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Underwater noise The "other" pollution

<https://i.ytimg.com/vi/lKwQX31Mans/maxresdefault.jpg>

Light decreases with depth in lakes

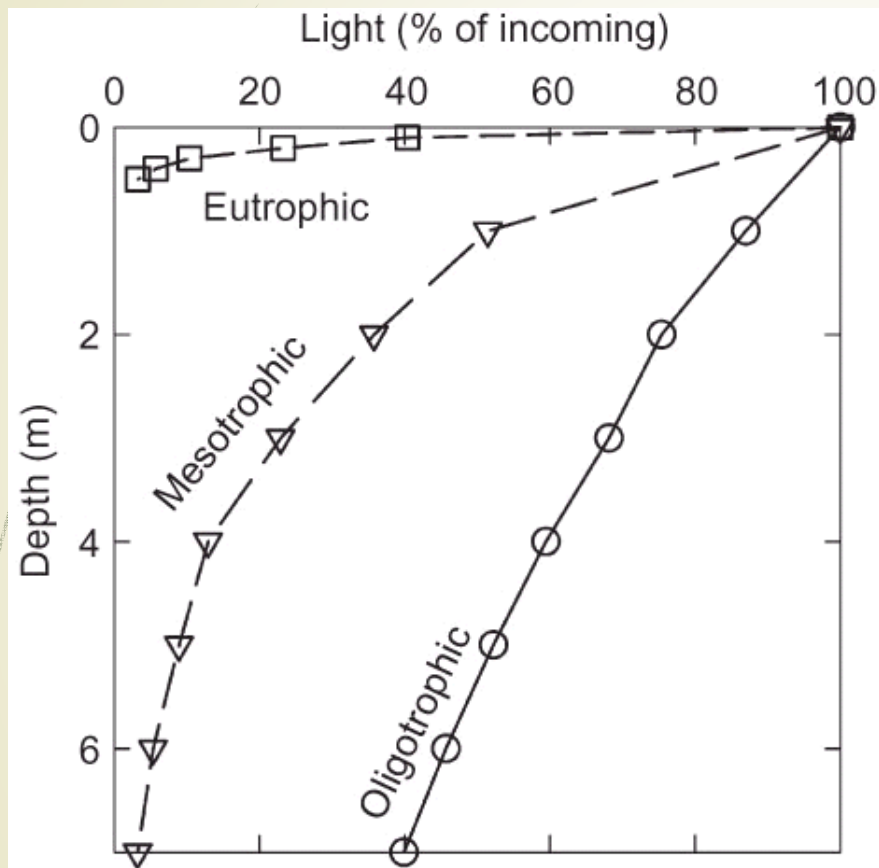
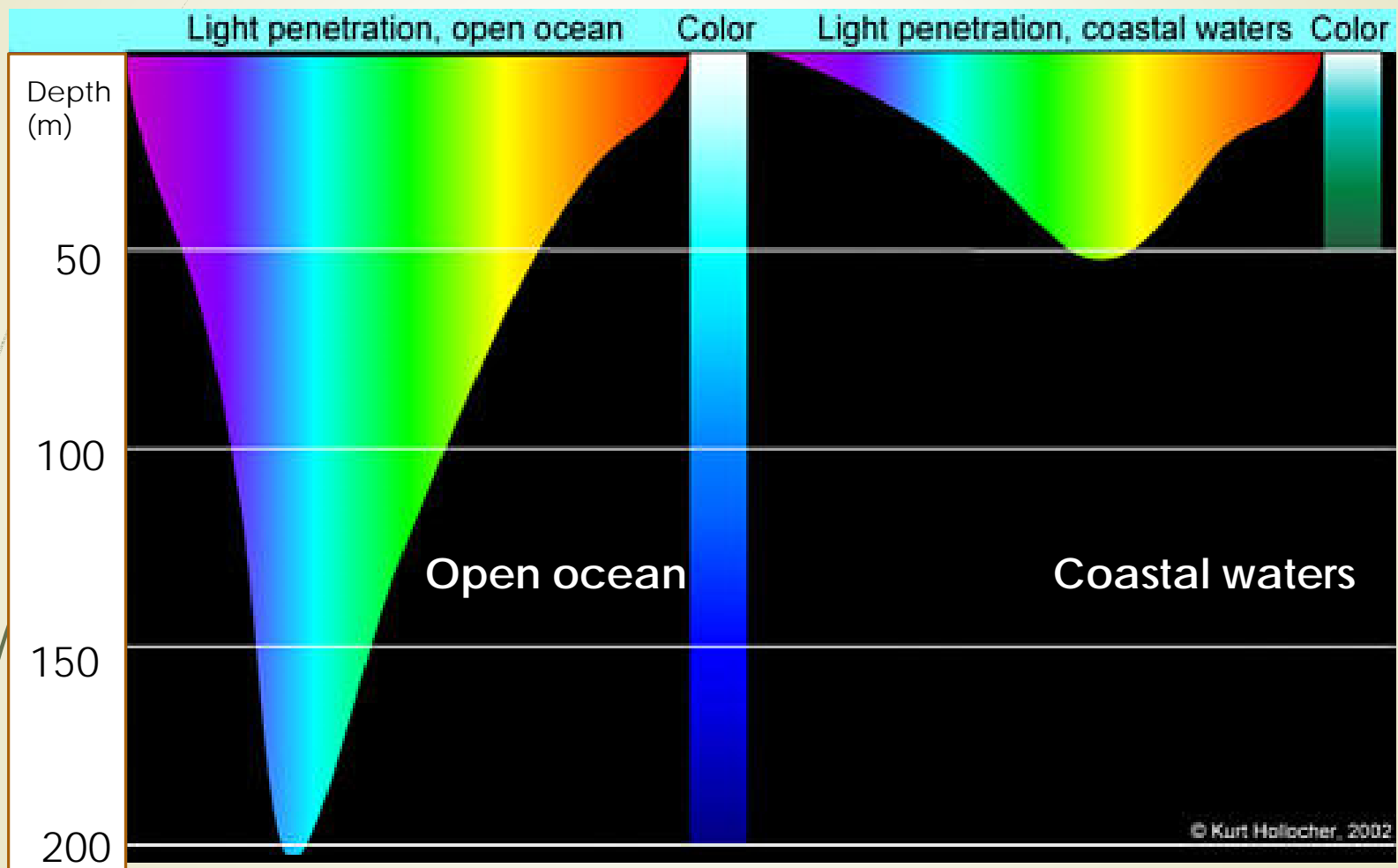


FIGURE 3.6

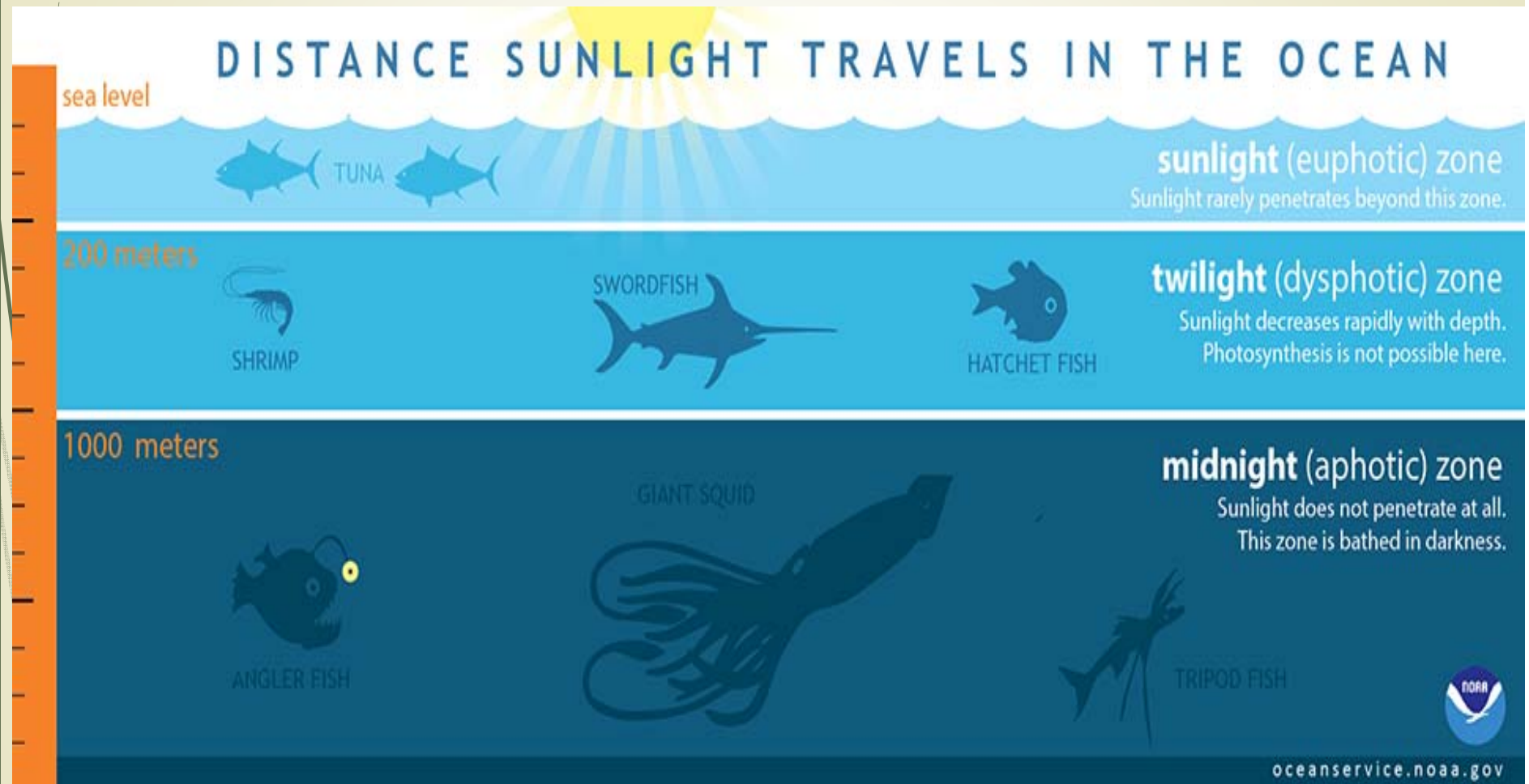
Light as a function of depth in three lakes—Waldo Lake (oligotrophic), Triangle Lake (mesotrophic), and a sewage oxidation pond (eutrophic), Oregon—plotted on linear (A) and log (B) scales. (*R. W. Castenholz, unpublished data*).



