Course Program

Penn Stater Conference Center

June 20- June 25, 2010

Organizers

Jennifer Miksis-Olds & Susan Parks

Applied Research Laboratory

The Pennsylvania State University

http://arl.psu.edu/

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Office of Naval Research

Applied Research Laboratory at Penn State University

National Oceanic and Atmospheric Administration

The Acoustical Society of America

FORWARD

Welcome to the first **B**io**A**coustics **S**ummer **S**chool program. SeaBASS was developed in response to the success of the long-standing Physical Acoustics Summer School (PASS), a biennial course that brings together educators and graduate students in the field of physical acoustics for a week long retreat.

The goal of the SeaBASS program was to provide the opportunity for graduate students interested in pursuing careers in marine bioacoustics to develop a strong foundation in marine animal biology and acoustics, foster technical communication across disciplines, and to develop professional relationships within the field. Experts within the field of marine animal bioacoustics provided half day seminars that described fundamental aspects of underwater sound and marine animal behavior, summarized the present state of the field, identified current obstacles and challenges, and discussed important "hot topics" areas. Each seminar included an introductory lecture followed by group discussions or group projects to gain a more in-depth understanding of the issues.

We hope that SeaBASS was more than a short course introducing students to the fundamental aspects of the field. We anticipated that the opportunity for close interaction would allow all of the participants, presenters and students alike, to develop lasting professional contacts that will help develop the next generation of marine bioacousticians.

Jennifer Miksis-Olds & Susan Parks

The Applied Research Laboratory
The Pennsylvania State University
P.O. Box 30
State College, PA 16804

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SCHEDULE

	Sunday June 20	Monday June 21	Tuesday June 22	Wednesday June 23	Thursday June 24	Friday June 25
7:00-8:00		Breakfast and Welcome by E. Liszka	Breakfast	Breakfast	Breakfast	Breakfast
8:00-12:00		**J. Miller** *Introduction to Underwater Sound*	**S. Van Parijs** *Communication and Behavior*	**M. Hastings** *Hearing*	**D. Mann** *Fish Acoustics*	**D. Mellinger** *Signal Processing*
12:00-13:00		Lunch	Lunch	Lunch	Lunch	Lunch and closing remarks
13:00-17:00	Registration opens at 16:00	**D. Bradley** *Sound Propagation*	**W. Au** *Echolocation*	**J. Miksis-Olds (For R. Gentry)** *Effects of noise*	**J. Warren** *Active Acoustics*	**M. Holt** *Masking*
18:00-19:30	Dinner	Dinner	Dinner	Dinner	Dinner	Closing Dinner
19:30-22:00	Participant Introduction and Social	Poster Session and Social	Spikes Baseball game	Informal Career Discussions	Evening in Downtown State College	

PARTICIPANT DIRECTORY

Whitlow W. Au

Whitlow W. L. Au, Ph.D., is an expert in marine bioacoustics specializing in the biosonar of odontocetes. He is known for his work with the U.S. Navy dolphin program, from over a 100 articles in The Journal of the Acoustical Society of America, as the author of The Sonar of Dolphins (1993) and senior-author of Principles of Marine Bioacoustics (2008) with Mardi Hastings, and as the senior editor of the book Hearing by Whales and Dolphins (2000) with Arthur Popper and Richard Fay. Dr. Au is the Chief Scientist of the Marine Mammal Research Program of the Hawaii Institute of Marine Biology at the University of Hawaii and is also past-president (2009) of the Acoustical Society of America.

David L. Bradley

David L Bradley received a Ph.D in Mechanical Engineering in1970 from The Catholic University of America. His work career has been a combination of US Navy supported research, Laboratory Directorship at the NATO Undersea Research Centre, La Spezia, Italy and university research and academic activity at The Pennsylvania State University and the Applied Research Laboratory. Currently a Professor of Acoustics, he is funded by the Office of Naval Research. He has served on review panels for the National Academy of Sciences for both the Ocean Studies and the Naval Studies Boards. He has served as associate editor for the Acoustical Society of America. A Fellow of the Acoustical Society, he has served on the Executive Council and is currently chair of two Society committees.

