Presentation at the First Plenary Meeting of the Advisory Committee on Acoustic Impacts on Marine Mammals

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MARINE MAMMALS, HEARING AND SOUND

ADVISORY COMMITTEE ON ACOUSTIC IMPACTS ON MARINE MAMMALS

FEBRUARY 4, 2004

PAUL E. NACHTIGALL

HAWAII INSTITUTE OF MARINE BIOLOGY

UNIVERSITY OF HAWAII

Key Questions:

1. **Why is sound important to marine mammals?**

2. **How do different marine mammals differ in their uses of sound?**

3. **What are the basics of marine mammal hearing?**

4. **What are the critical components of marine mammals use of sound for evaluating impacts?**

Hearing and Sound have shaped the evolution of marine mammals

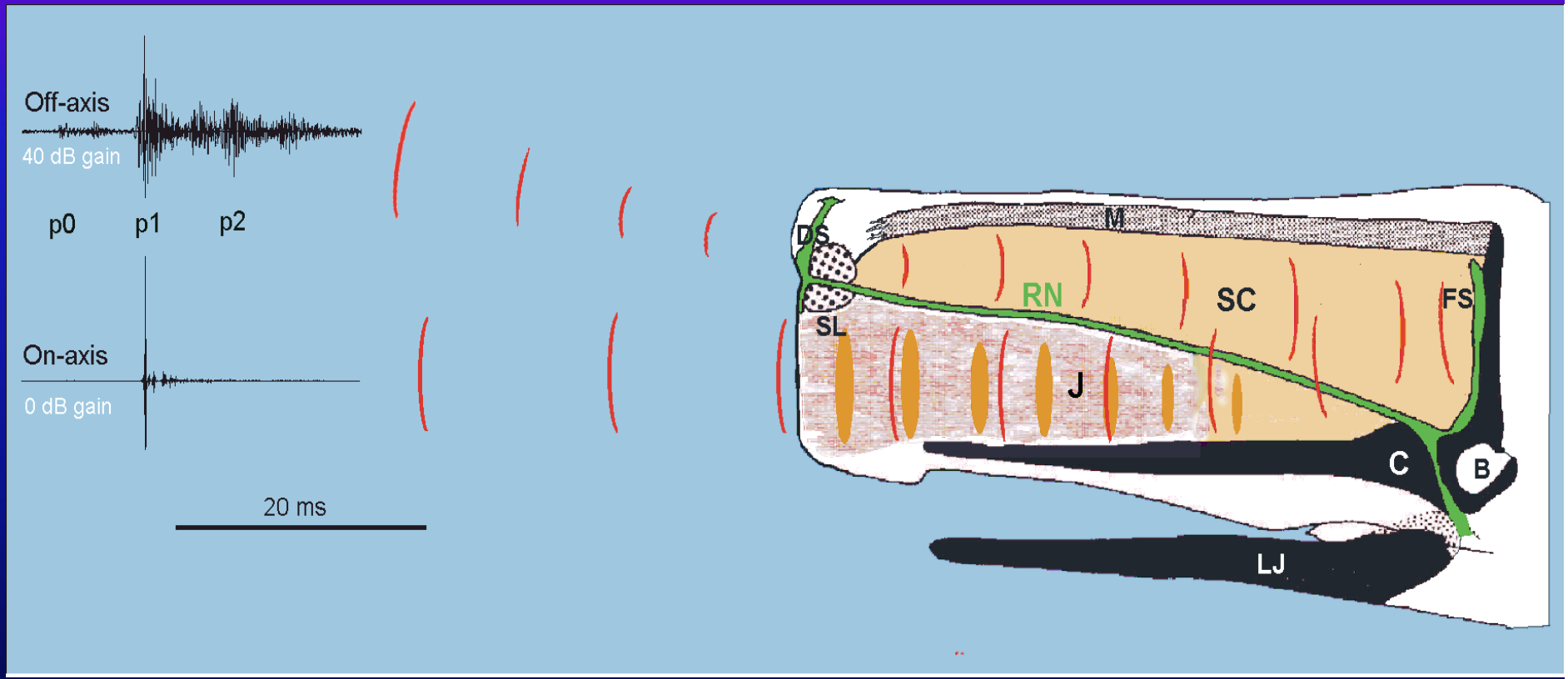
Norris, Kenneth S. (1968) The Evolution of Acoustic Mechanisms in Odontocete Cetaceans. In: *Evolution and Environment* E.T. Drake Editor, Yale University Press, New York 297 –324.

Norris, Kenneth S. and Harvey, G.W. (1972) A Theory for the Function of the Spermaceti Organ of the Sperm Whale (*Pyseter catadon L.*) In: S.R. Galler, K. Schmidt-Koenig, G.J. Jacobs and R.E. Belleville, eds *Animal Orientation And Navigation.* NASA Special Publication 262. NASA Scientific and Technical Office, Washington D.C.

