# WU-JUNG LEE

*Senior Oceanographer, Principal Investigator*
*Applied Physics Laboratory, University of Washington | leewujung.github.io*
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## EDUCATION

**2013** ***Ph.D.*, MIT-WHOI Joint Program in Oceanography/Applied Ocean Science and Engineering**
Massachusetts Institute of Technology, Cambridge, MA, USA
Woods Hole Oceanographic Institution, Woods Hole, MA, USA
Advisors: Drs. Timothy Stanton, Andone Lavery, Peter Tyack
Thesis: Broadband and statistical characterization of echoes from random scatterers: application to acoustic scattering by marine organisms

**2005** ***B.S. in Engineering*, Electrical Engineering**
***B.S.*, Life Science (with zoology focus) *double major**
**National Taiwan University**, Taipei, Taiwan

## CURRENT AND PAST POSITIONS

2019- **Senior Oceanographer, Principal Investigator**, Applied Physics Laboratory, University of Washington

2016-2018 **Research Associate (with Principal Investigator status)**, Applied Physics Laboratory, University of Washington

2013-2015 **F.V. Hunt Postdoctoral Fellow**, Department of Psychological and Brain Sciences, Johns Hopkins University (lab relocated from University of Maryland in Spring 2014)

2007-2013 **Graduate student**, Woods Hole Oceanographic Institution

2007 **Research Assistant**, Marine Mammal Research Project, Hawai'i Institute of Marine Biology

2006 **Research Assistant**, Electrophysiology Laboratory, Marine Research Station, Institute of Cellular and Organismic Biology, Academia Sinica, Taiwan

2005 **Intern**, BioSonar Project, Acoustic Research Laboratory, Tropical Marine Science Institute, National University of Singapore

2004-2005 **Research Assistant**, Cetacean Laboratory, Institute of Ecology and Evolutionary Biology, National Taiwan University

2003-2005 **Research Assistant**, Spatial Ecology Laboratory, Institute of Ecology and Evolutionary Biology, National Taiwan University

## EDITORIAL BOARD AND AFFLIATIONS

2019- **Affiliate faculty**, University of Washington eScience Institute

2018- **Faculty**, University of Washington Institute for Neuroengineering (UWIN)

2016- **Associate Editor**, Journal of the Acoustical Society of America Express Letters (JASA-EL)

## GRANTS AND CONTRACTS

**Research** ($ home institution component)

- **NOAA Office of Ocean Exploration and Research, 2020-2022**
  Principal Investigator ($412,200)
  "Coordinated simultaneous physical-biological sampling by ADCP-equipped ocean gliders"
  Collaborators: Sarah Webster, Aleksandr Aravkin, University of Washington;
  Dezhang Chu, NOAA Northwest Fisheries Science Center
- **National Science Foundation, Division of Ocean Sciences, 2019-2020**
  Principal Investigator ($281,608)
  "EAGER: Developing a temporally adaptive decomposition framework for analyzing long-term echosounder time series."
  Collaborator: Valentina Staneva, University of Washington

- **Office of Naval Research, Ocean Acoustics, 2018-2021**
  Co-Principal Investigator ($403,000)
  "MURI: Active sensing in echolocating humans and marine mammals."
  Collaborators: Barbara C. Shinn-Cunningham, Carnegie Mellon University; Peter L. Tyack, University of St. Andrews; John B. Buck, University of Massachusetts, Dartmouth; Kenneth Shorter, University of Michigan
- **NOAA Fisheries, Advanced Sampling Technology Work Group, 2018-2019**
  Co-Principal Investigator ($84,193)
  "Broadband acoustic species identification and enumeration using trans-dimensional Bayesian inversion."
  Collaborators: Dezhang Chu, Northwest Fisheries Science Center; Stan Dosso, University of Victoria

**Education**

- **National Science Foundation, Division of Ocean Sciences, 2020-2021**
  Co-Principal Investigator ($42,487)
  "Collaborative Conference: OceanHackWeek: A Workshop to Explore Data Science in Oceanography"
  Collaborators: Emilio Mayorga, University of Washington;
  Nick Records, Catherine Mitchell, Bigelow Laboratory for Ocean Sciences
- **National Science Foundation, Division of Ocean Sciences, 2019**
  Principal Investigator ($49,967)
  "Oceanhackweek: A Workshop to Explore Data Science in Oceanography."
  Collaborators: Valentina Staneva, Amanda Tan, University of Washington
- **Consortium of Ocean Leadership, 2018**
  Lead organizer ($109,265)
  "Oceanhackweek 2018: A hands-on, community-driven workshop on ocean observatory data science."
  Collaborators: Robert Fatland, Amanda Tan, Valentina Staneva, Friedrich Knuth, Landung Satiewan, Aaron Marburg, University of Washington

