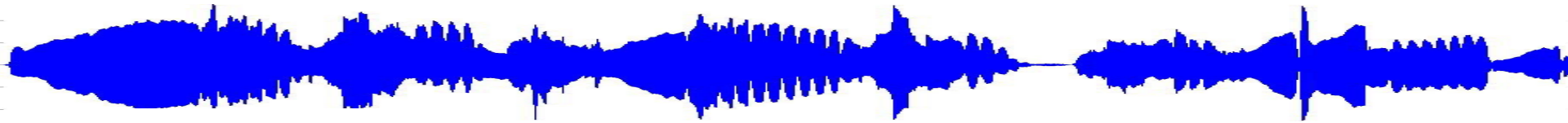
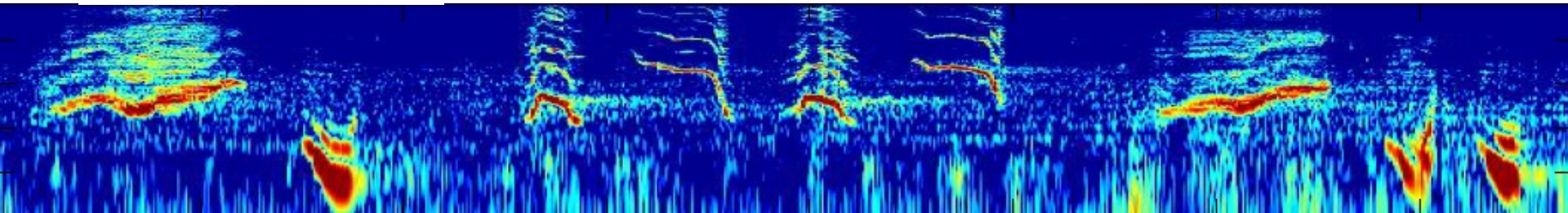
Characterizing underwater soundscapes on a global scale



Jennifer L. Miksis-Olds

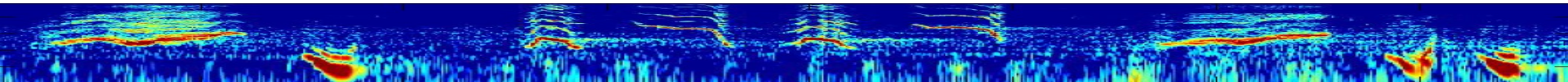
Center for Acoustics Research & Education

University of new Hampshire



Overview

- What is an underwater soundscape?
- Why care about the soundscape?
- Highlights of soundscape research
- Future soundscape outlook



Etymology

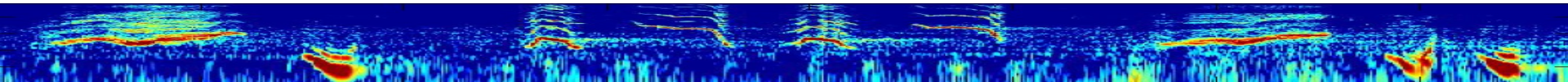
Soundscape

sound

- Origin: Latin *sonus* (to sound), Old English *swinn* (melody)
- Mechanical radiant energy that is transmitted by longitudinal pressure waves in a material medium (as air) and is the objective cause of hearing (Merriam-Webster Dictionary)
- Physical properties
- Perceptual properties

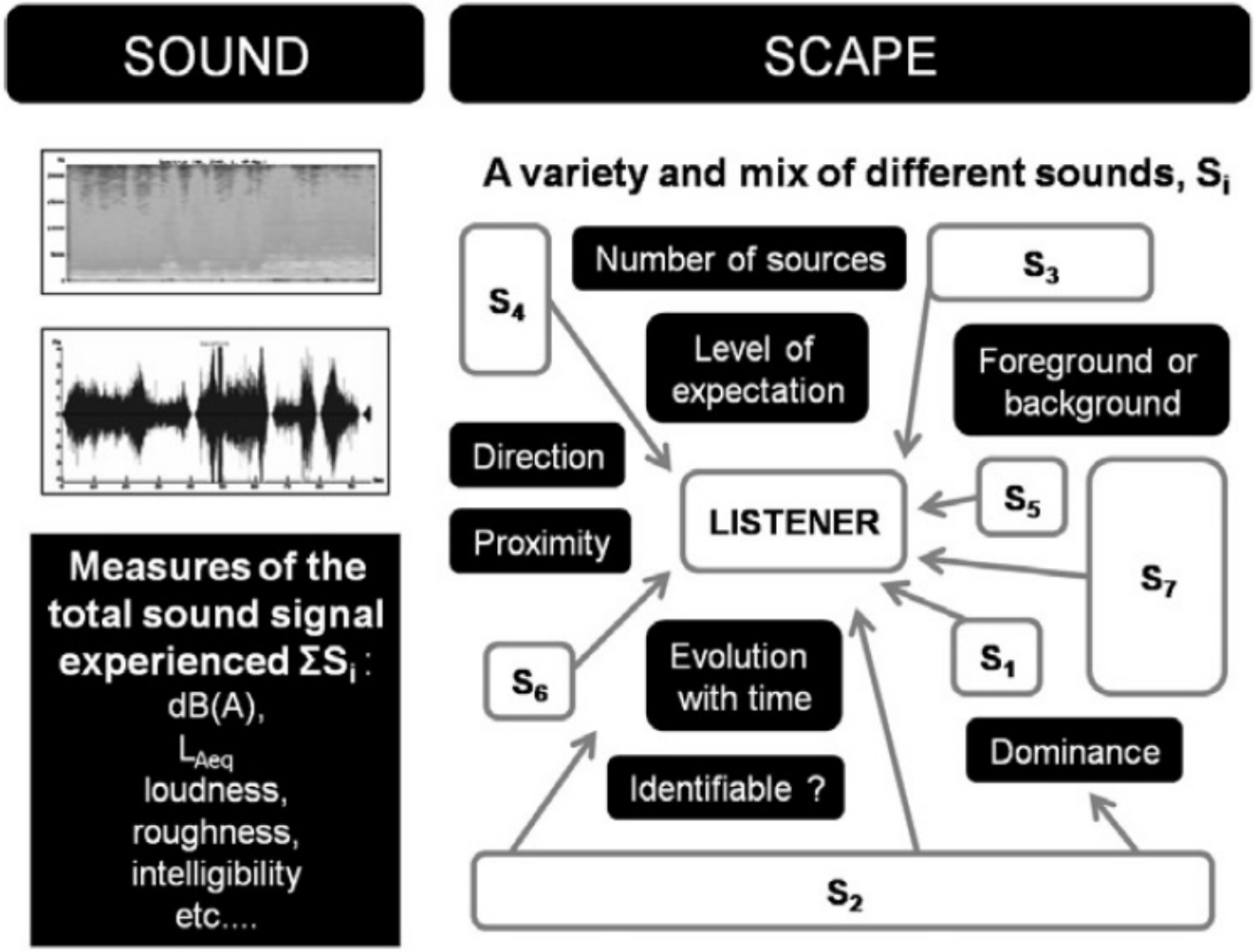
scape

- Origin: landscape, first known use in 1773
- A view or picture of a scene (Merriam-Webster Dictionary)
- Spatial component
- Temporal component



Ambient Sound vs Soundscape

Jennings & Cain, 2013



History

- Historical inherent bias towards humans and terrestrial environments

1969
Southworth (1969) discriminated between sounds useful to humans from background sound. Used in urban planning.

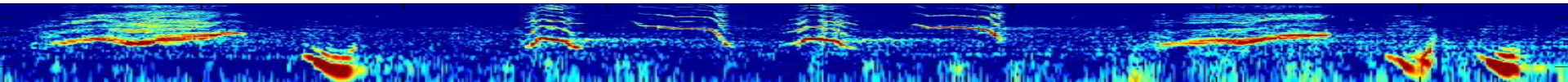
1977
Schafer (1977) used natural sounds to create music. Used "soundmarks" and "keynotes" related to acoustic landscape. Acoustic ecology

1985
Porteous et al. (1985) awareness of overall sonic environment and noise levels related to perceptions in urban areas.

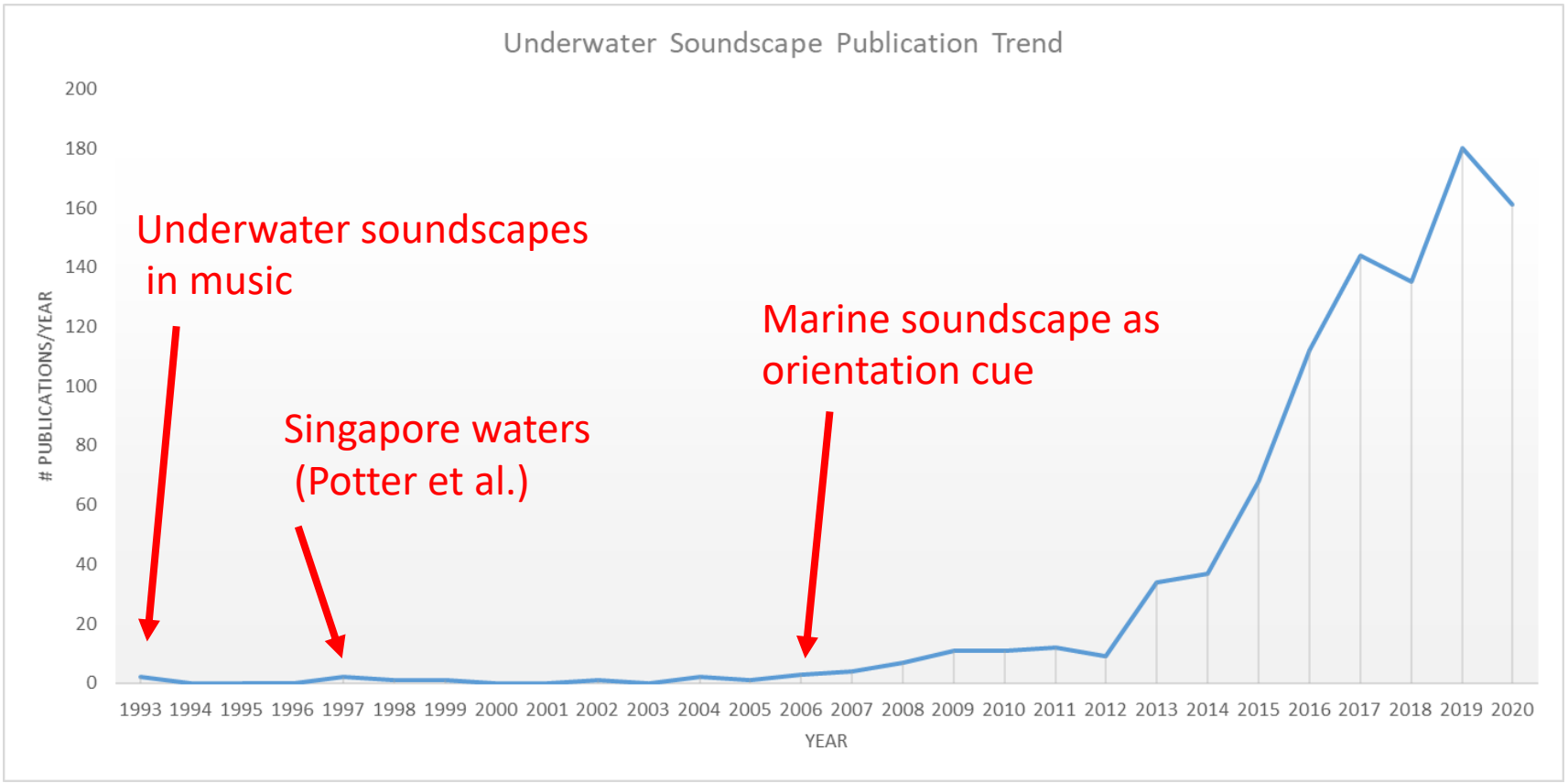
1993
Charles (1993) in Contemporary Music Review is first known use of underwater soundscape.

