Benefits of real-time object detection for environmental monitoring of marine energy devices

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Background

- Wildlife may be negatively impacted by marine energy devices
  - E.g., collision, disorientation

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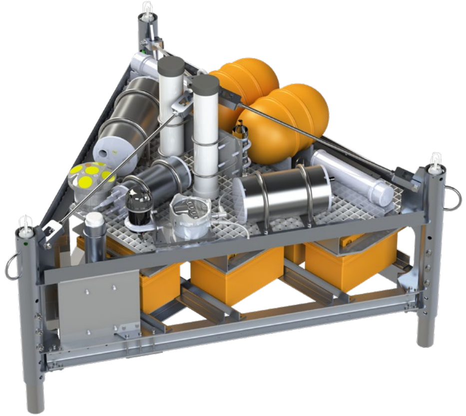
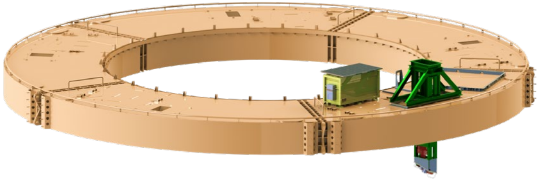
Background

AMP



AutoAMP



WAMP

Image credits: Polagye et al. (2020)

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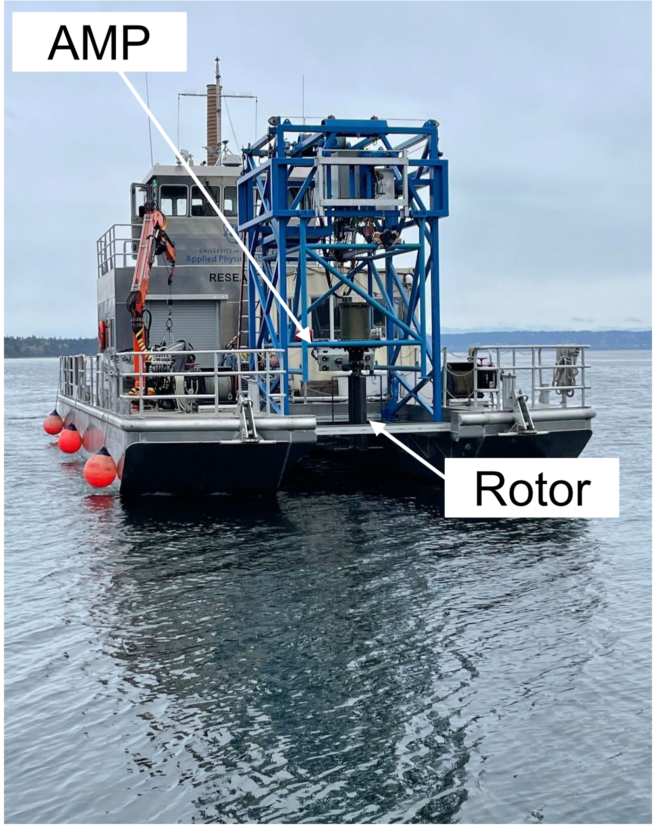
Background

- Wildlife may be negatively impacted by marine energy devices
  - E.g., collision, disorientation
- Observing rare events requires persistent monitoring
- Storage and review of large quantities of data is costly and time consuming
- Automated object detection and classification expedites post-processing
- Real-time detection and classification only captures events of interest, reducing data footprint and review time and enabling real-time actions (e.g., momentary illumination)

Collision Study

- Deployed LAMP off R/V Russell Davis Light in Agate Pass, WA
- Observed cross-flow turbine with optical and acoustic streams, monitoring for collision or near-collision events
- Data collection over 7 days (April 18, 2022 - April 24, 2022)
- Continuous data collection during daytime. Strobes used intermittently at night to avoid biasing animal behavior.
- ML model post-processing only (to date)