## PEER-REVIEWED PUBLICATIONS

**Acoustic Ocean Sensing**

**Lee W-J**, Staneva V. Compact representation of temporal processes in echosounder time series via matrix decomposition. *Accepted by Journal of the Acoustical Society of America. Preprint available at: https://arxiv.org/abs/2007.02906*.

**Lee W-J**, Tang D, Stanton TK, Thorsos EI. (2018) Macroscopic observations of diel fish movements around a shallow water artificial reef using a mid-frequency horizontal-looking sonar. *Journal of the Acoustical Society of America*, 144(3), 1424-1434. ***JASA Technical Area Pick of 2018.***

Stanton TK, **Lee W-J**, Baik K. (2018) Echo statistics associated with discrete scatterers: A tutorial on physics-based methods. *Journal of the Acoustical Society of America*, 144(6), 3124-3171. ***Cover of JASA December 2018 issue.***

**Lee W-J**, Stanton TK. (2016) Statistics of broadband echoes: application to acoustic estimates of numerical density of fish. *IEEE Journal of Oceanic Engineering*, 41(3): 709-723.

**Lee W-J**, Stanton TK. (2014). Statistics of echoes from mixed assemblages of scatterers with different scattering amplitudes and numerical densities. *IEEE Journal of Oceanic Engineering*, 39(4): 740-754.

**Lee W-J**, Lavery AC, Stanton TK. (2012). Orientation dependence of broadband acoustic backscattering from live squid. *Journal of the Acoustical Society of America*, 131(6): 4461-4475.

**Animal Echolocation**

**Lee W-J**, Falk B, Chiu C, Krishnan A, Arbour JA, Moss CF. (2017) Tongue-driven sonar beam steering by a lingual-echolocating fruit bat. *PLoS Biology*, 15(12): e2003148.

**Lee W-J**, Moss CF. (2016) Can the elongated hindwing tails of fluttering moths serve as false sonar targets to divert bat attacks? *Journal of the Acoustical Society of America*, 139(5): 2579-2588.

Warnecke M, **Lee W-J**, Krishnan A, Moss CF. (2016) Dynamic echo information guides flight in the big brown bat. *Frontiers in Behavioral Neuroscience*, 10:81.

Danilovich S, Krishnan A, **Lee W-J**, Borrisov I, Eitan O, Kosa G, Moss CF, Yovel Y. (2015) Bats regulate biosonar based on the availability of visual information. *Current Biology*, 25(23): R1124-R1125.

Au WWL, Houser DS, Finneran JJ, **Lee W-J**, Talmadge LA, Moore PW. (2010). The acoustic field on the forehead of echolocating Atlantic bottlenose dolphins (*Tursiops truncatus*). *Journal of the Acoustical Society of America*, 128(3), 1426-1434.

Mooney TA, **Lee W-J**, Hanlon RT. (2010). Long-duration anesthetization of squid (*Doryteuthis pealeii*). *Marine and Freshwater Behaviour and Physiology*, 43(4), 297-303.

## MANUSCRIPTS IN PREPARATION

**Lee W-J**, Buck J. Modeling echolocation as an information-guided active sensing behavior. *In preparation; figures available upon request.*

**Lee W-J**, Chu D, Dosso S. Are broadband echoes more informative? Bayesian quantification of uncertainty in acoustic biomass inversion. *In preparation; figures available upon request.*

**Lee W-J**, Yu H-Y, Au, WWL, Smith A, Jen IF, Yang W-C, Fan Y-C, Nachtigall PE, Chiou L-S. Modal changes of echolocation beamwidth by a foraging Risso's dolphin. *In preparation; figures available upon request.*

## TECHNICAL REPORTS

**Lee W-J.** (2014). Searching by active sensing: how the bat catches the bug. Final project presentation for the Methods in Computational Neuroscience summer course. Marine Biological Laboratory, Woods Hole, MA.