Foraging

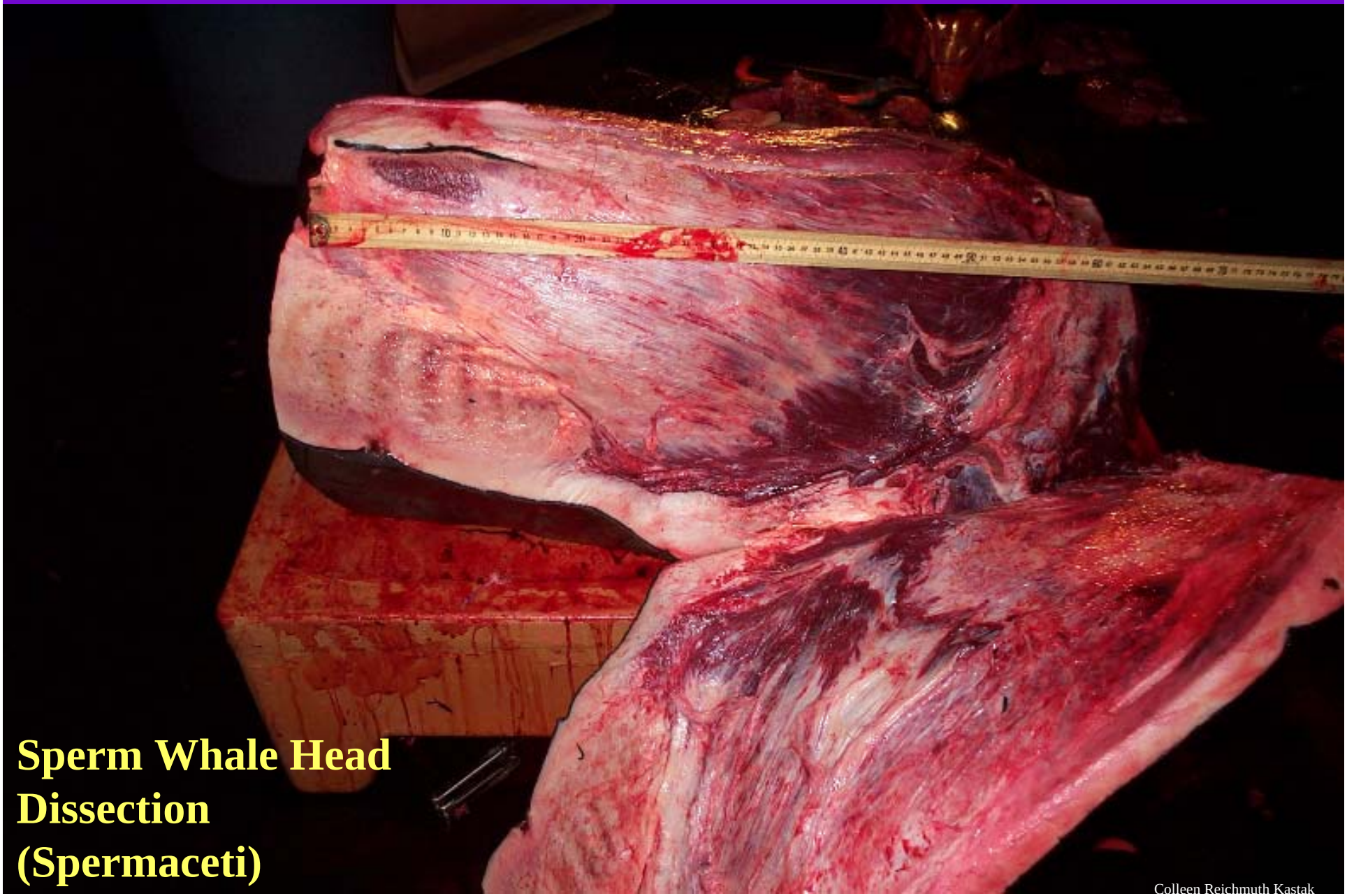
Joe mobley

The Møhl Model – Sperm Whale Click Production



DS, distal air sack, PL, phonic lips, M, layer of muscles, RN, right narial duct,SC, spermaceti case, FS, frontal airsac, C, cranium, B, brain case, LJ, lower jaw, J, junk, with lenses of spermaceti wax.