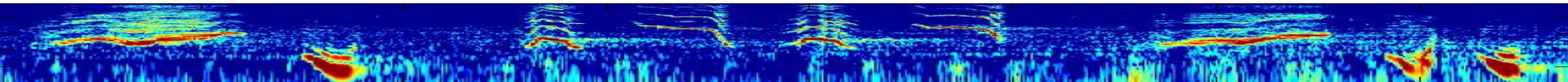
2011
Pijanowski et al. (2011) coined soundscape ecology: spatial and temporal elements related to biophony, geophony, anthrophony.

- Currently used in multiple disciplines: music, cognitive psychology, acoustic ecology, bioacoustics, noise control, and now acoustical oceanography



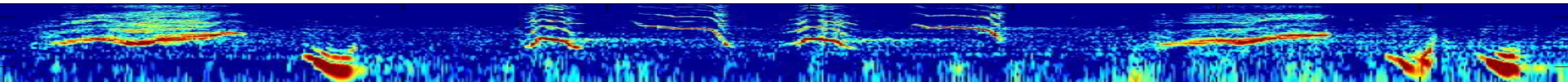
History


Underwater Soundscape Publication Trend
PUBLICATIONS/YEAR
200
180
160
140
120
100
80
60
40
20
0
1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
YEAR
Underwater soundscapes in music
Singapore waters (Potter et al.)
Marine soundscape as orientation cue



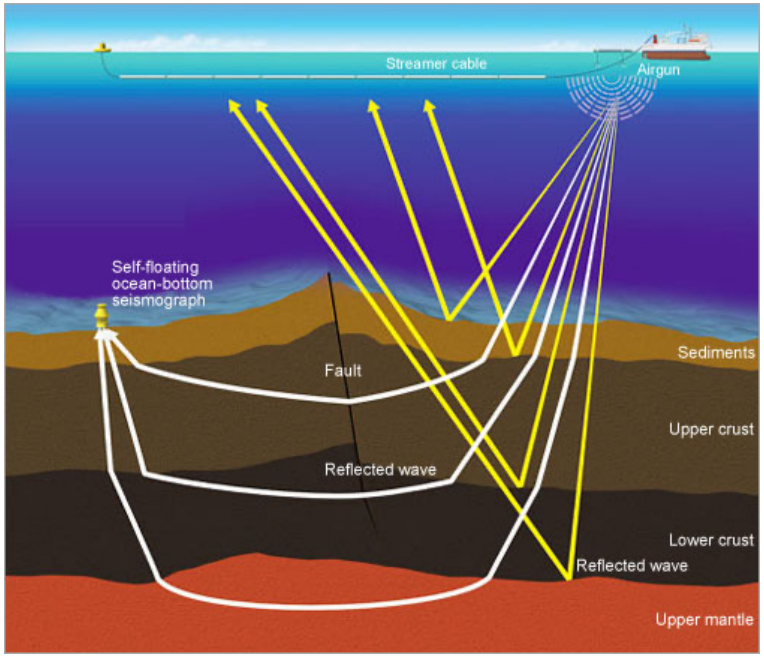
Terrestrial *vs.* Underwater Soundscapes

- Terrestrial conceptual framework and use exceeds that of underwater environments
  - Relative ease of recording sound in air vs. water
  - Ability of humans (dominantly visual creatures) to link sound to visible sources
  - Relative ease of exploring human and terrestrial animal perception compared to humans or aquatic animals in their natural habitat
- Ironic considering sound is the dominant mode of communication underwater
- Underwater challenges
  - Ability to link sounds to sources (distance, vision barrier)
  - Lack of standards (vocabulary, measurement parameters, presentation)
  - Difficulty in assessing perception



Why care about marine soundscapes?

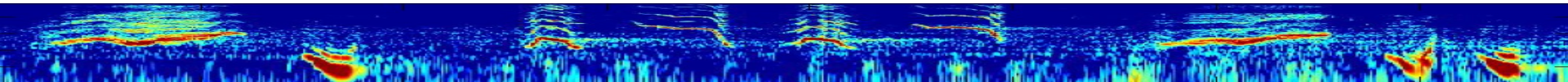
- Maximize signal detection
  - Military
    - Surveillance
    - Mitigation
  - Energy & Production activities
    - Seismic
    - Mitigation
  - Environmental managers
  - Researchers



- Determine how changes in ocean sound may impact marine life
- Censusing/monitoring

Why care about marine soundscapes?

- Maximize signal detection
- Determine how changes in ocean sound may impact marine life
  - Ocean users must comply with regulations and exhibit good environmental stewardship
  - Non-government organizations (NGO)
  - Researchers
- Censusing/monitoring



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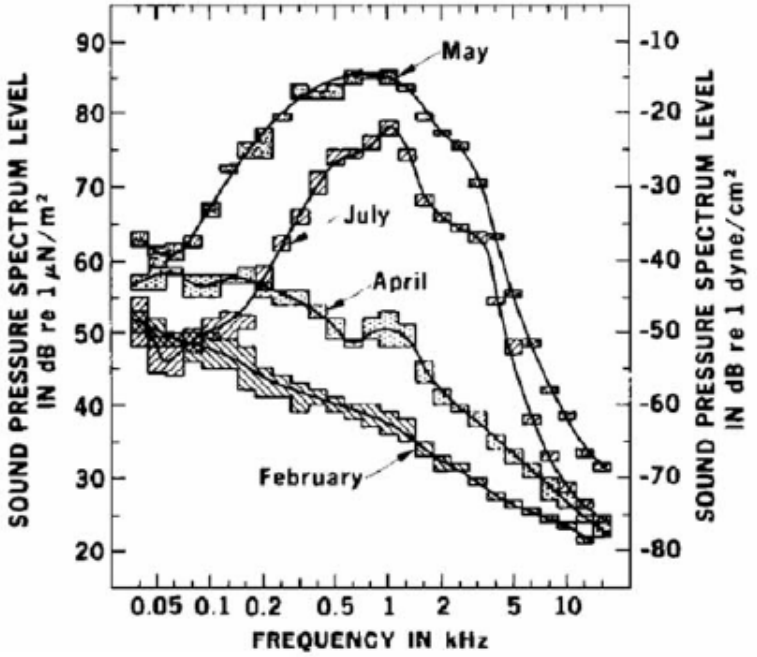
- Maximize signal detection
- Determine how changes in ocean sound may impact marine life
- Censusing/monitoring
  - Species range/distribution
  - Temporal patterns
  - Behavior



Fish, J. F., and Cummings, W. C. (**1973**). "A 50-dB increase in sustained ambient noise from fish (*Cynoscion xanthulus*)," J Acoust Soc Am 52, 1266-1270.

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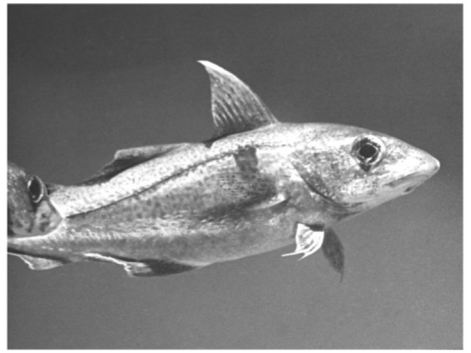
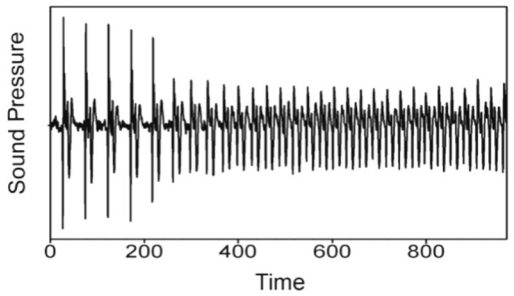


(a)



(b)

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- Determine how changes in ocean sound may impact marine life
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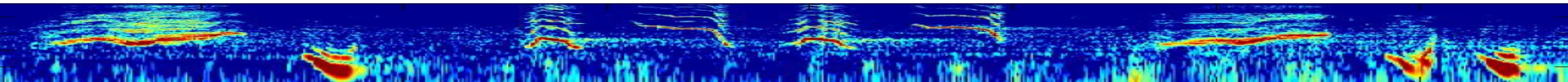
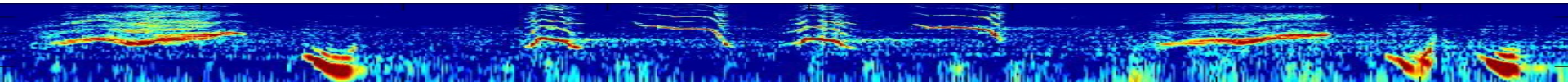


Why care about marine soundscapes?

