Annex IV Environmental Research Webinar Series

Recent Research of Interest to the MRE Industry

Presenters

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- Haley Viehman, Post-doctoral Fellow
  - Acadia University
- Ann Bull, Chief Emeritus, Environmental Sciences Section, Pacific Region Office
  - Bureau of Ocean Energy Management

BOEM Bureau of Ocean Energy Management

ACADIA UNIVERSITY

Presenter

- Haley Viehman, Post-doctoral Fellow
  - Acadia University
    - Using patterns in fish presence at a tidal power site to improve study design

Using patterns in fish presence at a tidal power site to improve study design

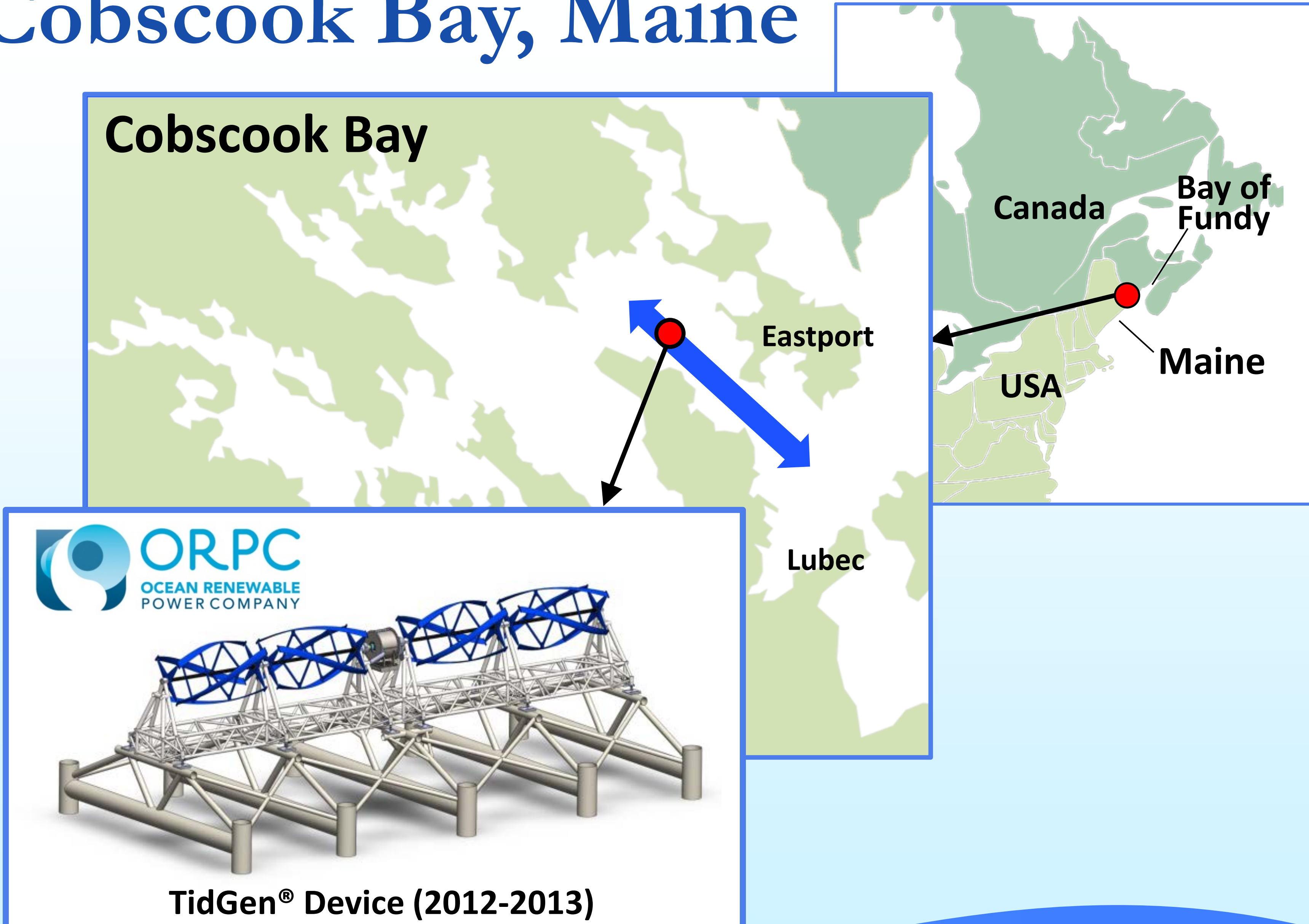
Haley Viehman

Post doc at Acadia University (Dr. Anna Redden)

Presenting PhD work from the University of Maine

(Advisor: Dr. Gayle Zydlewski)

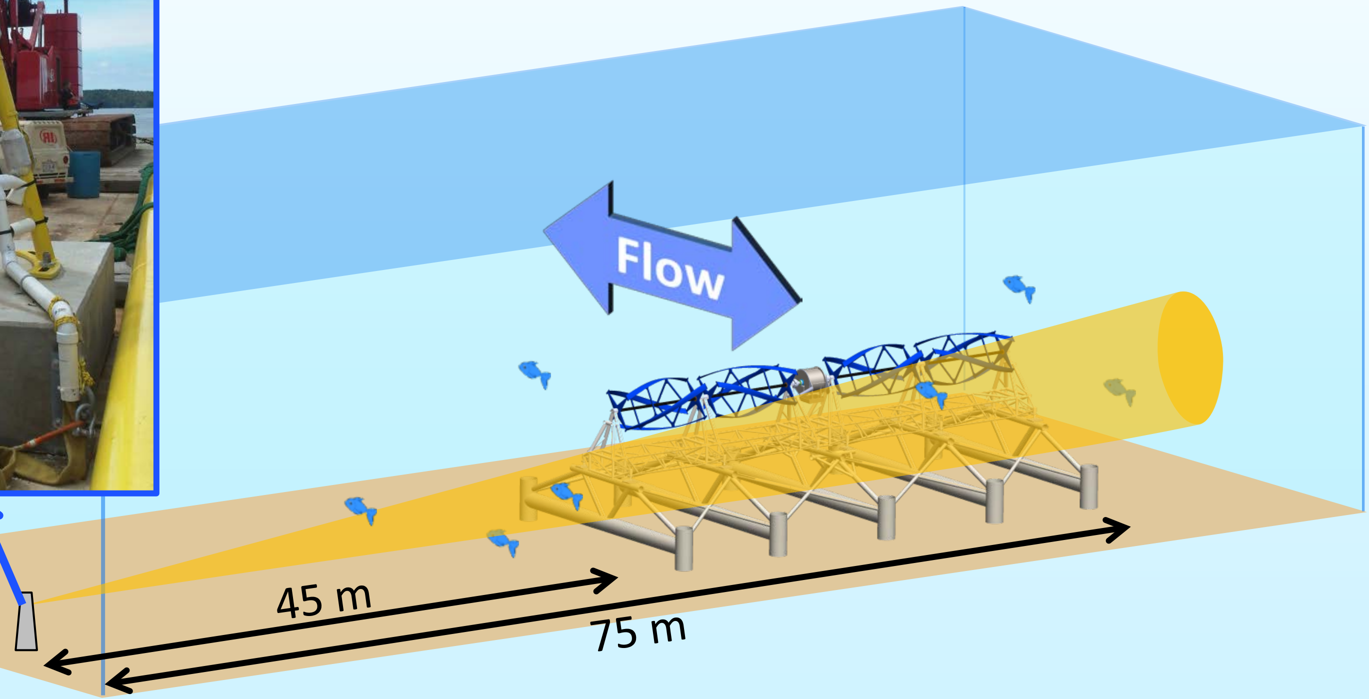
Cobscook Bay, Maine



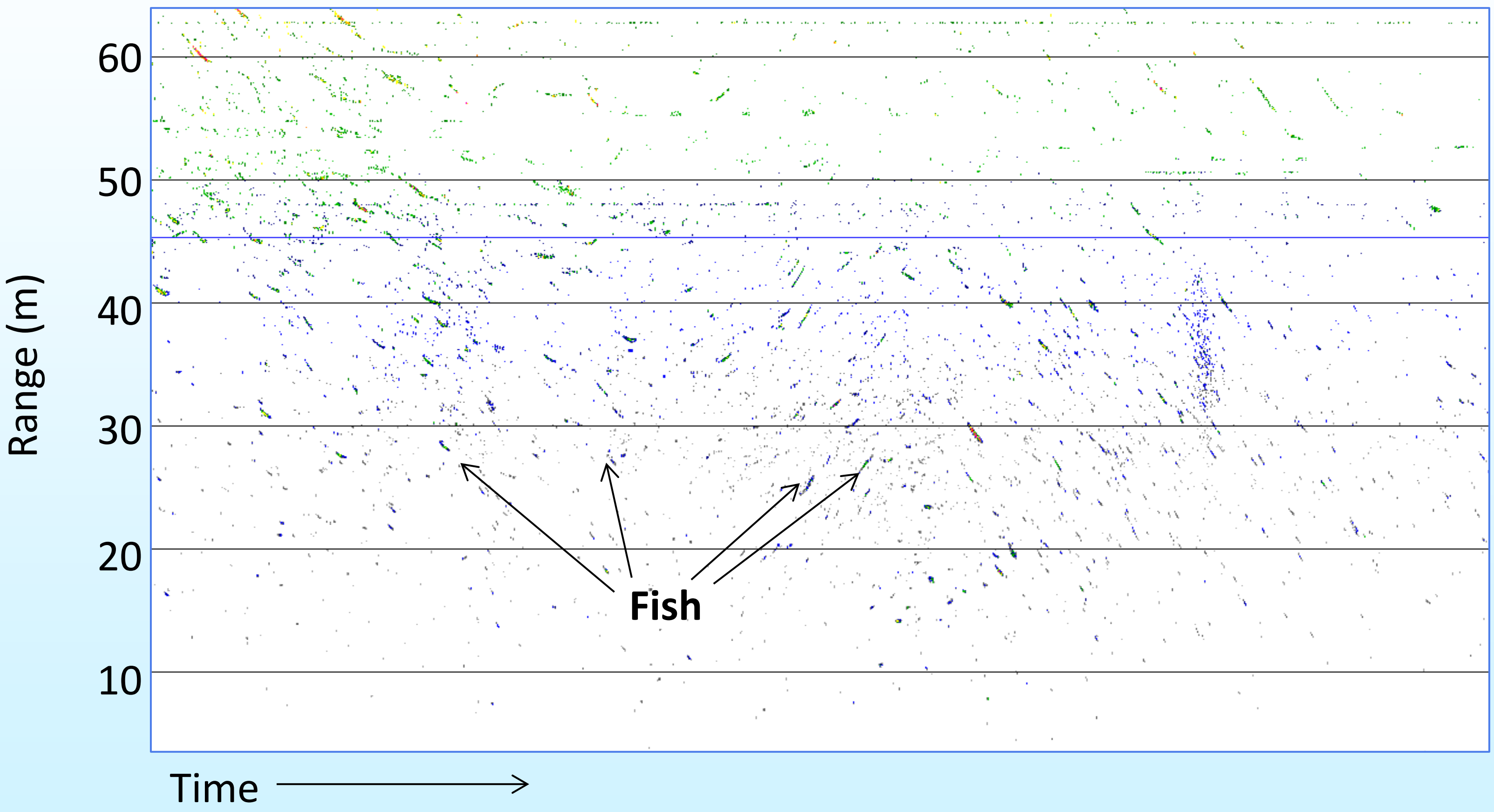
TidGen® Device (2012-2013)

Bottom-mounted, side-looking echosounder

- After turbine removal, sampled 5x per second for 2 years (July 2013-July 2015)