Darkness common in oceans



3 Zones based on light availability



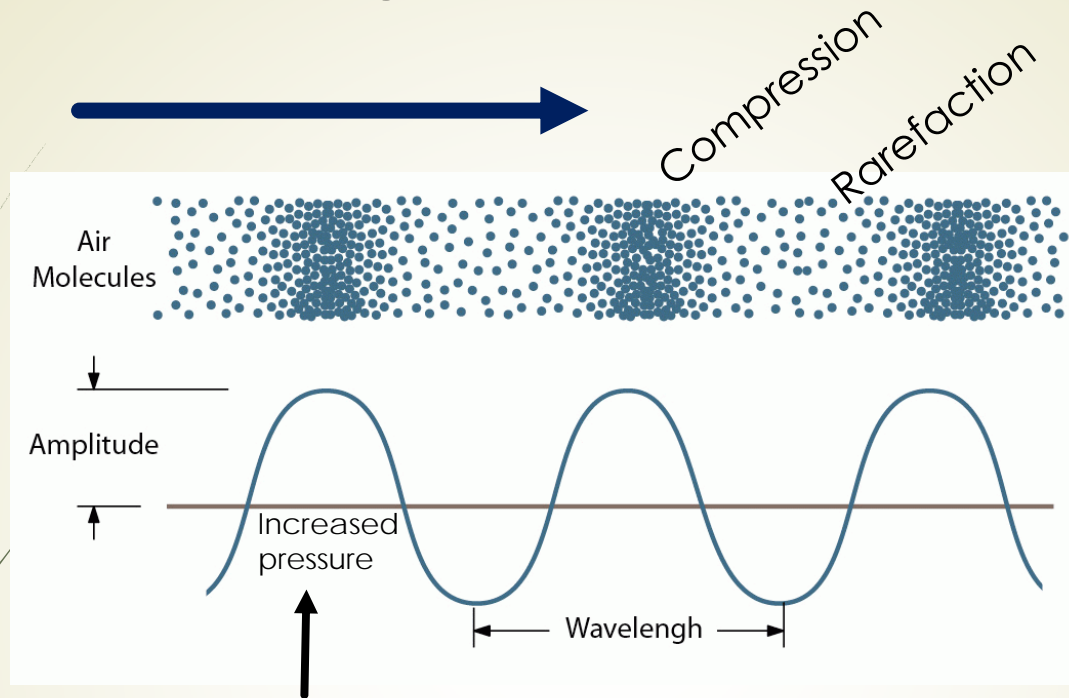
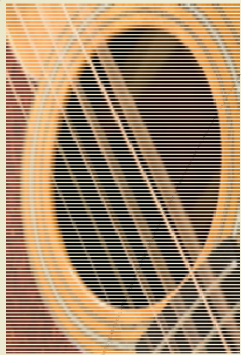
Aquatic animals depend on **sound** not just sight

Use vocalizations for all behaviors:

- Orienting and finding habitats
- Hunting Food
- Avoiding predators
- Keeping track of their young
- Finding mates



Basic physics of sound



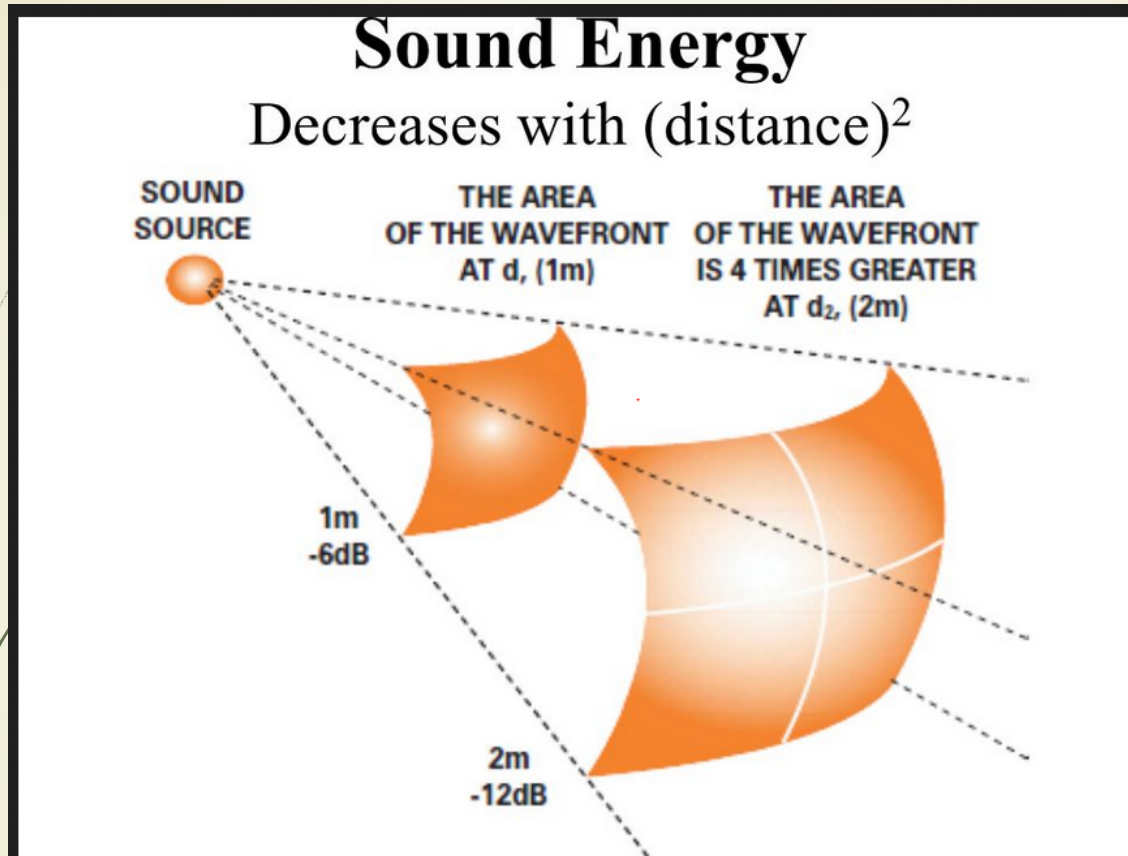
Amplitude (height of wave):

volume of sound is proportional to the height of the
wavelength: measured as **decibels**;
translates to **loudness**;

Frequency: (rate of oscillation) # of waves per/time
measured in cycles/sec - **hertz**

increase in frequency is perceived as a **higher pitched**
sound

Basic physics of sound



- logarithmic increase in dB scale
- measured relative to a reference:
dB re 1 μ Pa @ 1m
- dB = 10 x ratio of two sound intensities

ME 220 Measurements & Sensors; Mechanical Measurements Applications
By Mervyn Jefferson

Level

Sound Level

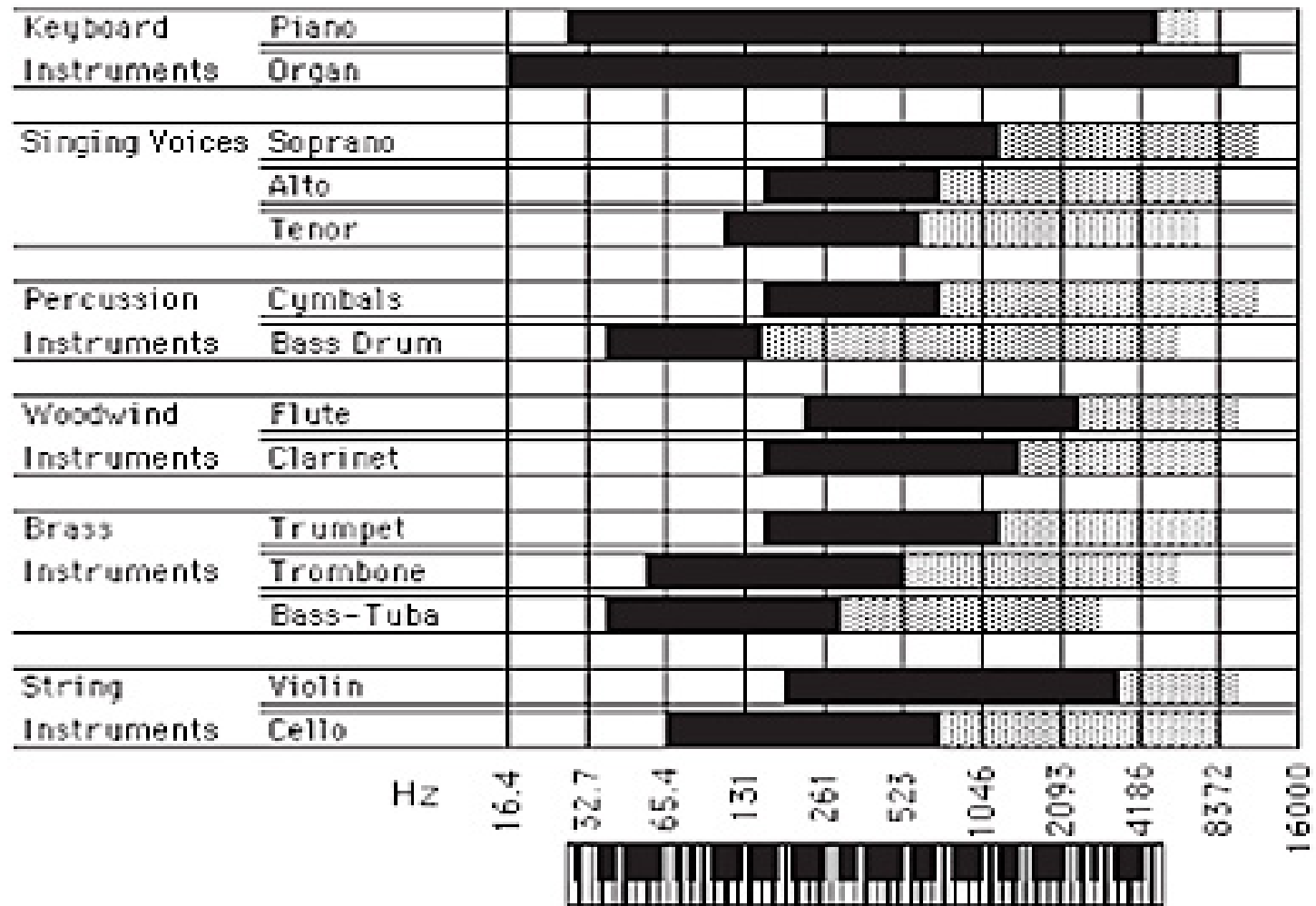
dB	μ Pa
160	2×10^9
150	
140	2×10^8
130	
120	2×10^7
110	
100	2×10^6
90	
80	2×10^5
70	
60	2×10^4
50	
40	2×10^3
30	
20	2×10^2
10	
0	2×10^1



