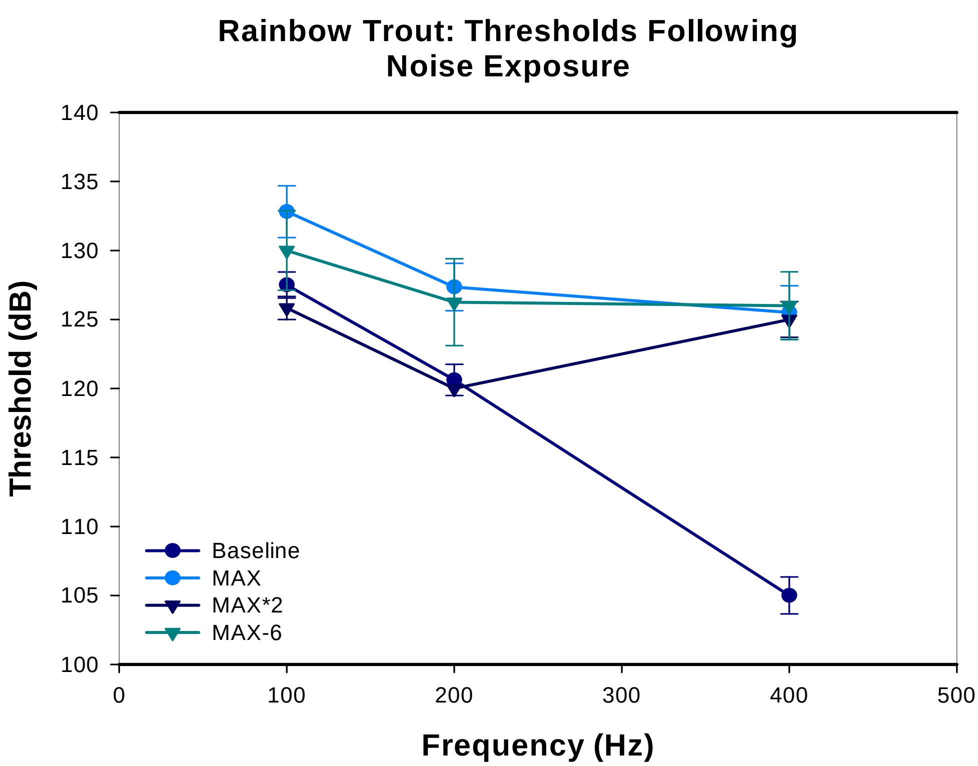
Sounds

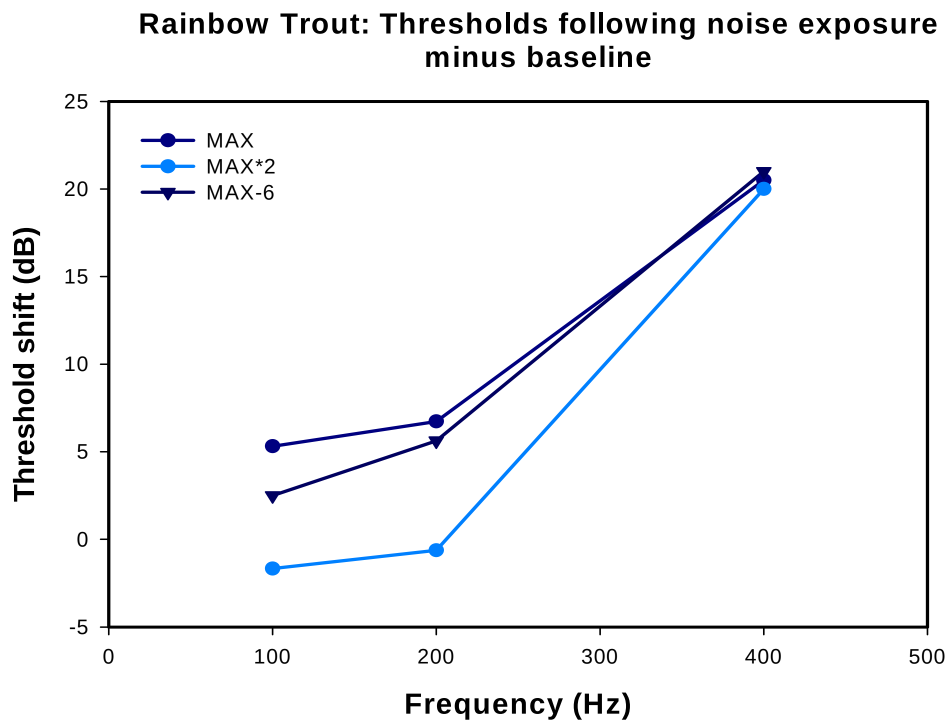
Initial SPL at cage around 193 dB re 1 μPa