Hydroacoustic data

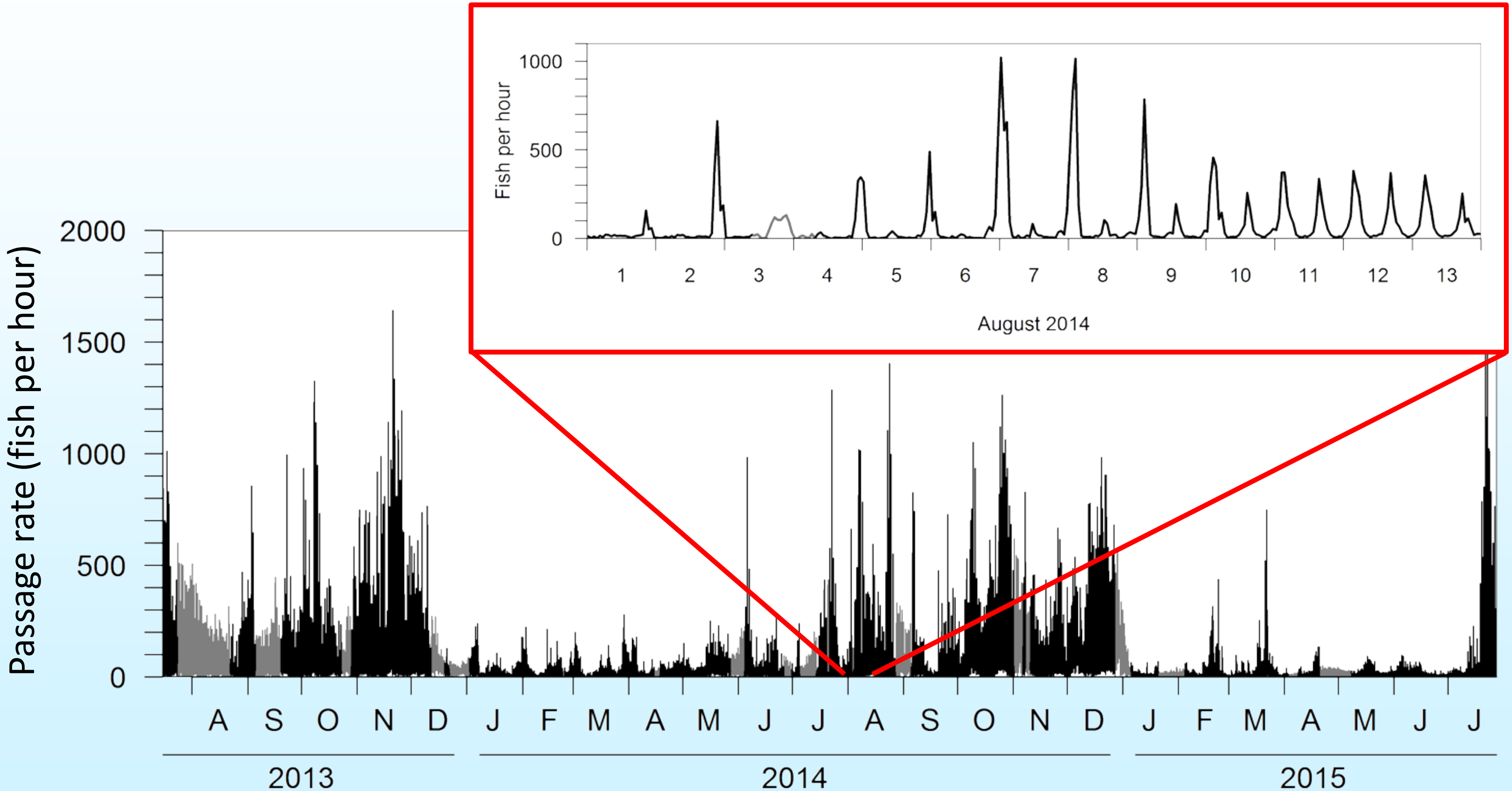


Objectives

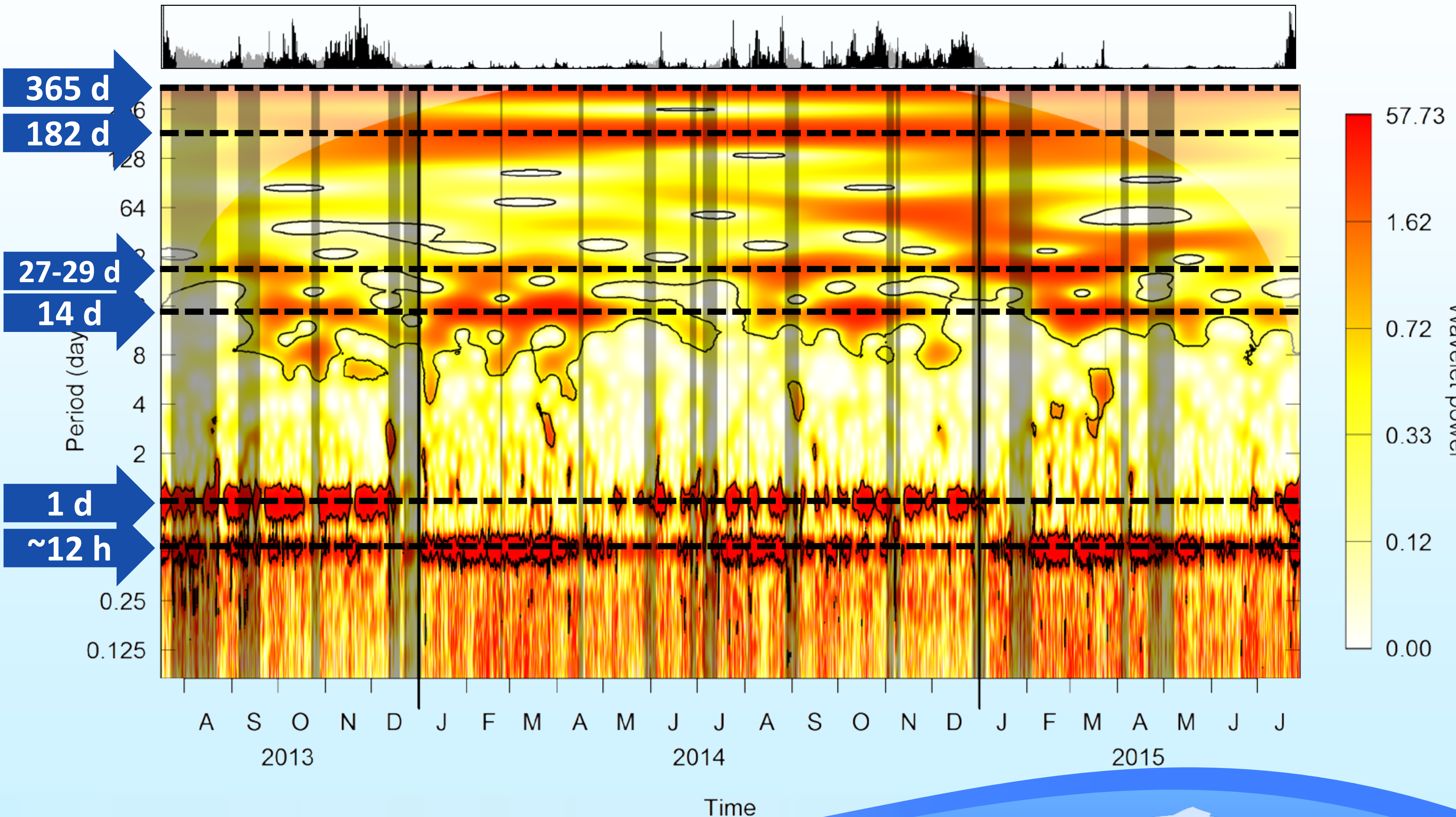
1) Describe natural temporal changes in fish presence at the tidal energy site

2) Use natural patterns in fish presence to improve longer-term site monitoring

1. Temporal changes in fish presence



1. Temporal changes in fish presence



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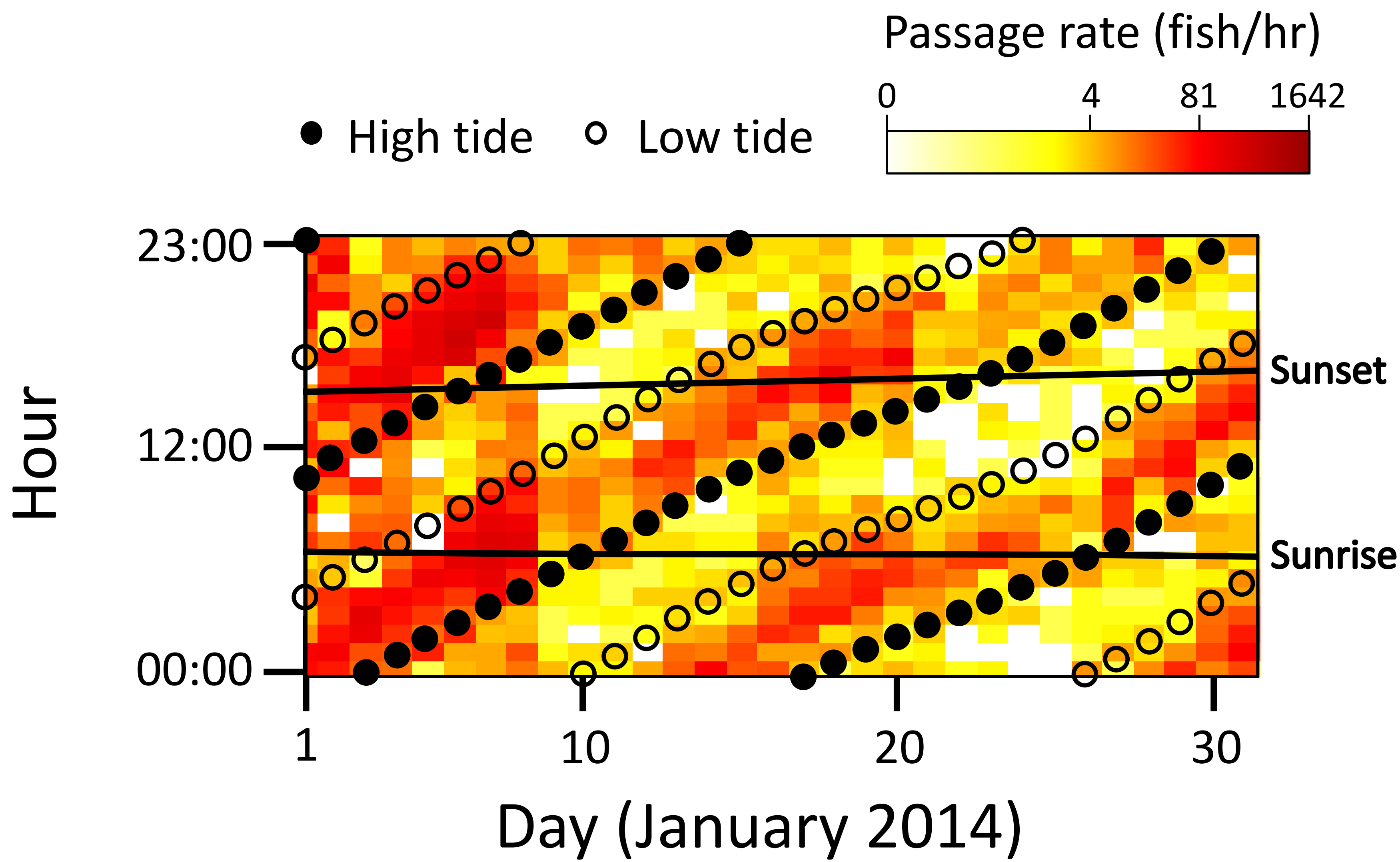