Echolocation



Sperm Whale Head Dissection (Spermaceti)

Colleen Reichmuth Kastak

Echolocation - False Killer Whale

Hawaiian Spinner Dolphin group foraging

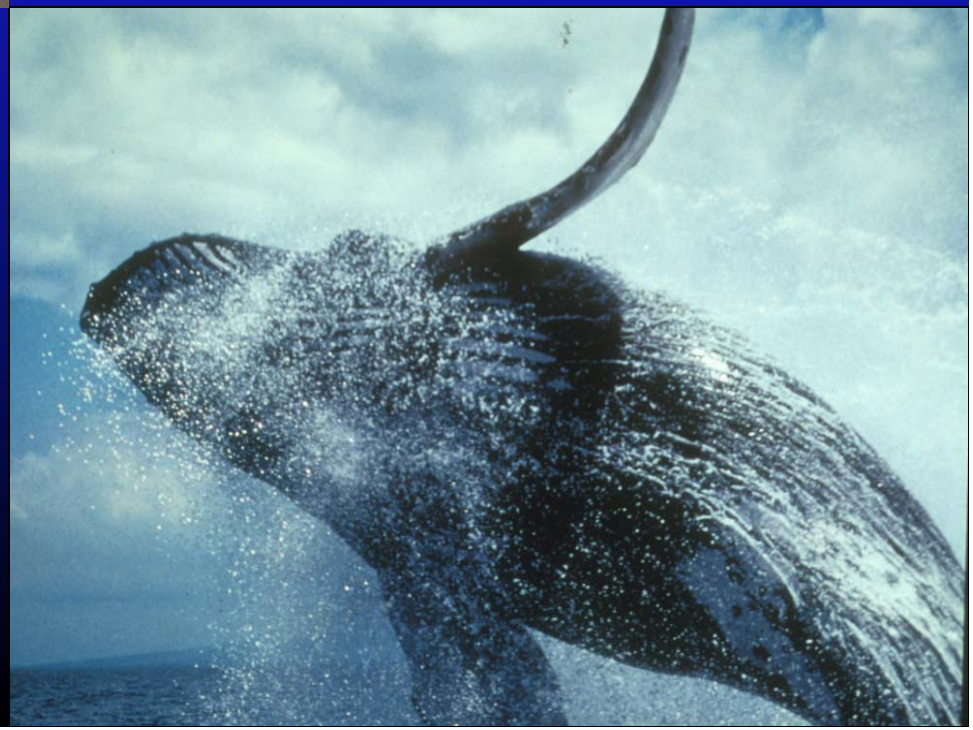
Mysticete Whale long Range communication

Communication

Parental Care

Male-Male Competition

Reproduction



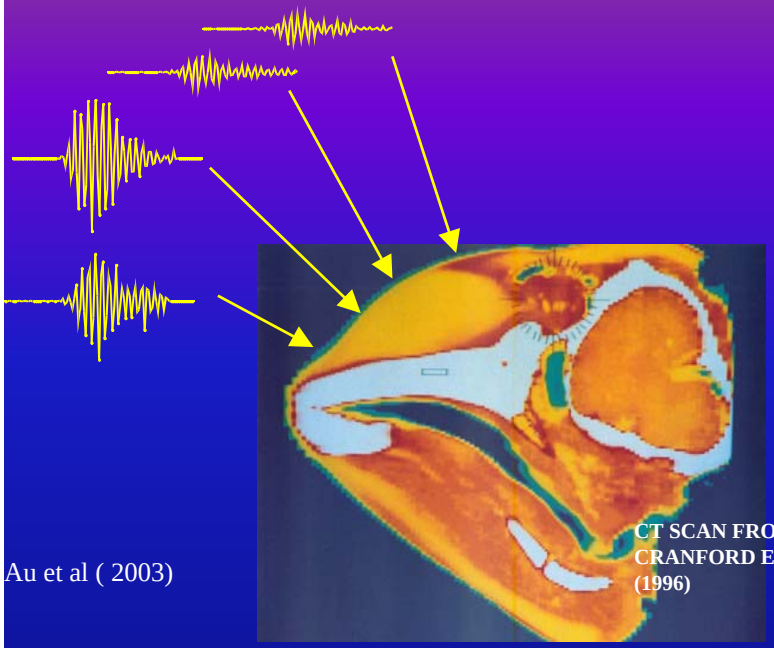
Hearing is necessary for the avoidance of Predators
Baby Humpback Whale – Large Tiger Shark

Why is sound important for marine mammals?

The use of sound has shaped the evolution of most Marine mammals.