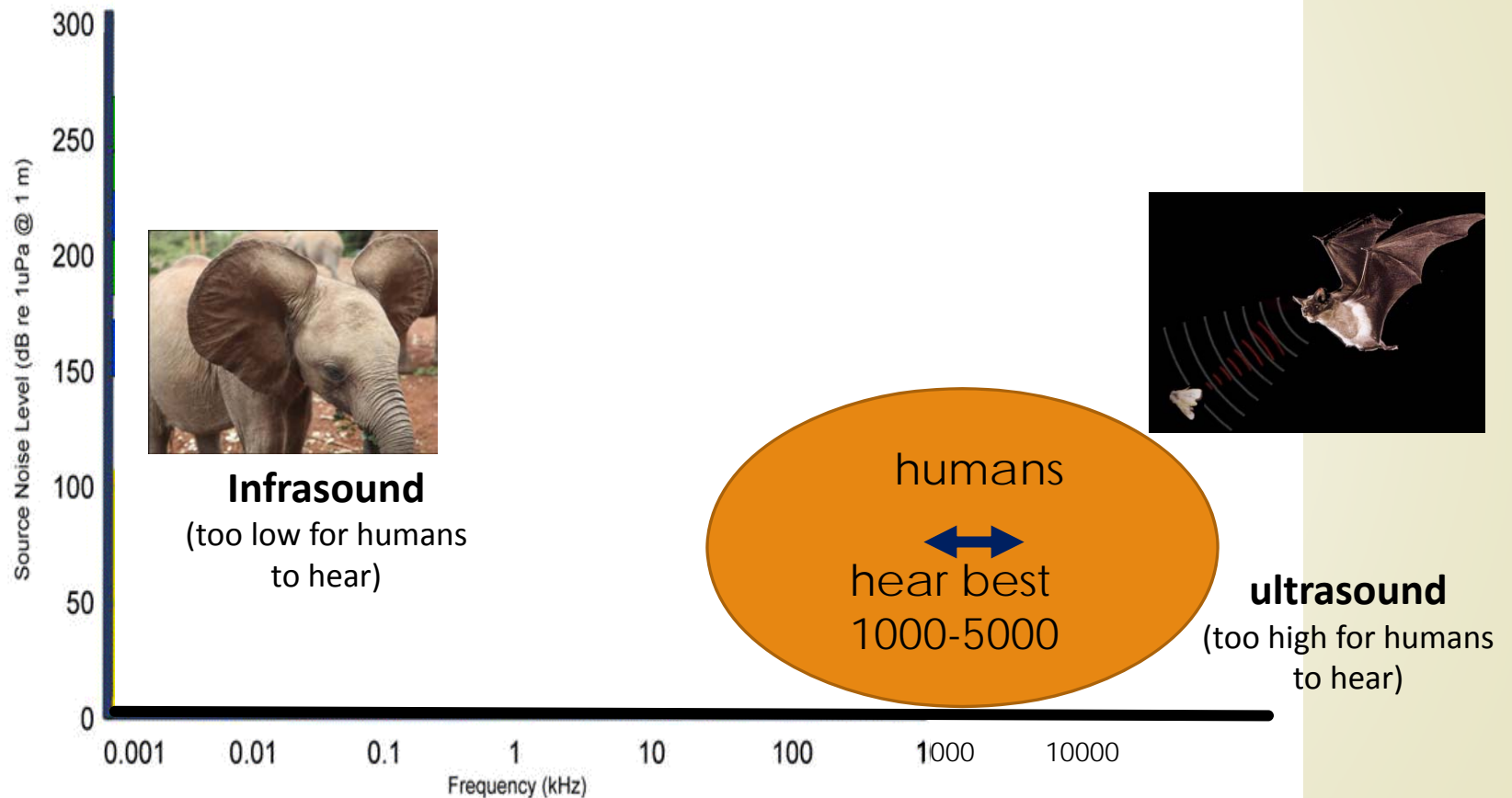
Sound as humans hear it – loudness (0 – 140 dB)

Sound sources (noise) Examples with distance	Sound pressure Level L_p dB SPL		dB
Jet aircraft, 50 m away	140	PAINFULLY LOUD	160
Threshold of pain	130		150
Threshold of discomfort	120	UNCOMFORTABLY LOUD	140
Chainsaw, 1 m distance	110		130
Disco, 1 m from speaker	100		120
Diesel truck, 10 m away	90	VERY LOUD	110
Kerbside of busy road, 5 m	80		100
Vacuum cleaner, distance 1 m	70	MODERATELY LOUD	90
Conversational speech, 1 m	60		80
Average home	50		70
Quiet library	40	QUIET	60
Quiet bedroom at night	30		50
Background in TV studio	20	VERY QUIET	40
Rustling leaves in the distance	10		30
Hearing threshold	0	BARELY AUDIBLE	20
			10
			0

Sound as humans hear it – pitch (20-20,000 hertz)



Sounds humans can't hear



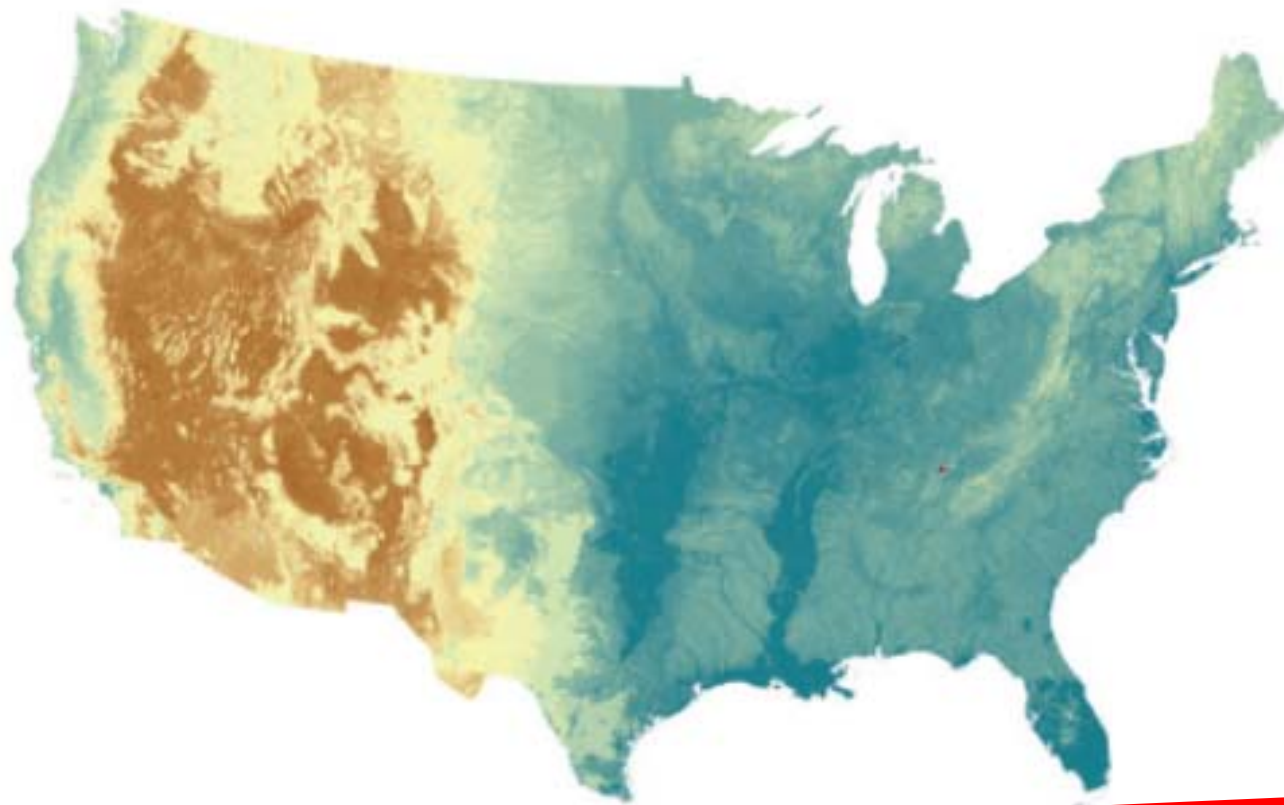
source: Coates, R., The Advanced SONAR Course, Seiche (2002) ISBN 1-904055-01-X

<http://www.listencarefully.org/elephant-ears/>

<http://news.discovery.com/tec/innovations-inspired-by-animals-130325.htm>

Natural levels of sound on land (the background “hum”)

Soundscape, without people



Estimated loudness of natural sounds, in decibels

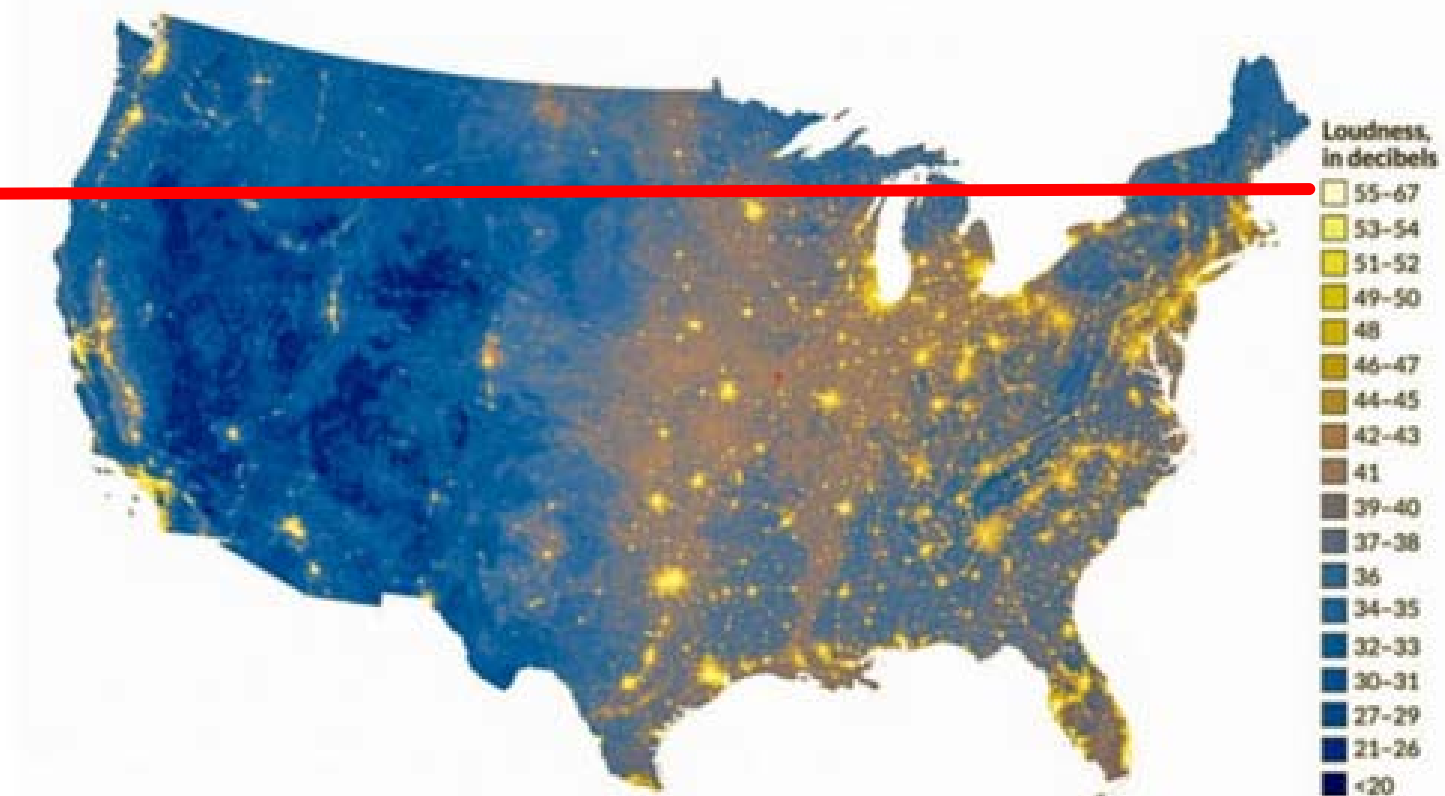
<20
20-22
23-24
25-26
27
28
29
30
31
32-33
34
35
36
36-37
37
38-40

	dB
PAINFULLY LOUD	160
	150
	140
UNCOMFORTABLY LOUD	130
	120
	110
VERY LOUD	100
	90
	80
MODERATELY LOUD	70
	60
	50
QUIET	40
	30
	20
VERY QUIET	10
	0
	BARELY AUDIBLE

