

Seismic testing and the impacts of high intensity sound on whales

Lindy Weilgart
Department of Biology
Dalhousie University
Halifax, Nova Scotia

Marine Seismic Surveys

- Main technique for finding and monitoring oil and gas reserves under sea floor
- An array of 12-48+ air guns towed behind ship
- Air guns release volume of air under high pressure to produce very intense sound pulses
- Sound pulses from air guns penetrate sea floor
- Echoes used to gain information about geological structure of earth's crust
- Can profile down to depths of >10 km under sea floor



- Air guns fired every 10-12 sec
- Arrays towed at 5 knots

Marine Seismic Surveys

- Most sound directed downward
- Most sound low frequency (5-300 Hz) but substantial levels in mid-frequency
- Air gun pulses are brief (10 msec)
- Animals directly below air guns receive more sound
- Animals deeper in water column receive more sound
- Seismic surveys often operate over extensive areas for long periods of time

Loudness of various Sound Sources (in dB re 1 μ Pa re 1 m—water standard)

0.5 kg TNT	267 dB
Undersea volcano	260 dB
Undersea earthquake	255 dB
Seismic array	235-256 dB
Single air gun	216-230 dB

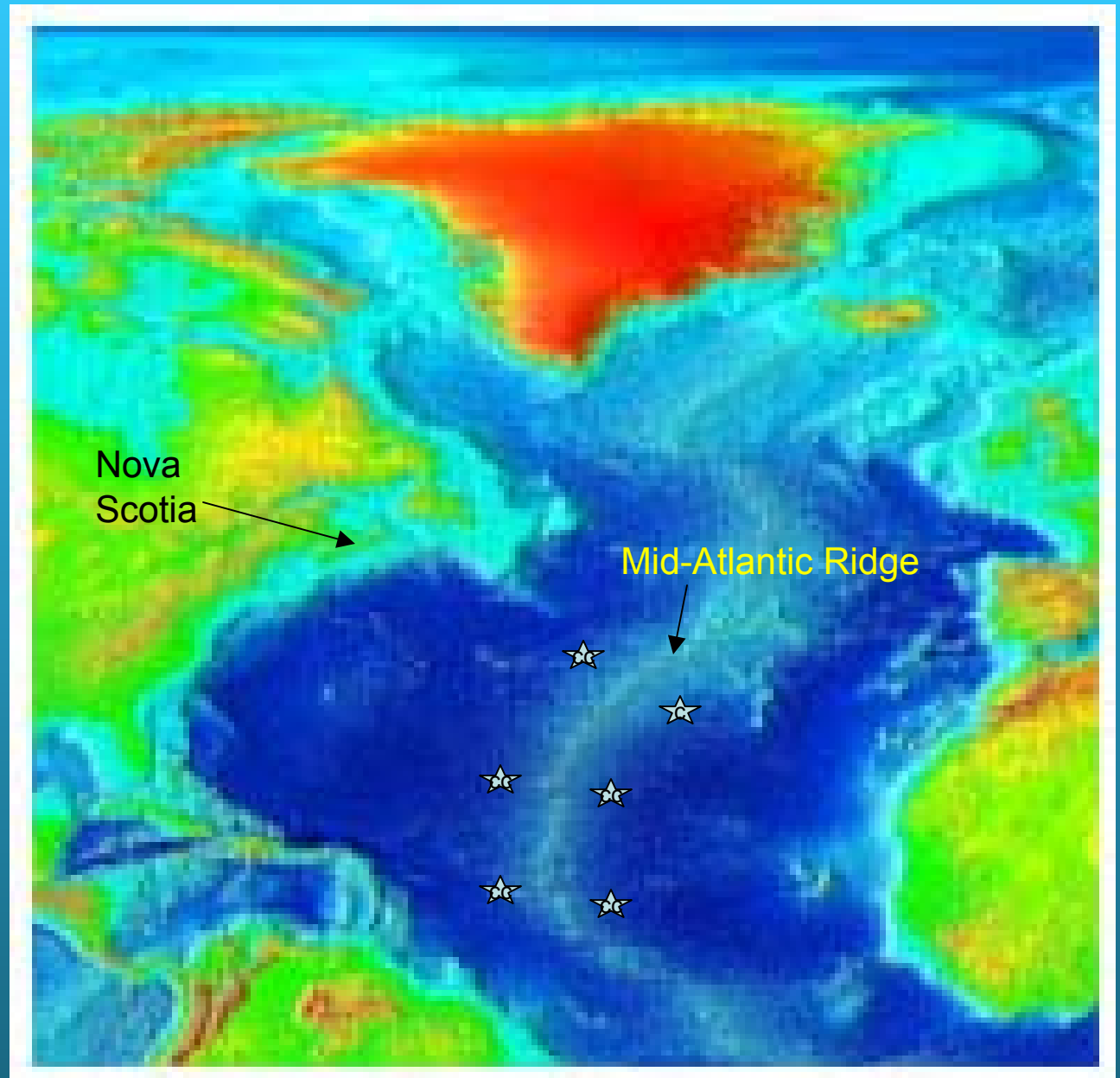
Decibel scale is logarithmic; each increase in 3 dB is a doubling of intensity