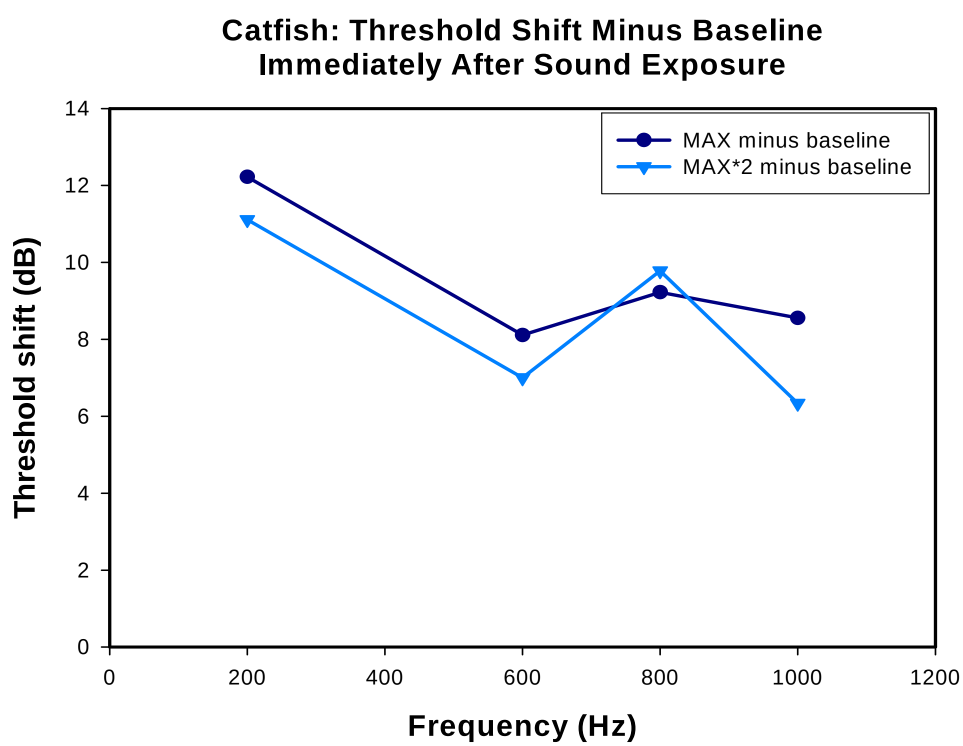
- **Loudest sound we can get at a distance that is in the acoustic far field of the source**
- **Three repetitions of sounds – 15% duty cycle, three sound presentations, total 26 minutes.**