ANIMAL USE

- Animals rely on soundscapes for survival
  - Habitat selection
  - Navigation/migration
  - Foraging
  - Detecting predators



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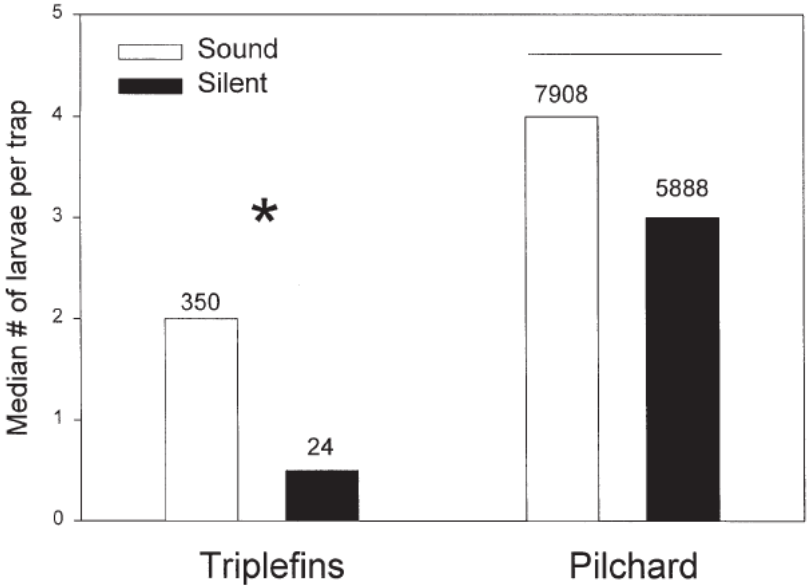

Vol. 207: 219–224, 2000 | MARINE ECOLOGY PROGRESS SERIES Mar Ecol Prog Ser | Published November 22

Ambient sound as a cue for navigation by the pelagic larvae of reef fishes

Nick Tolimieri[1,2,*], Andrew Jeffs[3], John C. Montgomery[1]

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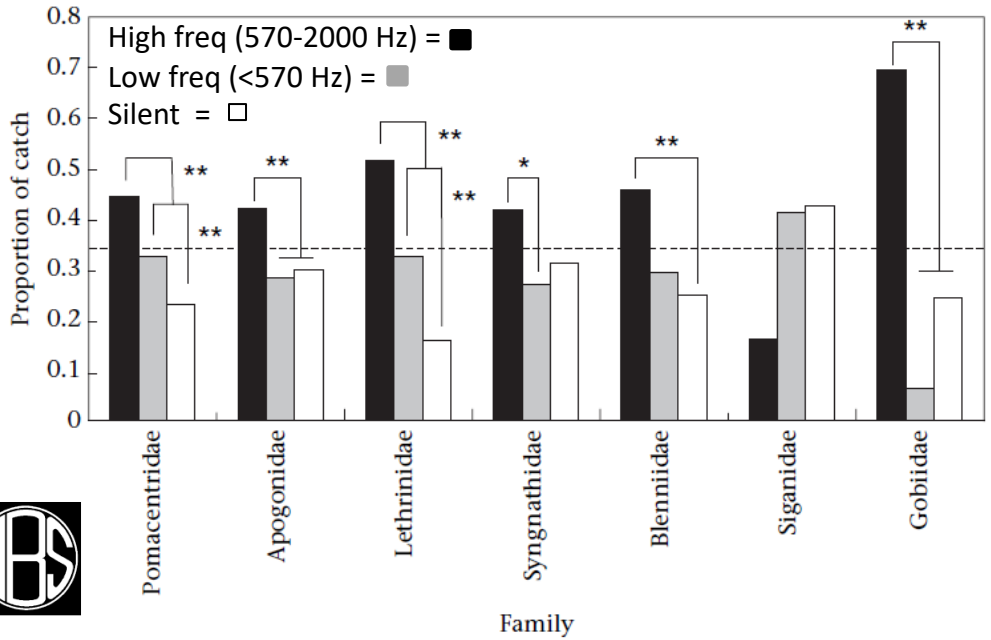

ELSEVIER

ANIMAL BEHAVIOUR, 2008, 75, 1861–1868
doi:10.1016/j.anbehav.2007.11.004

Available online at www.sciencedirect.com
ScienceDirect

Settlement-stage coral reef fish prefer the higher-frequency invertebrate-generated audible component of reef noise

S. D. SIMPSON*, M. G. MEEKAN†, A. JEFFS‡, J. C. MONTGOMERY‡ & R. D. McCAULEY§

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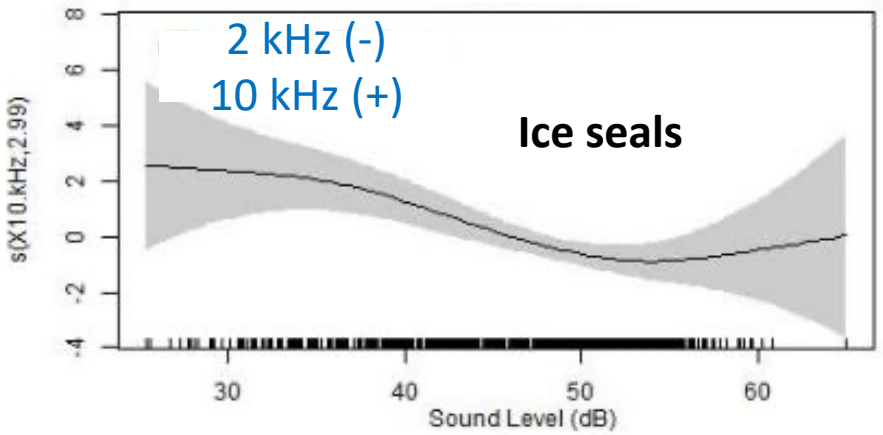
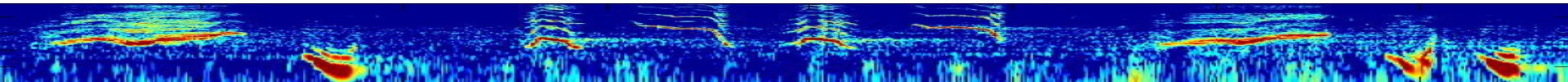


Miksis-Olds & Madden (2014). Environmental predictors of ice seal presence in the Bering Sea. PLOS ONE.

Why care about marine soundscapes?

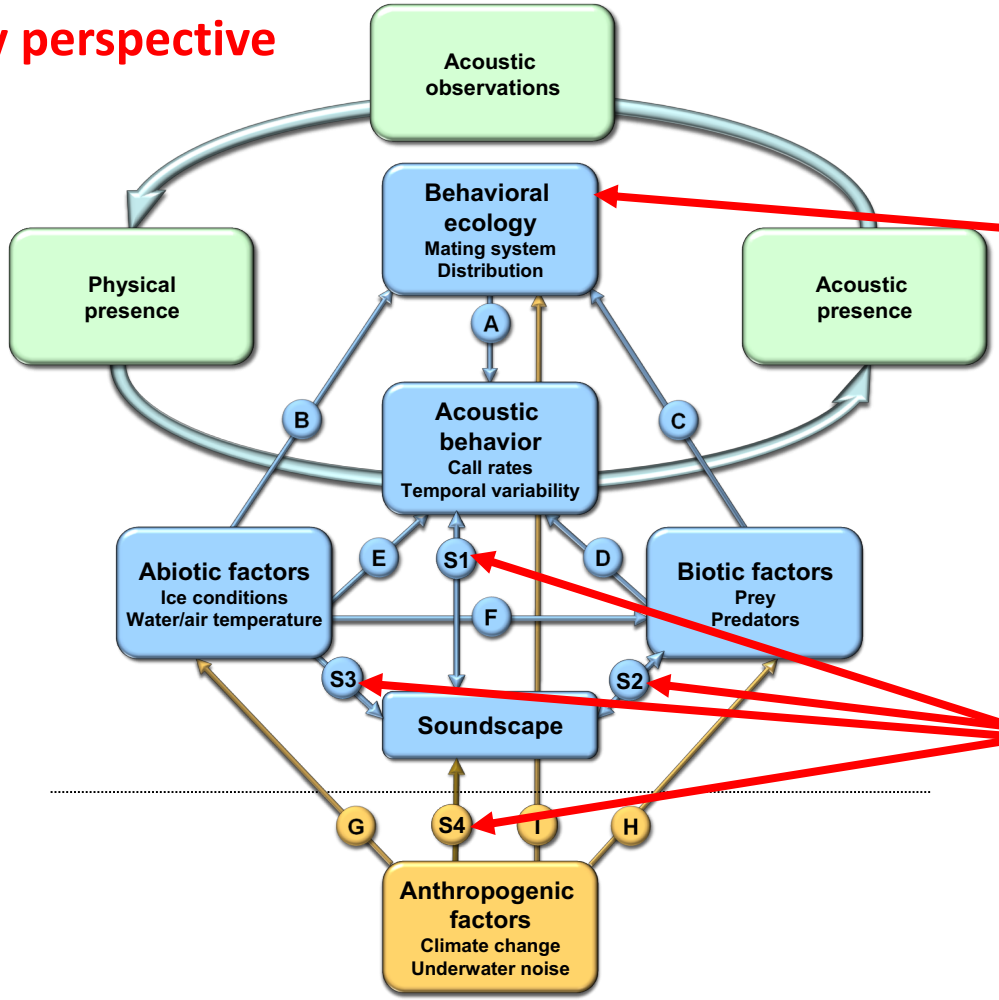
ANIMAL USE

- Animals rely on soundscapes for survival
  - Habitat selection
  - Navigation/migration
  - Foraging
  - Detecting predators
- Must fully understand how animals are using the soundscape to fully assess impact
- Birth of new fields (sub-fields) of study
  - Soundscape ecology (Van Opzeeland & Slabbekoorn, 2012)
  - Soundscape orientation (Pijanowski et al., 2011; Bormpoudakis et al., 2013)