1. **Foraging and Echolocation**
2. **Communication**
3. **Social Behavior**
4. **Reproduction**
5. **Parental Care**
6. **Avoidance of Predators**
7. **Overall Awareness of the Environment**

2. How do different marine mammals differ in their uses of sound?



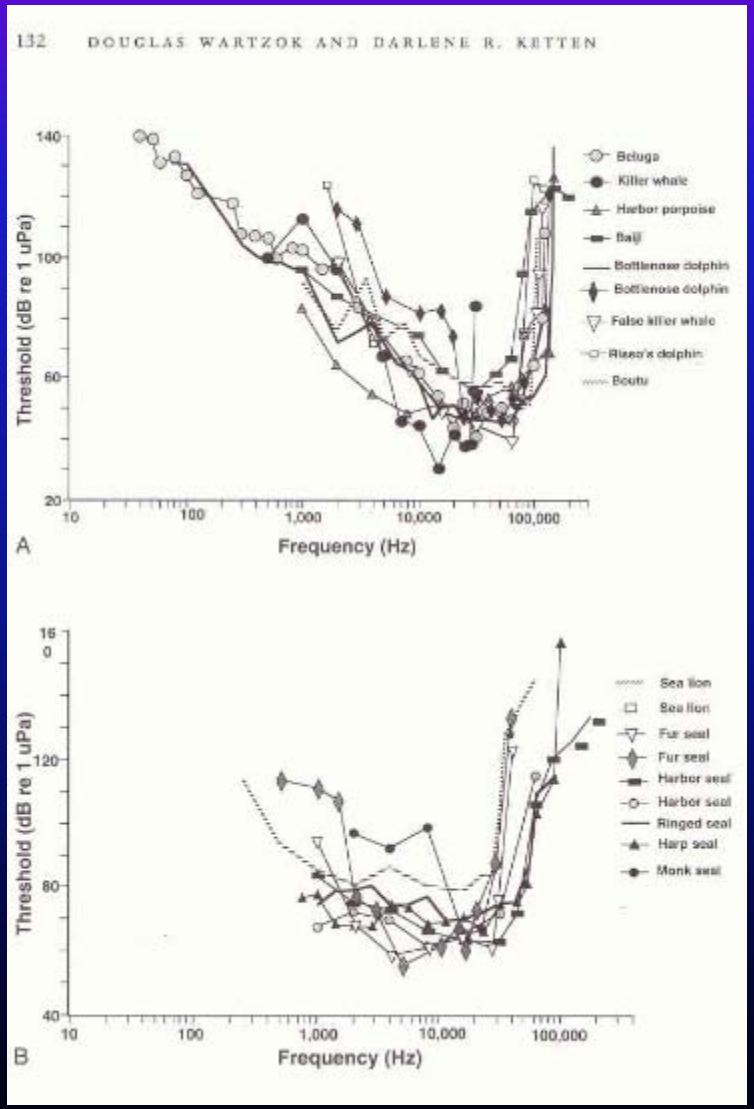
Au et al (2003)

CT SCAN FROM CRANFORD ET AL (1996)

Phil Colla

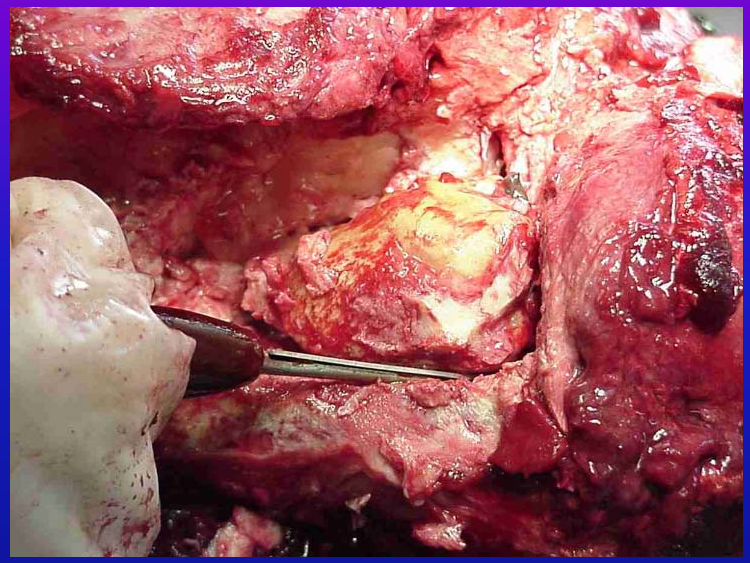
Harbor Seal

Bottlenosed Dolphin



Odontocetes

Pinnipeds



3. What are the basics of marine mammal hearing?

Source Level – The level where the sound is produced

Received Level – The level where the sound is received

Why are both the level and the frequency that the animal hears important?

ATOC example

75 Hz 195 db source level 800M deep

That sound traveling upward and 500M to either side would be reduced to 130 db. An animal at the surface would ‘experience’ A 130 db sound. But, both the False killer whale and the Risso’s dolphin tested at 75 Hz could not hear below 140 dB.