R/V light with turbine and LAMP monitoring system

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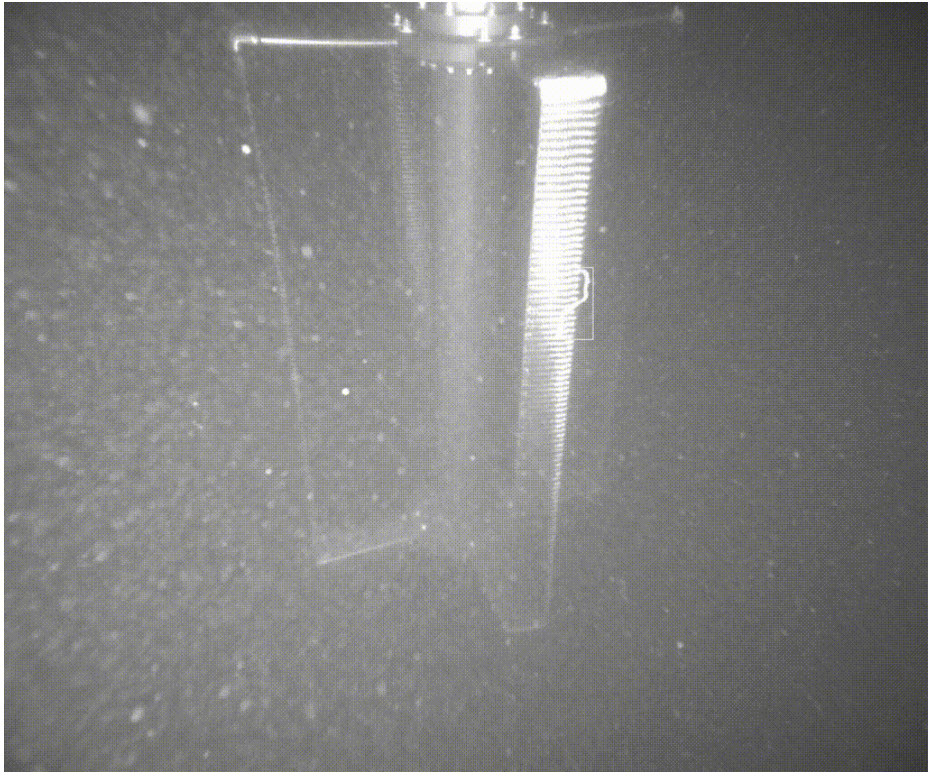
Image credit: University of Washington

Collision Study

- Targets of interest (small fish, jellyfish, krill, plants) in camera and sonar data hand-labelled and used to train ML model (YOLO-v3) for autonomous object detection
- Model lifecycle: curate and label data, train model, process data, repeat
- Iterated until target accuracy achieved



Fish (?) passes through moving turbine blades without collision. Detections hand labeled.

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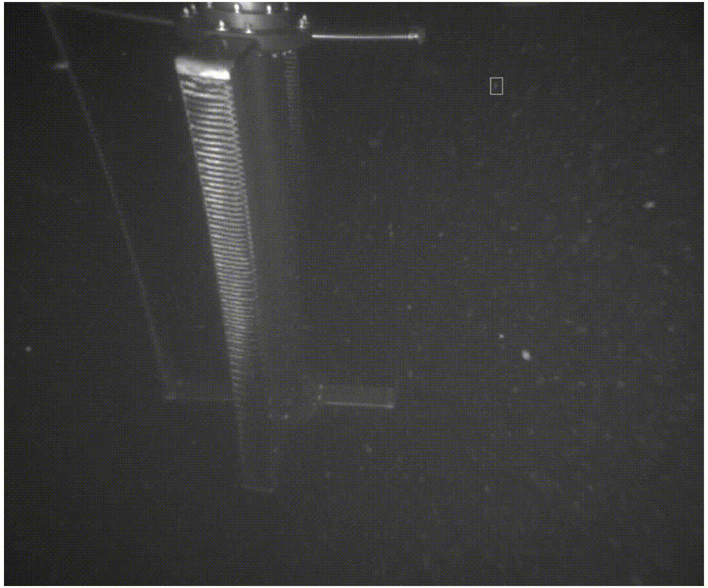
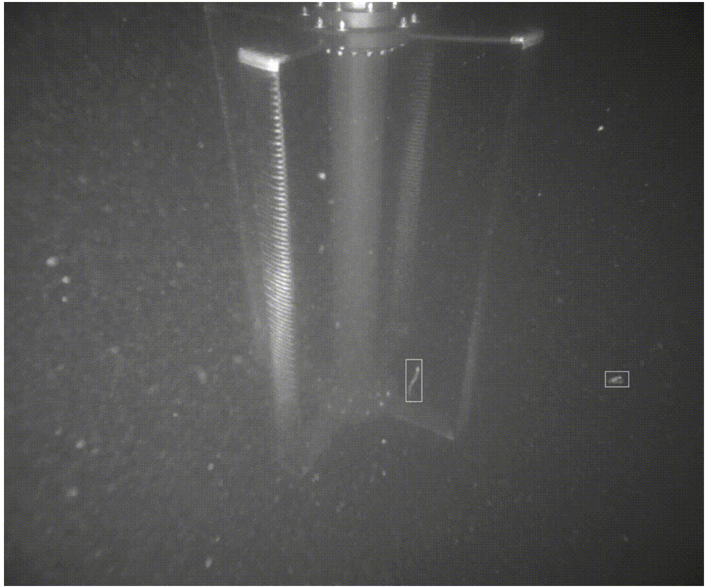
Video credit: University of Washington