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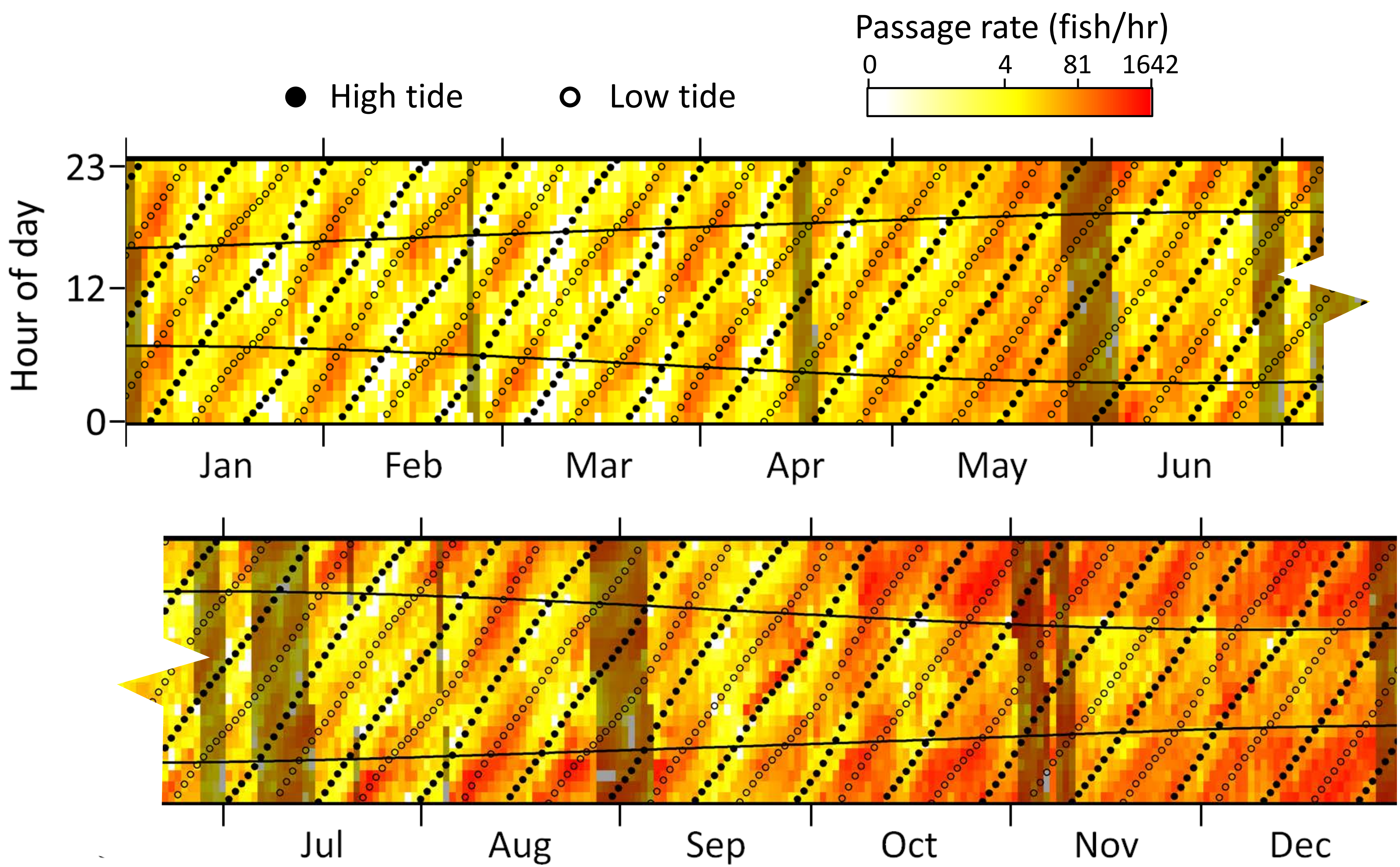

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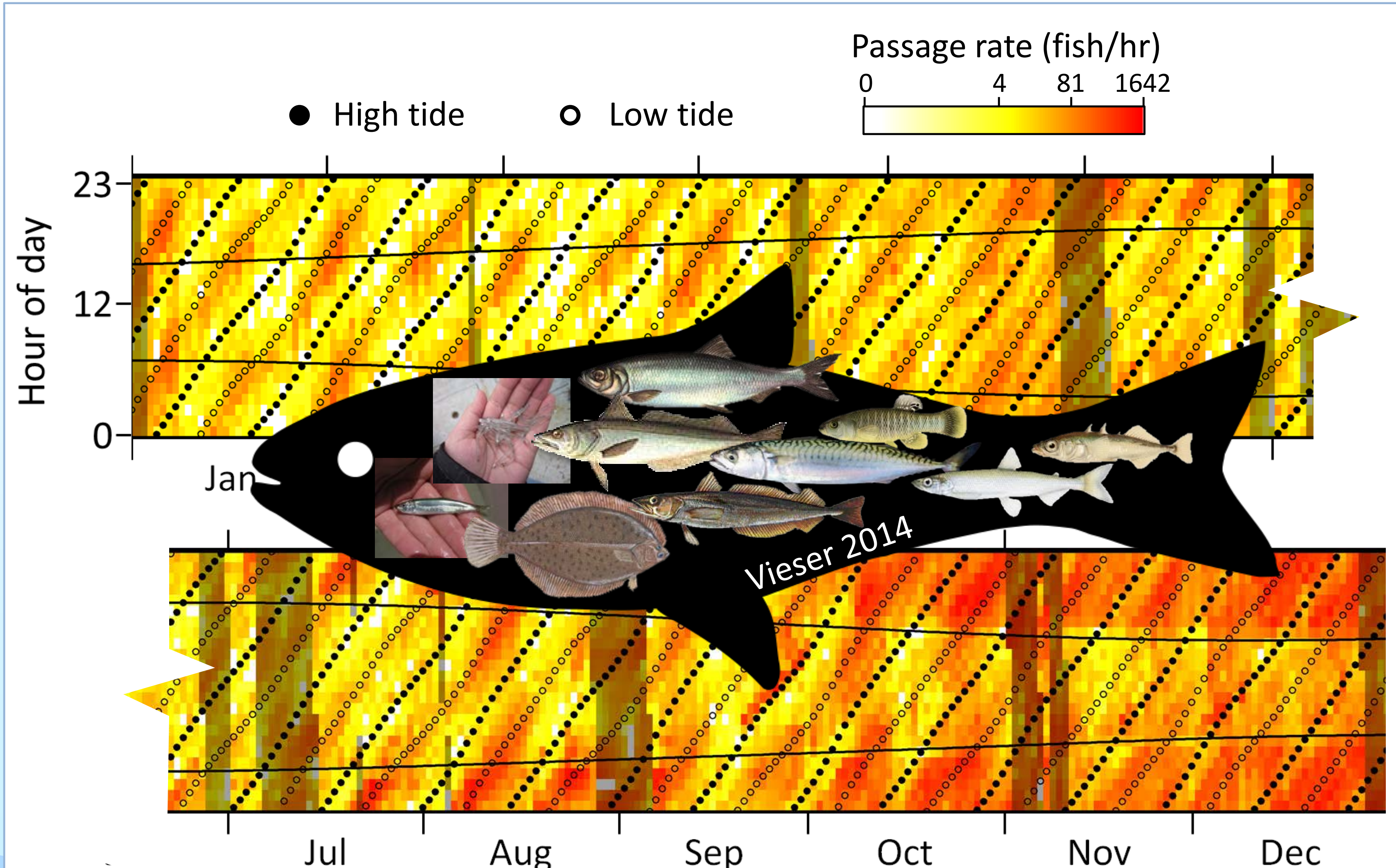

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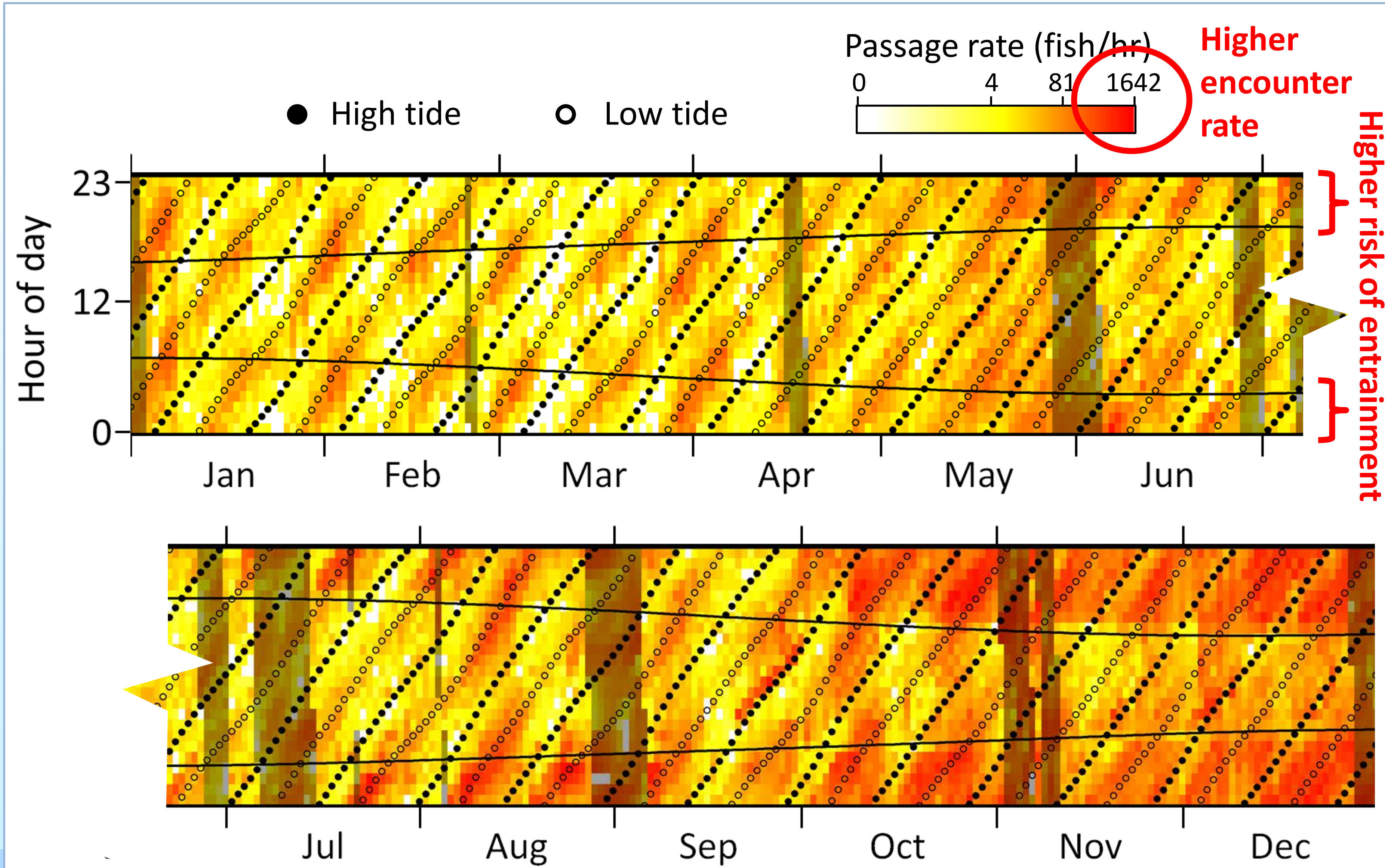


1. Temporal changes in fish presence

Summary

- Passage rate (encounter rate) varies greatly over time, and is related to interacting environmental cycles
- *Presence not linked to current speed*
  - Contrasts other sites (e.g. Broadhurst et al. 2014)
- Sampling time could greatly affect observations
- To observe fish interactions, target times of high passage rate