**Lee W-J.** (2009). Target discrimination and classification using broadband acoustic techniques – Saanich Inlet: a case study. Final project report for the Marine Bioacoustics summer course. Friday Harbor Laboratories, University of Washington, Friday Harbor, WA, USA.

## INVITED TALKS

Mathematics Colloquium, Calvin University, October 29, 2020.
School of Aquatic and Fishery Sciences, University of Washington. November 1, 2019.
Department of Electrical and Computer Engineering, Univ of Massachusetts Dartmouth. September 27, 2019.
Department of Electrical and Computer Engineering, Dalhousie University. April 6, 2017.
Institute of Cellular and Organismic Biology, Academia Sinica, Taiwan. December 12, 2016.
School of Earth and Ocean Sciences, University of Victoria, BC, Canada. September 13, 2016.
Applied Physics Laboratory, University of Washington, Seattle, WA. September 1, 2015.
Hatfield Marine Station, Oregon State University, Corvallis, OR. July 7, 2015.
Department of Mechanical Engineering, University of New Hampshire, Durham, NH. June 1, 2015.
Spring 2015 Meeting of the Acoustical Society of America, Pittsburgh, PA. May 18, 2015.
Endemic Species Research Institute, Council of Agriculture, Executive Yuan. Nantou, Taiwan. April 20, 2015.
Spring 2014 Meeting of the Acoustical Society of America, Providence, RI. May 5, 2015.
Department of Engineering Science and Ocean Engineering, National Taiwan University. May 1, 2013.
Institute of Oceanography, National Taiwan University, Taipei, Taiwan. January 6, 2010; January 12, 2012.

## SELECTED CONFERENCE PRESENTATIONS

**Acoustic Ocean Sensing**

**Lee W-J**, Chu D, Dosso S. (2019) How much more informative are broadband compared to narrowband echoes for biological interpretation? *The 178th Meeting of the Acoustical Society of America*, San Diego, CA, USA, December 2-6, 2019.

**Lee W-J**, Staneva S. (2019) Tensor decomposition of multi-frequency echosounder time series. *IEEE OCEANS 2019 Seattle*, Seattle, WA, USA, October 28-31, 2019.

**Lee W-J**, Staneva S. (2019) Echopype: Enhancing the interoperability and scalability of ocean sonar data processing for biological information. *SciPy 2019 (Scientific Computing with Python)*. Austin, TX, USA, July 8-14, 2019.

**Lee W-J**, Staneva S. (2018) Exploring matrix and tensor factorization for discovering latent structures in large echosounder datasets. *The 176th Meeting of the Acoustical Society of America and the 2018 Acoustics Week in Canada*. Victoria, BC, Canada, November 5-9, 2018.

**Lee W-J**, Staneva S, Herman B, Aravkin A. (2018) Data-driven decomposition of ocean observatory echosounder time series for ecological insights. *The 2018 Ocean Sciences Meeting*, Portland, OR, USA, February 11-16, 2018.

**Lee W-J**, Tang D, Thorsos EI, Stanton TK. (2016) Mid-frequency clutter and reverberation characteristics of fish in a shallow ocean waveguide. *The 5th Joint Meeting of the Acoustical Society of America and the Acoustical Society of Japan*, Honolulu, HI, USA, November 28-December 2, 2016.

**Lee W-J**, Stanton TK. (2014). Accounting for the non-Rayleigh echo statistics of individual elongated scatterers in an aggregation. *The 167th Meeting of the Acoustical Society of America*, Providence, RI, USA, May 5-9, 2014.

**Lee W-J**, Stanton TK, Lavery AC. (2012). Estimating numerical density of scatterers in monotype aggregations using the statistics of broadband echoes: applications to fish echoes. *The 164th Meeting of the Acoustical Society of America*, Kansas City, MO, USA, October 22-26, 2012.

Ross T, **Lee W-J**, Keister JE, Lara-Lopez A, Greene C. (2012). Broadband acoustics on the VENUS observatory in Saanich Inlet. *The 2012 Ocean Sciences Meeting*, Salt Lake City, UT, USA, February 20-24, 2012.