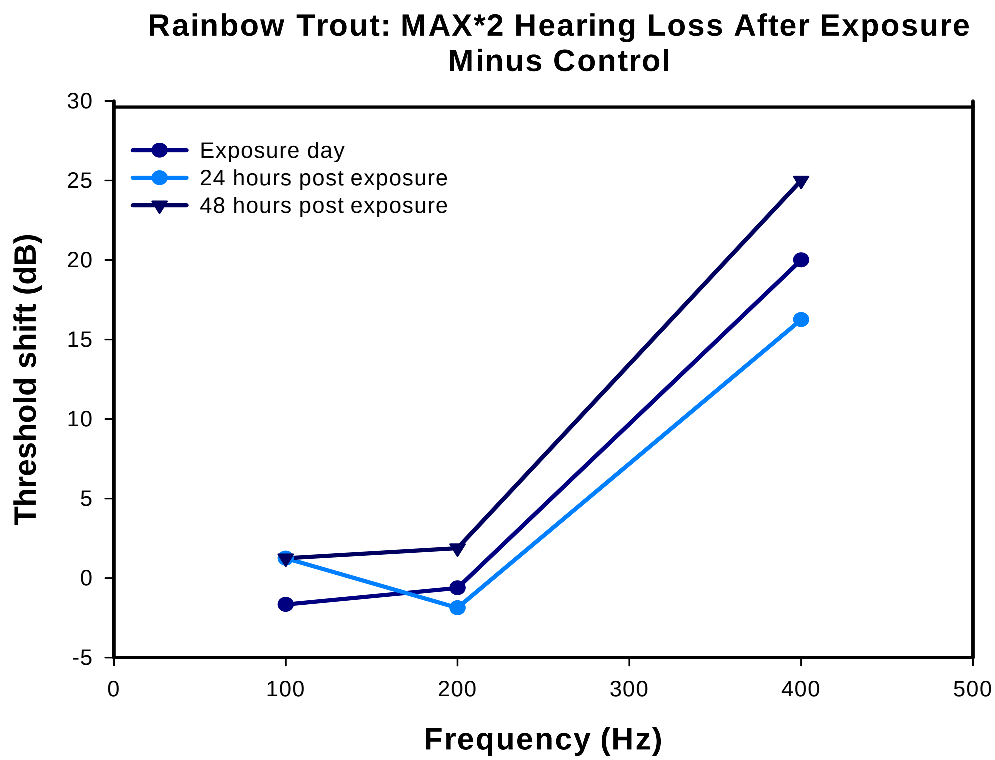


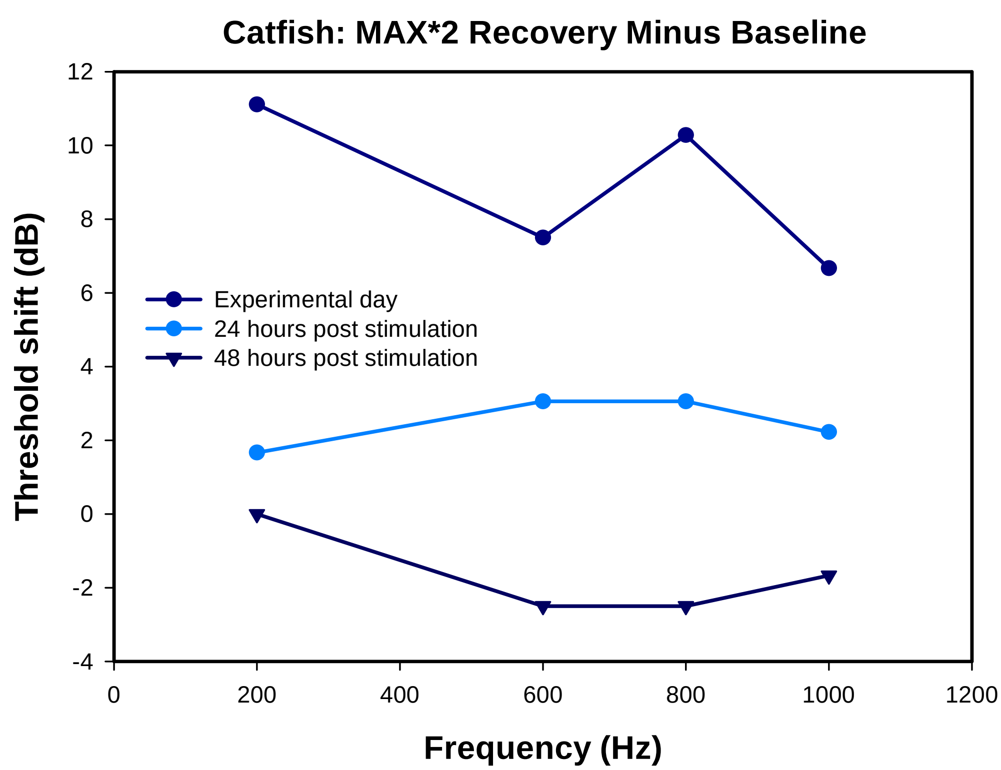
Results


Rainbow Trout: Thresholds Following Noise Exposure
Threshold (dB)
140
135
130
125
120
115
110
105
100
0
100
200
300
400
500
Frequency (Hz)
Baseline
MAX
MAX*2
MAX-6