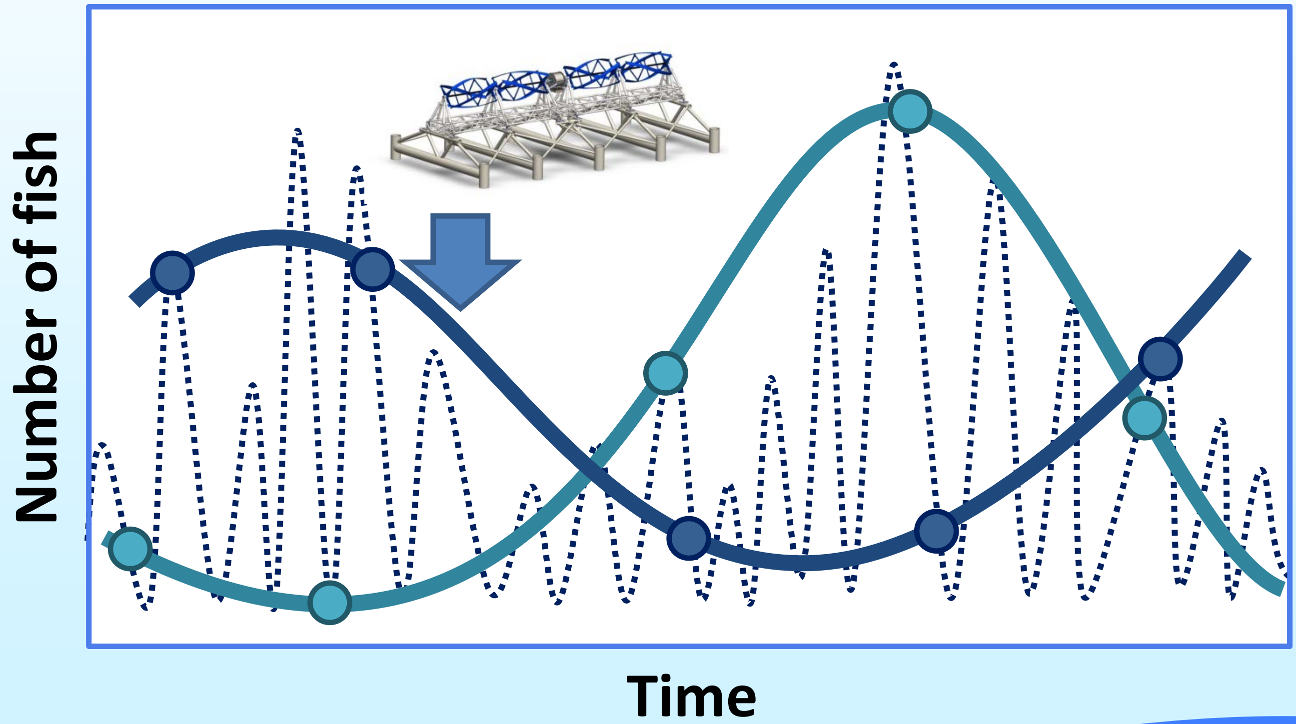
Objectives

1) Describe natural temporal changes in fish presence at the tidal energy site

2) Use natural patterns in fish presence to improve longer-term site monitoring

2. Improve study design for site monitoring

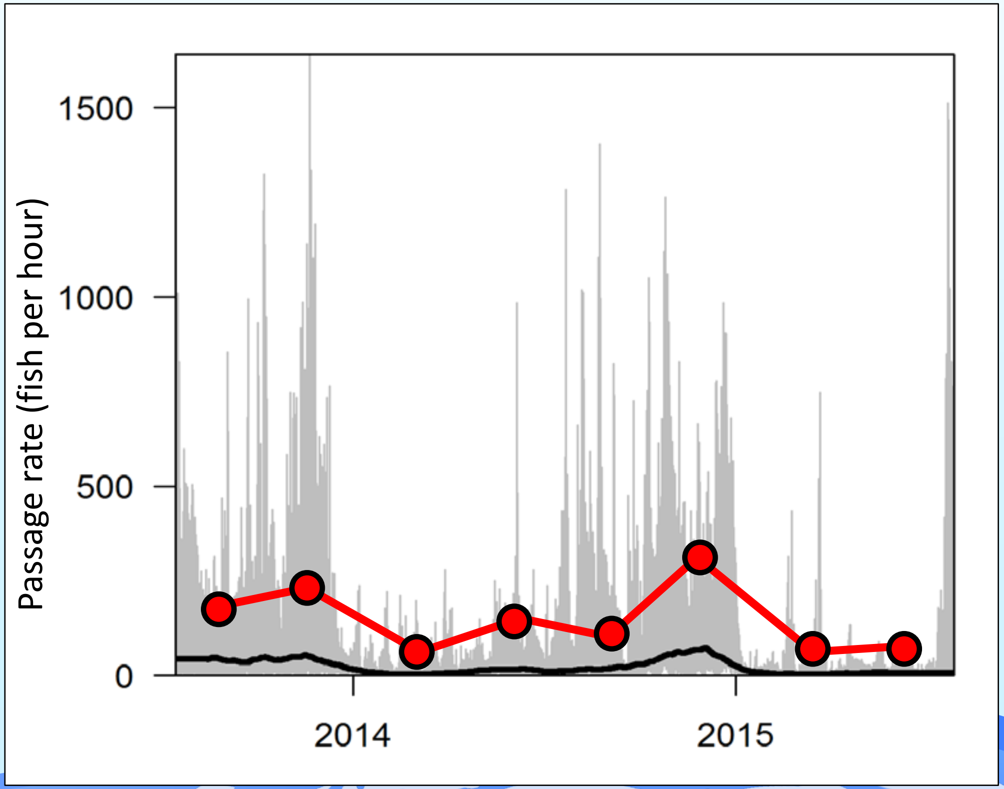
- Ideally, sample continuously for a long time.
- Realistically, sample intermittently.



2. Improve study design for site monitoring

Can the underlying patterns be used to design an accurate *and* economic study?

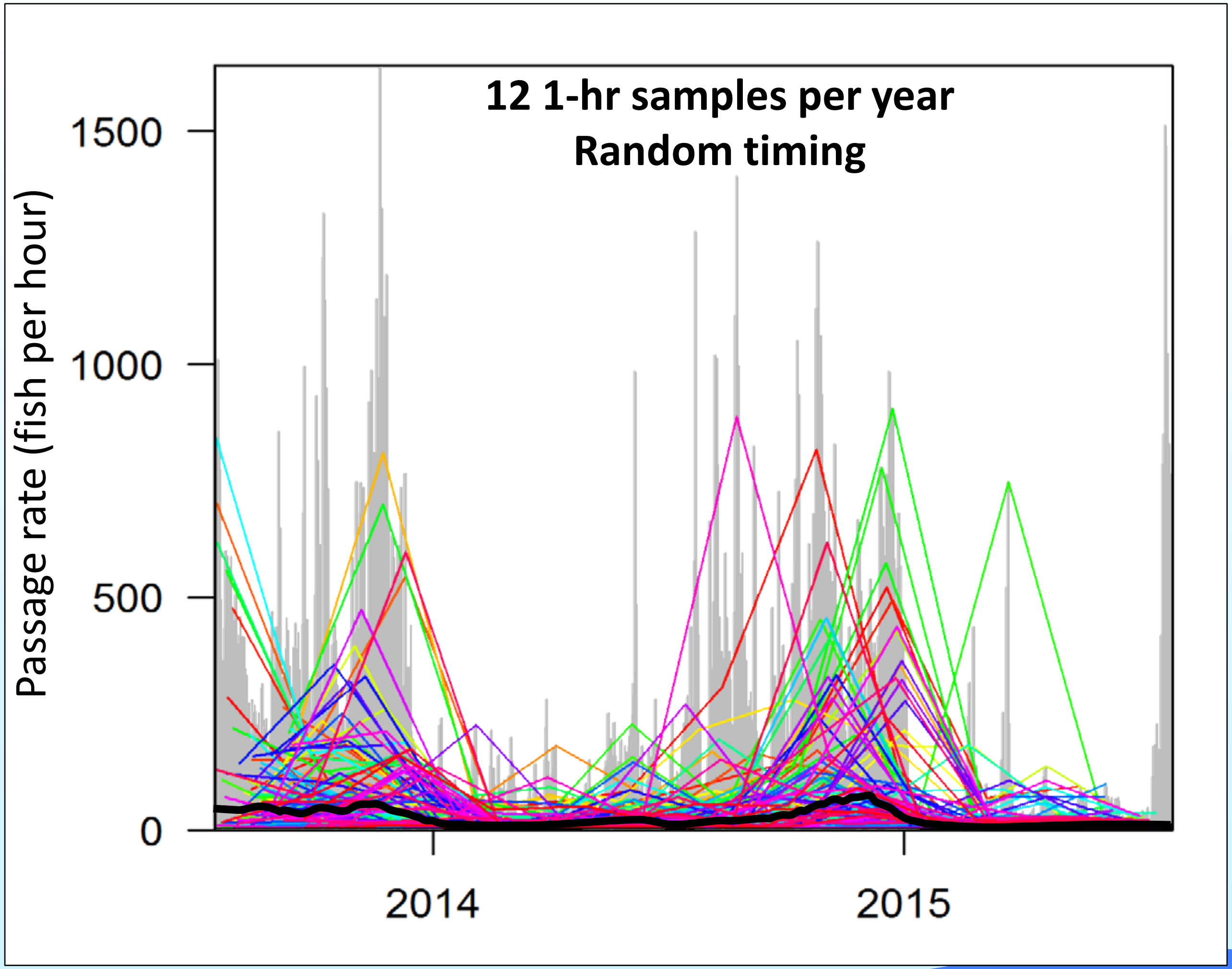
- Goal: Use discrete samples to capture seasonal pattern in fish presence
- Subsample the time series to simulate different study designs



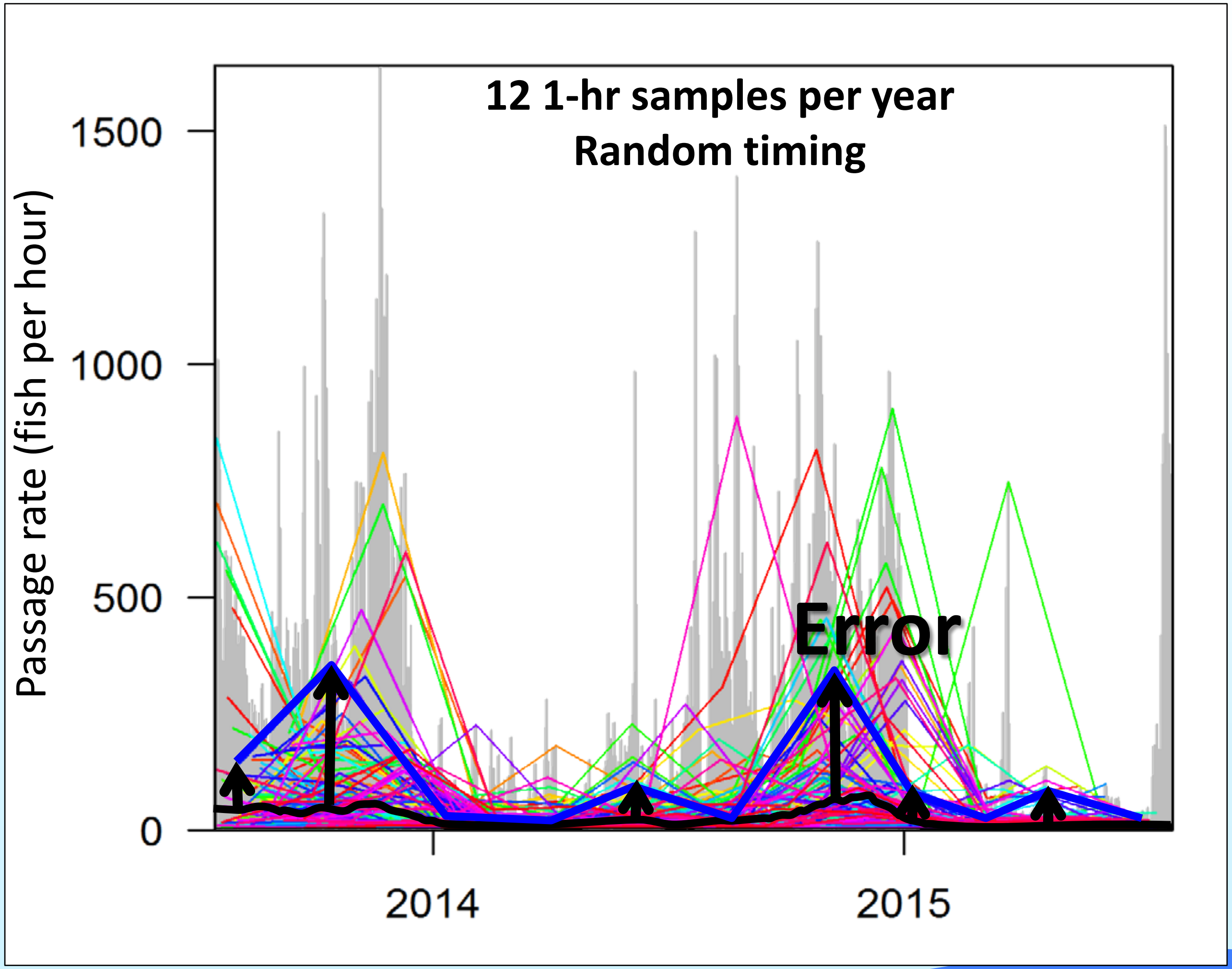
2. Improve study design for site monitoring