Moored hydrophones (underwater microphones) ★ along Mid-Atlantic Ridge:

seismic air gun sounds predom. part of backgnd. noise

3,000 km away off Nova Scotia

Source levels ca. 194 dB



Nieukirk et al. 2003

Off Nova Scotia, three simultaneous surveys at any one time over the summer

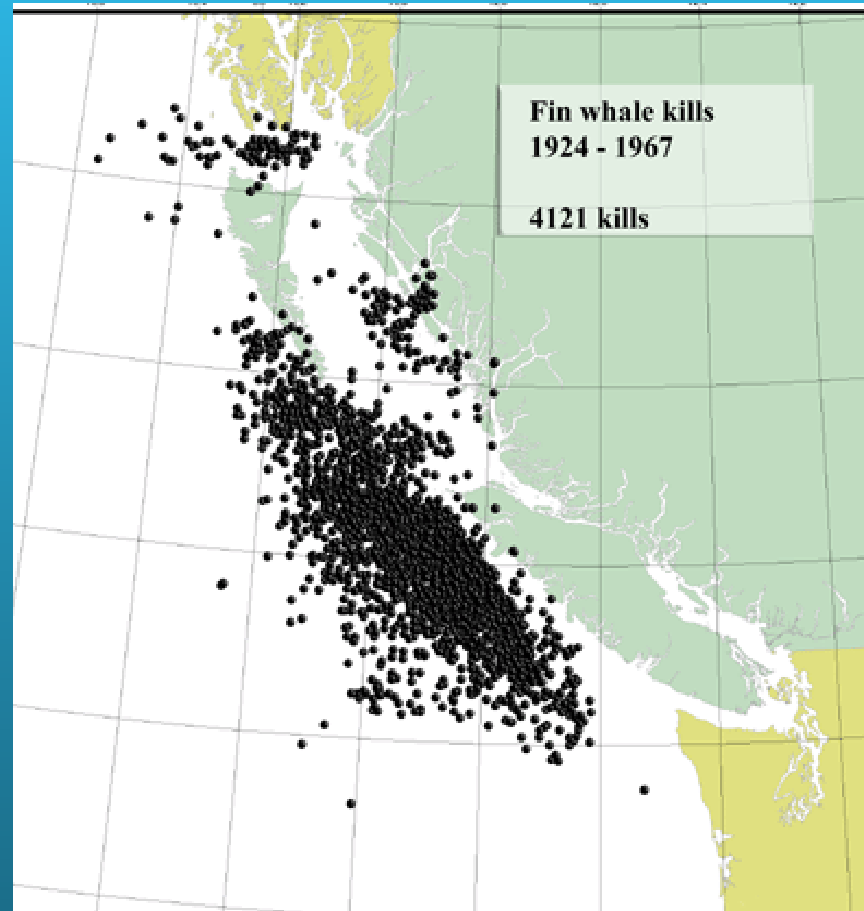
Why whales are vulnerable to noise:

- Depend on sound as we do on sight
- Use sound to:
 - Communicate with calves
 - Communicate with group members
 - Mate
 - Find prey
 - Detect predators
 - Detect hazards like beaches, fishing nets, etc.
 - Navigate