Cetacea (Rice,1998)

Right Whales
Balaena glacialis
Balaena mysticetus
Pygmy Right Whales
Caperea marginata
Gray Whale
Eschrichtius robustus
Rorquals
Megaptera Novaeangliae
Balaenoptera acutorostrata
Balaenoptera bonaerensis
Balaenoptera edeni
Balaenoptera brydei
Balaenoptera borealis
Balaenoptera physalus
Balaenoptera musculus
Sperm Whale
Physeter macrocephalus
Pygmy Sperm Whales
Kogia Breviceps
Kogia Sima
Beaked Whales
Ziphius cavirostris
Berardius arnuxii
Berardius bairdii
Tasmacetus shepherdi
Indopacetus pacificus
Hyperoodon ampullatus
Hyperoodon planifrons
Mesoplodon hectori
Mesoplodon mirus
Mesoplodon europaeus
Mesoplodon bidens
Mesoplodon grayi
Mesoplodon peruvianus
Mesoplodon bowdoini
Mesoplodon behamondi
Mesoplodon carlhubbsi
Mesoplodon genkgodens
Mesoplodon stejnegeri
Mesoplodon layardii
Mesoplodon densirostris
Indian River Dolphin
Platanista gangetica
Amazon River Dolphin
Inia geoffrensis

Chinese River Dolphin
Lipotes vexillifer

La Plata Dolphin
Pontoporia blainvillei
Beluga and Narwhal
Delphinapterus leucas

Monodon monoceros
Dolphins
Cephalorhynchus commersoni
Cephalhynchus eutropia
Cephalorhynchus heavididii
Cephalorhynchus hectori
Steno brenanensis
Sousa plumbea
Sousa chinensis
Sotalia fluviatilis
Tursiops truncatus

Stenella attenuata
Stenella frontalis
Stenella longirostris
Stenella clymene
Stenella coeruleoalba
Delphinus delphis

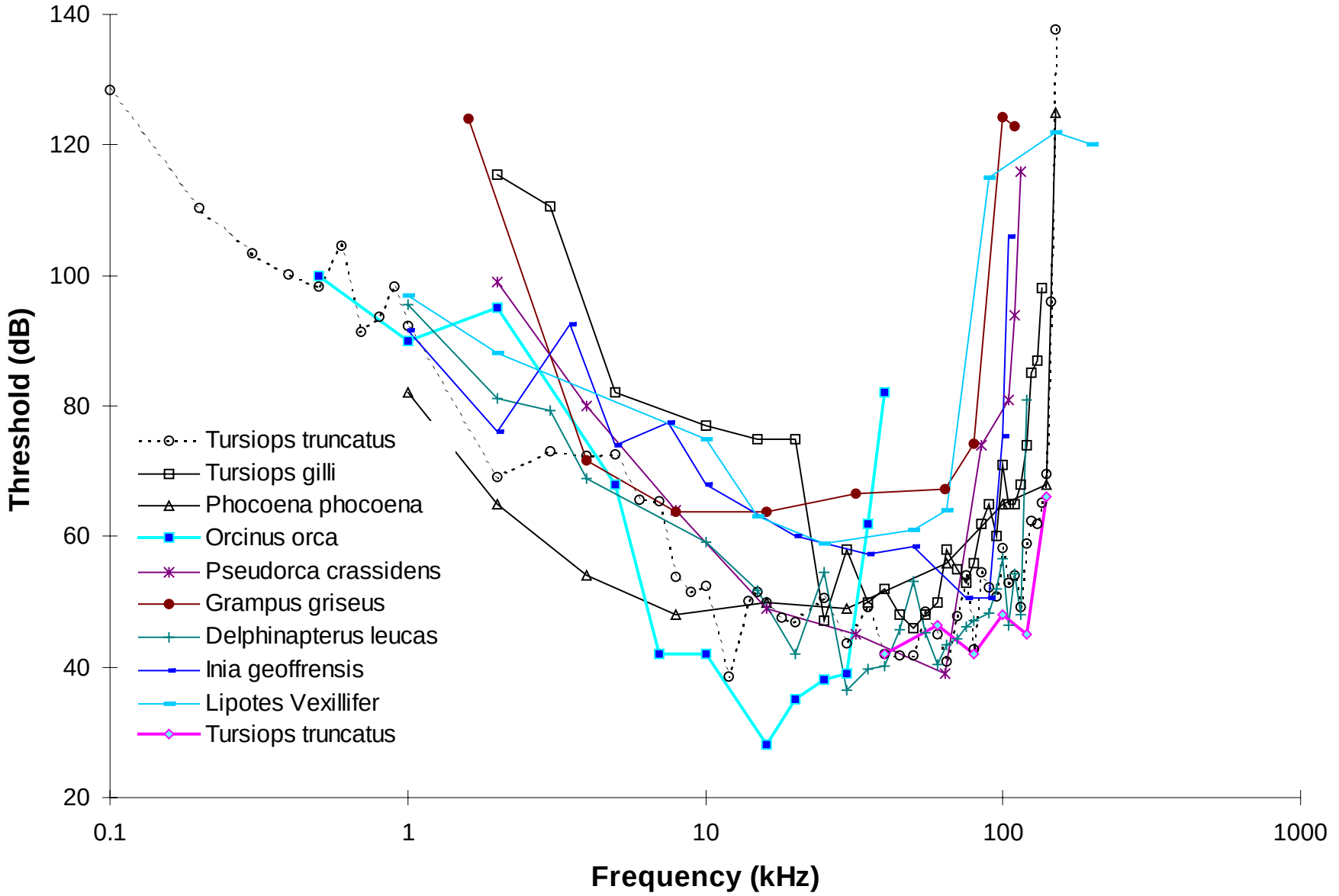
Delphins capensis
lagenodelphis hosei
Lagenorhynchus albirostris
Lagenorhynchus acutus
Lagenorhynchus obliquidens
Lagenorhynchus obscurus
Lagenorhynchus australis
Lagenorhynchus cruciger
Lissodelphis borealis
Lissodelphis peronii
Grampus griseus