- Sample **duration**: 1-, 12-, 24-hr samples
- Sample **frequency**: 3 to 12 times per year
- Sample **timing**:
  - – Random
  - – Informed: cyclic environmental factors held constant
    - 1 hr: tidal, diel, lunar cycles
    - 12 hr: diel, lunar cycles
    - 24 hr: lunar cycle
- 500 iterations of each study design

2. Improve study design for site monitoring



2. Improve study design for site monitoring



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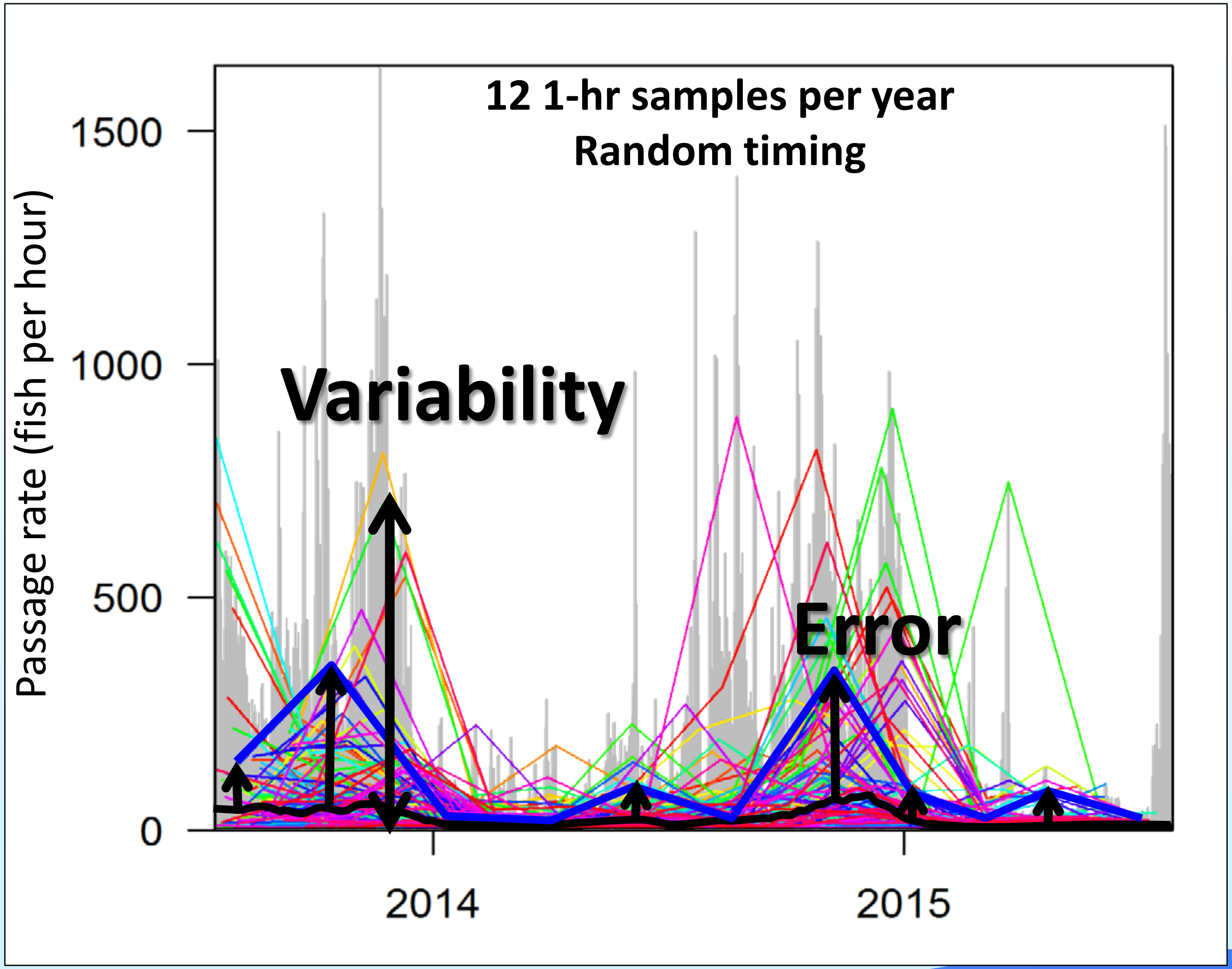

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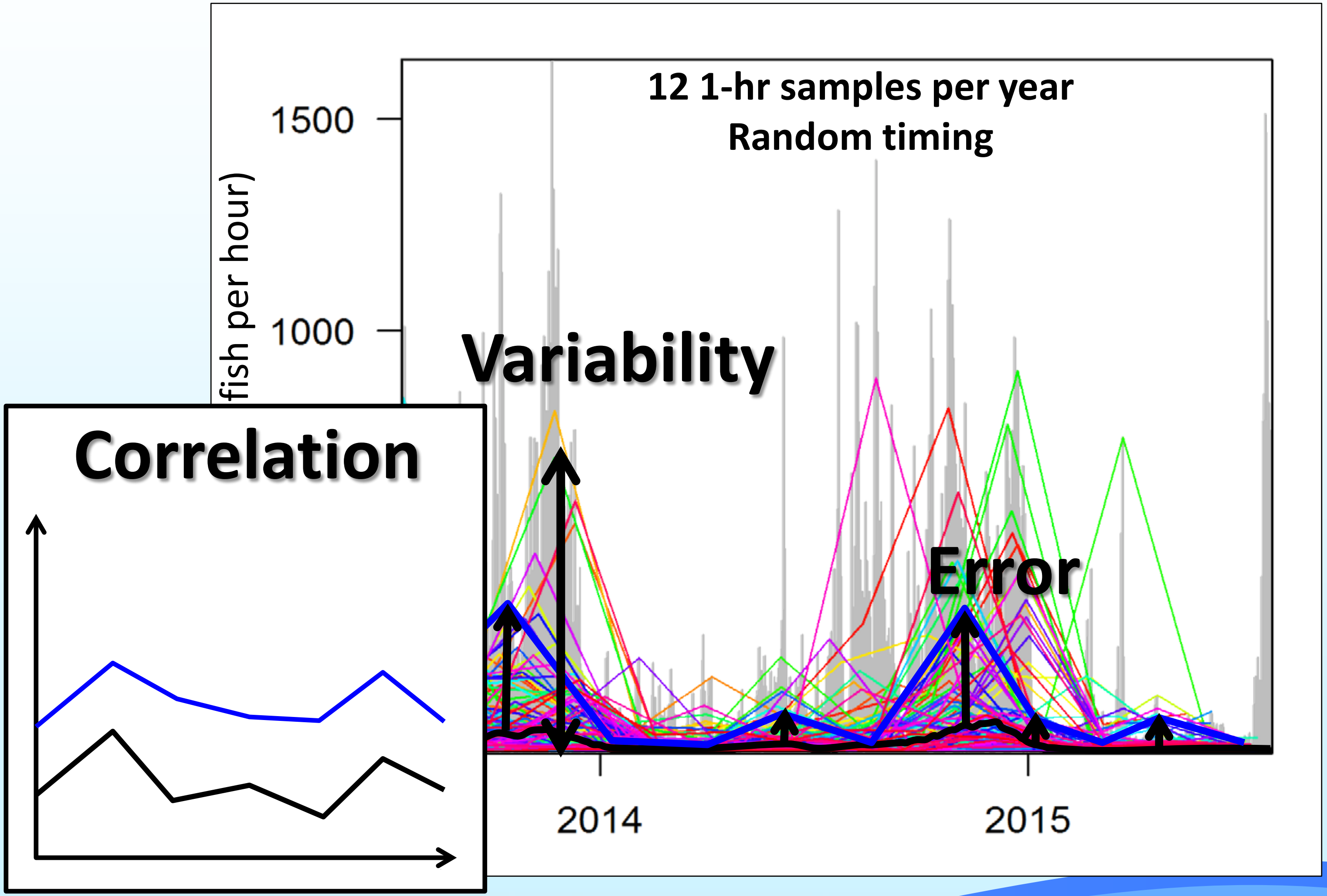

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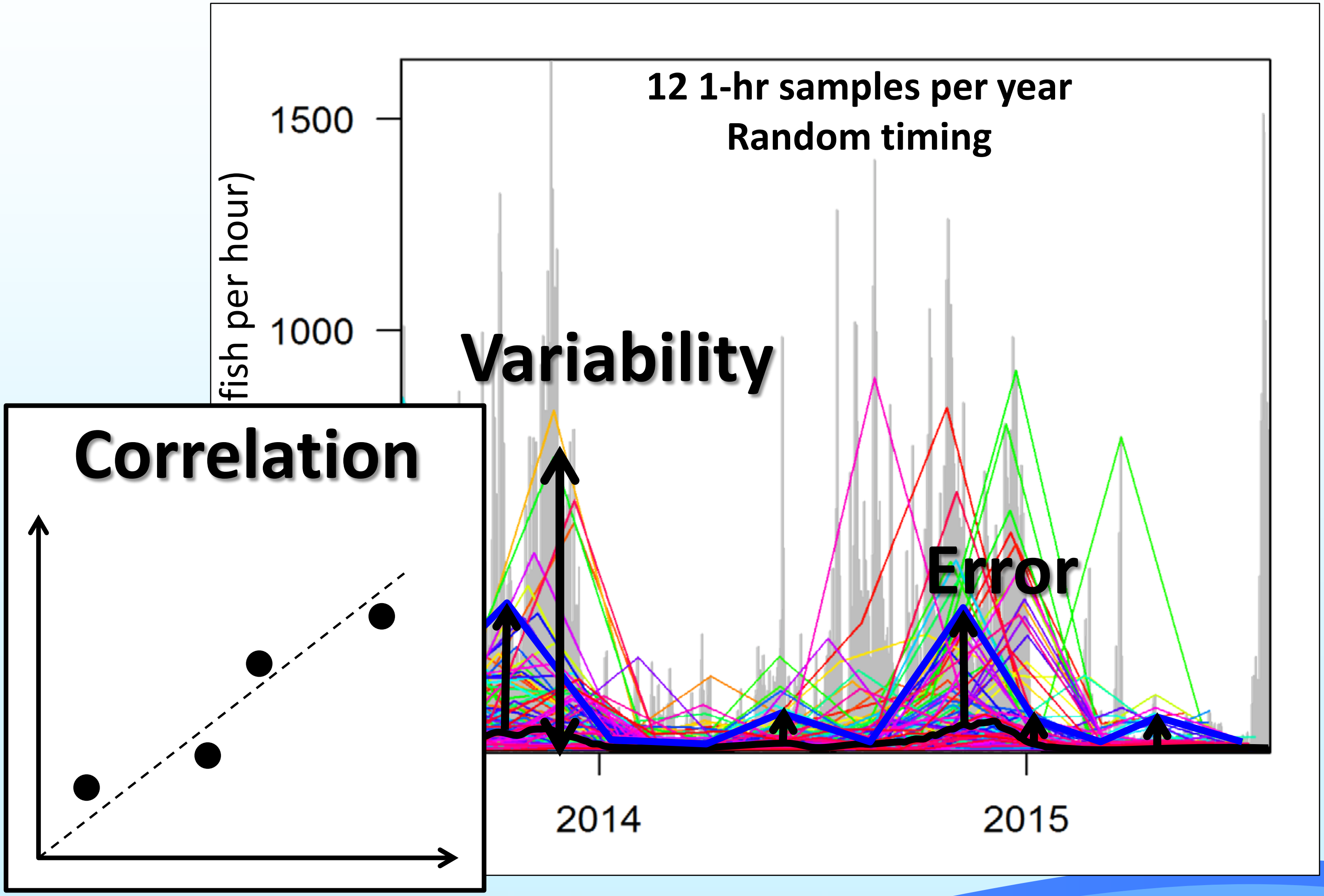