Mardi Hastings

Dr. Mardi Hastings received B.S. and M.S. degrees in 1976 and 1978 from The Ohio State University, and worked in industry five years prior to enrolling in the Georgia Institute of Technology, where she received a Ph.D. in 1987. Dr. Hastings stayed on as an Assistant Professor of Mechanical Engineering at Georgia Tech until June 1988 when she joined the technical staff at AT&T Bell Laboratories. In 1990 Dr. Hastings joined the faculty in mechanical engineering at the Ohio State University, where she established a research program in acoustics and fiber optics. In 2003 she became a Program Manager for Marine Mammal Science and Bio-effects of Non-lethal Weapons at the Office of Naval Research (ONR). Prior to joining the faculty as a Professor of Mechanical Engineering at the Georgia Institute of Technology in January 2010, Dr. Hastings spent three years as a Senior Scientist in Environmental Acoustics at the Applied Research Lab of Penn State University. Dr. Hastings has studied auditory mechanics and effects of sound on marine animals for over 25 years. She has advised 30 graduate students and is the author of over 50 journal and proceedings articles and co-author of the book, Principles of Marine Bioacoustics (Springer-Verlag, 2008). She served on the National Academy of Sciences Study Panel on Potential Impacts of Ambient Noise on Marine Mammals (2001-2002), the Barotrauma Blue Ribbon Panel for the State of California (2007), and has received numerous awards including the Presidential Young Investigator award from the National Science Foundation and 2005 Environmental Excellence award from the U. S. Federal Highway Administration for her work with the California Department of Transportation on the effects of pile driving in San Francisco Bay. Dr. Hastings is a

Fellow and President- Elect of the Acoustical Society of America (ASA), former member of the Board of Directors of the Institute of Noise Control Engineering, past chair of the ASA Animal Bioacoustics Technical Committee, and past chair of the ASME Noise Control and Acoustics Division Executive Committee.

Marla Holt

Dr. Marla Holt is a Research Wildlife Biologist for the Marine Mammal Ecology Team at the NOAA Northwest Fisheries Science Center in Seattle, WA. She joined the NWFSC in 2006 as a National Research Council (NRC) Postdoctoral Associate to investigate the effects of vessel noise on the acoustic signals of Southern Resident killer whales. Marla received her Ph.D. from the University of California, Santa Cruz in Ocean Sciences. Her dissertation focused on pinniped spatial acoustics including sound localization and auditory masking in captive seals and sea lions and call directionality in free-ranging northern elephant seals. As a graduate student, she was also involved in studies on absolute hearing capabilities, auditory temporal summation, and temporary threshold shift in pinnipeds. Marla's current research focuses on the effects of anthropogenic sounds on endangered Southern Resident killer whales, their use of sound during different activity states, the cost of sound production in odontocetes, and the ecology of cetaceans using passive acoustic monitoring. Her research interests include sound production and acoustic communication, sensory ecology, behavioral ecology, conservation and acoustic risk factors of marine mammals.

David Mann

David Mann, PhD is an Associate Professor at the University of South Florida College of Marine Science. He received his undergraduate degree in Neurobiology and Behavior from Cornell University. He received his PhD from the MIT/Woods Hole Oceanographic Institution in 1995 where he studied sound production by the domino damselfish at Johnston Atoll with Dr. Phillip Lobel. Following his Ph.D., Dr. Mann undertook a post-doctoral fellowship at the University of Maryland, College Park with Dr. Arthur Popper, where he studied ultrasound detection by American shad. This led to a position with Tucker-Davis Technologies (TDT) a manufacturer of signal processing workstations for auditory research, where he worked for four years in a number of roles (technical support, sales, marketing, software development, and R&D). Dr. Mann joined USF as an Assistant Professor in 2001, where he has worked on a wide range of bioacoustics topics including hearing in fishes, manatees, and dolphins and passive acoustic studies on fishes and dolphins.