Multi-disciplinary (Super Listeners)

Soundscape ecology perspective

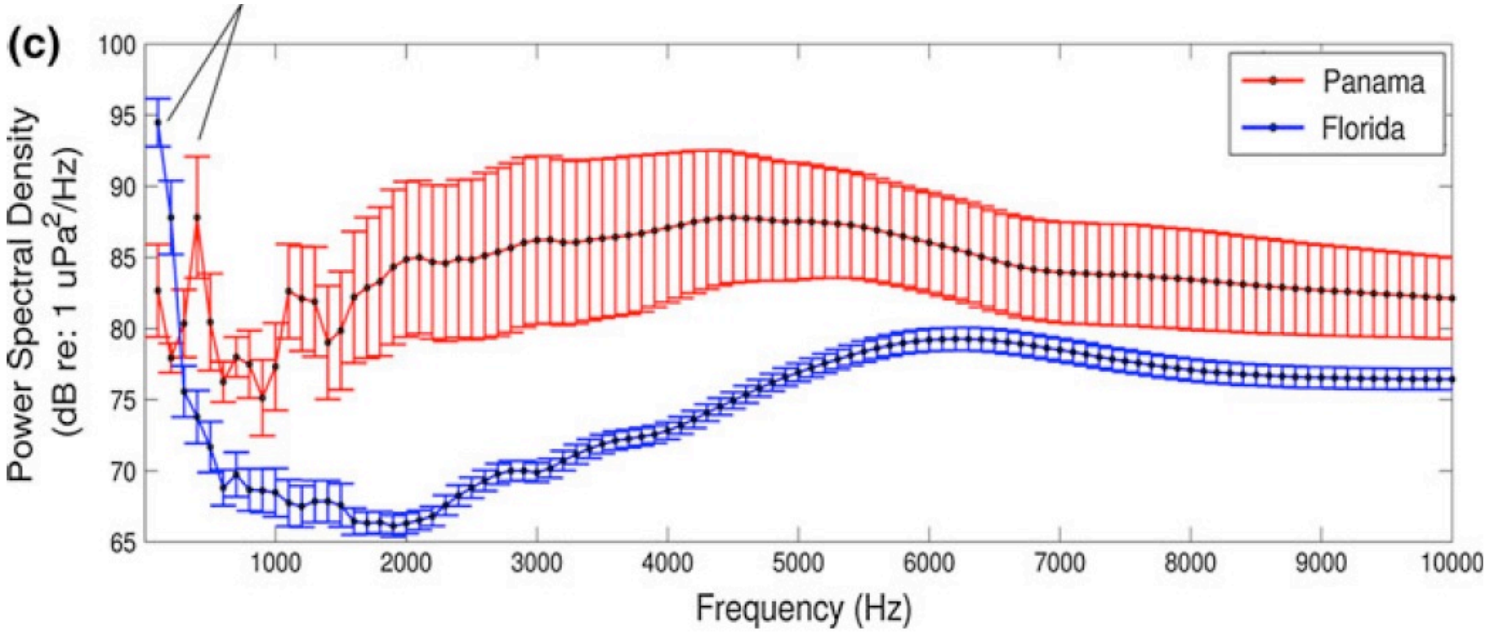


Acoustics
Biology
Ecology
Cognition

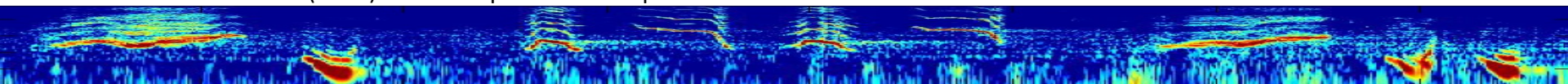
Acoustics
Signal processing
Oceanography

Van Opzeeland & Miksis-Olds (2012). Aquatic Animals: Biology, Habitats, and Threats. Nova.

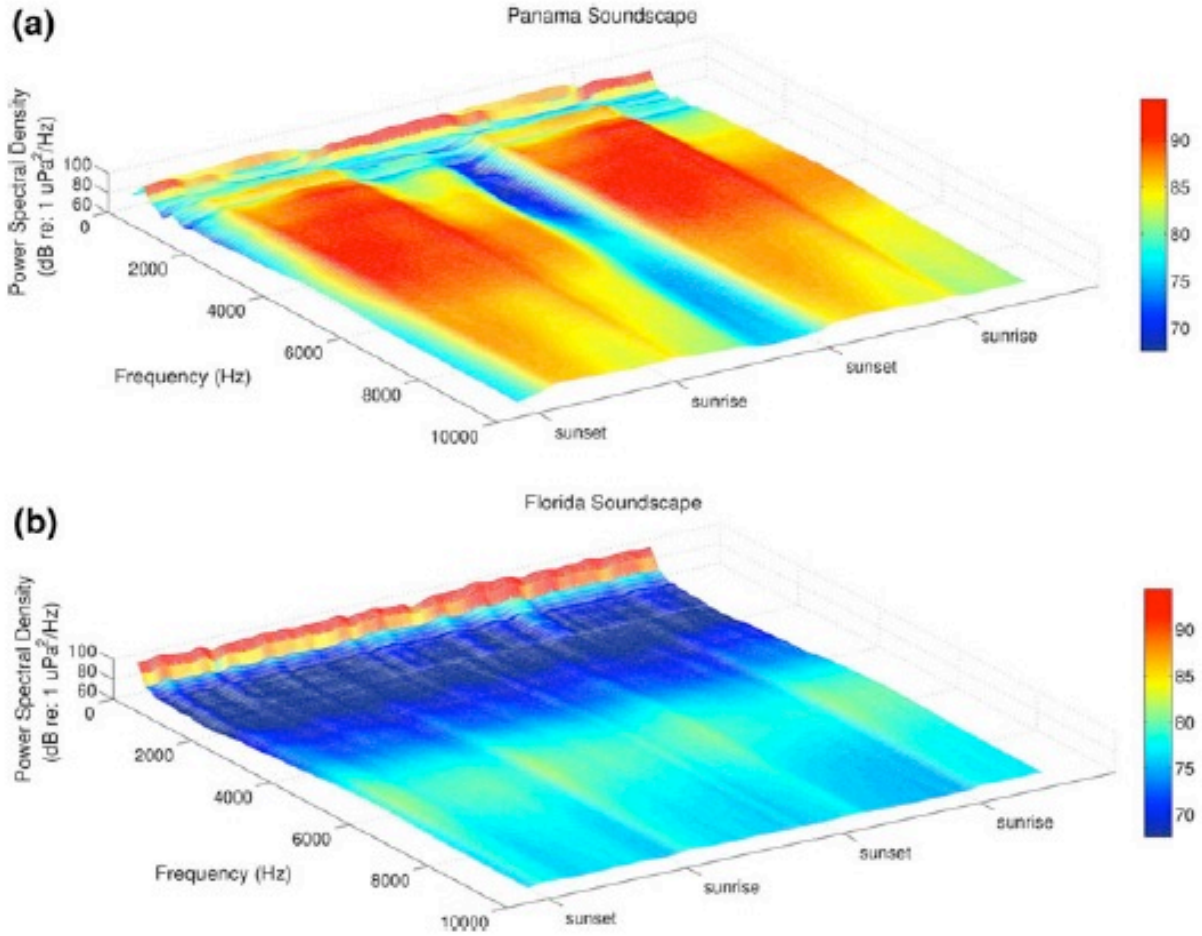
Spatial Approach



Staaterman et al. (2013). Soundscapes from a Tropical Eastern Pacific reef and a Caribbean reef. Coral Reefs 32: 553-557.



Spatial Approach



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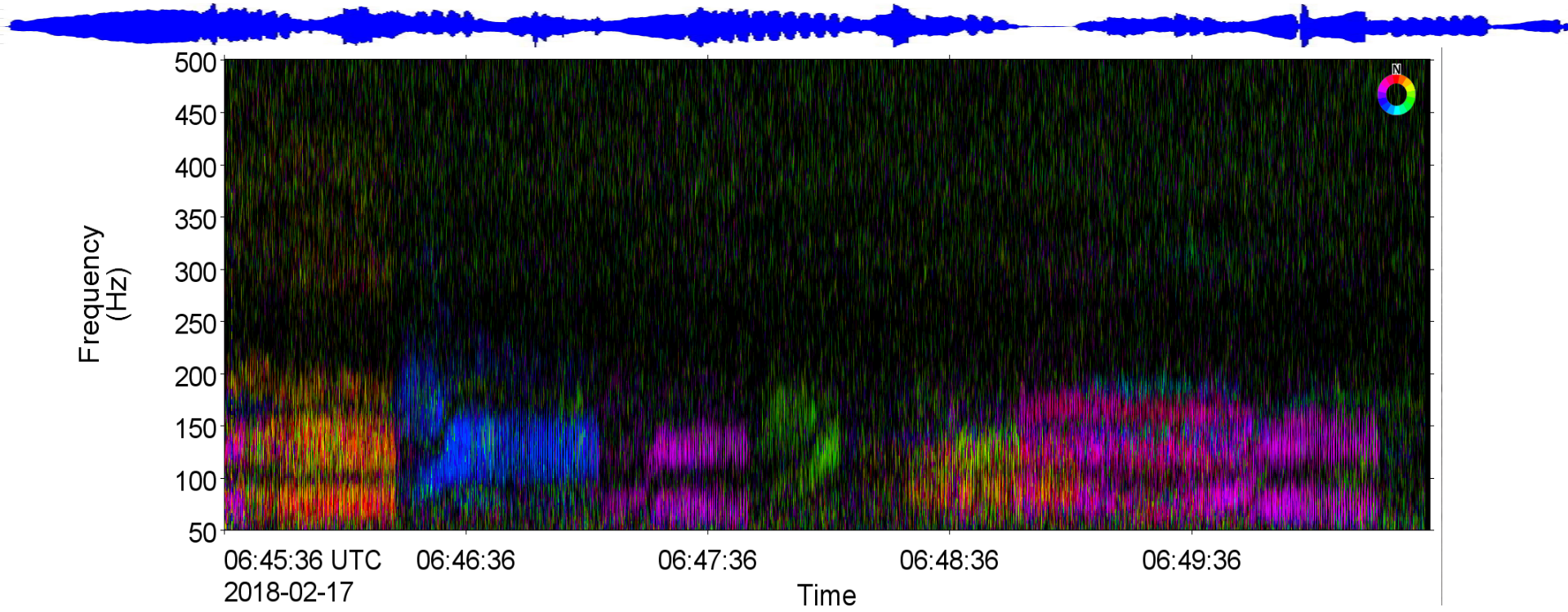
Spatial Approach