Peponocephala electra
Feresa attenuata
Pseudorca crassidens

Orcinus orca
Globicephala melas
Globicephala macrorhynchus
Orcaella brevirostris

Porpoises
Neophocaena phocaenoides
Phocoena phocoena

Phocaena sinus
Phocoena spinipinnis
Phocoena dioptrica
Phocoena dalli


140
120
100
80
60
40
20
Threshold (dB)
0.1
1
10
100
1000
Frequency (kHz)
Tursiops truncatus
Tursiops gilli
Phocoena phocoena
Orcinus orca
Pseudorca crassidens
Grampus griseus
Delphinapterus leucas
Inia geoffrensis
Lipotes Vexillifer
Tursiops truncatus

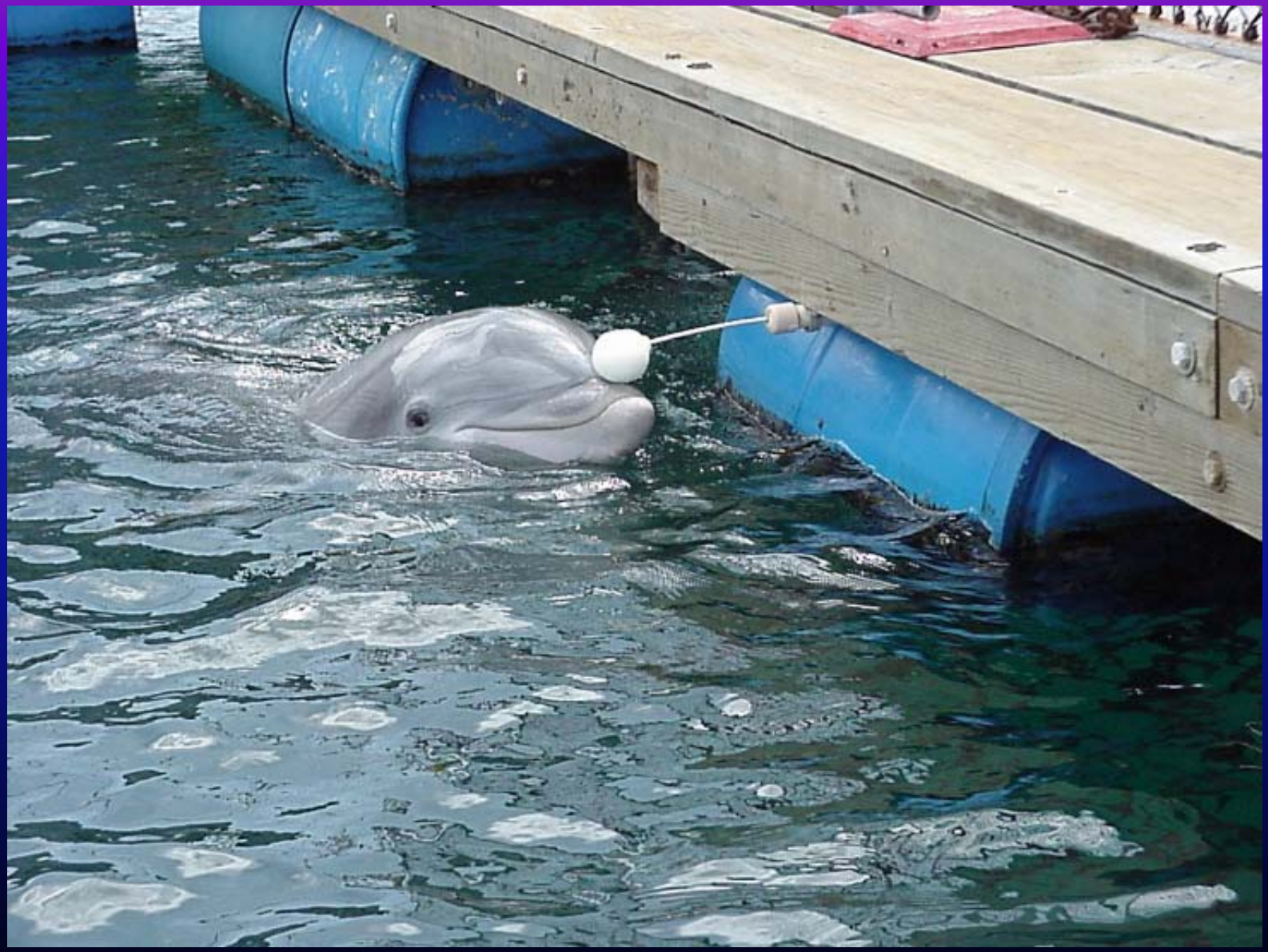
HOW DO YOU TEST THE HEARING OF A DOLPHIN OR WHALE?