David Mellinger

Dr. David K. Mellinger is an Associate Professor in the Cooperative Institute for Marine Resources Studies at Oregon State University. A specialist in analyzing whale sounds, Dr. David Mellinger has worked since the early 1990's on ways to learn more about whales from the sounds they make. He has worked extensively on developing methods for automatic call recognition, and has applied these methods to studying sperm, blue, fin, minke, bowhead, and right whales and harbor seals. He has developed software for acoustic processing, including the widely-used program Ishmael for

acoustic analysis. He has applied his expertise in bioacoustics to projects in the Pacific from the tropics to the Bering and Beaufort Seas, in the Atlantic from the tropics to Nova Scotia, in the Indian Ocean, and off Antarctica. Dr. Mellinger received B.S. degrees in math and philosophy at MIT in 1983, and a Ph.D. in computer science from Stanford in 1992. He studied whale sounds in the Bioacoustics Research Program at Cornell from 1992-96 and worked on seal sounds at the Monterey Bay Aquarium Research Institute from 1997-99. Since 2000, he has been at a joint Oregon State University/NOAA laboratory in Newport, Oregon, where leads a group of researchers studying bioacoustics.

Jennifer L. Miksis-Olds

Jennifer L. Miksis-Olds earned her A.B. in Biology from Harvard University in 1996, her M.S. in Biology at the University of Massachusetts Dartmouth in 2000, and completed her doctorate at the University of Rhode Island, Graduate School of Oceanography in 2006. She served as a Postdoctoral Fellow in the Department of Estuarine and Oceanic Science at the University of Massachusetts School for Marine and Science Technology and a Postdoctoral Research Associate in the Department of Fisheries Oceanography at the University of Massachusetts School for Marine and Science Technology. She is currently a Research Associate at the Applied Research Laboratory at Penn State where she continues research in marine animal bioacoustics. She has been funded by the Office of Naval Research through the National Defense for Science and Engineering Graduate Fellowship from 2002-2005 and through competitive grants from 2007 to the present. Since 1996, she has also been involved with developing acoustic techniques and technology to improve acoustical and physiological observations of the marine environment and animals including plankton, fish, and marine mammals. She has been invited to participate in the Workshop on Ocean Ambient Noise Budgets and Long Term Monitoring: Implications for Marine Mammals. This 2004 series of workshops was sponsored by NOAA/NMFS in order to plan a long term ocean noise monitoring project. Jennifer serves as a Scientific Advisor to the Technical Management Committee of the Joint Industry Programme (Oil and Gas Producers) on the behavioral effects of marine organisms to sound.

James H. Miller

James H. Miller earned his B.S. in Electrical Engineering in 1979 from Worcester Polytechnic Institute, his M.S. in Electrical Engineering in 1981 from Stanford University, and his Doctor of Science in Oceanographic Engineering in 1987 from Massachusetts Institute of Technology and Woods Hole Oceanographic Institution. He was on the faculty of the Department of Electrical and Computer Engineering at the Naval Postgraduate School in Monterey, California from 1987 through 1995. Since 1995 he has been on the faculty of the Department of Ocean Engineering at the University of Rhode Island where he holds the rank of Professor and Chair. He also holds a joint appointment in the Graduate School of Oceanography. In 2001, Dr. Miller co-founded FarSounder, Inc. of Warwick which manufactures forward-looking, 3D sonars for large yachts, cruise ships, and commercial vessels. He presently serves on the Board of Directors. Dr. Miller conducts research in the fields of underwater acoustics, sonar, acoustical oceanography, marine bioacoustics, and, recently, the noise

from offshore wind farms and effects on the marine environment. He was recently elected Fellow of the Acoustical Society of America and serves on its Executive Council.

Susan E. Parks

Susan E. Parks, PhD, is currently employed as a Research Associate at the Applied Research Laboratory and an Assistant Professor of Acoustics and Ecology at the Pennsylvania State University. She has been involved in animal bioacoustics studies since 1995, first as an undergraduate working on whale acoustic census data and studying male frog calling behavior, then as a graduate student focusing on acoustic communication of the North Atlantic right whale. She earned her A.B. in Biology (Neurobiology and Behavior) from Cornell University in 1998, and her PhD. in Biological Oceanography in the M.I.T./W.H.O.I. Joint Program in Oceanography in 2003 studying the acoustic behavior and hearing of North Atlantic right whales with Dr. Peter Tyack. She was a postdoctoral associate with Dr. Chris Clark at the Bioacoustics Research Program at Cornell University from 2003-2006. She has received numerous awards in her career including a National Defense for Science and Engineering Graduate Fellowship and a Presidential Early Career Award for Scientists and Engineers from the White House. She served as PI and Co-PI on several federally funded research projects through NOAA and the Office of Naval Research (ONR) related to studies of baleen whale acoustic behavior and hearing. Her primary research interests are the behavioral function of sound production in marine organisms, their perceptual abilities, and the impact of noise on their ability to communicate.