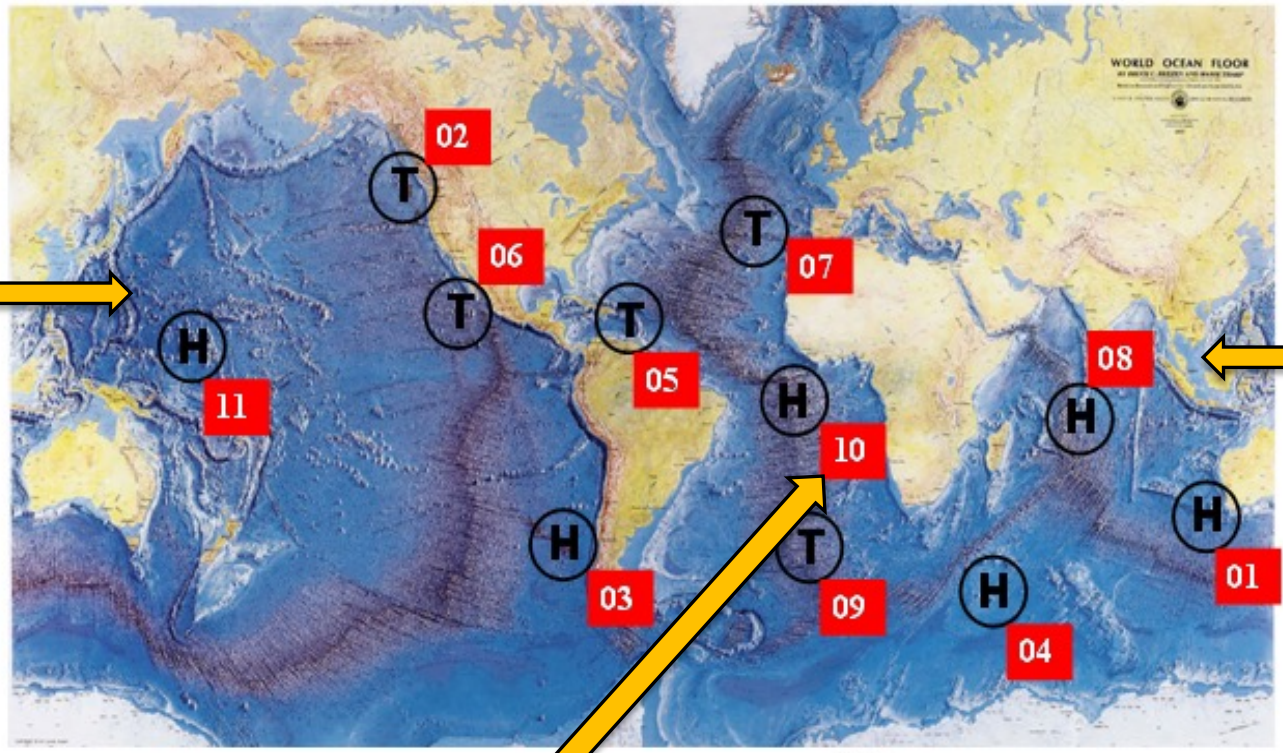
Directogram of at least 5 minke whales vocalizing at the SAV site on 27 Feb 2018

ADEON

https://adeon.unh.edu/

Temporal Approach

Comprehensive Nuclear Test Ban Treaty Organization International Monitoring System (CTBTO IMS) Site Locations



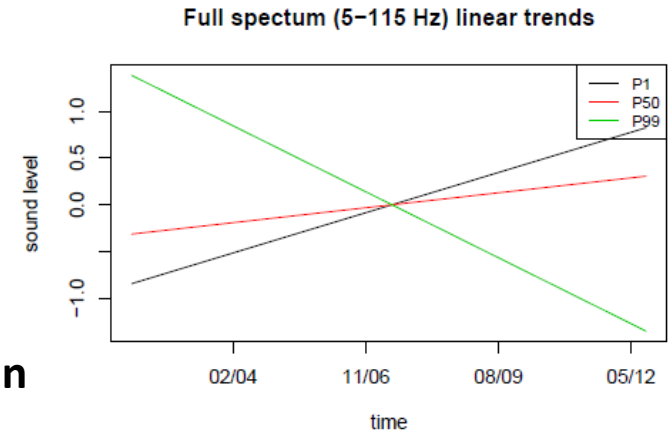
Wake Island
Pacific Ocean

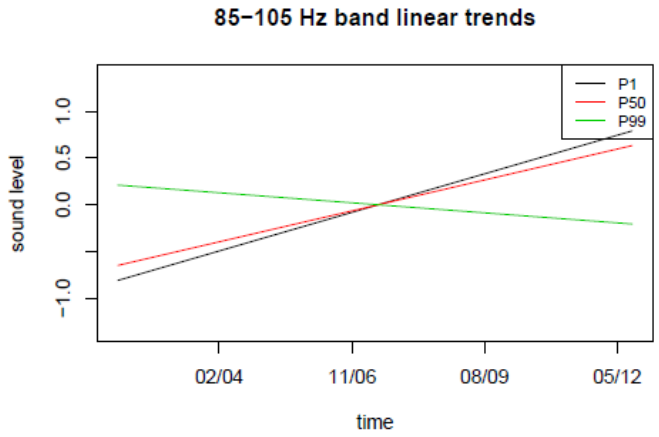
Diego Garcia
Indian Ocean

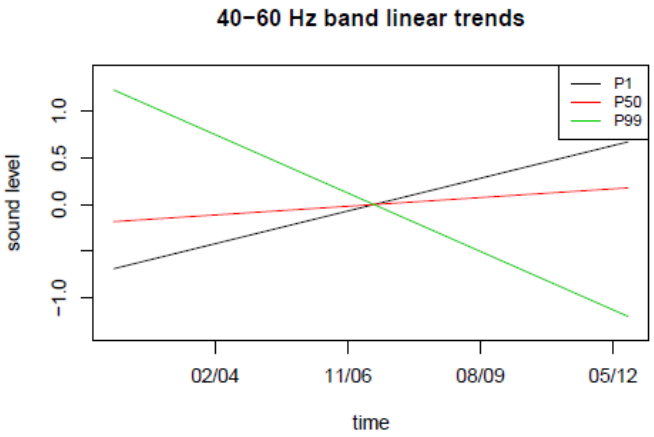
Ascension Island
Atlantic Ocean

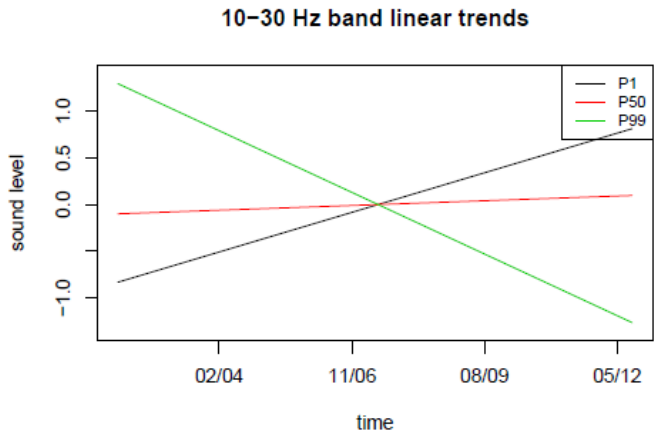
Temporal Approach

Indian Ocean (H08) 10 years

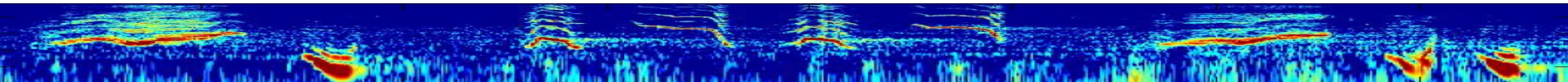






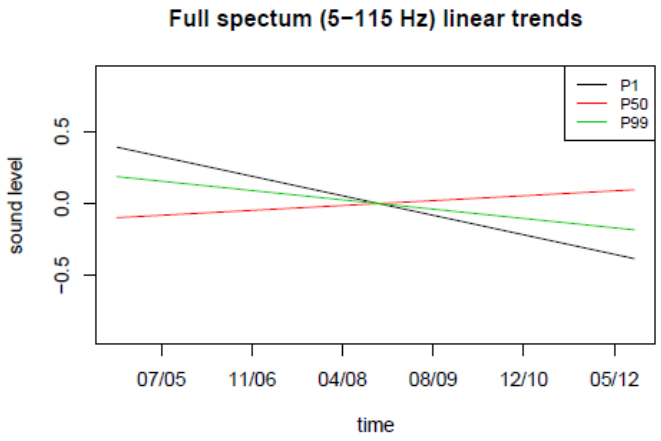


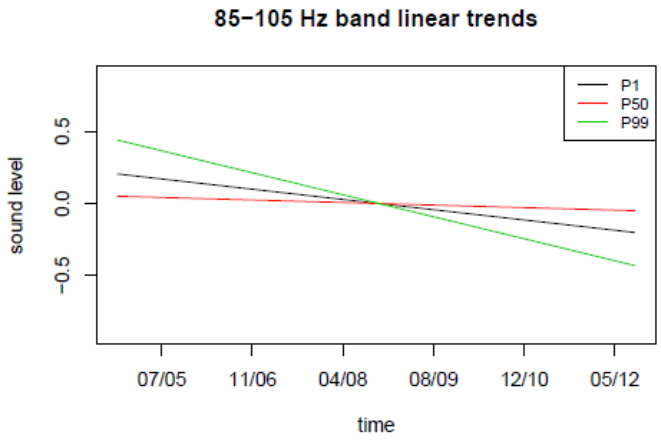
Miksis-Olds et al. (2013). Decadal trends in Indian Ocean ambient sound. JASA