Lavery AC, Geyer WR, Scully ME, Lawson GK, Wiebe PH, **Lee W-J**, Stanton T K, Fincke JR. (2012). Development of high-frequency broadband acoustic scattering techniques for imaging, classification, and quantification of stratified turbulence and zooplankton. *The 2012 Ocean Sciences Meeting*, Salt Lake City, UT, USA, February 20-24, 2012.

**Lee W-J**, Stanton TK. (2011). Statistics of echoes from mixed assemblages of scatterers with different scattering strengths and numerical densities. *The 162th Meeting of the Acoustical Society of America*, San Diego, CA, USA, October 31-November 4, 2011.

**Lee W-J**, Stanton TK. (2010). Analysis of mixed assemblages of fish using the statistics of echoes from a single beam broadband echosounder. *The 2nd Pan-American/Iberian Meeting on Acoustics*, Cancun, Mexico, November 15-19, 2010.

**Lee W-J**, Lavery AC, Stanton TK. (2010). Interpretation of the compressed pulse output for broadband acoustic scattering from inhomogeneous weakly scattering objects. *The 2nd Pan-American/Iberian Meeting on Acoustics*, Cancun, Mexico, November 15-19, 2010.

**Lee W-J**, Lavery AC, Stanton TK. (2009). Broadband acoustic scattering from squid: implications for toothed-whale foraging. *The 5th Animal Sonar Symposium*, Kyoto, Japan, September 14-18, 2009.

**Lee W-J**, Stanton TK, Lavery AC. (2009). Broadband acoustic backscattering from live squid: Experiment and analysis. *The 157th Meeting of the Acoustical Society of America*, Portland, OR, USA, May 18-22 2009.

**Animal Echolocation and Bioacoustics**

**Lee W-J**, Buck JR, Tyack, PL, Shinn-Cunningham B. (2019) Active infotaxis as a model for echolocation. *The 178th Meeting of the Acoustical Society of America*, San Diego, CA, USA, December 2-6, 2019.

**Lee W-J** (2017) I wonder how animals can do it so well: An ongoing detour to build better sonar, enabled by the Hunt fellowship. *The 174th Meeting of the Acoustical Society of America*, New Orleans, LA, USA, December 4-8, 2017.

**Lee W-J**, Yu H-Y, Au WWL, Smith A, Jen IF, Yang WC, Fan YC, Nachtigall PE, Chou L-S. (2016) Biosonar radiation field on the forehead of a Risso's dolphin during prey capture. *The 5th Joint Meeting of the Acoustical Society of America and the Acoustical Society of Japan*, Honolulu, HI, USA, November 28-December 2, 2016.

**Lee W-J**, Falk B, Chiu C, Krishnan A, Moss CF. (2016) Asymmetric multi-frequency biosonar beam pattern of tongue-clicking bat, *Rousettus aegyptiacus*. *The 171th Meeting of the Acoustical Society of America*, Salt Lake City, UT, USA, May 23-27, 2016.

**Lee W-J**, Moss CF. (2015). Detection and tracking of fluttering moths by echolocating bats. *The 169th Meeting of the Acoustical Society of America*, Pittsburgh, PA, USA, May 18-22, 2015.

Krishnan A, **Lee W-J**, Moss CF. (2014). Use of multisensory information by flying bats. Presented at *the 2014 Annual meeting of the Society for Neuroscience*, Washington, D.C., USA, November 15-19, 2014.

**Lee W-J**, Sändig S, Denzinger A, Schnitzler H-U, Horiuchi TK, Moss CF. (2014). Reconstructing the acoustic scenes encountered by free-flying, foraging bats. *The 167th Meeting of the Acoustical Society of America*. Providence, RI, USA, May 5-9, 2014.

**Lee W-J**, Sayigh LS, Jensen FJ, Tyack PL. (2011). Tonal whistles or burst pulses? Linking potential sound production mechanisms to the classification of toothed whale sounds. *The 19th Biennial Conference on the Biology of Marine Mammals*, Tampa, FL, USA, November 27-December 2, 2011.

**Lee W-J**, Yu H-Y, Chou L-S. (2005). Vocalization repertoire of the three strayed rough-toothed dolphins (*Steno bredanensis*) in Danshui River, Taipei, Taiwan. *The 16th Biennial Conference on the Biology of Marine Mammals*, San Diego, CA, USA, December 12-16 2005.