Sofie Van Parijs

I am currently the program leader for the large whale and passive acoustics research groups at the Protected Species Branch at the Northeast Fisheries Science Center, NOAA, based in Woods Hole, MA. Within this program we are responsible for all research conducted on large whales, from vessel based photo ID, biopsy, tagging, foraging ecology and behavioral ecology, as well as large scale synoptic aerial surveys. The passive acoustics program aims are to use sound for understanding the behavioral ecology of marine animals (fish and marine mammals) throughout the northeast region. To do this we use bottom mounted recorders, real time acoustic buoys as well as underwater autonomous vehicles for collecting our data. My main area of expertise is in using the calls of marine mammals to better understand their behavioral ecology. I then apply knowledge of their behavior towards conservation and management objectives. I have been at NOAA for over 5 years, however I started my career in acoustics by working on bat echolocation while an undergraduate at Cambridge University in the UK. I then went on to do my PhD on harbor seal acoustic behavioral ecology at Aberdeen University in Scotland. After which I moved to Australia to work on a postdoctoral project looking at acoustic communication of Irrawaddy and Indo-Pacific humpback dolphins at James Cook University. After which I moved to northern Norway where I was a postdoctoral researcher at the Norwegian Polar Institute. There I worked on acoustic behavioral ecology of bearded seals, harp seals, walrus, beluga whales and orca throughout the Svalbard archipelago in the Arctic and around the pack ice off Greenland. Lastly, I moved to the US to continue working on bearded seal acoustics at the Bioacoustics Research Program at

Cornell University, after which I applied for a position as passive acoustic research scientist at the Northeast Fisheries Science Center in Woods Hole.

Joseph D. Warren

I'm an assistant professor in the School of Marine and Atmospheric Sciences at Stony Brook University. I was an engineering major as an undergraduate and discovered underwater acoustics as a summer student researcher at WHOI working on acoustic measurements of sediment transport. I quickly realized that animals are more interesting than sand grains and started working with Tim Stanton (a physicist) and Peter Wiebe (a biologist) on using active acoustics to measure zooplankton populations in the Gulf of Maine. The majority of my field work involves acoustic surveys of zooplankton populations (most often krill is our target species) and my research interests are improving our ability to get “biologically-meaningful” information from acoustic echosounders, development of acoustic scattering models for different types of scattering processes, and examining predator-prey relationships between zooplankton and their charismatic megafauna consumers (I include penguins and seabirds in this category). If everything goes according to schedule, I'll arrive at SEABASS a few days after returning from a project studying the krill and humpback whale interactions in Antarctica.

COURSE PARTICIPANTS – STUDENT NAME AND AFFILIATION

1. **Jose Alicea-Pou**
Inter American University of Puerto Rico, School of Law
2. **Alyson Azzara**
Texas A&M University at Galveston
3. **Catherine Bacon**
Nova Southeastern University
4. **Celia Barroso**
San Diego State University
5. **Jacqueline Bort**
College of the Atlantic
6. **Beth Brady**
Nova Southeastern University
7. **Julia Burrows**
Duke University
8. **Adrienne Copeland**
University of Hawaii at Manoa
9. **Samuel Denes**
Penn State
10. **Anneli Englund**
University College Cork
11. H**elen Carter Esch**
MIT/WHOI Joint Program, Biological Oceanography
12. **Lourdes Marie Gonzalez-Caraballo**
University of Puerto Rico-Rio Piedras
13. **Danielle Greenhow**
University of South Florida
14. **Shane Guan**
Catholic University of America
15. **Heather Heenehan**
Duke University
16. **Cara Hotchkin**
Penn State
17. **Jennifer Karnik**
University of Otago
18. **Jennifer L. Keating**
California State University, San Marcos
19. **Nelmarie Landrau**
Inter American University at Bayamón
20. **Laura Madden**
Penn State
21. **Sarah Mallette**
George Mason University
22. **Jeffrey Mangel**
University of Exeter
23. **Hannah Moir**
University of Strathclyde
24. **Christin Murphy**
University of South Florida
25. **Nicole Nichols**
University of Washington
26. **Julia O'Hern**
Texas A&M University
27. **Marcos Rossi-Santos**
Universidade Federal do Rio Grande do Norte
28. **Alexis Rudd**
Univesrity of Hawaii at Manoa
29. **Athena Rycyk**
Florida State University
30. **Jennifer Tennessen**
Penn State
31. **Elizabeth Vu**
University of California, San Diego
32. **Carrie Wall**
University of South Florida
33. **Maya Yamato**
MIT/WHOI Joint Program in Biological Oceanography