Most Common Whale and Dolphin Species off Queen Charlotte Islands

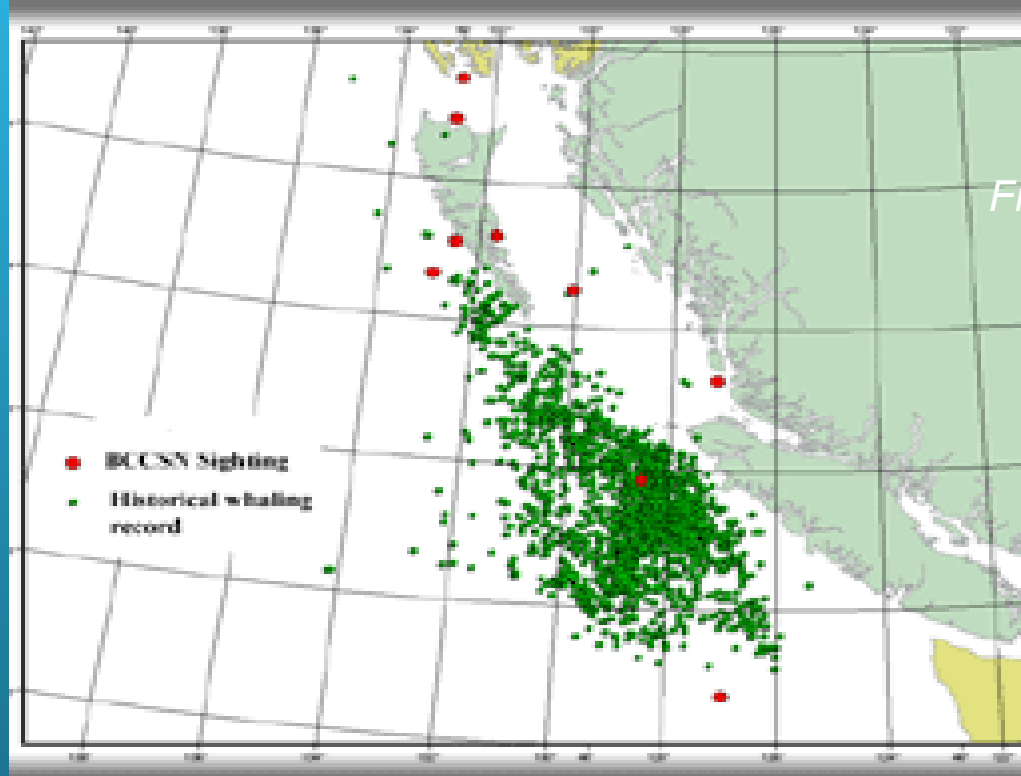
- Gray whale: common, migrates along coast
- Minke whale
- Humpback whale
- Fin whale
- Sei whale
- Blue whale
- North Pacific right whale:
 - Most endangered whale (only tens of animals left)
 - Most recent Canadian sightings near Queen Charlotte Islands
 - Threats include increased ship traffic (strikes and noise)
- Harbour porpoise
- Dall's porpoise
- Pacific white-sided dolphin
- Killer whale:
 - Hunt using stealth, listening for their prey (acute hearing)
 - Subjected to boat noise levels high enough to cause hearing loss
- Sperm whale
- Short-finned pilot whale
- False killer whale
- Cuvier's beaked whale