National Park Services Natural Sounds and Night Skies

Anthropogenic noise pollution (increased background “din”)

	dB
PAINFULLY LOUD	160
	150
	140
UNCOMFORTABLY LOUD	130
	120
	110
VERY LOUD	100
	90
MODERATELY LOUD	80
	70
QUIET	60
	50
VERY QUIET	40
	30
BARELY AUDIBLE	20
	10
	0



<https://dabrownstein.com/tag/anthropogenic-noise/>

What about underwater sound?

Speed of sound (c)

rate at which vibrations move or propagate through a medium

$c = \text{wavelength} \times \text{frequency}$

Air : $C_{\text{air}} \sim 340 \text{ m/sec}$

Water: $C_{\text{h}_2\text{O}} \sim 1500 \text{ m/sec}$

4x as fast in water as in air

Air attenuates sound much more rapidly than salt water

(~factor of 1,000,000!), which attenuates sound more rapidly than fresh water (~factor of 100)

What about underwater sound?

Water attenuates sound waves –

but amount is proportional to frequency of the sound
so lower frequency sounds go much longer distance

ex. whales call in low frequencies, ~150 dB re 1 μ Pa @ 1m

Sound movement is dependent on water density

- is affected by temperature, depth, salinity
 - as pressure increases, speed of sound increases
 - as temperature decreases, speed of sound decreases
- in the ocean, pressure/temp create the SOFAR channel

SIL water = SIL air + 62

Sound Intensity Level (SIL) = loudness

120 dB in air does not equal 120dB in water

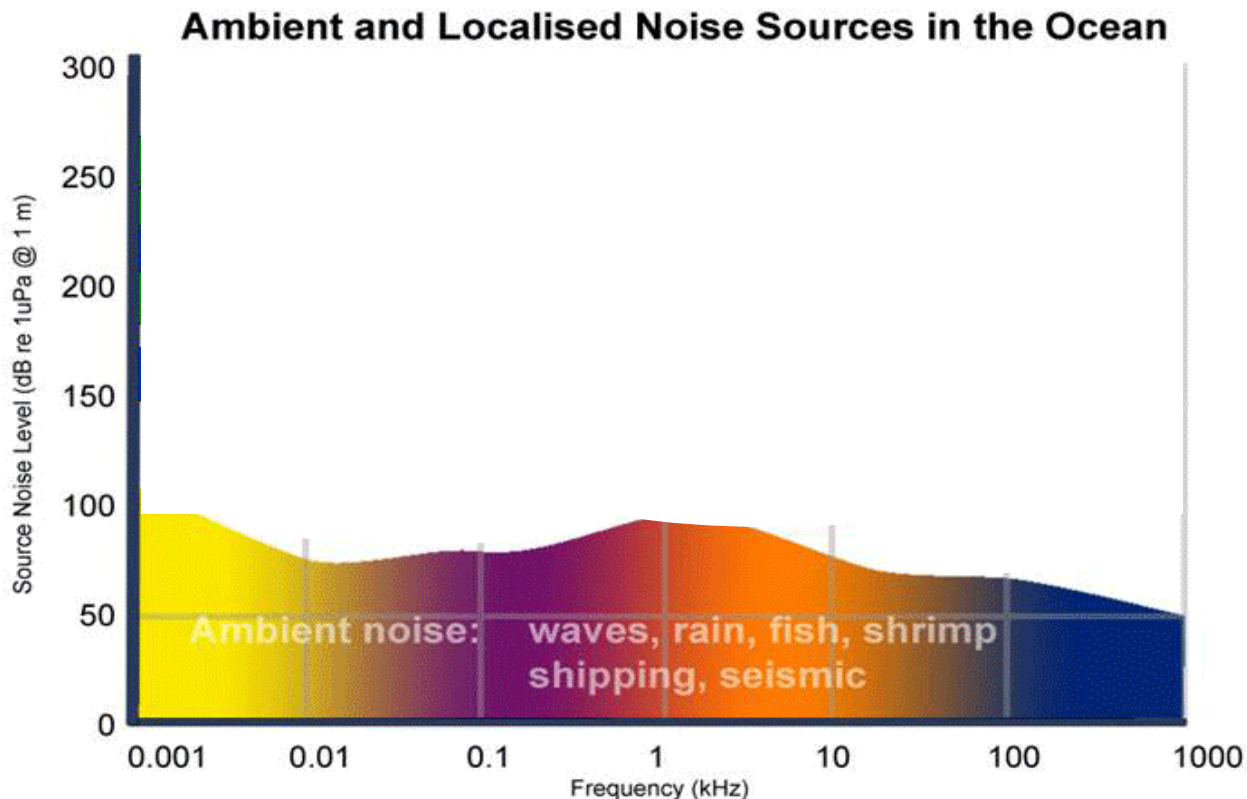
Ex. Jet engine 140 dB ref 20 μ Pa @ 1m air >>> 202 dB re 1 μ Pa underwater