Rainbow Trout: Thresholds following noise exposure minus baseline
MAX
MAX*2
MAX-6
Threshold shift (dB)
25
20
15
10
5
0
-5
0
100
200
300
400
500
Frequency (Hz)


Catfish: Threshold Shift Minus Baseline Immediately After Sound Exposure
MAX minus baseline
MAX*2 minus baseline
Threshold shift (dB)
14
12
10
8
6
4
2
0
0
200
400
600
800
1000
1200
Frequency (Hz)

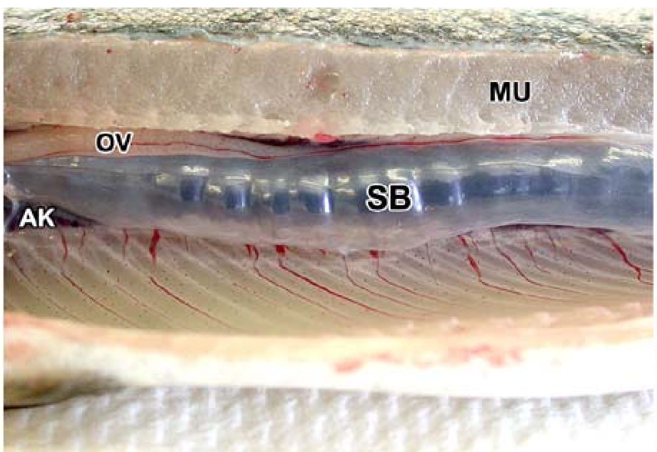

Rainbow Trout: MAX*2 Hearing Loss After Exposure Minus Control
Exposure day
24 hours post exposure
48 hours post exposure
Threshold shift (dB)
Frequency (Hz)
30
25
20
15
10
5
0
-5
0
100
200
300
400
500

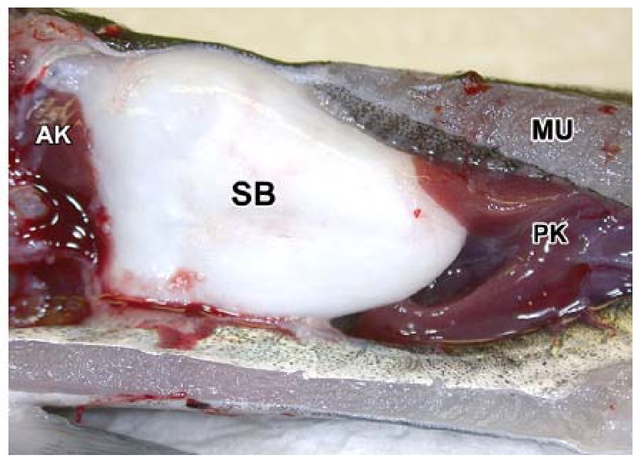

Catfish: MAX*2 Recovery Minus Baseline
Experimental day
24 hours post stimulation
48 hours post stimulation
Threshold shift (dB)
Frequency (Hz)
12
10
8
6
4
2
0
-2
-4
0
200
400
600
800
1000
1200