Fin Whale



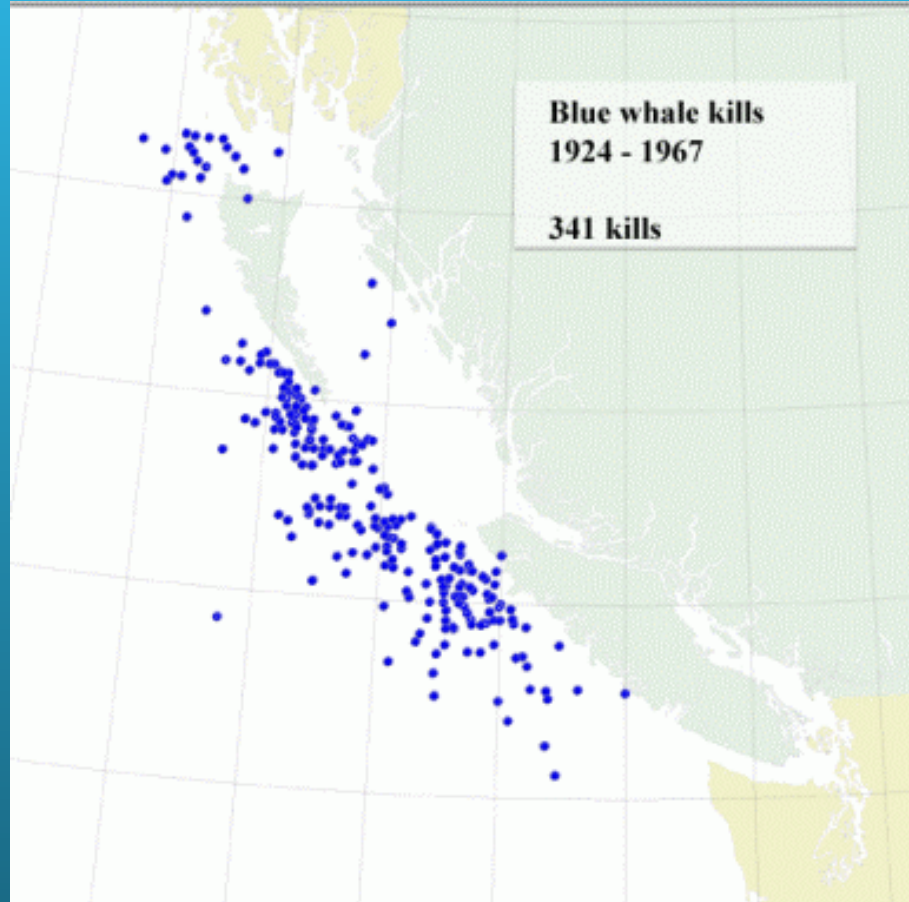
From BCCSN webpage

Sei Whale



From BCCSN webpage

Blue Whale



Cuvier's Beaked Whale

- 1838-1963
- 1963-present
- 1960's
- No mass strandings of Cuvier's
- 25 mass strandings
- Advent of naval anti-submarine warfare (ASW) sonars

- At least 1/3 of all Cuvier's mass strandings associated with naval maneuvers
- "Miner's canary" for high-intensity sound impacts

- Bahamas 2000
- Canary Is. 2002

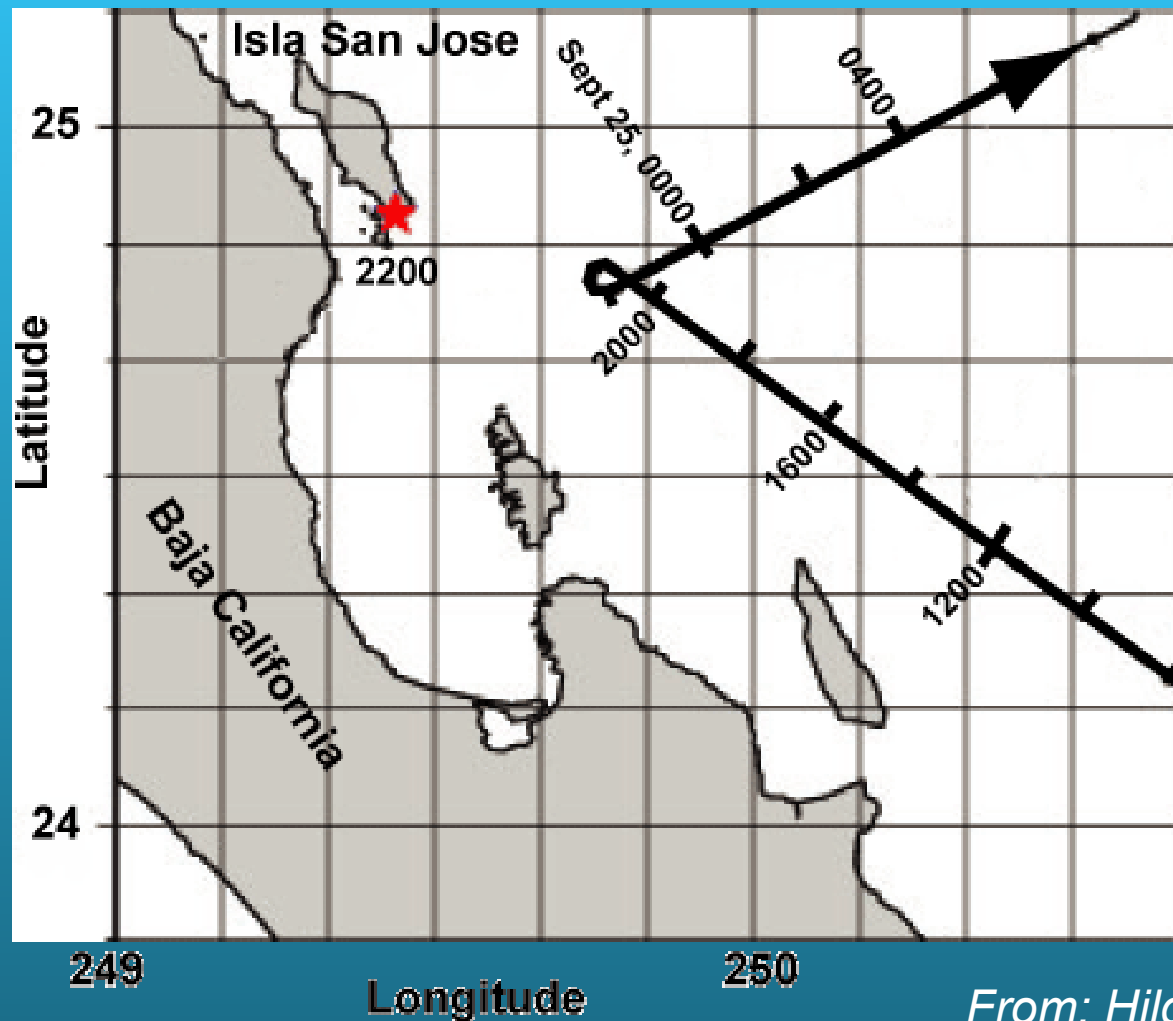
This photo was of a dead Cuvier's beaked whale that was bleeding profusely from its eye—if you would like to obtain a copy, contact the photographer below.