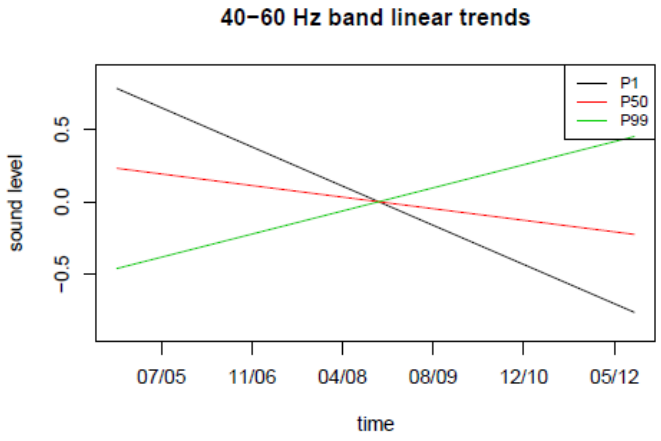


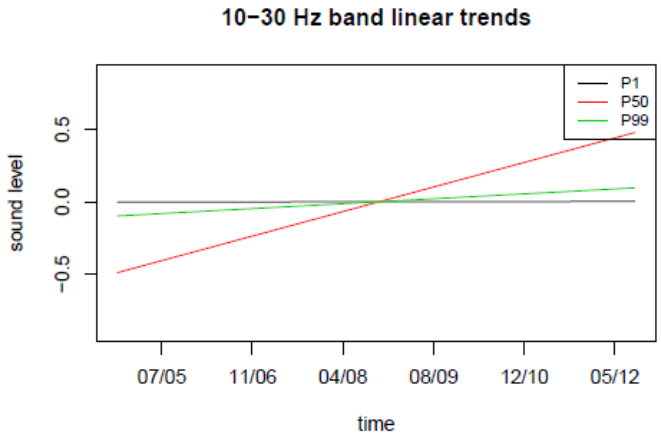
Temporal Approach

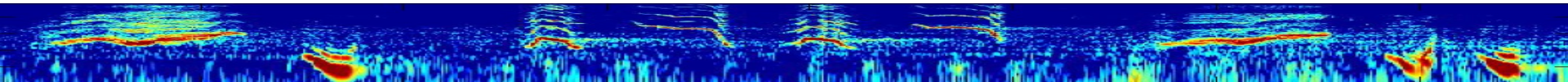
Atlantic Ocean (H10) 8 years





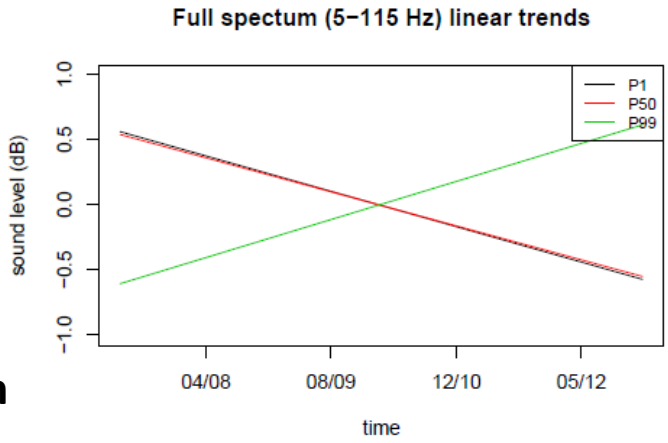


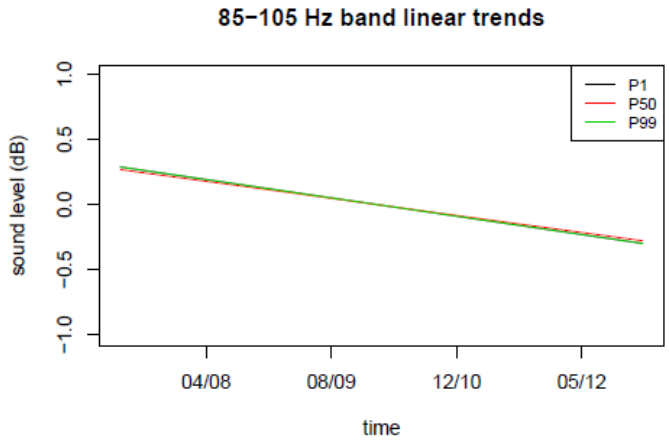


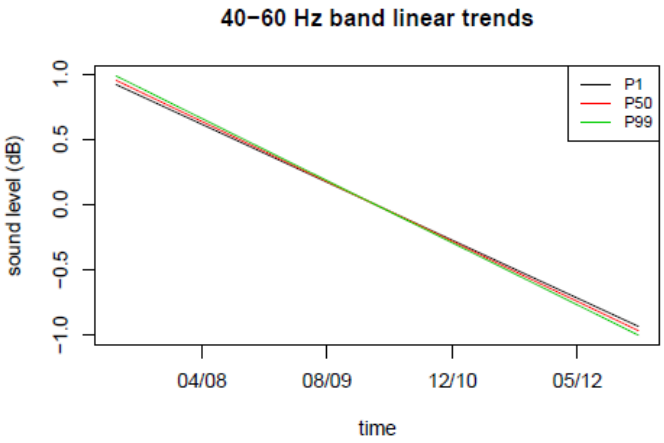


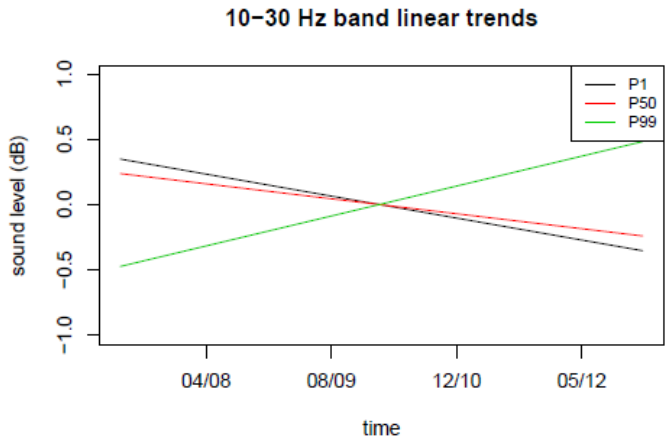
Temporal Approach

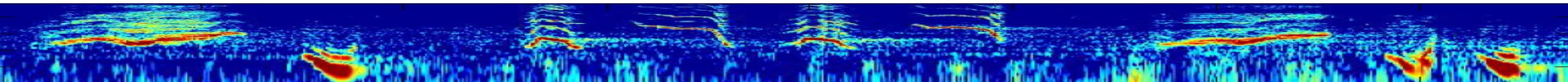
Pacific Ocean (H11) 6 years











Temporal Approach

Lessons Learned from Long-Term Analyses

- Ocean sound levels are not uniformly increasing worldwide
- A single sound level parameter is not sufficient to describe long-term trends
  - Sound floor and median levels increasing in Indian Ocean
  - Loudest sound levels are decreasing in the Indian Ocean
  - Sound floor is decreasing in the Equatorial Pacific Ocean, while loudest sounds are increasing
- Trends are frequency dependent
  - Indian Ocean P50 levels
    - Increase in 10-30 Hz and 85-105 Hz bands
    - No change in 40-60 Hz band