Natural background noise level in the Ocean

Sources: Waves, wind, rain, earthquakes

ex. Snowflakes add 30dB at 50-200 KHZ

reason: an air bubble gets pushed underwater and it changes size and oscillates

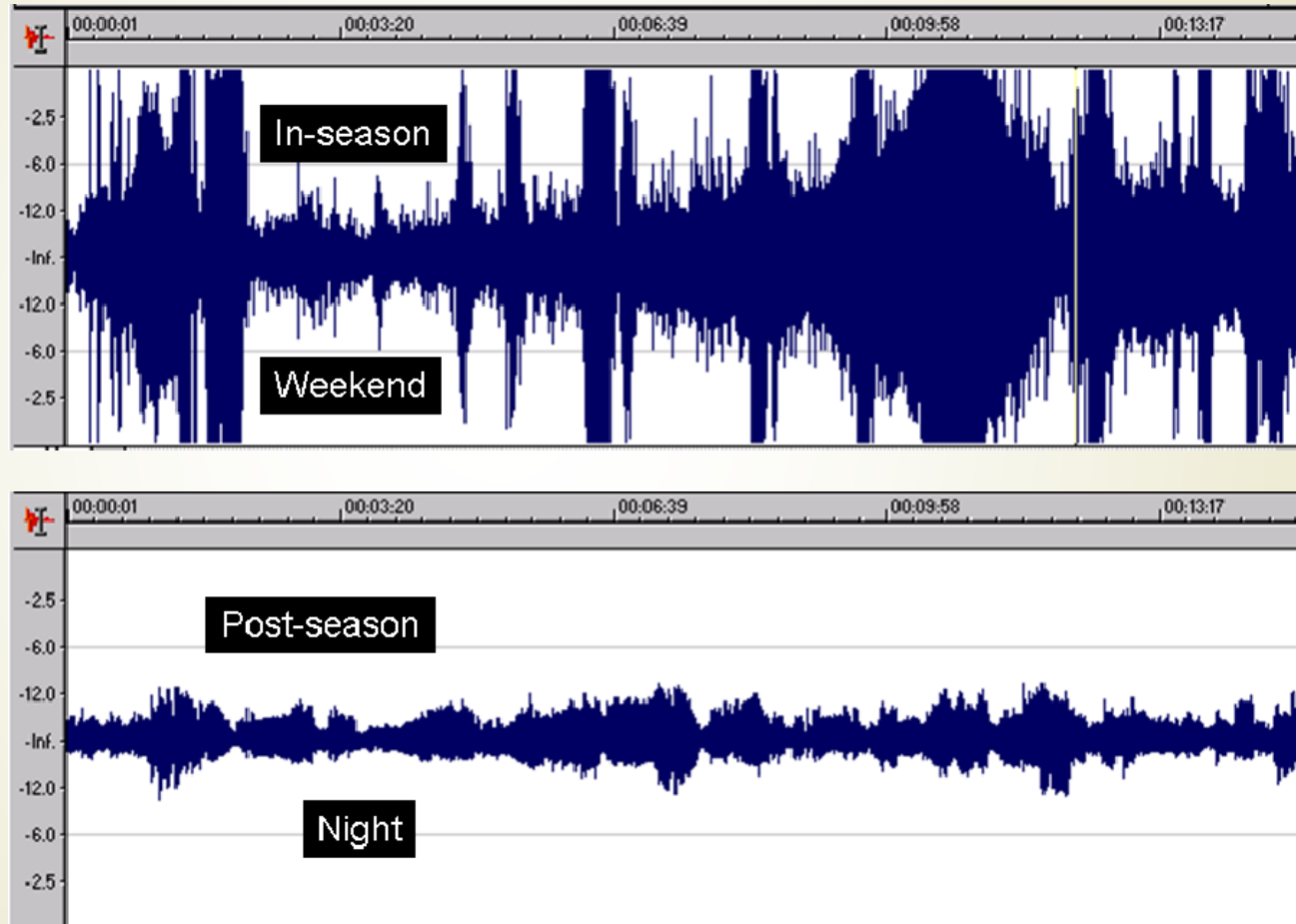


source: Coates, R., The Advanced SONAR Course, Seiche (2002) ISBN 1-904055-01-X

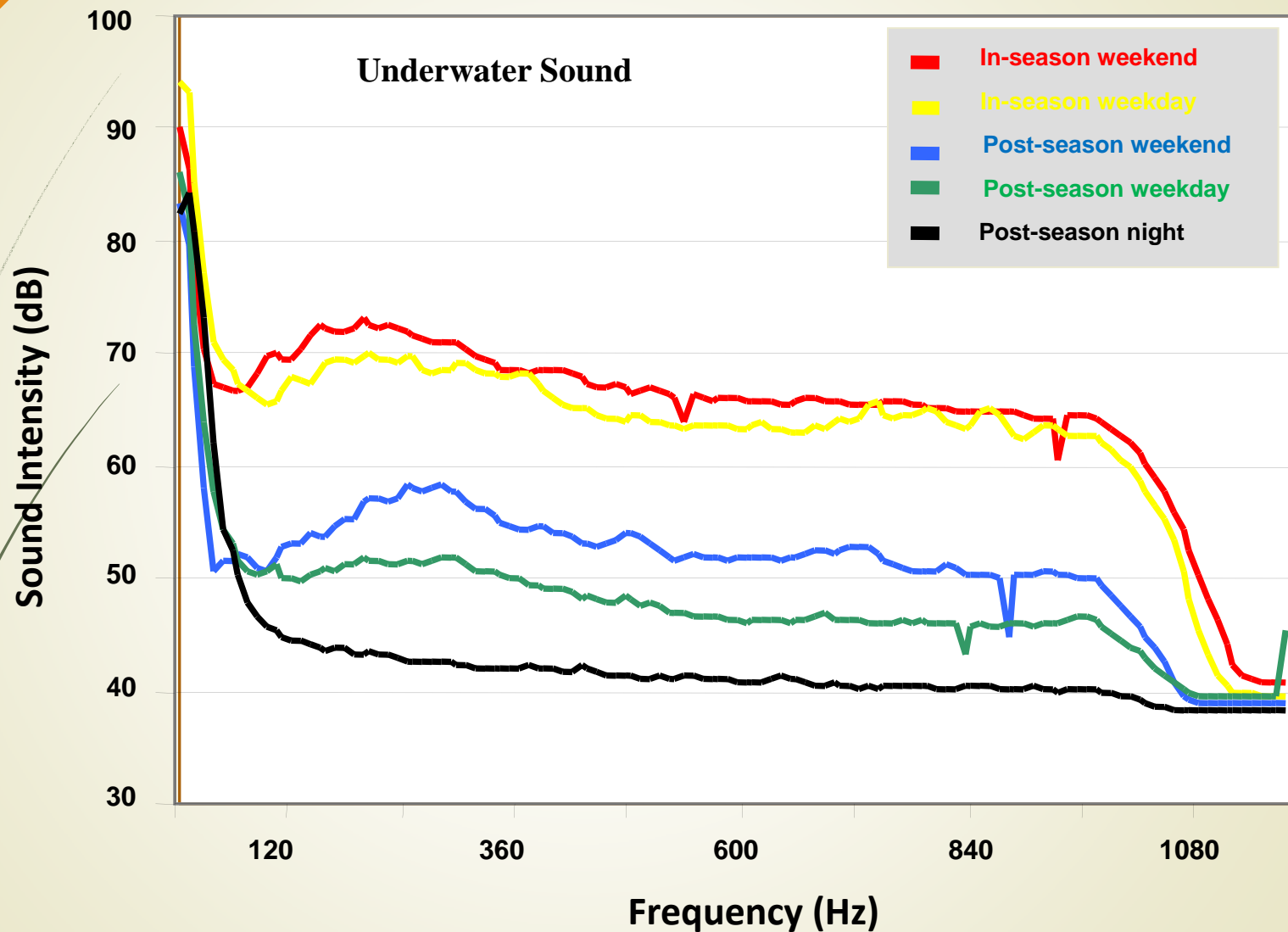
Case study: Underwater anthropogenic noise in Hampton Bays, NY

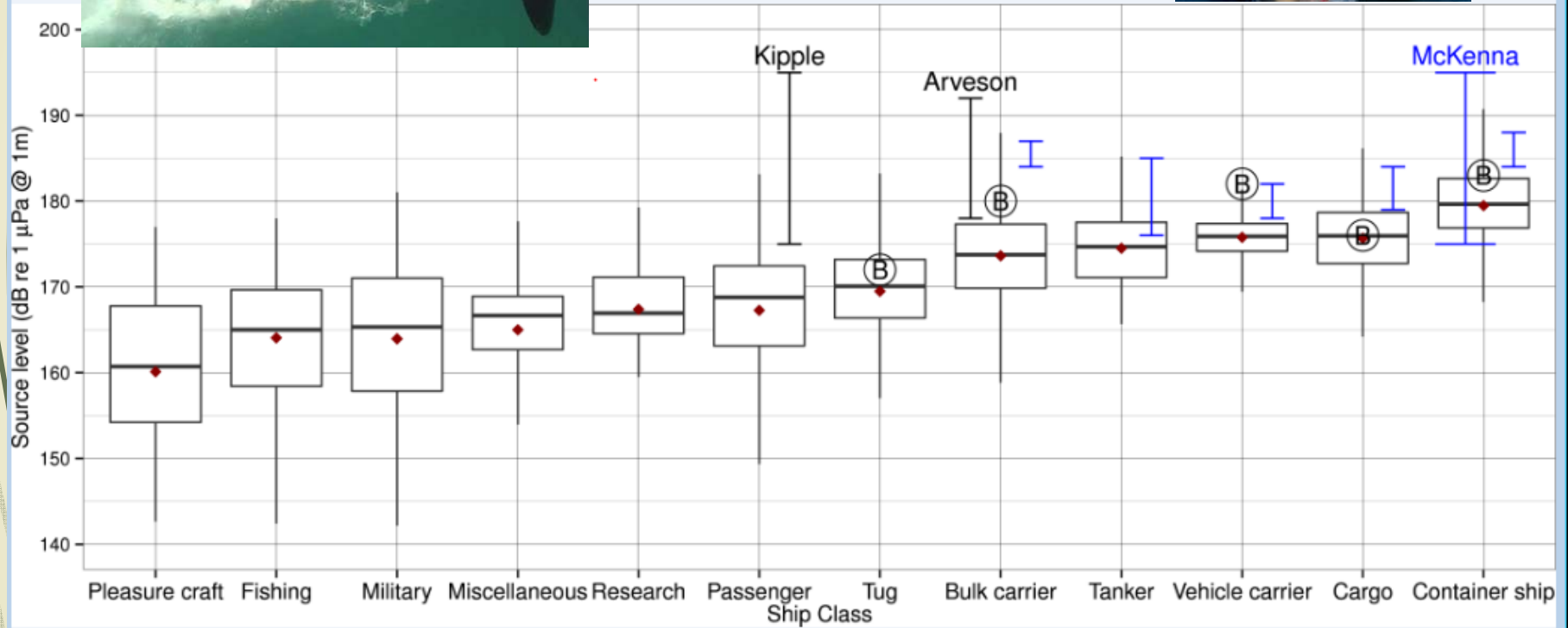
Environmental noise recording and analysis

Cacophony:
- loud,
unexpected,
random ,
unpredictable



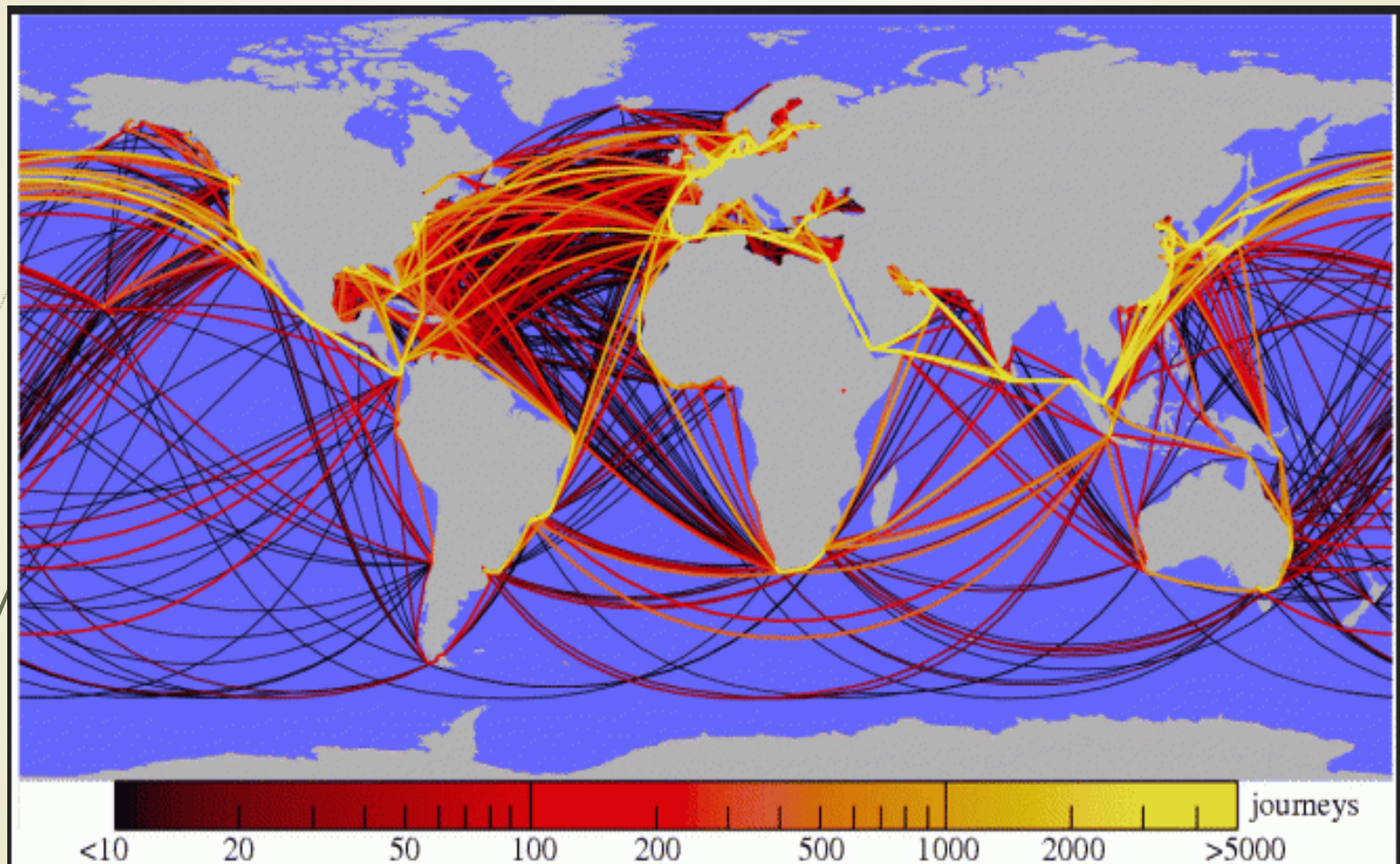
Summer daytime vs post- Sept Sound environment Hampton Bays, L.I., NY





Ship noise extends to frequencies used for echolocation by endangered killer whales. Scott Veirs, Val Veirs, and Jason Wood. Published February 2, 2016 PeerJ