Gross and Histopathology

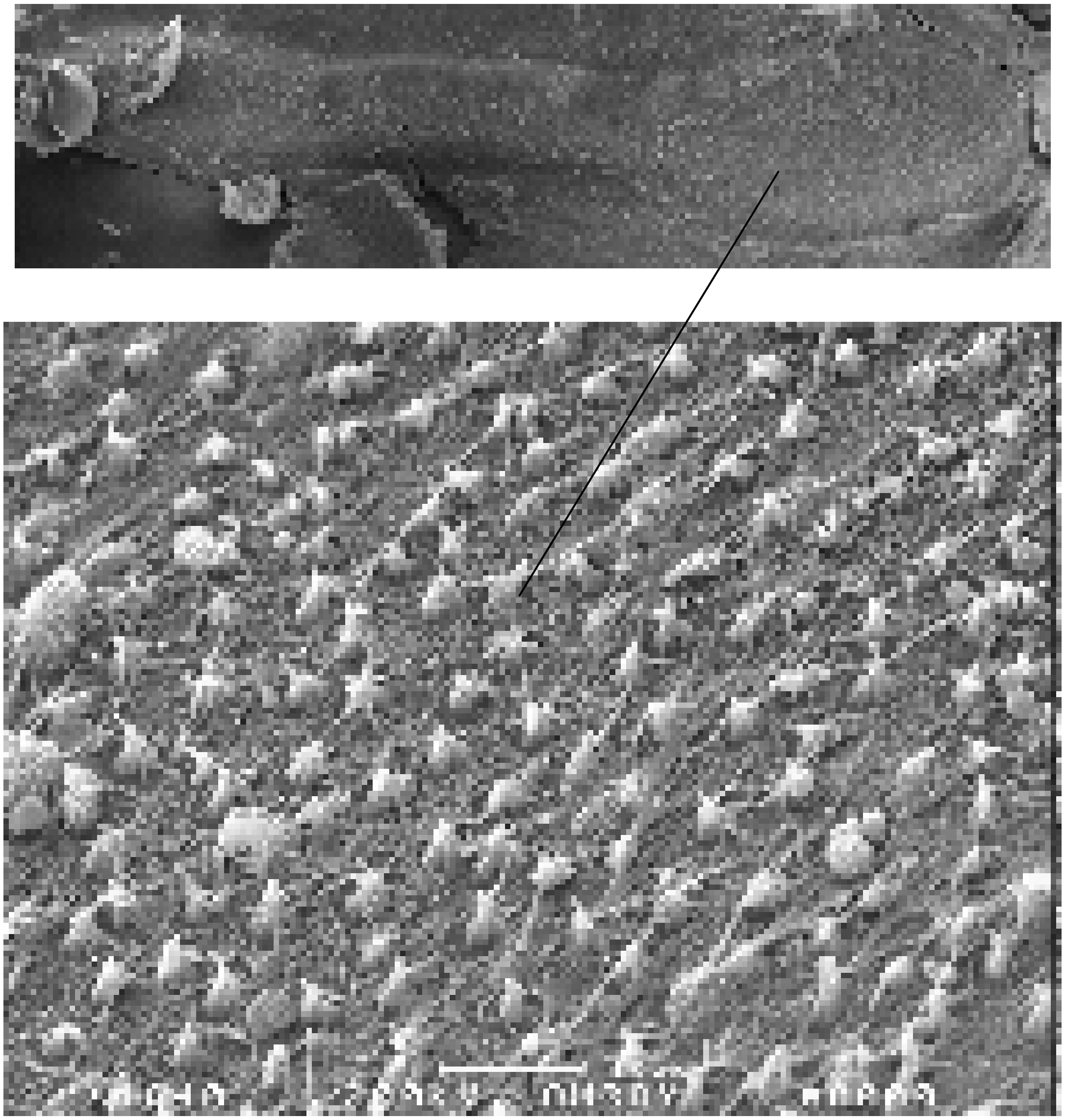
- **Fish veterinary pathologist examined all organ systems for gross pathology (including swim bladder) and no effects**
- **Pathologist examined all organ systems with extensive histopathology to look for cellular effects and none found**

Trout swim bladder **Catfish swim bladder**





Ear Tissue
Immediately post exposure



CONCLUSIONS

- **Exposure to SURTASS LFA was a "worst case" situation in this test**
- ***All* animals (both species) healthy post exposure, even when kept four days**
- **No gross pathological effects**
- **No histopathological effects to any organ system**
- **Found hearing loss in both species immediately post exposure**
- **Recovery occurs within 48 hours in catfish, 96 hours in rainbow trout**
- **Initial findings suggest very little effect on these species by SURTASS LFA**
- **Still not sure how readily we can extrapolate results to other species**
- **Fish will generally not receive this intense an exposure to LFA sounds, so effects on hearing is likely to be less, or non-existent**
- ***However*: during the time that fish are subject to TTS they may be at a disadvantage in finding food and/or detecting predators!**