Lee P-F, **Lee W-J**, Chen Y-A, Yeh C-C, Chou L-S. (2005). Distribution of cetaceans in the waters off eastern Taiwan. *The 16th Biennial Conference on the Biology of Marine Mammals*, San Diego, CA, USA, December 12-16 2005.

**Lee W-J**, Tsai P-Y, Chen Y-H, Chou L-S. (2005). Exploration of the behavior and movement patterns of spinner dolphins in North Ilan waters. *The 8th Animal Behavior and Ecology Conference*, Taiwan.

## HONORS AND AWARDS

- SEED Postdoctoral Fellowship, Applied Physics Laboratory, University of Washington (2016-2017)
- Young Investigator Travel Grant, Acoustical Society of America (2016)
- Frederick V. Hunt Postdoctoral Fellowship in Acoustics, the Acoustical Society of America (2014-2015)
- Best student papers in Acoustical Oceanography (ASA 157th, 2009; ASA164th, 2012), Underwater Acoustics (ASA 160th, 2010)
- Ocean Life Institute Student Fellow, Woods Hole Oceanographic Institution (2011-2012)
- Innovative Technology Program Award, Woods Hole Oceanographic Institution (2010-2012)
- Ocean Life Institute Research Funds, Woods Hole Oceanographic Institution (2010-2012)
- Coastal Ocean Institute Student Research Award, Woods Hole Oceanographic Institution (2009)
- Awards for Outstanding Poster Presentations, the 5th Animal Sonar Symposium, Kyoto, Japan (2009)
- Taiwan Merit Scholarships, jointly supported by Taiwan's Ministry of Education, Council for Economic Planning and Development, and National Science Council in Taiwan (2007-2009)

## PROFESSIONAL ACTIVITIES

- Associate Editor for the Journal of the Acoustical Society of America Express Letters (JASA-EL)
- Subject Matter Expert (SME) for the Bio-acoustic sonar for the Ocean Observatories Initiative (OOI)
- Grant reviewer for NOAA Office of Ocean Exploration and Research (OER)
- Reviewer for:
  - Journal of the Acoustical Society of America
  - Proceedings of the National Academy of Sciences
  - Limnology and Oceanography
  - Scientific Reports
  - Fisheries Research
  - Frontiers in Behavioral Neuroscience
  - Acta Acustica united with Acustica
  - Animal Behaviour
  - PLoS ONE
  - Journal of Marine Science and Technology
- Member of the Technical Committees in Acoustical Oceanography (TCAO) and Animal Bioacoustics (TCAB), Acoustical Society of America
- Member of Acoustical Society of America, IEEE Oceanic Engineering Society, Signal Processing Society, Women in Engineering Society
- Member of the Woods Hole Oceanographic Institution Diversity Committee (2012-2013)

## SOFTWARE AND INSTRUMENT DEVELOPENT

- Echopype: Enhancing the interoperability and scalability of ocean sonar data processing for biological information. https://doi.org/10.5281/zenodo.4066742. February 2018-present. (Python)
- Complete compilation of code for reproducing figures in the tutorial "Echo statistics associated with discrete scatterers: A tutorial on physics-based method" published in the Journal of the Acoustical Society of America. https://doi.org/10.5281/zenodo.1313729. December 2018. (Matlab)
- An open-source package for beampattern reconstruction and analysis. https://github.com/leewujung/beampattern_processing. August 2015-present. (Matlab)

- A scalable broadband ultrasonic microphone array for bat echolocation research (hardware and software). February-July 2014. (LabVIEW)

## FIELD AND LABORATORY EXPERIENCES

*Field experiences*

- VISIONS'17; VISIONS'18: Ocean Observatories Initiative (OOI) Cabled Array maintenance cruise. August 20-27, 2017; July 19-August 5, 2018.
- NOAA Northwest Fisheries Science Center 2017 hake acoustic-trawl survey. July 23-August 7, 2017
- Zooplankton patchiness and ecosystem dynamics at the shelf break, led by Dr. Gareth Lawson. September 21-30, 2010 and October 26-November 6, 2010.
- Broadband acoustic studies of fish in Georges Bank and the Gulf of Maine, led by Dr. Timothy Stanton. September 8-18, 2010.
- Active acoustic and net sampling of zooplankton in Saanich Inlet, British Columbia, Canada, led by Drs. John Horne, Julie Keister, and Charles Greene. July 30-31, 2009.
- Various day trips for at-sea instrument test near Cape Cod, MA. 2007-2012.
- Behavioral observation and visual survey of marine mammals in the waters off Taiwan. 2003-2006.