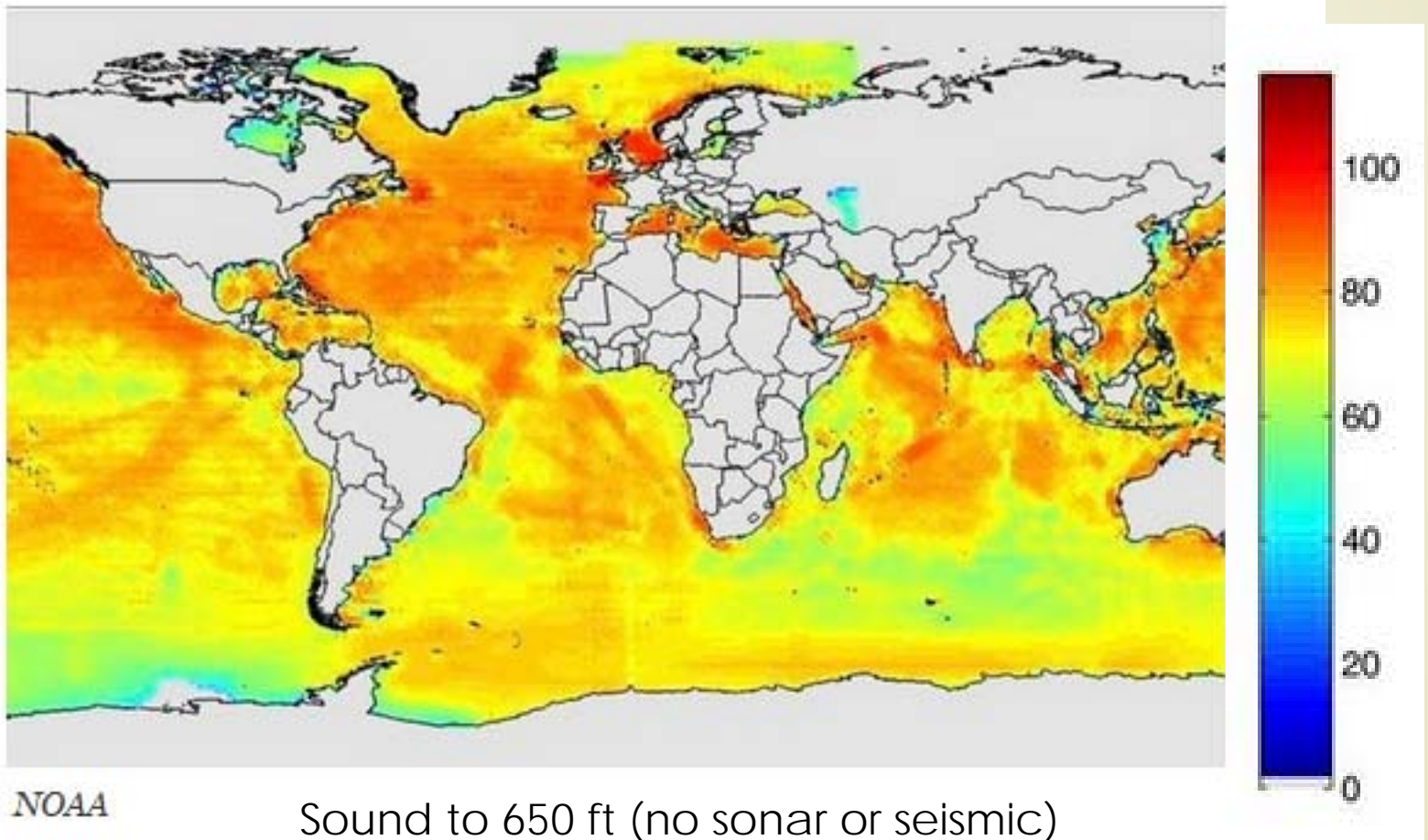
Summary of one year's cargo ship movements around the globe 16,693 cargo ship trips



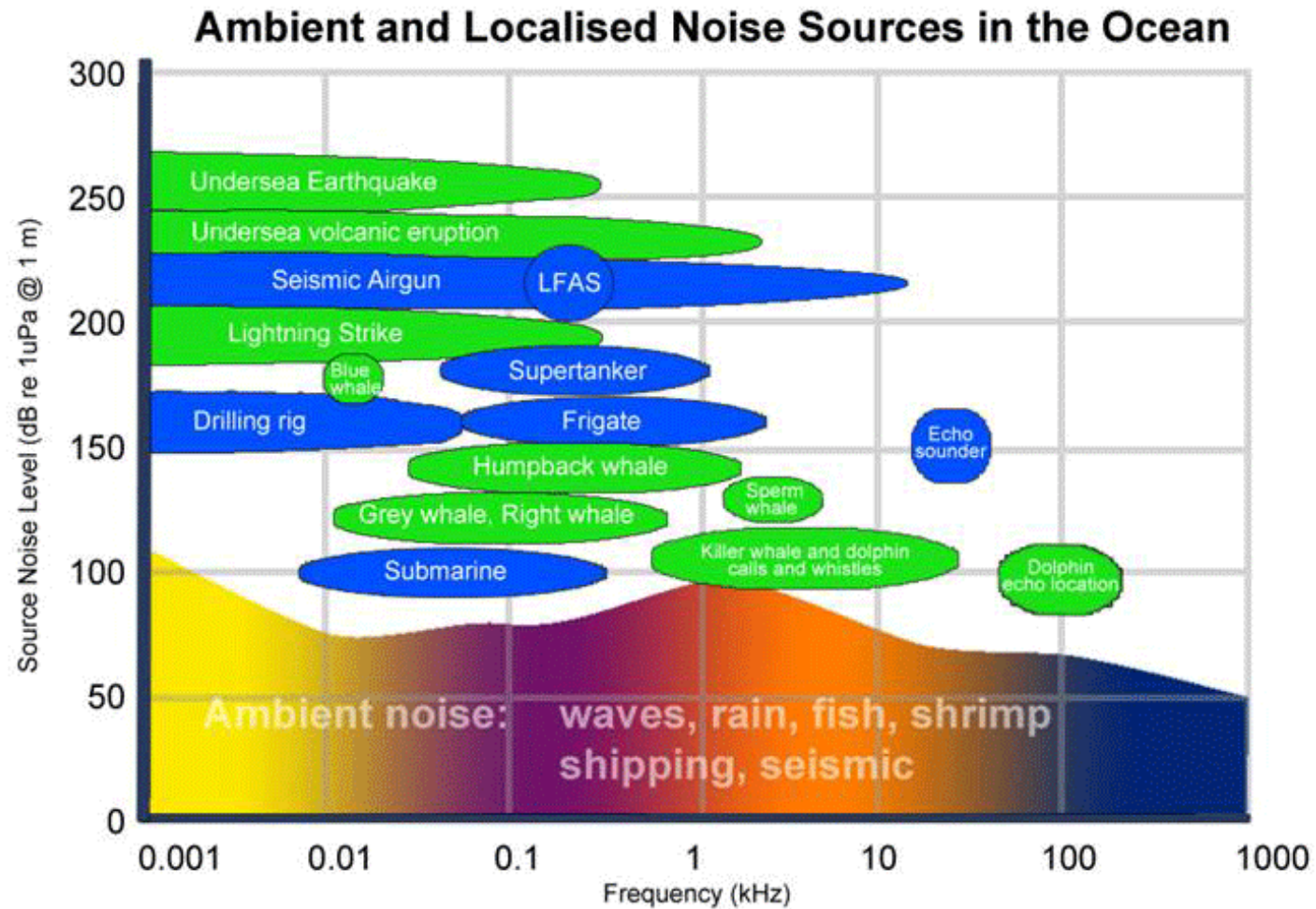
Journal of the Royal Society: Interface - ation: "The complex network of global cargo ship movements" Pablo Kaluza, Andrea Kölzsch, Michael T. Gastner and Bernd Blasius, J. Royal Society: Interface

Increased background, ambient noise ... from hum to din

Increased the ambient noise of the entire ocean
by + 10dB from 1950 to 1975 due to ship
propellers and engines



Increase in dangerous sound levels

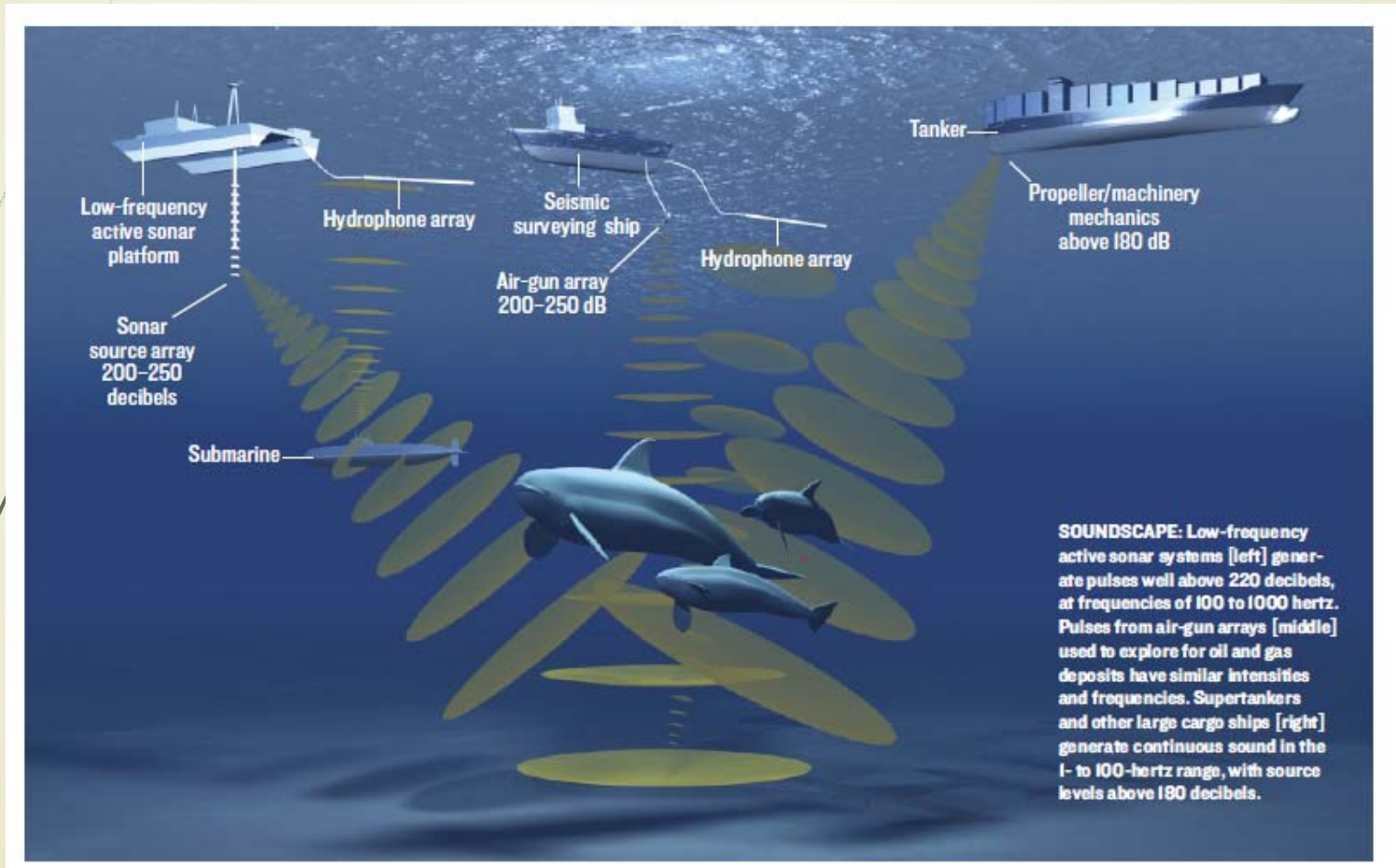


source: Coates, R., The Advanced SONAR Course, Seiche (2002) ISBN 1-904055-01-X

Ex. Well drilling operations – blast at 250dB

greater than 500 new wells drilled per year

Ex. Low frequency active transmission sonar by the military
sweeps ocean with low frequency sound at 230 db at source