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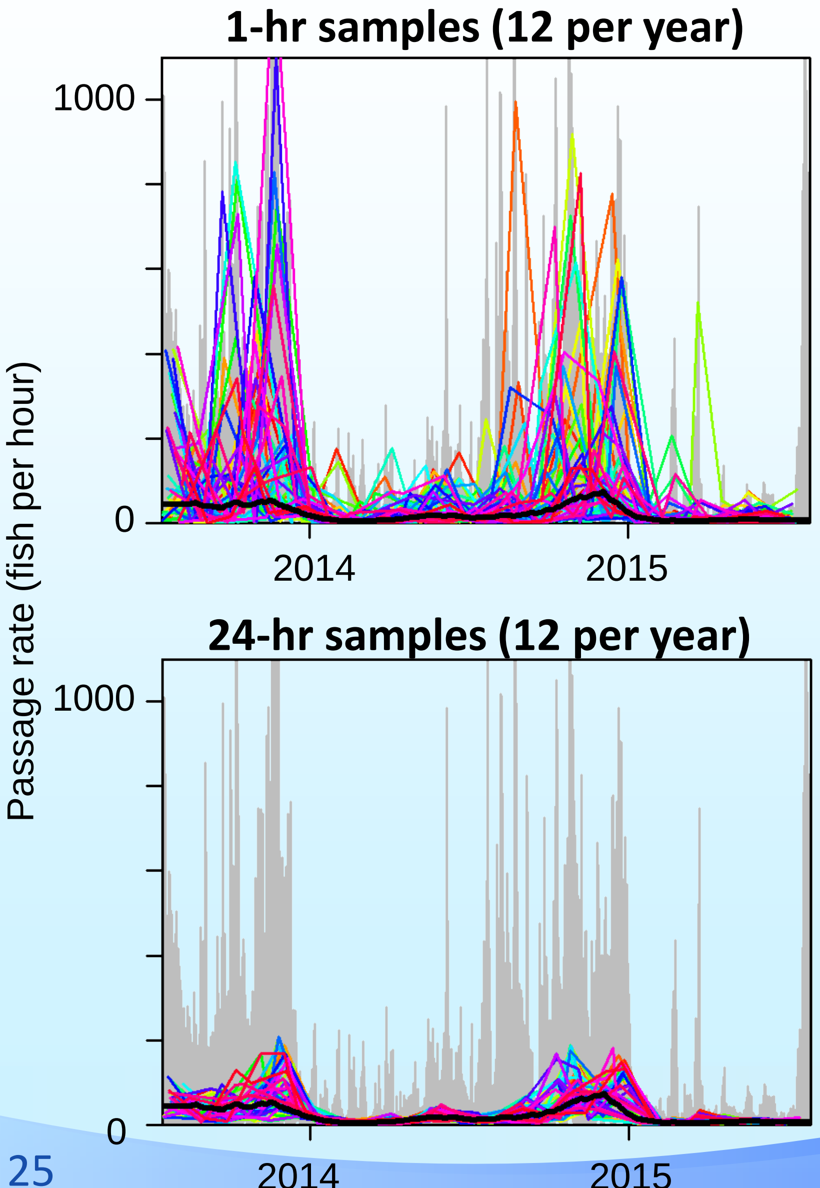

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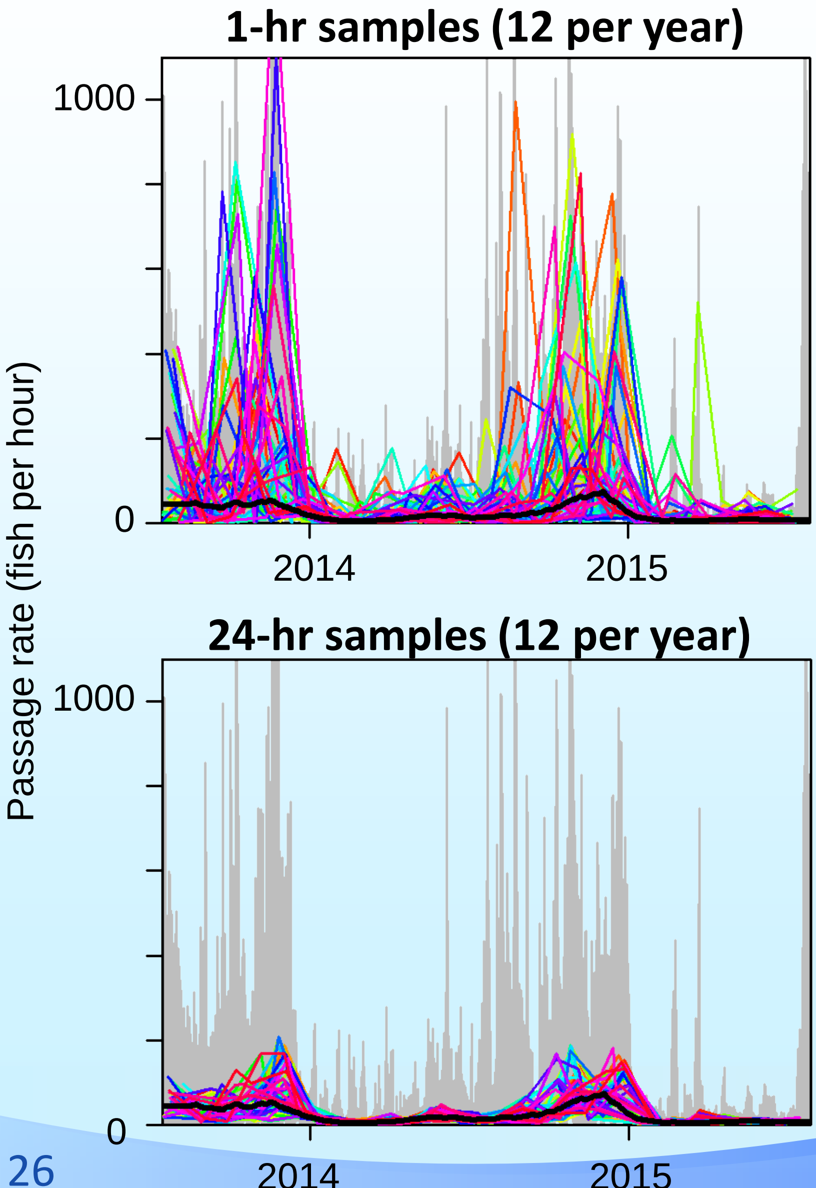

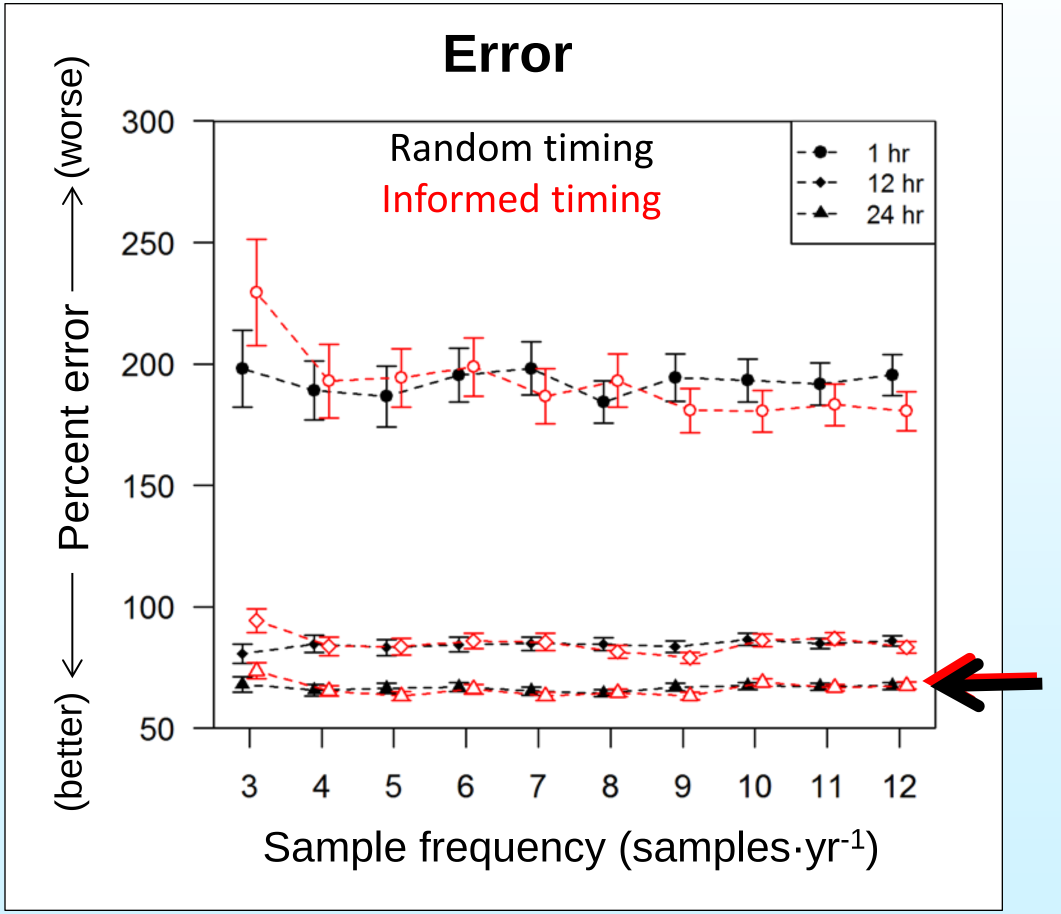

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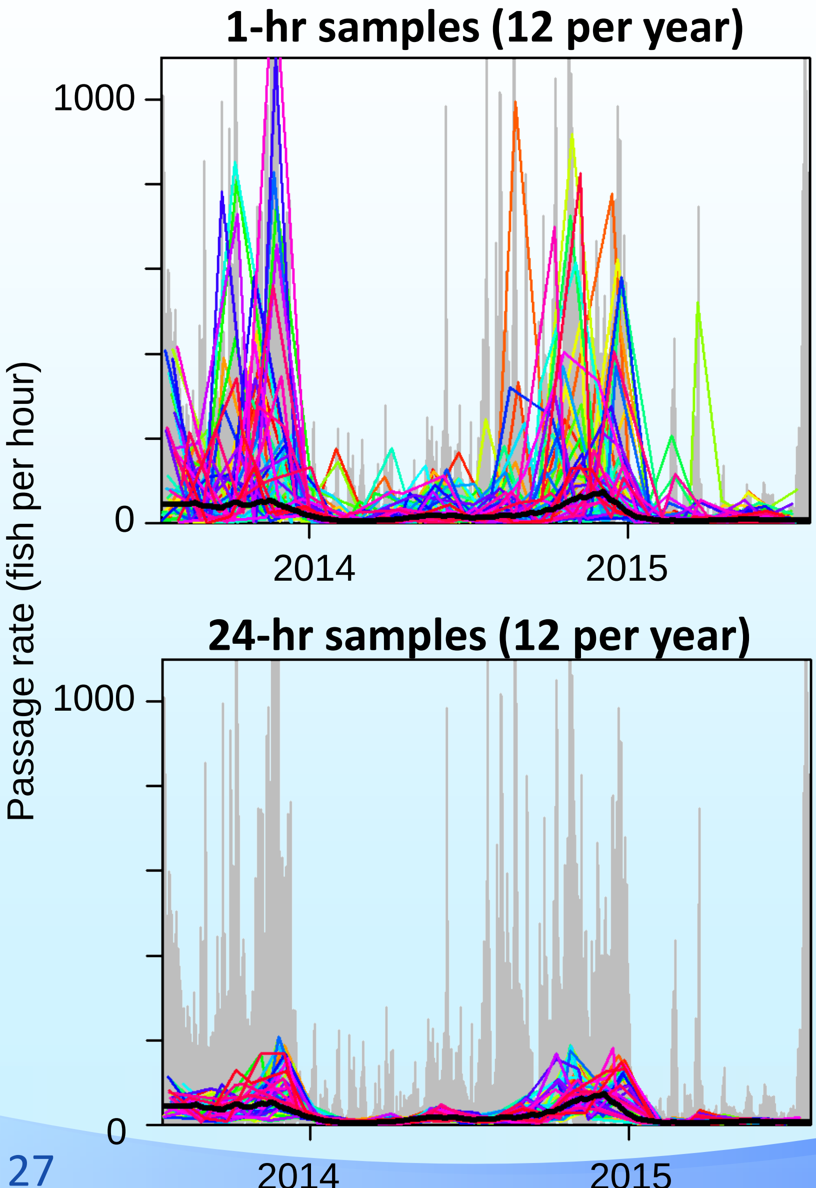