Collision Study



Small fish near turbine. Detections hand labeled.



Small targets near turbine. Detections hand labeled.

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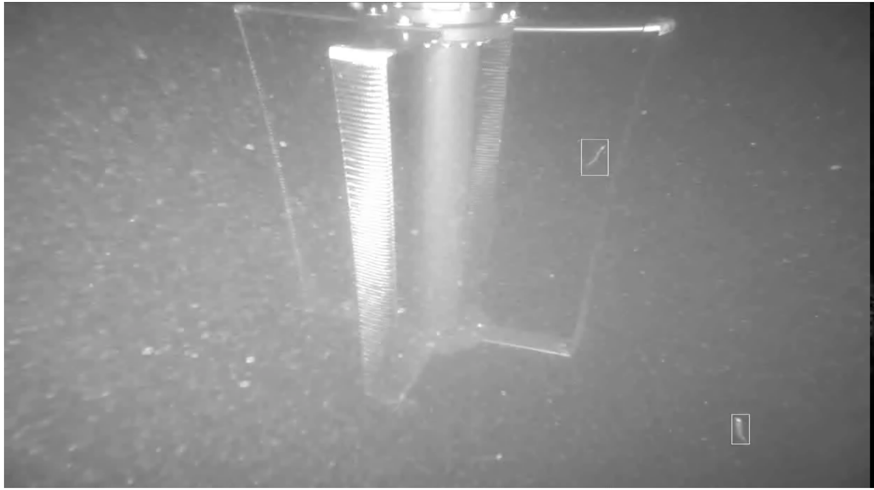
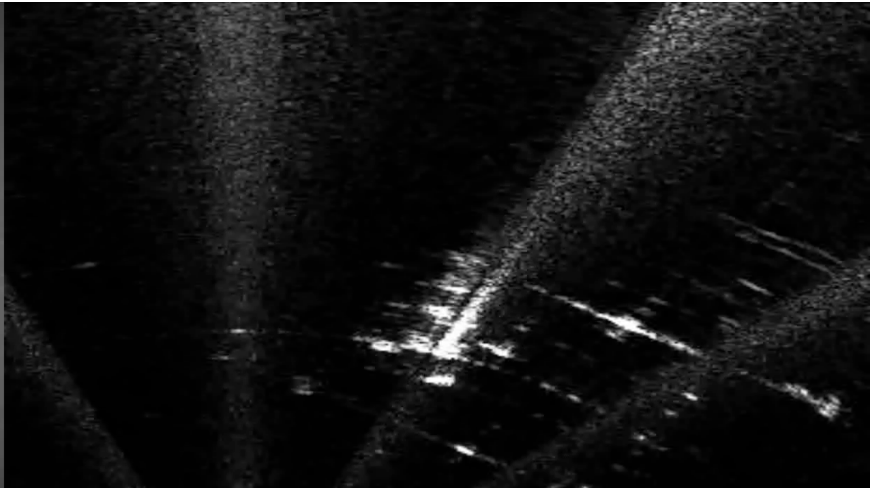
Video credit: University of Washington

Collision Study



Small fish near turbine. Detections by trained model.