Temporal Approach

Short-Term Soundscape Dynamics Impact Size of Detection Area

Colorbar: 0-10 dB

Modeled frequency: 20 Hz

Depth: 0-300 m

SL: 180 dB

Changing variable: Sound level

Temporal Approach

Short-Term Soundscape Dynamics Impact Size of Detection Area

Colorbar: 0-10 dB

Modeled frequency: 20 Hz

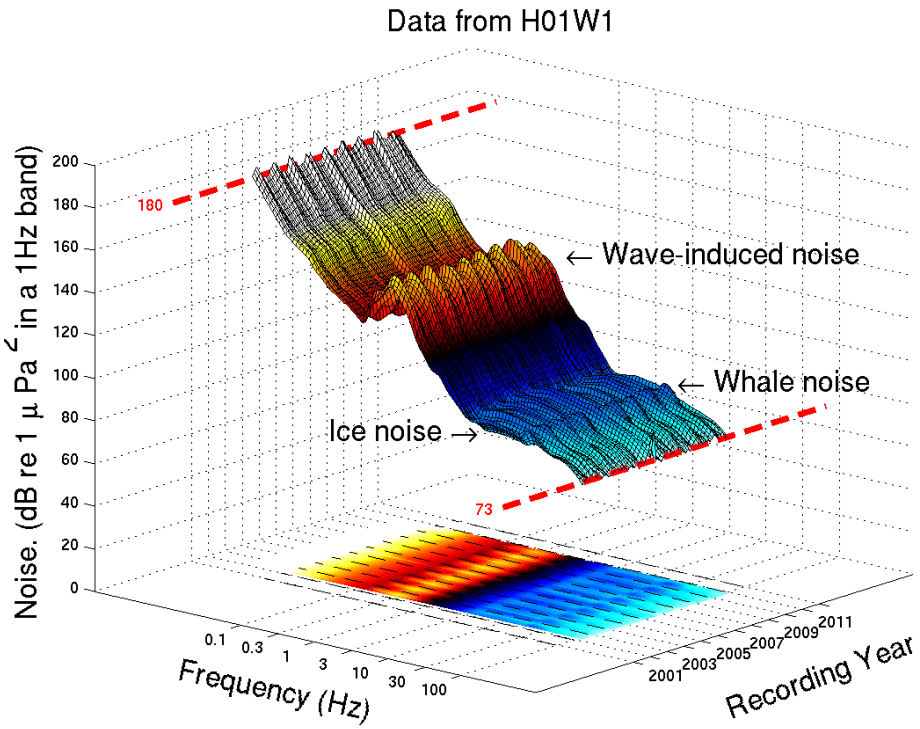
Depth: 0-300 m

SL: 180 dB

Changing variable: Sound level

Spectral Approach

- Gain knowledge of source contributions
  - Directly from spectra



Prior et al 2012

Spectral Approach

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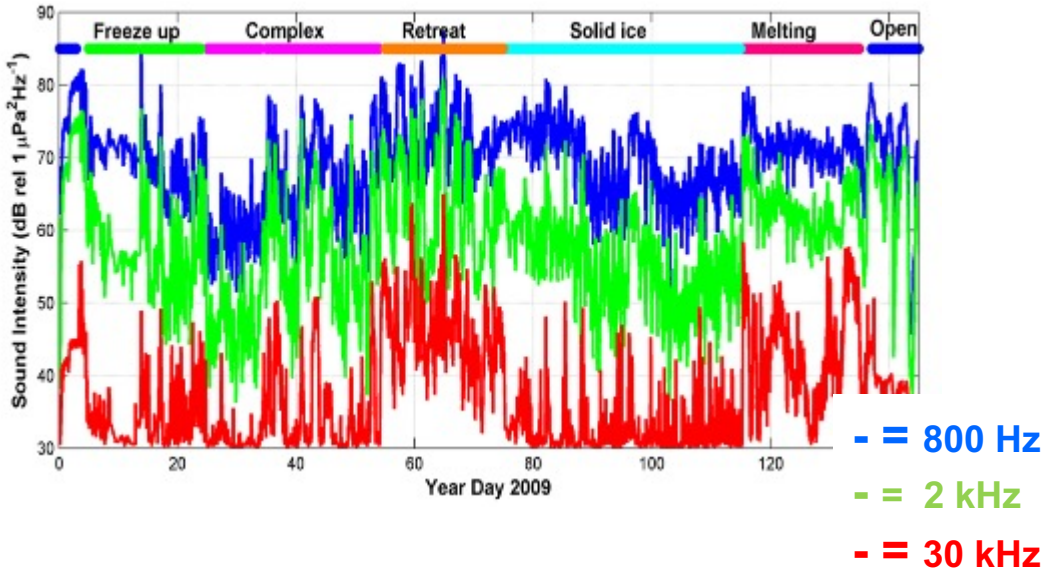
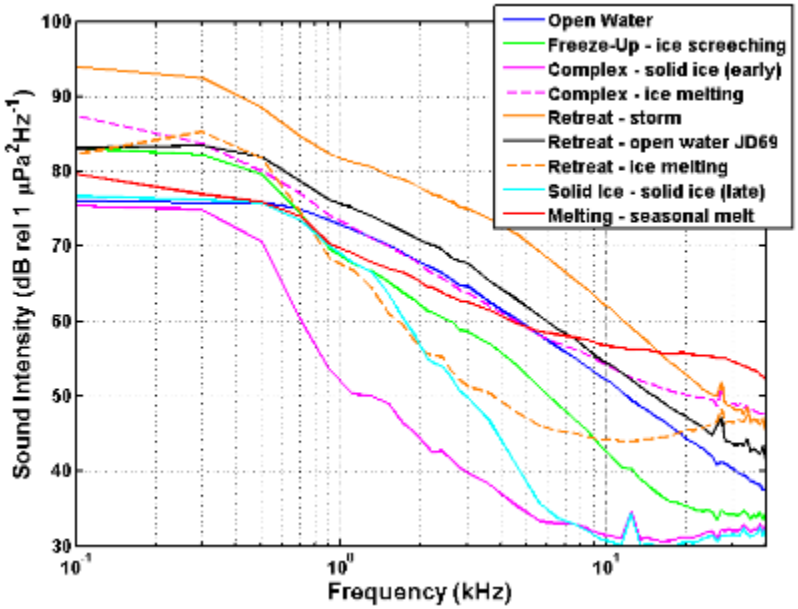
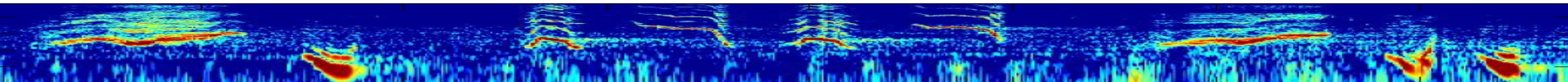


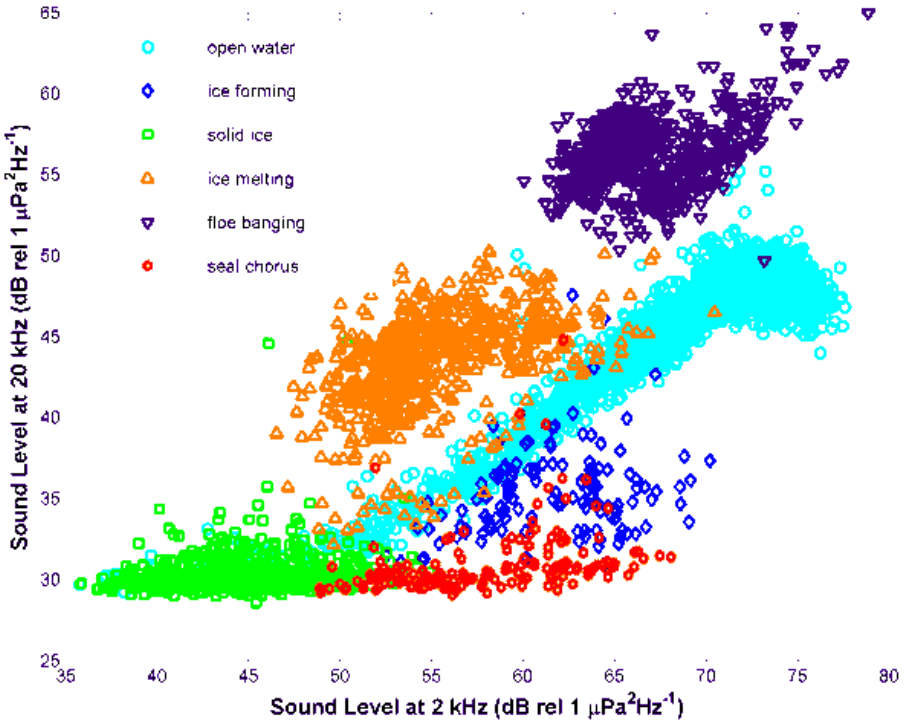


Miksis-Olds et al. (2013). Ecosystem response to a temporary sea ice retreat in the Bering Sea: Winter 2009. Progress in Oceanography 111: 38-51.



Spectral Approach

- Gain knowledge of source contributions
  - Directly from spectra
  - From processed spectra characteristics

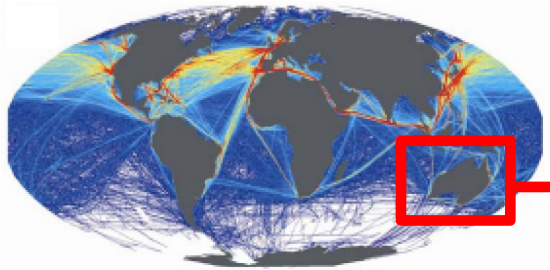


Van Opzeeland & Miksis-Olds et al 2012

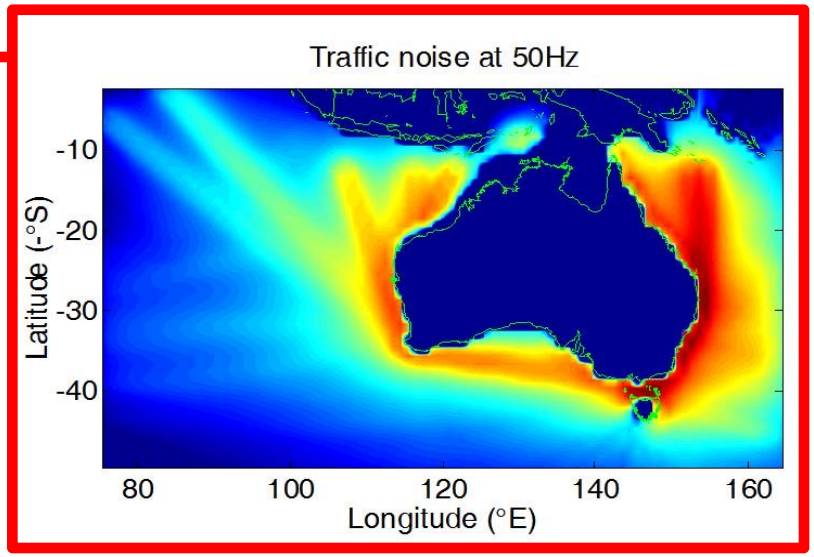
Challenges/Data Gaps/Needs

Challenges

- Predicting soundscapes from source inputs/predictive sound mapping



Shipping density map. From Halpern *et al*. 2008. A Global Map of Human Impact on Marine Ecosystems. *Science* 319:948-952.

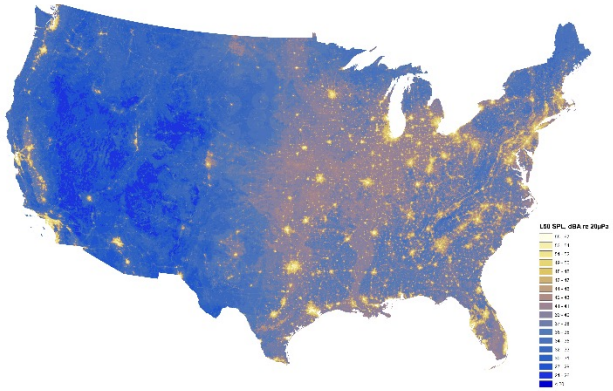


Example of what can be done by combining knowledge of shipping activity with soundscape modeling. From Doug Cato

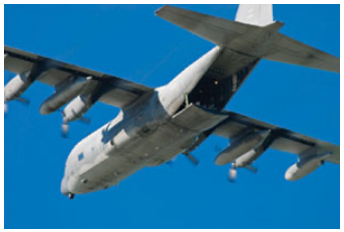
Challenges/Data Gaps/Needs

Challenges

- Predicting soundscapes from source inputs/predictive sound mapping
- Apply sound mapping to predict masking
- How to incorporate an animal's perspective into soundscape concept and studies