INTRODUCTION TO UNDERWATER SOUND - DR. JAMES H. MILLER

I. Fundamentals

   a. Mathematical background

      i. Sines and Cosines

      ii. Differentiation & Integration

      iii. Waves

      iv. Force

      v. Pressure

      vi. Velocity

   b. Sound

      i. Intensity vs. Power

      ii. Decibel

      iii. Sound Pressure Level

      iv. Sound Exposure Level

      v. Sound in Air vs. Water

      vi. Ocean sound propagation conditions

      vii. Directivity, Beamwidth

      viii. SONAR equation

      ix. Transmission Loss

SOUND PROPAGATION AND LOCALIZATION – DR. DAVID L. BRADLEY

I. Physical Characteristics of the Ocean Environment and effects on sound
    a. Characteristics of Sea water
    b. Surface effects
    c. Characteristics of the seafloor/seabed

II. Ambient noise in the ocean

III. Passive and Active Acoustics for Detection
    a. Wave Equation
    b. Ray Theory
    c. Normal Modes
    d. Parabolic Equation

IV. Localization
    a. Effects of frequency on localization
    b. Beam Patterns for 2, 6 and 8 element arrays
    c. The Sonar Equation

Hands On Activity led Dr. Jennifer Miksis-Olds:

INTRODUCTION TO THE MONTEREY-MIAMI PARABOLIC EQUATION

http://oalib.hlsresearch.com/PE/MMPE/mmpeintro.html.

ACOUSTIC COMMUNICATION AND BEHAVIOR – DR. SOFIE VAN PARIJS

I. Tinbergen's questions
    a. Ultimate vs. Proximate explanations
        i. Function
        ii. Phylogeny
        iii. Causation
        iv. Development

II. Communication
    a. Modes
    b. Meanings
    c. Sexual Selection
    d. Environmental Selection
    e. Habitat

III. Marine Passive Acoustics
    a. Methods
    b. Acoustic Communication in Pinnipeds
    c. Exercise/Activity

ECHOLOCATION - DR. WHITLOW W. AU

I. The Sonar of Dolphins

II. Biosonar Signals

    a. Waveform and Spectrum

    b. Signal Type

    c. Range Resolution

    d. Beam Pattern & Directivity Index

    e. Dolphins in the field

III. Detection in Noise

IV. Discrimination Capabilities

V. Detection in Reverberation

VI. Detection & Discrimination of Fish

HEARING & SENSING – DR. MARDI HASTINGS

I. Hearing in Marine Animals
    a. Hearing Sensitivity
    b. Audiograms
II. Measuring Hearing Thresholds
    a. Psychophysical methods
        i. Staircase Procedure
        ii. Classical Conditioning
        iii. Operant Conditioning
    b. Electrophysiological methods
        i. ABR
        ii. AEP
III. Special Issues with fishes
IV. Measuring temporary threshold shifts (TTS)

EFFECTS OF NOISE – DR. ROGER GENTRY/ DR. MIKSIS-OLDS

I. Hot topics related to the effects of noise on marine life

FISH ACOUSTICS- DR. DAVID MANN

I. Sound Production by Invertebrates and Fishes
    a. Snapping Shrimp
    b. Fishes
        i. Toadfish
        ii. Spotted Sea Trout
        iii. Silver Perch
        iv. Sand Seatrout
        v. Striped Cusk Eel
        vi. Sciaenids
    c. Mechanisms of sound production

II. Passive Acoustic Monitoring – ocean observatory
    a. Diel patterns in sound production
    b. Seasonal trends in sound production

III. Future Areas of Research

IV. Practical equipment calibration discussion

ACTIVE ACOUSTICS – DR. JOSEPH D. WARREN

Active acoustics offers scientists an amazing tool to explore, measure, and study marine life in the ocean. Fish and zooplankton can be observed with acoustic methods at a much higher resolution (in both space and time) than traditional net surveys or optical methods which can provide novel insights into animal behavior and ecology. This lecture will introduce the basics of scattering theory for biological organisms in the ocean, design of active acoustic studies, and examination of active acoustic data to see first-hand the advantages (and limitations) of this approach.