- Traditional Psychophysical trained animal experiments.

- Acoustic brainstem response (ABR) experiments where hearing is determined by measuring the animals brainwave responses to sound.

Behavioral Audiograms

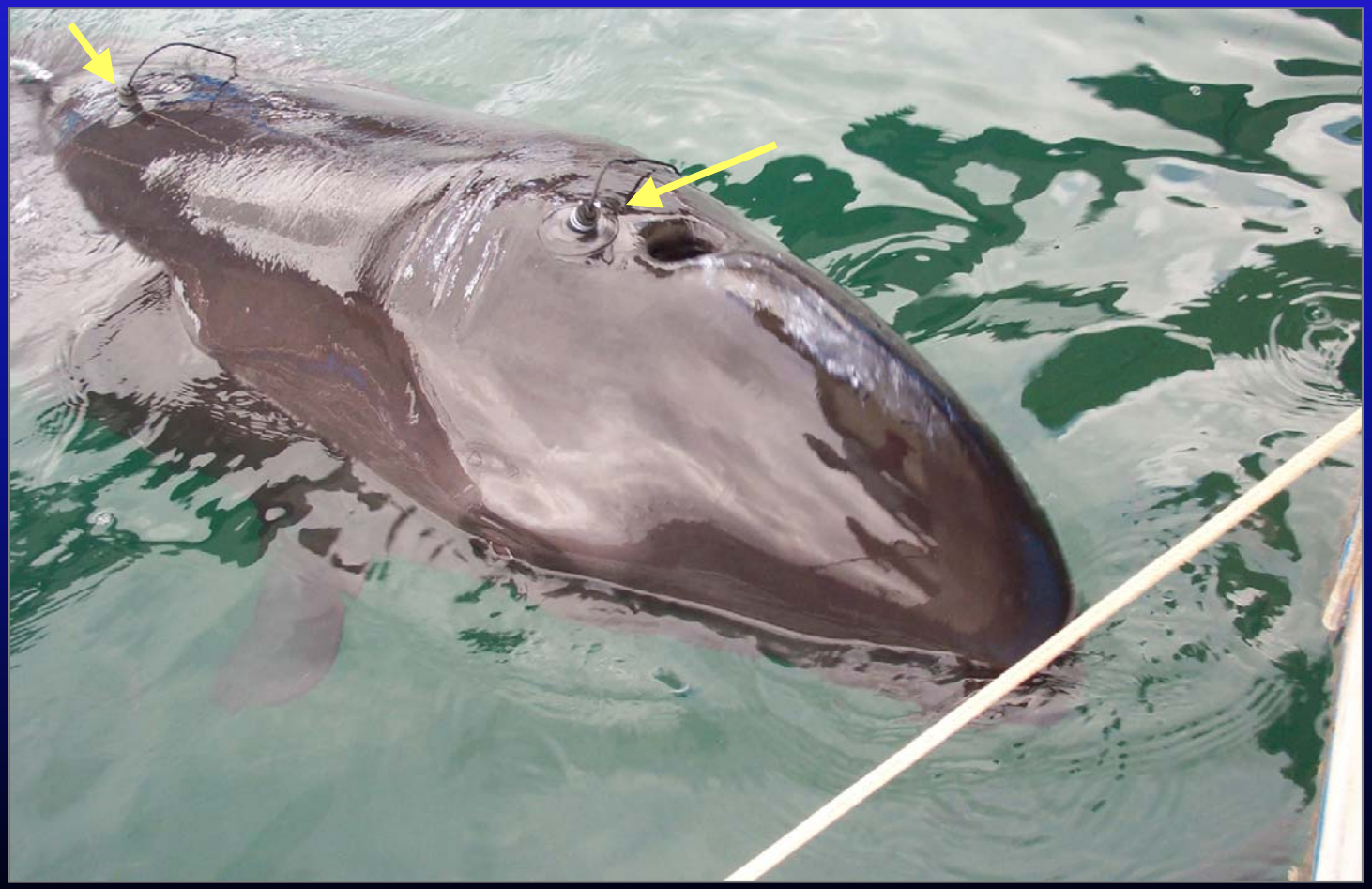
- Train animal to sit quietly in fixed position
- Animal taps a response ball if a sound is presented and sits still if no sound is presented.
- Each time a sound is presented, and the animal is right, give him a fish and make the sound quieter.
- When the animal can no longer hear, and says it can't, gradually increase the sound level until it indicates that it can hear it.
- Play lots of different frequencies (pitches) and determine the threshold (point at which the animal can just barely hear) for each frequency