Co-temporal acoustic image (Teledyne BlueView)

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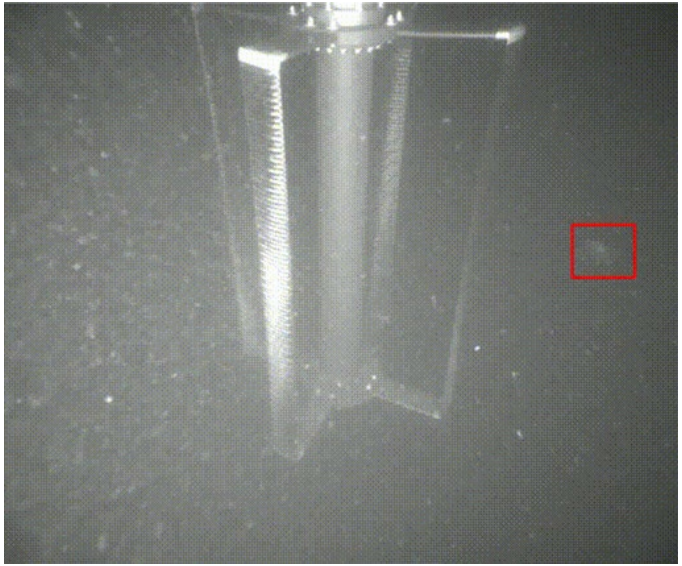
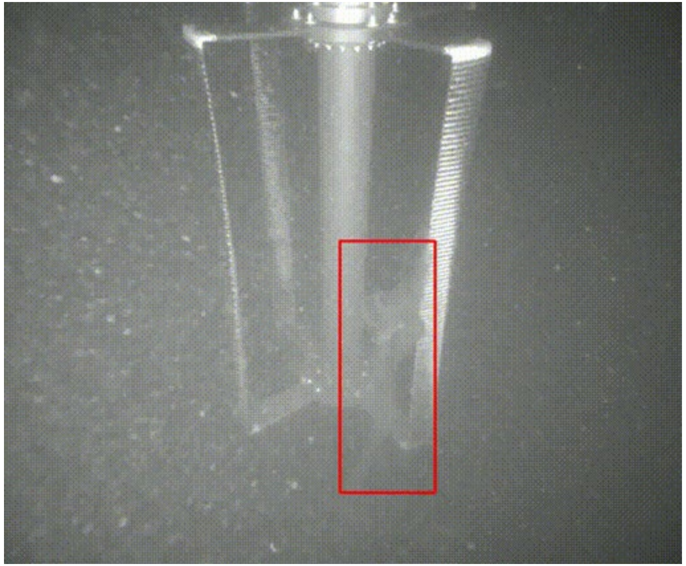
Video credit: University of Washington

Collision Study





Jellyfish collisions. Data played in reverse. Bounding boxes hand drawn.

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Video credit: University of Washington

Collision Study

Accuracy

- Highly dependent on site and model parameters
- 8,467 targets were identified in optical data and hand labelled
- 184,387 targets were identified by the trained ML model
    - False positive rate of all data: 35.1% (random sample of 100 images)
    - False positive rate of night data only: 7.6% (random sample of 100 images)
- Accuracy suggests more model tuning is necessary
- High biological productivity, poor visibility
- Artificial lighting at night was superior to natural lighting during day-time

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Preparation Time

- Annotation is the most time-consuming component of model preparation
- At 5 seconds per annotation, approximately 12 hours to hand label 8,467 objects
- Labelling services and automated labelling features available to further reduce time and cost, though class designations by domain experts may still be necessary

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Data Footprint

- At 125 KB per image (1232 x 1028, 8-bit mono)
    - 875 GB required for ~7 million captured images
    - 21 GB required for 170,969 images containing 184,387 detections*