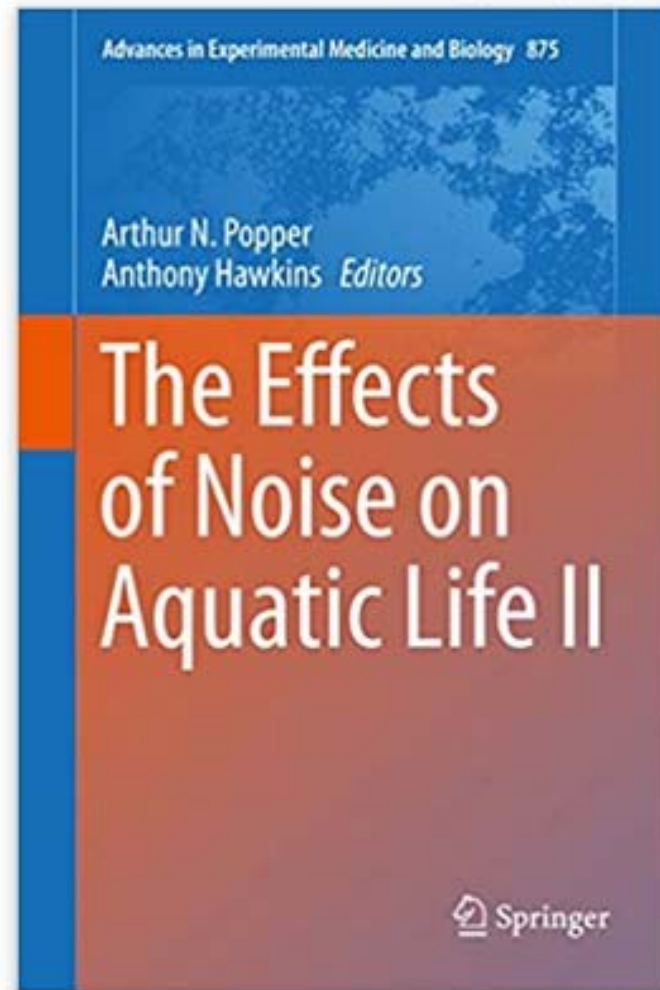
Natural Resources Defense Council

Sounding the Depths 1999

Sounding the Depths II 2005

The rising toll of sonar, shipping and
industrial ocean noise on marine life

Jasny et al.



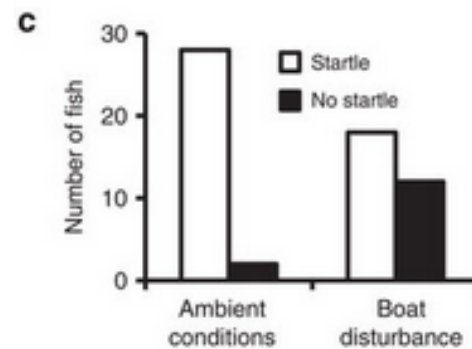
The Effects of Noise on Aquatic Life II (Advances in Experimental Medicine and Biology) 1st ed. 2016 Edition, Kindle Edition By Arthur Popper (ED) and Anthony Hawkins (Ed.) **162 chapters**

Impact on Aquatic Organisms

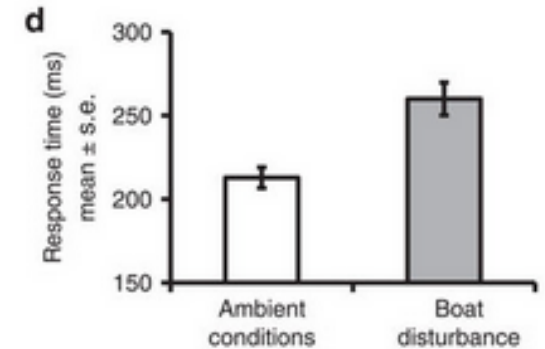
Masking: Higher background noise reduces their ability to hear important signals

Simpson et al. 2016. **Anthropogenic noise increases fish mortality by predation.** Nature Communications.

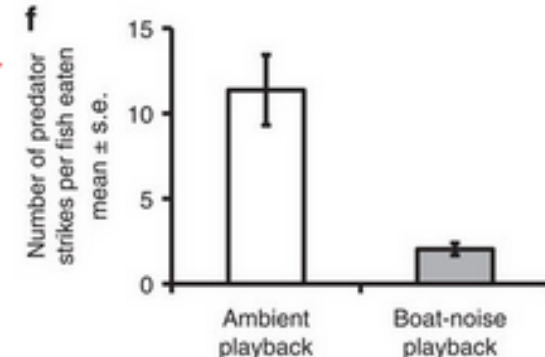
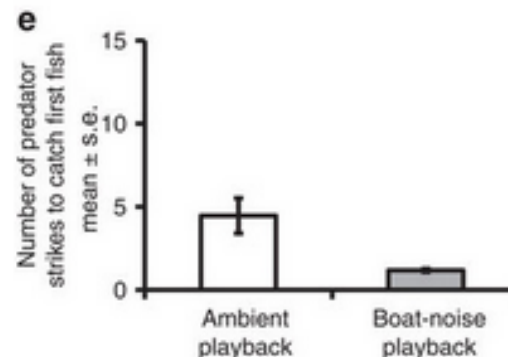
c. Number of prey fish exhibiting a startle response to a looming stimulus with or without boats motoring nearby



d. Time to startle



e. Number of predator fish strikes to catch prey

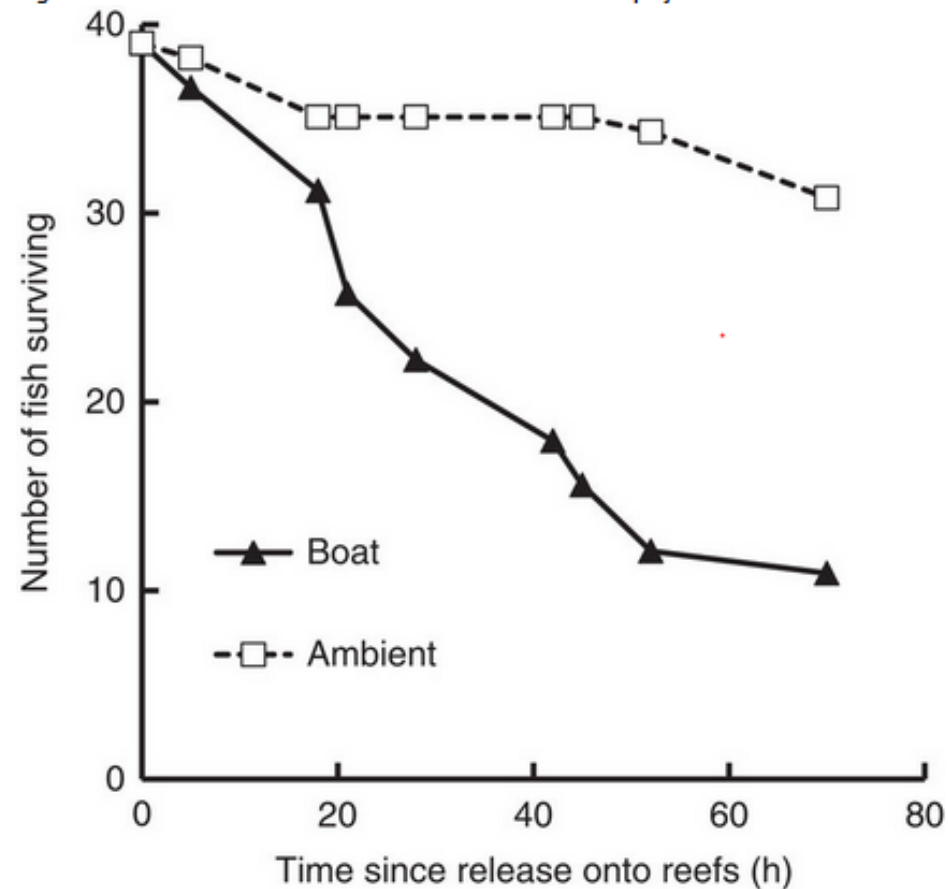


Impact on Aquatic Organisms

Simpson et al. 2016. **Anthropogenic noise increases fish mortality by predation.** Nature Communications.

Masking:

Figure 1: Survival of *P. amboinensis* on reefs with and without playback of boat noise.



Field-based survival of *P. amboinensis* during 72 h following release onto experimental patch reefs with playback of ambient or boat-noise recordings using underwater speakers.