What is an Auditory Brainstem Response (ABR) Hearing Measurement

- A way to study what an animal hears through the detection and recording of electrical impulses in the lower portion of the brain that occur in response to sound
- It is used to measure hearing in human babies just after they are born
- It is measured from the surface of the dolphin's skin with gold EEG sensors
- It is benign and harmless

FALSE KILLER WHALE VOLUNTARILY WEARING EEG SENSORS IN RUBBER SUCTION CUPS TO MEASURE HEARING THROUGH ABRs/EFRs



Drs. Sam Ridgway and Bob Braun caring for a stranded infant sperm whale

Most Rehabilitating stranded marine mammals are evaluated and treated in temporary holding facilities.

Alexander Supin collecting ABRs to evaluate the hearing of a stranded sperm whale

Since we have not measured hearing thresholds for over 70 dolphin and whale species, we should advocate ABR hearing tests for as many stranded animals as feasible.

ABRs should be considered as a medical diagnostic test

We need to know about hearing in as many species as possible

WE NEED TO KNOW IF STRANDINGS ARE ASSOCIATED WITH ACOUSTIC TRAUMA AND EARS ARE THE MOST SENSITIVE ORGAN TO ACOUSTIC ENERGY

4. **What are the critical components of marine mammals use of sound for evaluating impacts?**

Key word here is SOUND. The word sound only makes sense if one is there to HEAR, otherwise acoustic energy is simply a series of small pressure waves. Therefore, the critical components have to do with hearing.

Hearing is the necessary component for the use of sound for:

1. **Foraging and Echolocation**
2. **Communication**
3. **Social Behavior**
4. **Reproduction**
5. **Parental Care**
6. **Avoidance of Predators**
7. **Overall Awareness of the Environment**

WHY BOTHER TO LOOK AT THE EFFECTS OF LOUD SOUND ON ANIMAL HEARING?

Acoustic intensity levels in the oceans are increasing

It is unlikely that these levels will soon be lowered or stopped
If the intensity of the sound cannot be stopped, the perhaps it can be regulated.

Objectively, if sound is to be regulated, what levels can be Scientifically defended?

MEASURED EFFECTS OF LOUD SOUND ON MARINE MAMMALS

How do you examine the effects of loud sound on people?

National Research Council – National Academy of Sciences Ocean Studies Board Recommendation

Expose animals to loud sound to the point where hearing is Temporarily reduced for a short period of time

‘Rock Concert effect’ – Temporary threshold shift

TEMPORARY HEARING THRESHOLD SHIFTS

SCHUSTERMAN, KASTAK, REICHMUTH, SOUTHALL

SEA LIONS, FUR SEALS, HARBOR SEALS ELEPHANT SEALS

RIDGWAY, FINNERAN, CARDER

BELUGA WHALE, BOTTLENOSE DOLPHIN, SEA LION SHORT IMPULSIVE SOUNDS

NACHTIGALL, AU, PAWLOSKI, SUPIN

BOTTLENOSED DOLPHIN LONGER LOWER INTENSITY SOUNDS

Temporary Threshold Shifts: Examples of Results

Marine Mammals show shifts like other mammals. Shifts are dependent on amplitude and duration of the noise.

- Short sounds (1 sec) if intense enough,(>200dB) can cause shifts in dolphins and beluga whales

- 160 dB noise presented for 50-55 min can result in an 5-8 dB shift in a bottlenosed dolphin

- Elephant Seals, Harbor Seals, and California Sea Lions all show shifts both in air and under water. e.g. 12 dB Shift In California sea lions exposed to 170 dB under water for 50 min

4. **What are the critical components of marine mammals use of sound for evaluating impacts?**

At least one critical component – hearing temporary threshold shifts- has been identified and measured in some animals. It is a quantifiable level that can be defended and understood.