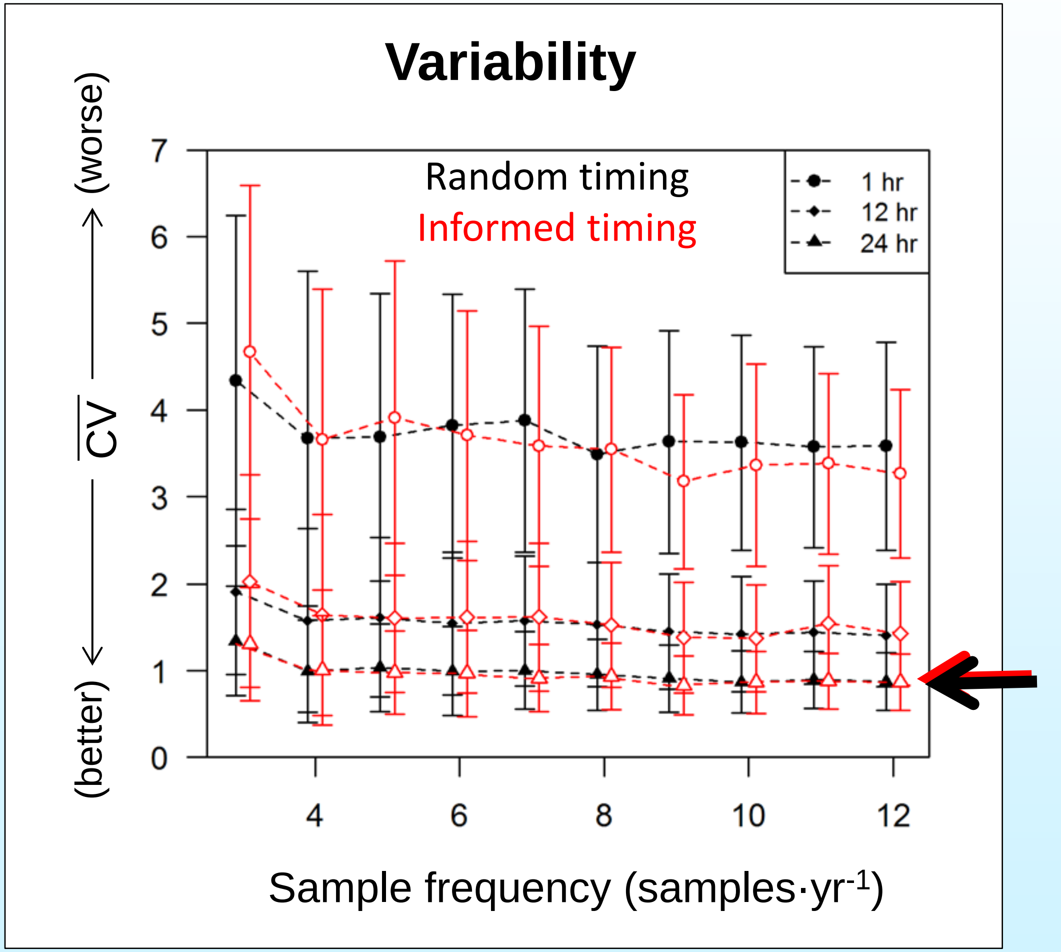

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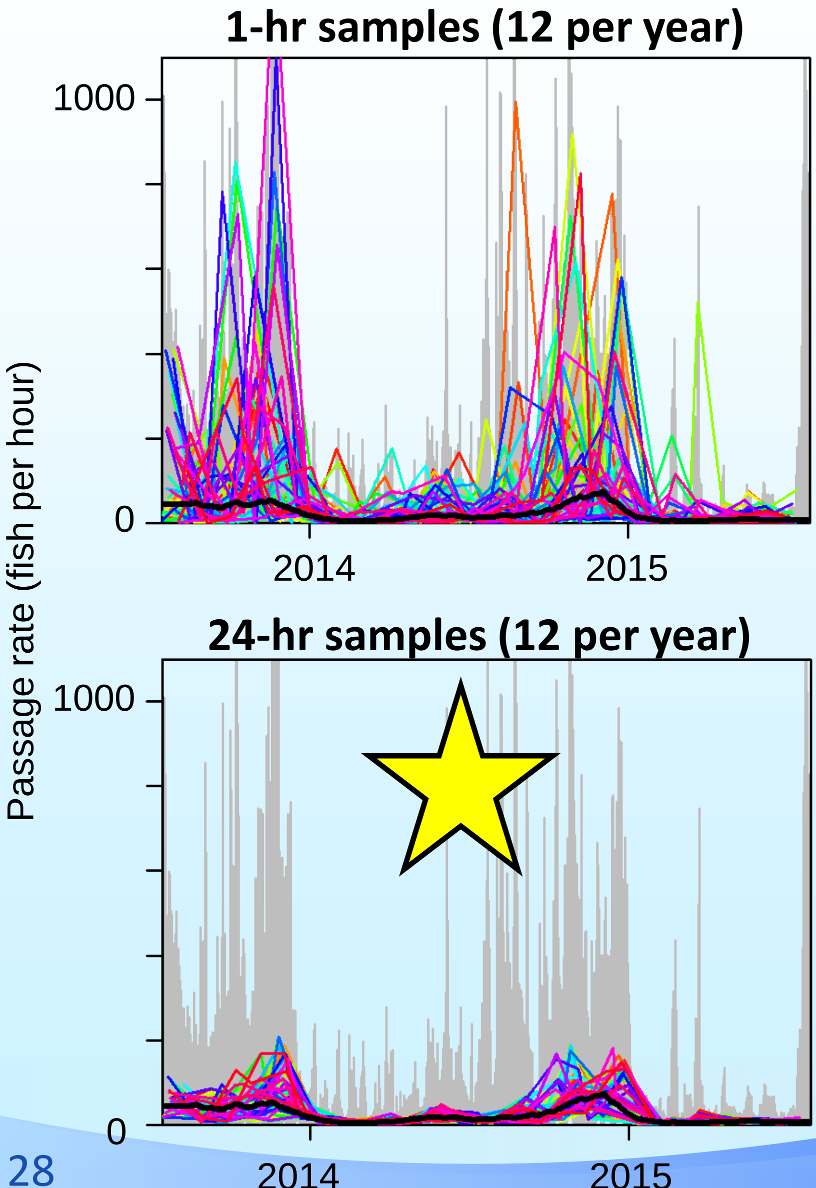