*Laboratory experiments*

- Two-dimensional broadband beampattern of Egyptian fruit bat (*Rousettus aegyptiacus*), big brown bat (*Eptesicus fuscus*), Seba's short-tailed fruit bat (*Carollia perspicillata*), and Formosan Leaf-nosed bat (*Hipposideros armiger terasensis*). August-September 2015
- Concurrent on-head radiation field and two-dimensional beampattern of Risso's dolphin (*Grampus griseus*). April-May 2015. In collaboration with Dr. Whitlow Au at the Hawai'i Institute of Marine Biology and Dr. Wei-Cheng Yang at the National Chiayi University, Taiwan.
- Broadband acoustic scattering from fluttering moth prey of bats. June, 2014 and December-February 2015.
- Broadband acoustic scattering from live squid. June-August 2008.

## STUDENTS MENTORED

| | |
|---|---|
| 2019 | Darshan Metha, master student, Master of Science in Data Science program, UW |
| 2019 | Kavin Nguyen, undergraduate student, Department of Physics, UW |
| 2018 | Aidan Johnson, undergraduate student, Department of Electrical and Computer Engineering, UW |
| 2017 | Douglas Pham, undergraduate student, Department of Physics, UW |
| 2014-2015 | Neil Chapel, undergraduate student, Behavioral Biology, Johns Hopkins University |
| 2014-2015 | Grant Shewmaker, undergraduate student, Behavioral Sciences, Johns Hopkins University |
| 2014-2015 | Dan Ju, undergraduate student, Behavioral Biology, Johns Hopkins University |

## TEACHING AND OUTREACH

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|---|---|
| 2018-2019 | **Lead and co-lead organizer** for Oceanhackweek 2018-2020 and Cabled Array Hackweek at University of Washington, Seattle. |
| 2018 | **Guest lecturer** for Wildlife Sciences Seminar to non-science background undergraduate students, University of Washington |
| 2016 | **Guest lecturer** for university-wide General Education Lectures, National Cheng Kung University, Taiwan |
| 2013 | **Co-organizer and lecturer** (acoustics and signal processing), Bioacoustics workshop, National Museum of Natural Science, Taichung, Taiwan |
| 2013 | **Guest lecturer**, on women in science and engineering in Gender Equality Education, National Pingtung University of Education, Pingtung, Taiwan |
| 2011 | **Presenter and panelist** in the Ocean Science Journalism workshop, Woods Hole Oceanographic Institution |
| 2003-2006 | **Trainer for marine mammal visual observer and stranding response**, Cetacean Lab, Institute of Ecology and Evolutionary Biology, National Taiwan University |
| 2002-2006 | **Lecturer** (marine mammal biology) for elementary school outreach program, Taiwan Cetacean Society |

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| 2002 | **Co-organizer**, National Taiwan University Summer Camp for Cetacean and the Ocean, for high school students, Hualien, Taiwan |
| 2002 | **Tutor** (mathematics and natural sciences) for elementary school and high school students in aboriginal Katipul Village, Taitung, Taiwan |
| 2001-2003 | **Wildlife and geology interpreter** on dolphin-watching boats, Ilan, Taiwan |
| 2000-2003 | **Tutor** (mathematics and physics) for high school students |

## PRESS

- Featured article: Big data and fisheries acoustics. International Council for the Exploration of the Sea (ICES) September 15, 2020.
- Wu-Jung Lee's journey into ocean sound from dolphins to bats and back to the sea. Ocean Observatories Initiative. August 8, 2018.
- Fruit bat's locating clicks echo sophisticated radar. Reuters | Video – Technology, April 22, 2018.
- Navigating with the tongue, the Egyptian fruit bat way! Research Matters, April 3, 2018.
- Phased arrays & the Egyptian fruit bat. Lab Animal Magazine, February 2018.
- Fruit bat's echolocation may work like sophisticated surveillance sonar. UW Today, February 6, 2018.
- Luna moth's long tail could confuse bat sonar through its twist. UW Today, August 15, 2016.
- The Squid, the Whale, and the Grad Student – A young scientist deciphers meaning embedded in sonar signals. Oceanus Magazine, 2009.