Link to Dr. Warren's lecture material:

http://www.somas.stonybrook.edu/~warren/seabass/seabass.html

Recommended Background Reading :

MacLennan and Holliday, "Fisheries and plankton acoustics: past, present, and future." ICES J. Mar. Sci. 53:513-516. 1996

Holliday and Pieper "Bioacoustical oceanography at high frequencies." ICES J. Mar. Sci. 52: 279-296. 1995

Stanton, Chu, and Wiebe. "Sound scatteirng by several zooplankton groups. II. Scattering models." JASA. 103:236-253.1998

Warren, Santora, and Demer. 'Submesoscale distribution of Antarctic krill and its avian and pinniped predators before or after a near gale." Marine Biology. 156:479-491. 2009

Lecture Outline: Active Acoustics – Fish and Zooplankton

I. Basic Acoustic Scattering Theory

A. Terms

B. Sound propagation

C. Reflection vs. Scattering

D. Frequency Dependence

i. 1. Rayleigh regime

ii. 2. Geometric regime

II. Scatterer Types and TS Models

A. Fluid-like animals

B. Elastic-shelled animals

C. Gas-bearing animals

D. Fish and Zooplankton

III. Forward and Inverse Problem

A. Inverse problem

B. Forward problem

IV. Survey Design and Planning

A. Platforms

1. Ship-based
2. Towed systems
3. Moored systems
4. Profiling systems

B. Equipment

1. Scientific echosounders
2. Multibeam systems
3. Broadband systems
    a. Multiple-frequency
    b. High bandwidth systems
4. Ground truthing
    a. nets
    b. optics
5. Other
    a. Hydrography
    b. lower trophic levels
    c. higher trophic levels

C. Survey / Sampling / Experiment Design

V. Error Analysis and Uncertainty?

PASSIVE ACOUSTIC MONITORING - DR. DAVID K. MELLINGER

Outline for Signal Processing in Marine Bioacoustics

1. Filtering
    a. Anti-alias filtering
    b. Down- and up-sampling
    c. Frequency response
2. Detection and classification – common concerns
    a. Features
    b. Measurement
    c. Decision criteria
    d. Degree of automation
    e. Level of specificity
3. Detection
    a. The detection function
    b. Matched filtering
    c. Energy summation
    d. Frequency contour tracking
    e. Spectrogram correlation
4. Classification
    a. Generative vs. discriminative classifiers
    b. Parametric vs. non-parametric classifiers
    c. Template matching
    d. Nearest-neighbor search
    e. Tree-based classifiers
    f. Neural networks
5. Localization
    a. Time-of-arrival differences
        i. Manual and Cross-correlation
    b. Bearing estimation
    c. Hyperbolic localization
    d. Beamforming
    e. Reflection methods
    f. Propagation models
    g. Error estimation
    h. Directional hydrophones

MASKING – DR. MARLA HOLT

Outline:

I. What is masking?
   a. Review of source-path-receiver
   b. Effects of sound exposure
   c. Masking definitions
      i. energetic vs. informational masking

II. Auditory masking
   a. Review of hearing function and research methods
   b. Masking of tones by tones
      i. tuning curves
      ii. upward spread of masking
   c. Masking of tones by noise
      i. concept of critical ratio
   d. Critical bands
      i. the inner ear as a series of bandpass filters
      ii. why critical bandwidth is important
   e. Temporal Masking
   f. Demo

III. Receiver strategies to reduce masking
   a. Frequency effects
   b. Spatial effects
      i. directional hearing, spatial release from masking (spatial unmasking)
   c. Temporal effects
      i. comodulation masking release
   d. Auditory scene analysis
   e. Demo