Cuvier's and other beaked whale species suffered hemorrhaging in:

- Brain
- Inner ear
- Lungs
- Eyes
- **Consistent with injury from intense sound**

*Evans and England 2001;
Fernandez et al. 2003;
Jepson et al. 2003*

Only recorded Gulf of Calif. strandings ever of Cuvier's beaked whales (2): location and seismic ship *R/V Maurice Ewing*'s track for 24-25 Sept. 2002



From: Hildebrand 2003

The ship track is directed toward the stranding site, reaching the closest point-of-approach (within 22 km) at 1400 local time (2100 GMT) .

Locations of Cuvier's beaked whale sightings and strandings near Queen Charlotte Basin as reported by Willis and Baird (1998)



Courtesy of Rob Williams and Doug Sandilands

Noise-induced strandings often occur near deep channels between islands

Other known impacts of seismic surveys

Gray whales

- Shifts in behaviour >30 km away
- Faster, straighter swimming over larger areas (disturbance to feeding?)
- More rapid breathing during seismic
- Displacement, closer to shore

Würsig et al. 1999

Other known impacts of seismic surveys

Bowhead whales

(related to North Pacific right whale)

- *Previous research*: active avoidance at 7-8 km
Newer research: active avoidance at 20-30 km
(diff. In tolerated loudness of 10,000x), returning 24 hrs. later
- More tolerant feeding in summer than migrating in fall
- Changes in dive cycles, breathing rates, up to 73 km away

Richardson et al. 1995; Richardson 2003

Other known impacts of seismic surveys

Humpback whales

- Avoidance at >4 km
- Resting females more sensitive, stayed 7-12 km away
- Males sometimes attracted

McCauley et al. 2000

Other known impacts of seismic surveys

Blue whales

- Avoidance at 3-20 km
- Stopped vocalizing for 1 hr. at 10 km distance
- Feeding <10-20 km away

McDonald et al. 1995; P. Gill, pers. comm.

Other known impacts of seismic surveys

Sperm whales

- Stopped vocalizing for 36 hrs. at 370 km distance
- Apparently tolerant in Gulf of Mexico and off Norway

*Bowles et al. 1994; Madsen 2002;
Jaquet, pers. comm.*

Conclusion:

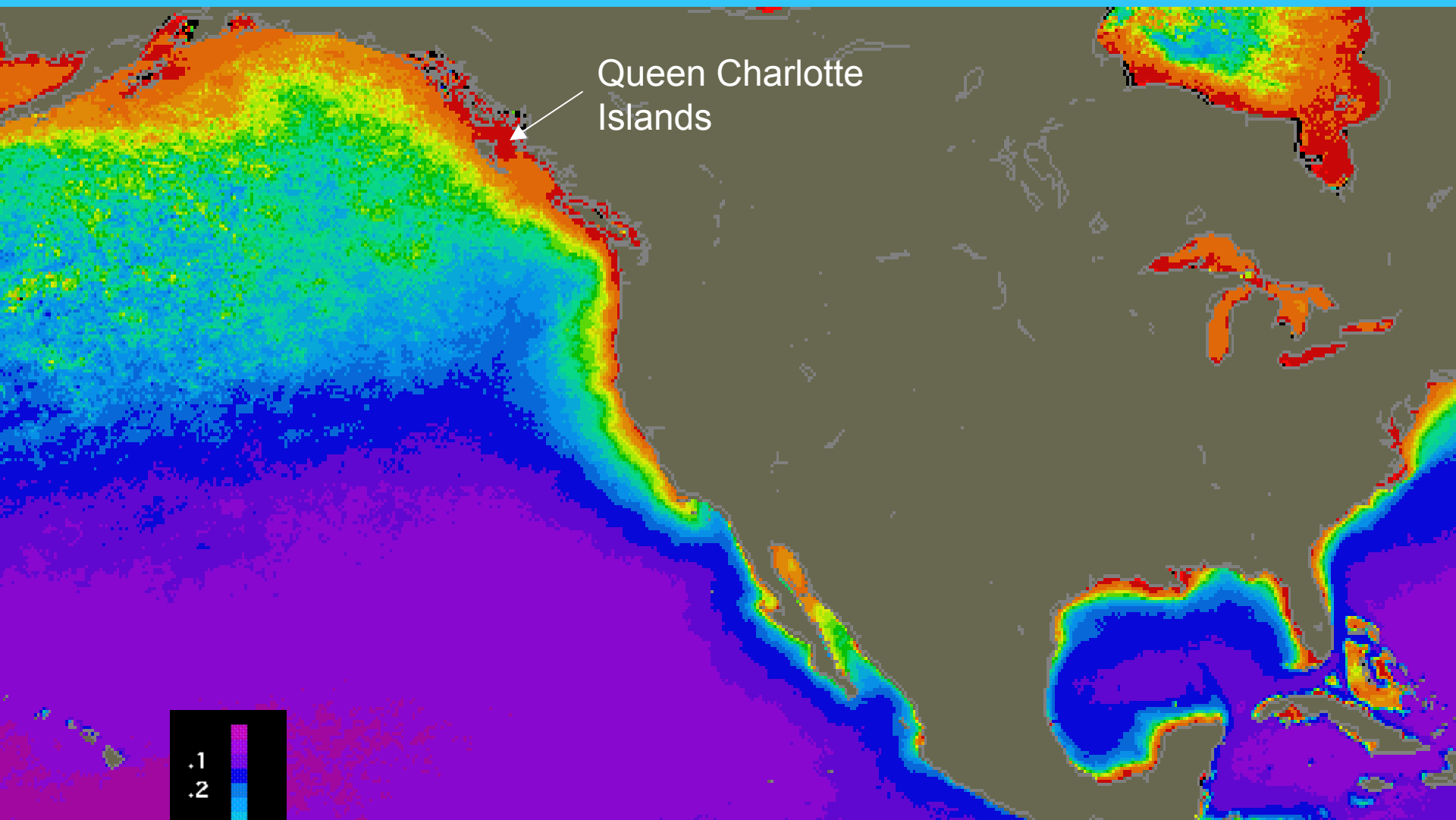
Disturbance clearly demonstrated but situations where seismic sounds are apparently tolerated

Problems with research:

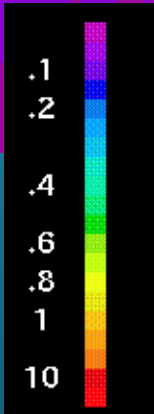
- No long-term, population effects studied
(difficult animal to study)
- Many undetectable effects in whales
(hearing damage, stress, decreased fertility, increased mortality, etc.)
- Reactions differ depending on experience, behavioural state, individual, age, sex, etc.
- Reactions difficult to interpret (ex.: more sightings may mean seeking sound shadow of surface)

Mitigation

- Visual and acoustic monitoring for whales (under best conditions, only visible at 2-3 km, though)
- To minimize horizontal output, use more small air guns, not fewer large ones
- Develop quieter technologies
- Avoid duplicating surveys (share data)
- Avoid areas with profusion of life, i.e. inshore areas



Queen Charlotte
Islands



Phytoplankton pigment
Concentration (mg/m³)

Summary

- Seismic surveys produce intense pulses of sound to image beneath the sea floor for oil and gas reserves
- Are among the most intense noises in the ocean (prominent in background 3,000 km away)
- Whales use sound for all aspects of life

Summary (cont'd.)

- Seismic pulses can cause whale stranding and death
- Other documented disturbance, esp. for gray and bowhead whales, over 10's of km
- No long-term population effects studied
- Queen Charlotte Basin important habitat for many species including Cuvier's beaked whale
- Highly endangered North Pacific right whale sightings
- Most important mitigation: avoid areas with profusion of life, like Queen Charlotte Basin