Impact on Aquatic Organisms

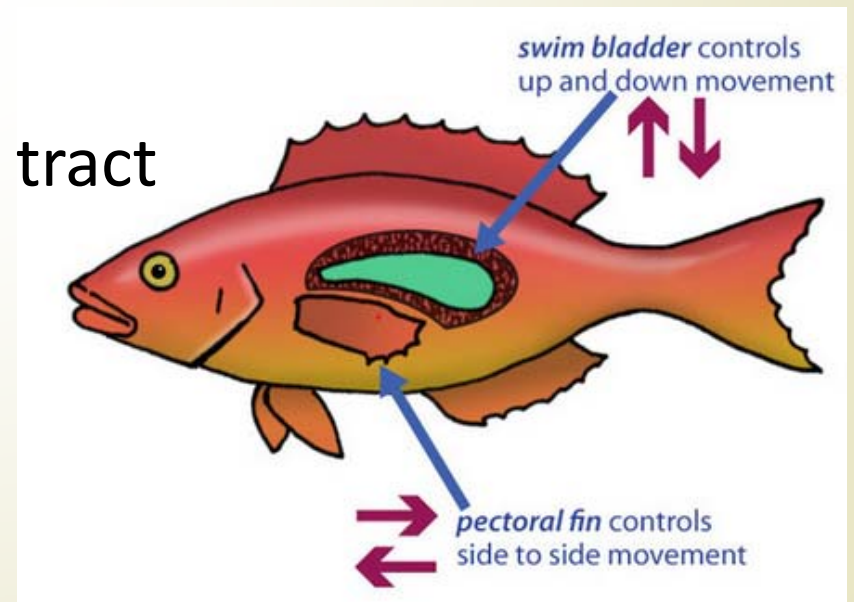
Increasing intensity of sound

Behavioral:

- Noise avoidance
- Cease vocalizations for hours to days
- Exhibit increased aggression, reduced eating

Physiological

- Hearing loss
- Form gas bubbles in GI tract
- Damage air bladder



Lagardere, J. P. et al. 1982. Effects of noise on growth and reproduction of *Crangon crangon* in rearing tanks.
Marine Biology 71(2): 177-185

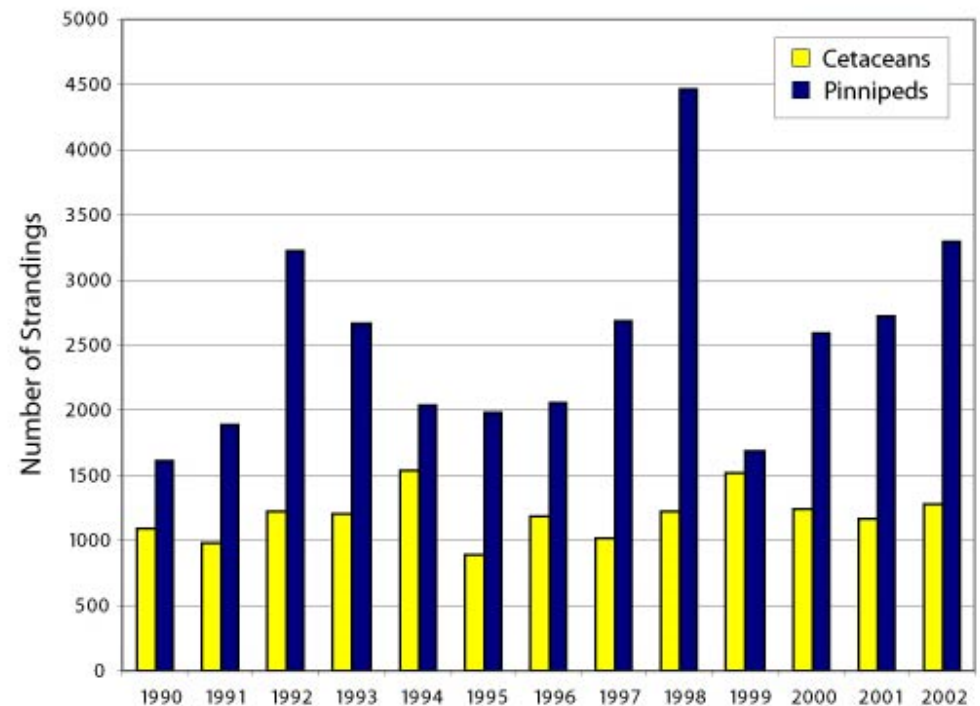
Abstract

Brown shrimp, *Crangon crangon* (L.), were reared in Angoulins, France from April to June 1981. Rearing in a soundproof box reproduced acoustical conditions similar to those prevailing in the shrimps' original environment. Growth and reproduction were compared to those of shrimp from the same source but reared in acoustical conditions prevailing in a thermoregulated aquarium; other experimental conditions were identical. In the aquarium, the noise-level attained 30 dB in the 25 to 400 Hz frequency range; this permanently high sound-level resulted in a significant reduction in growth and reproduction rates of the shrimp. To a lesser degree, noise also appears to increase aggression (cannibalism) and mortality rate and to decrease food uptake. These symptoms are extremely similar to those induced by adaptation to stress.



Whale Mass Strandings Linked To Hearing Loss

BY BRENT LAMBERT • NOVEMBER 8, 2010 • NATURE • COMMENTS (0) • ♥1949



Total number of strandings of cetaceans (yellow bars) and pinnipeds (blue bars) in the U.S. each year from 1992-2002. Data provided by Janet E. Whaley and Teri K. Rowles, NOAA Marine Mammal Health and Stranding Response Program.

<http://www.dosits.org/animals/effectsofsound/marinemammals/strandings/>

Bruintjes et al. 2016. **Rapid recovery following short-term acoustic disturbance in two fish species.** Royal Society Open Science.

European eel

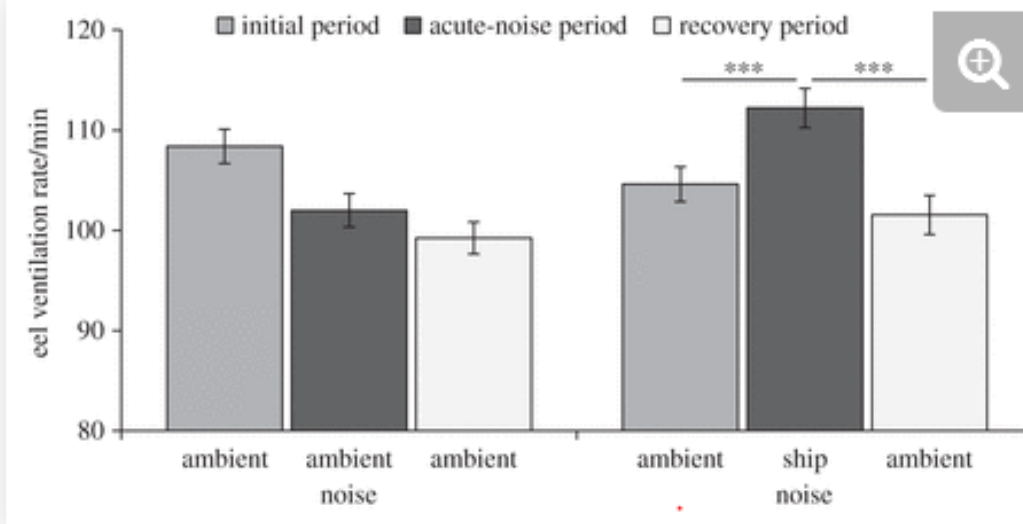


Figure 5.

[Download figure](#) | [Open in new tab](#) | [Download powerpoint](#)

Mean \pm s.e. ventilation rates of eels during three consecutive 2-min periods (initial period, acute-noise period, recovery period) of either different ambient-noise playbacks (control treatment) or an ambient-noise playback followed by ship-noise playback followed by ambient-noise playback (additional-noise treatment). $N=78$ per treatment. Asterisks (***) denote $p < 0.001$.

Bolga, Chorazyczewska, Winfriedl, Codarin, O'Brine, Jammell. **2016. First observations of anthropogenic underwater noise in a large multi-use lake.** Journal of Limnology, 75(3): 644-651.

Over the last fifty years, anthropogenic noise has increased dramatically in aquatic environments and is now recognised as a chronic form of pollution in coastal waters. However, this form of pollution has been largely neglected in inland water bodies. To date, very few studies have investigated the noise spectra in freshwater environments and at present no legislation exists to protect freshwater organisms from anthropogenic noise. The present study represents the first assessment of



Smith, M., A.S. Kane, and A. N. Popper. 2004.
Noise-induced stress response and hearing loss in goldfish
(*Carassius auratus*).
Journal of Experimental Biology 207: 427-435.



<https://i.ytimg.com/vi/AkERbjVbkLE/maxresdefault.jpg>

Research on freshwater fish

Amoser S, Ladich F, 2010. Year-round variability of ambient noise in temperate freshwater habitats and its implications for fishes. *Aquat. Sci.* 72:371-378.

Amoser S, Wysocki LE, Ladich F, 2004. Noise emission during the first powerboat race in an Alpine lake and potential impact on fish communities. *J. Acoust. Soc. Am.* 116:3789-3797.

Boussard A, 1981. The reactions of roach (*Rutilus rutilus*) and rudd (*Scardinus erythrophthalmus*) to noises produced by high speed boating, p. 188-200. *Proceedings Second British Freshwater Fisheries Conference.*

Graham AL, Cooke SJ, 2008. The effects of noise disturbance from various recreational boating activities common to inland waters on the cardiac physiology of a freshwater fish, the largemouth bass (*Micropterus salmoides*). *Aquat. Conserv.* 18:1315-1324.

Mann DA, Cott PA, Hanna BW, Popper AN, 2007. Hearing in eight species of northern Canadian freshwater fishes. *J. Fish Biol.* 70:109-120.

Wysocki LE, Dittami JP, Ladich F, 2006. Ship noise and cortisol secretion in European freshwater fishes. *Biol. Conserv.* 128:501-508.

Impact on Aquatic Organisms

“It might be that fish are well-adapted to noise. Maybe it’s not a problem. We don’t know,” said Rob McCauley, a marine biologist at Australia’s Curtin University of Technology. “The work that’s been done has only scratched the surface.”

“Findings suggest that human-generated sounds, even from very high intensity sources, might have no effect in some cases or might result in effects that range from small and temporary shifts in behavior all the way to immediate death. At this point, however, it is nearly impossible to extrapolate from results with one sound source, one fish species, or even fish of one size to other sources, species, or fish sizes.” Popper and Hastings 2009



Why underwater noise matters

One more source of stress that acts synergistically to reduce health of fish and other organisms, making them more vulnerable to heat and impacts associated with climate change.

What we can do:

1. Simply reducing the amount of nose can help fix it
2. Shallow areas amplify noise, so drive slowly or avoid them
3. Keep your engine in proper condition –it makes less noise
4. Clean your propeller
5. Reduce the use of depth finders which depend on sonar
6. Insulate your engine from the hull to avoid resonating.
7. Slow down speeds which increase cavitation.

What we can do:

- “Develop a report card system that identifies the noisiest 10% of vessels passing over a noise monitoring station. In the absence of legislation, letters could be sent to vessel owners advising them of their noisy ships, and a list of worst offenders could be published. Letters could also be sent to the owners of quiet ships, congratulating them on their reduced contribution to the soundscape.
- “MARINAS/ Ports could adopt maintenance requirements for noisy ships, as poor vessel maintenance is the source of extraneous noise on approximately 10 percent of merchant ships.
- “A mandatory phased-in program could be established to incentivize quietening technologies for retrofitted vessels. Proposed new projects could require quietened ships.”

Rebecca Schneider
Dept. Natural Resources, Cornell Univ.

Questions?

<https://i.ytimg.com/vi/IKwQX31Mans/maxresdefault.jpg>