IV. Communication and masking
   a. Communication space
      i. concept of active space and how masking noise affects it
   b. Sender strategies to reduce masking - group activity
      i. signal design
      ii. compensation

V. Summary and Conclusions

Additional Readings on Masking and Related Topics

Books and Book Chapters

Brumm H, Slabberkoorn H. 2005. Acoustic Communication in Noise, *In* Advances in the Study of Behavior, Vol 35 pp. 151-209 (Ed. by Slater PJB, Snowden CT, Brockmann HJ et al.), Elsevier, San Diego, CA

Fastl H, Zwicker E. 2007. Psychoacoustics: Facts and Models. Springer-Verlag, Berlin

Yost WA. 2007. Fundamentals of Hearing: An Introduction. Academic Press, San Diego

Journal Articles

Branstetter BK, Finneran JJ. Comodulation masking release in bottlenose dolphins (*Tursiops truncatus*). 2008. The Journal of the Acoustical Society of America 124: 625-633.

Clark CW, Ellison WT, Southall BL. et al. 2009. Acoustic masking in marine ecosystems: intuition, analysis, and implications. Marine Ecological Progress Series 395: 201–222

Dunlop RA, Cato DH, and Noad, MJ. 2010. Your attention please: increasing ambient noise levels elicits a change in communication behaviour in humpback whales (*Megaptera novaeangliae*). The Proceedings of the Royal Society B published online 14 April 2010 doi: 10.1098/rspb.2009.2319

Holt MM and Schusterman RJ. 2007. Spatial release of masking of aerial pure tones in pinnipeds. The Journal of the Acoustical Society of America 121: 1219-1225

Holt MM, Noren, DP, Veirs V, Emmons CK, Veirs, S. 2009. Speaking up: Killer whales (*Orcinus orca*) increase their call amplitude in response to vessel noise. JASA Express Letters 125: EL27-31

Jensen FH, Bejder L, Wahlberg M et al. 2009. Vessel noise effects on delphinid communication. Marine Ecological Progress Series 395: 161-175

Miksis-Olds JL, Tyack PL. 2009. Manatee (*Trichechus manatus*) vocalization usage in relation to environmental noise levels. The Journal of the Acoustical Society of America 125: 1806-1815.

Parks SE, Clark CW, Tyack PL. 2007. Short- and long-term changes in right whale calling behavior: The potential effects of noise on acoustic communication. The Journal of the Acoustical Society of America 122: 3725-3731.

Southall BL, Schusterman RJ, and Kastak, D. 2003. Auditory masking in three pinnipeds: aerial critical ratios and direct critical bandwidth measurements. The Journal of the Acoustical Society of America 114: 1660–1666.

BIBLIOGRAPHY

Suggested Extra Reading Material for Background:

Echolocation:

1. Au, W.W.L, Penner, R.H. 1981. Target detection in noise by echolocating Atlantic bottlenose dolphins. J. Acoust. Soc. Am 70(3), 687-693.
2. Au W, W. L., Benoit-Bird KJ (2003) Automatic gain control in the echolocation system of dolphins. Nature 423:861-863.
3. Au, W. W. L. (2004). "Echolocation Signals of Wild Dolphins," Acoustical Physics (Russia),50, 454-462.
4. Au, W.W.L, Branstetter, B.K., Benoit-Bird, K.J., Kastelein, R.A. 2009 "Acoustic basis for fish prey discrimination by echolocating dolphins and porpoise." Journal of the Acoustical Society of America 126: 460-467

Hearing:

5. Popper, A. N., and Fay, R. R. (1999). The auditory periphery in fishes. In: Fay, R. R. and Popper, A. N. (eds.) Comparative Hearing: Fish and Amphibians, Springer-Verlag, New York
6. Ketten, D.R. 1997. Structure and Function in whale ears. Bioacoustics,8, 103-135.

Fish Acoustics:

7. Mann DA, Hawkins AD, Jech JM (2008) Active and Passive Acoustics to Locate and Study Fish. In: Fish Bioacoustics, pp 279-309

Noise:

8. Nowacek DP, Thorne LH, Johnston DW, Tyack PL (2007) Responses of cetaceans to anthropogenic noise. Mammal Review 37:81-115