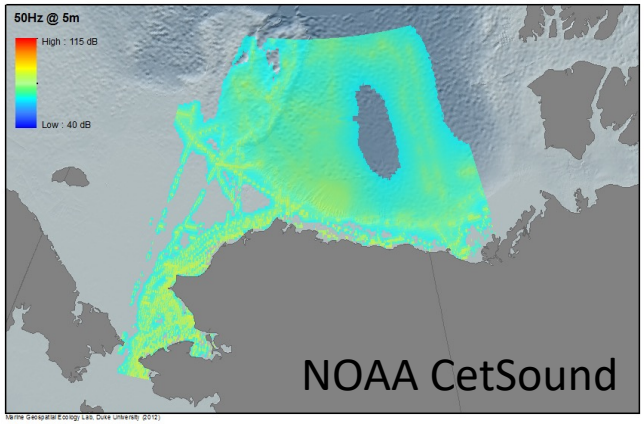
National Park Service – Natural Sounds and Night Skies



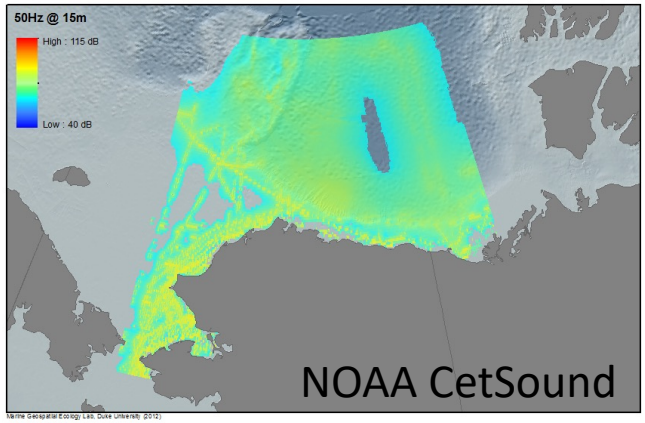
Challenges/Data Gaps/Needs

Data Gaps

- Knowledge to address the scale over which the measured soundscape and variability is representative
- Long-term, continuous full-bandwidth recordings
- Better ways to visualize and compare soundscapes



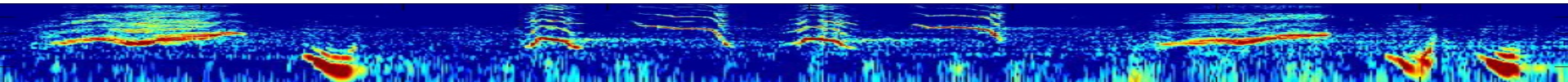
vs.



Challenges/Data Gaps/Needs

Needs

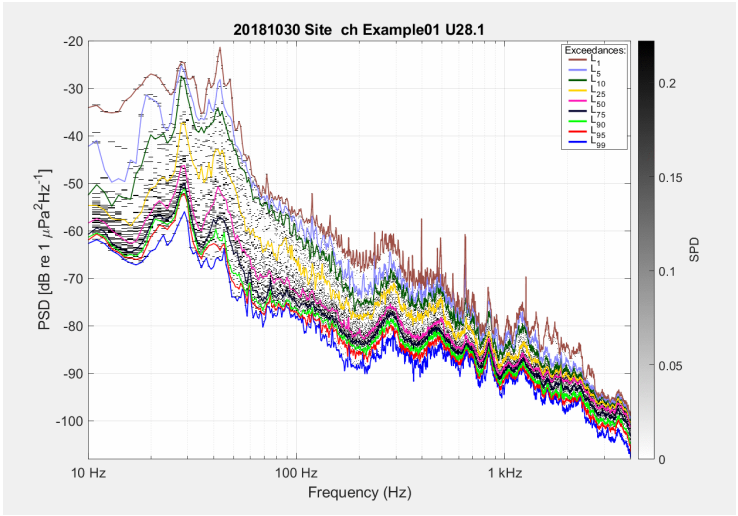
- Definitions
  - Ambient (sound, noise, levels) vs soundscape
  - Multi-modal perception (pressure, particle motion)
- Standards
  - What kind of average? Over what duration?
  - Should transients be included? When to exclude loud transients?
  - Visualization techniques

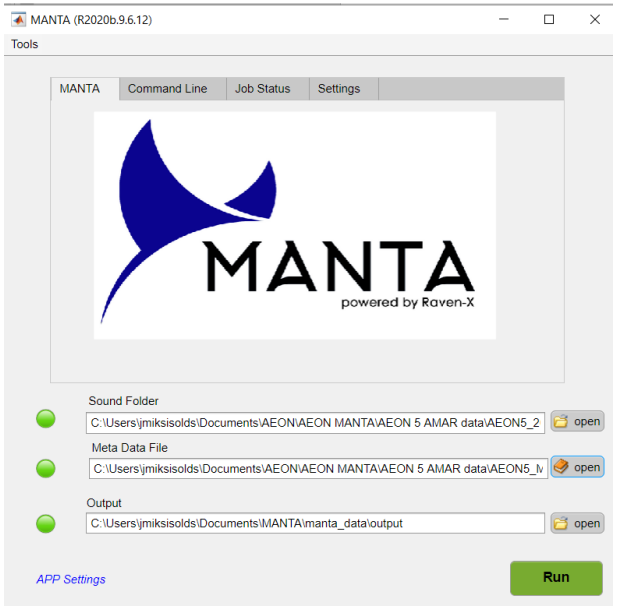


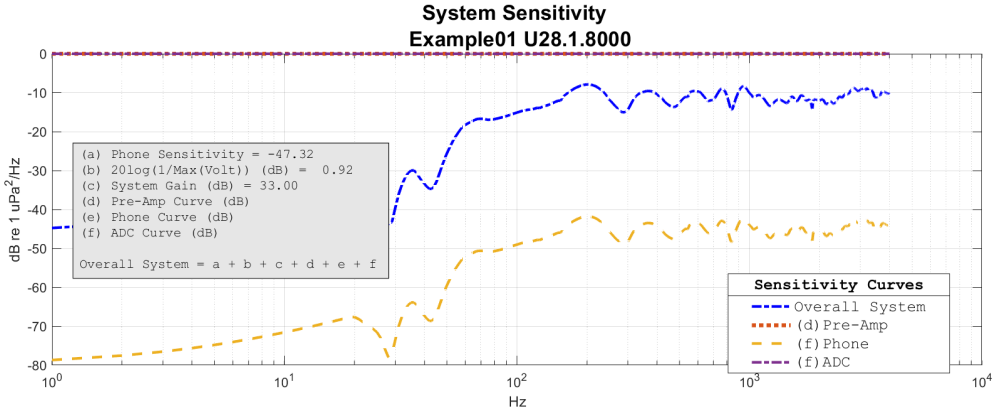
Challenges/Data Gaps/Needs

Solutions

- Standards
  - MANTA – Making Ambient Noise Trends Accessible







https://bitbucket.org/CLO-BRP/manta-wiki/wiki/Home

Challenges/Data Gaps/Needs

Solutions

- Standards
  - Soundscape Code

BLE	BB		Low		Mid		High		Ult-High	
	med	C95	med	C95	med	C95	med	C95	med	C95
Amplitude	103	16	101	18	93	20	94	23	87	12
	118	25	114	19	108	26	110	24	105	36
Impulsiveness	3	7	3	1	3	12	3	12	3	1042
Uniformity	0.015	0.041	0.022	0.029	0.015	0.038	0.012	0.019	0.012	0.025
Periodicity	0	1	0	1	0	1	0	1	0	1

RH	BB		Low		Mid		High		Ult-High	
	med	CI95	med	CI95	med	CI95	med	CI95	med	CI95
Amplitude	100	32	94	34	94	26	94	27	87	16
	118	38	110	41	111	36	111	36	106	37
Impulsiveness	3	149	3	153	3	188	3	506	3	687
Uniformity	0.015	0.082	0.025	0.091	0.015	0.095	0.011	0.034	0.011	0.032
Periodicity	0	5	0	5	0	11	0	3	0	1

SAV	BB		Low		Mid		High		Ult-High	
	med	C95	med	C95	med	C95	med	C95	med	C95
Amplitude	101	33	93	38	94	29	95	26	87	11
	117	34	108	41	109	27	110	25	105	25
Impulsiveness	3	7	3	8	3	13	3	11	3	19
Uniformity	0.016	0.066	0.025	0.066	0.013	0.05	0.012	0.031	0.012	0.011
Periodicity	0	1	0	2	0	1	0	1	0	0

GBR	BB		Low		Mid		High		Ult-High	
	med	CI95	med	CI95	med	CI95	med	CI95	med	CI95
Amplitude	116	6	92	15	103	10	113	6	113	7
	157	8	114	21	132	16	154	9	153	10
Impulsiveness	391	1412	11	273	43	459	619	3154	351	1028
Uniformity	0.018	0.005	0.023	0.038	0.022	0.035	0.018	0.006	0.017	0.002
Periodicity	0	1	0	2	0	1	0	2	0	1

WIL	BB		Low		Mid		High		Ult-High	
	med	CI95	med	CI95	med	CI95	med	CI95	med	CI95
Amplitude	102	21	97	25	93	25	95	26	88	12
	120	26	111	27	109	30	113	27	111	28
Impulsiveness	3	25	3	10	3	134	3	47	3	122
Uniformity	0.016	0.047	0.031	0.05	0.014	0.057	0.012	0.03	0.012	0.012
Periodicity	0	10	0	10	0	2	0	1	0	1

RANGE	BB		Low		Mid		High		Ult-High	
	min	max	min	max	min	max	min	max	min	max
Amplitude	**100**	**116**	**92**	**101**	**93**	**103**	**94**	**113**	**87**	**113**
	117	**157**	**108**	**114**	**108**	**132**	**110**	**154**	**105**	**153**
Impulsiveness	**3**	**391**	**3**	**11**	**3**	**43**	**3**	**619**	**3**	**351**
Uniformity	**0.015**	**0.018**	**0.022**	**0.031**	**0.013**	**0.022**	**0.011**	**0.018**	**0.011**	**0.017**
Periodicity	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Wilford DC, Miksis-Olds JL, Martin BS, Howard DR, Lowell K, Lyons, AP, Smith MJ (2021) Quantitative soundscape analysis to understand multidimensional features. Frontiers in Marine Science 8: 949. doi: 10.3389/fmars.2021.672336

Unraveling Soundscapes: Learning to be good ocean listeners

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