*biased higher by false positives

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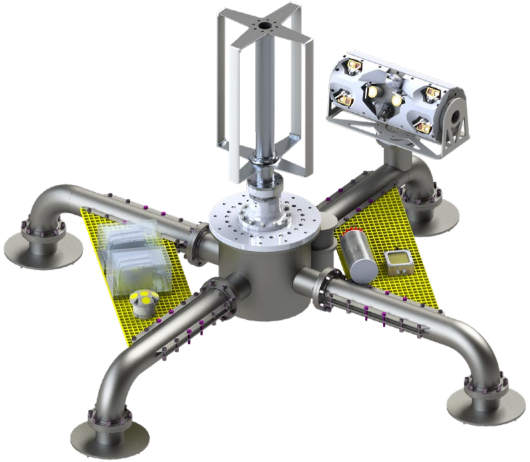
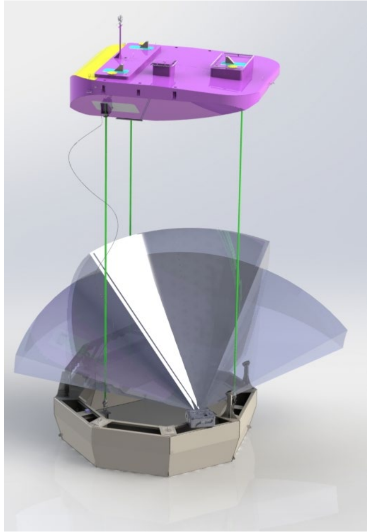
Future Work

- Further model refinement and development of fish tracking and collision detection
- UW will deploy LAMP and Turbine Lander at MCRL in Sequim Bay
    - Based on prior experience, we expect to see larger fish, fish school, seals, diving birds, detritus, bubble clouds
- ML model will be retrained with newly collected site-specific data and operated in real-time
- As with prior AMP deployments, detection events will trigger actions
    - Data stored in buffers will be written to disk
    - LED lighting will provide momentary exposure synced illumination

LAMP and 3G-AMP Support



LAMP at Marine and Coastal Research Laboratory (MCRL, PNNL)



3G-AMP integration with Oscilla Triton-C at Wave Energy Test Site (WETS)

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Image credits: University of Washington

ORPC RivGen Real-Time Detection

- MarineSitu supporting monitoring of ORPC RivGen turbines with camera systems and software
- Currently recording at 16.67% duty cycle
- With support from TEAMER, MarineSitu is preparing a real-time detection model for a trial deployment this Fall
- Work by Courtney et al. (2022) suggests need for automated fish orientation estimation (detection of disorientation) and collision detection

Salmon smolt passing RivGen turbine, Spring 2021

Image credit: Courtney et al. (2022)

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Related Projects

- SBIR Phases I and II (Low-Cost, User-Friendly Monitoring Tools for MHK Sites)
    - Continued tech transfer of AMP technology from UW to MarineSitu
    - Research into transferability of machine learning models between sites
    - Novel hardware and software development
    - Web-based data management and visualization platform
- PNNL AMP
- Pursuing projects in fish passage monitoring at traditional hydroelectric dams
    - Current real-time monitoring primarily relies upon human observers

Acknowledgements

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Citations

1. Polagye B, Joslin J, Murphy P, Cotter E, Scott M, Gibbs P, Bassett C, Stewart A. Adaptable Monitoring Package Development and Deployment: Lessons Learned for Integrated Instrumentation at Marine Energy Sites. Journal of Marine Science and Engineering. 2020; 8(8):553. https://doi.org/10.3390/jmse8080553

2. Courtney, M.B., Flanigan, A.J., Hostetter, M. and Seitz, A.C. (2022), Characterizing Sockeye Salmon Smolt Interactions with a Hydrokinetic Turbine in the Kvichak River, Alaska. North Am J Fish Manage, 42: 1054-1065. https://doi.org/10.1002/nafm.10806

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Questions

Camera and Light Hardware

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Camera Control and Acquisition Software