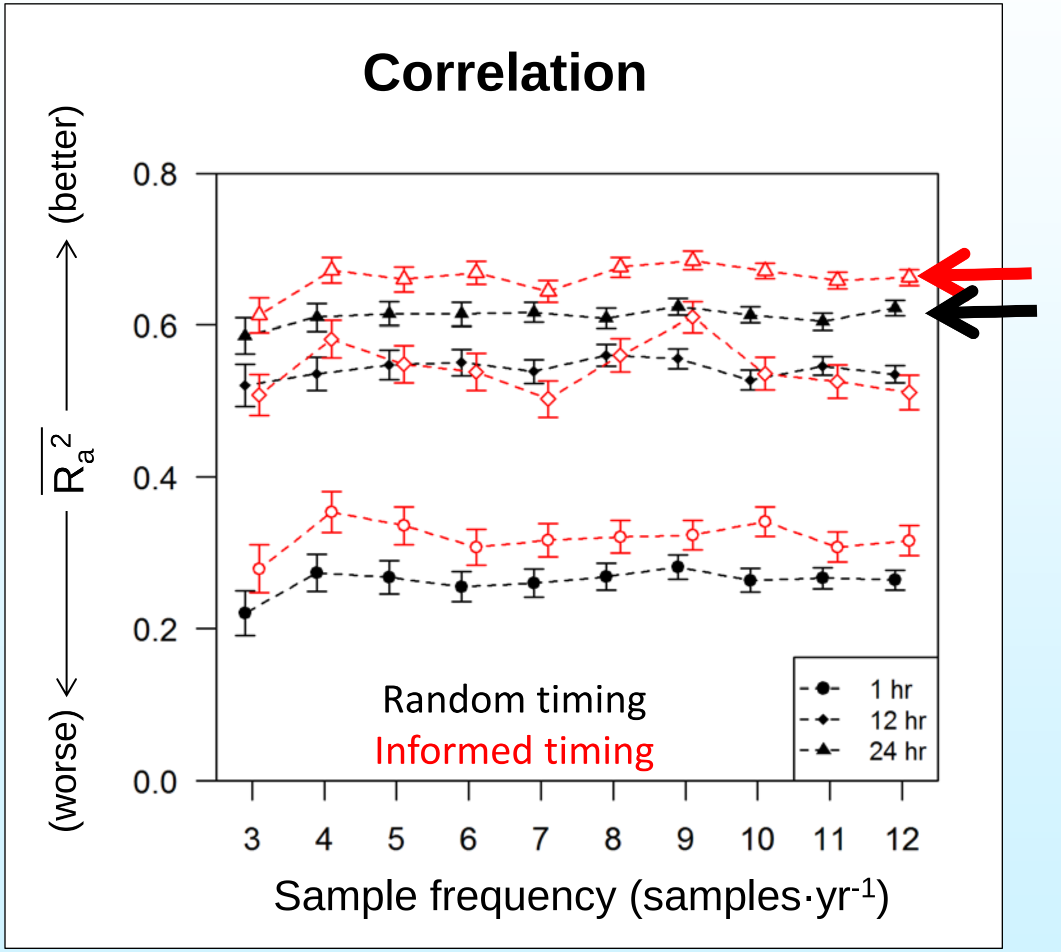

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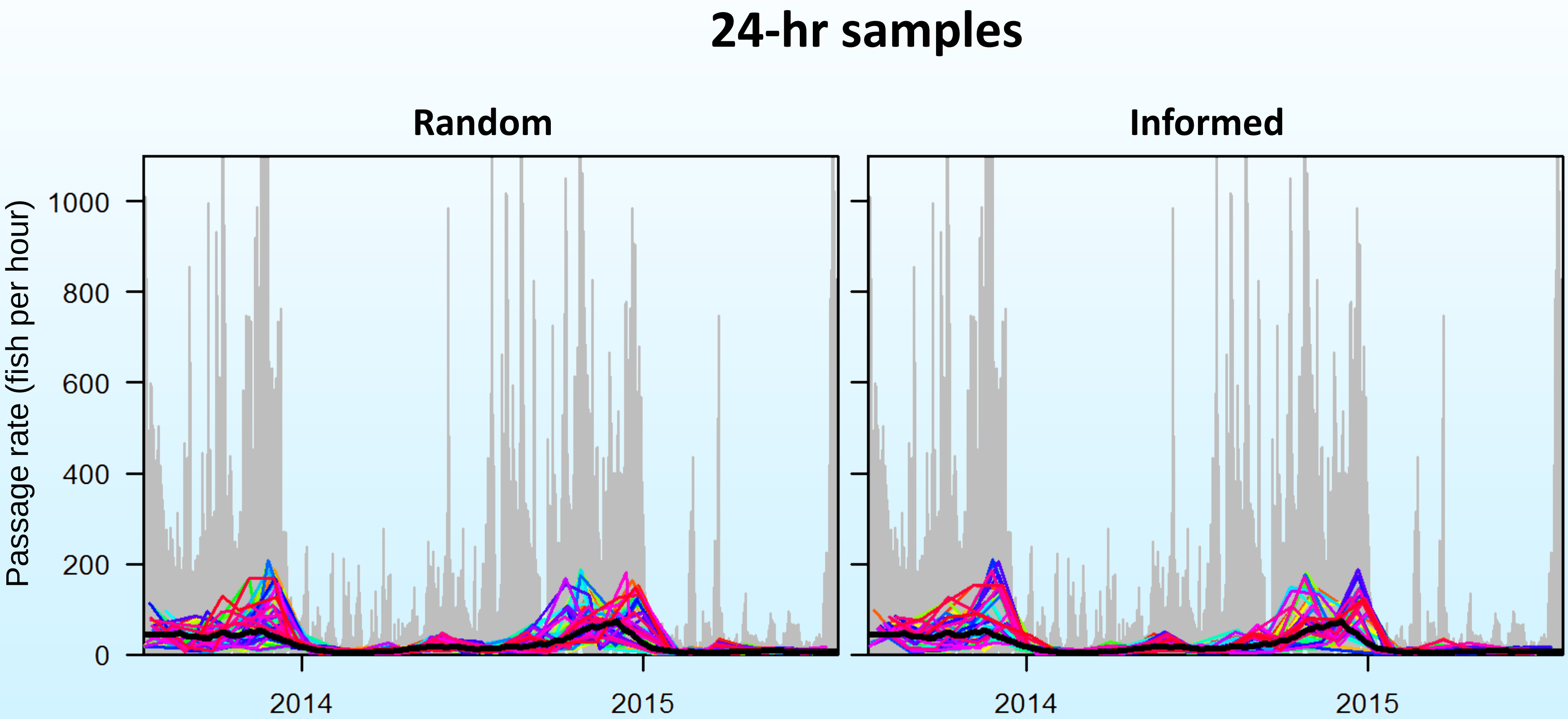

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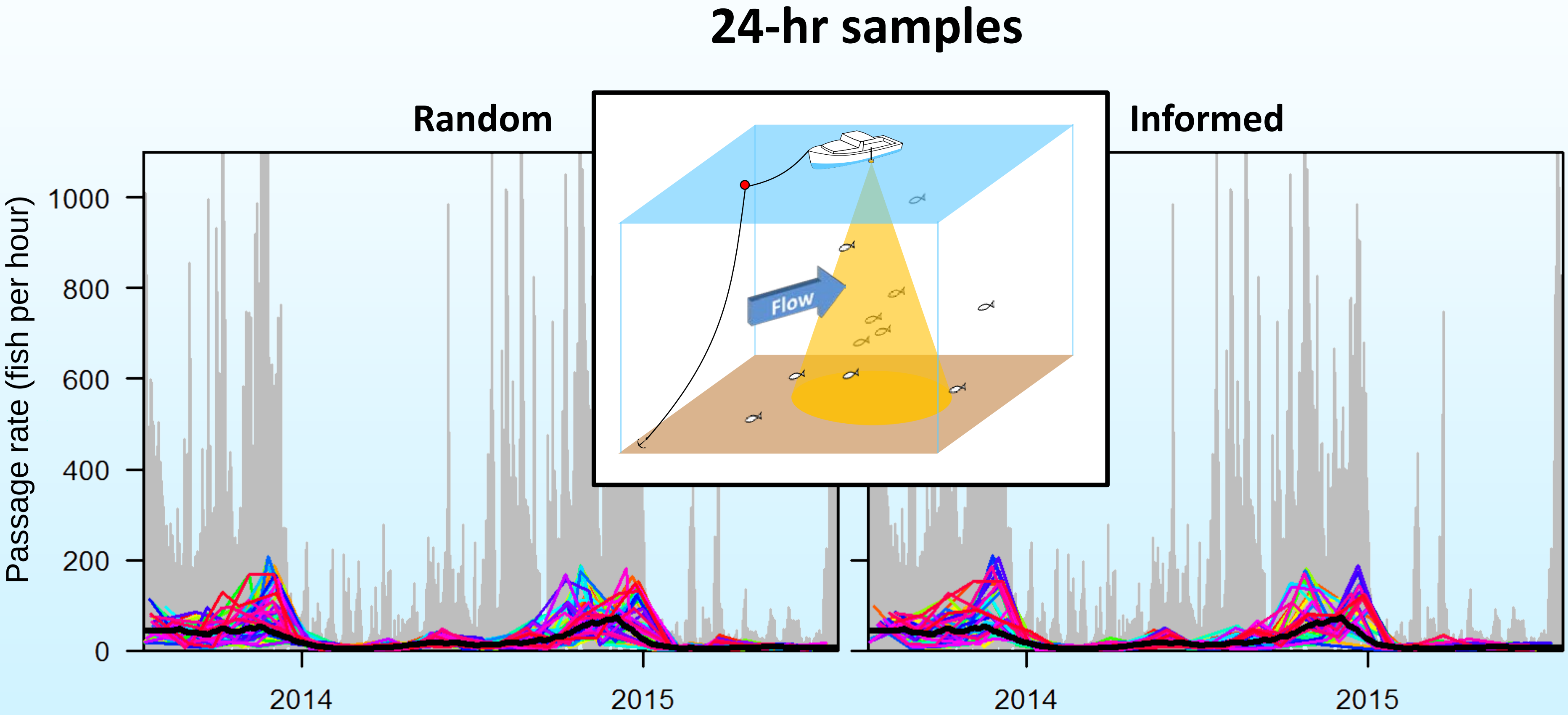
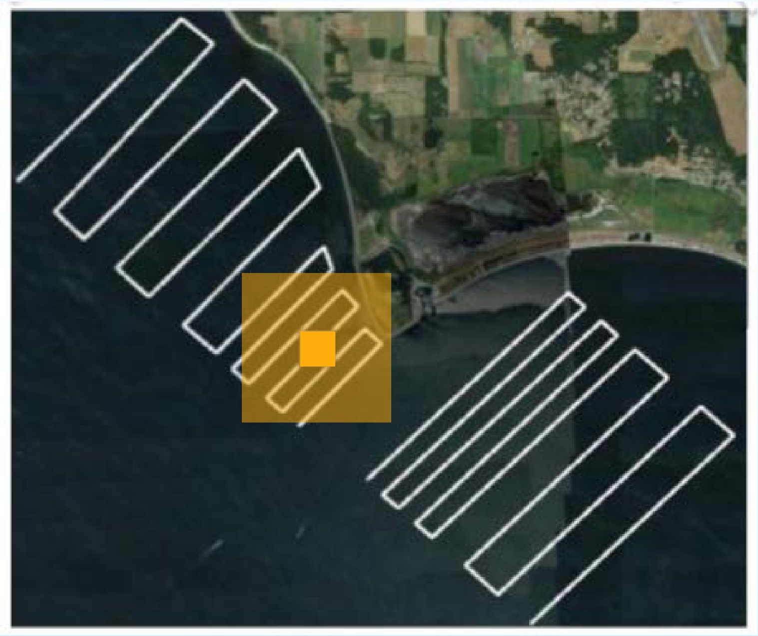


Viehman et al. 2015, Staines et al. 2015

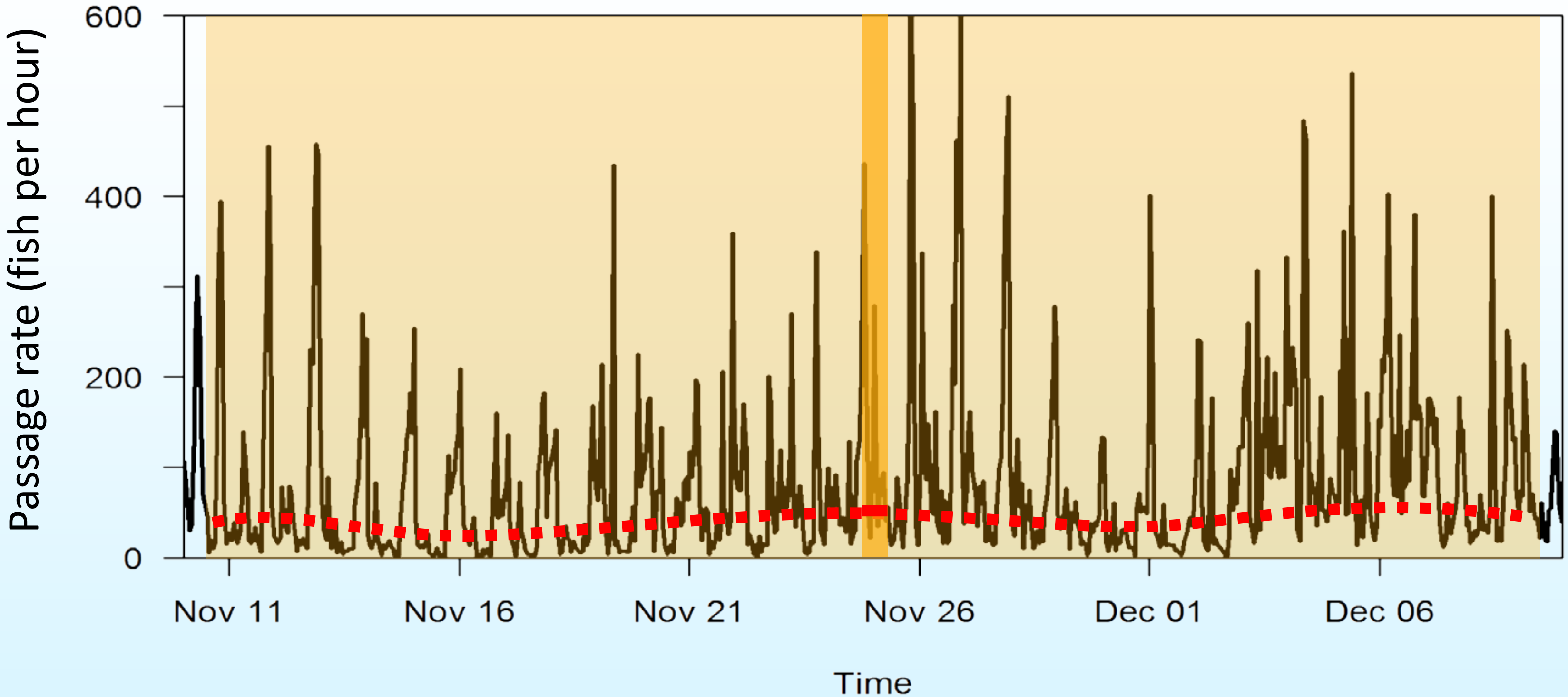
2. Improve study design for site monitoring

How much time is represented by one sample?



Jacques and Horne 2014

2. Improve study design for site monitoring



Sample duration	Time represented
1 hr	72 hr
12 hr	29 days
24 hr	44 days

2. Improve study design for site monitoring

Summary

- Cyclic nature of fish presence can be used in study design to improve results
- 24-hr surveys, timed with lunar cycle, provided best estimate of seasonal changes at this site
- Longer surveys are representative of longer time spans
- Approach likely applicable to other tidal energy sites, which have similar environmental forcing


Thank you!

Thank you

- G.Zydlewski Lab
- The Maine Tidal Power Initiative
- ORPC
- Captain Butch Harris and crew
- Chris Bartlet (Maine Sea Grant)
- Echoview support (Briony Hutton, Toby Jarvis)

References

Broadhurst M, Barr S, Orme CDL (2014) In-situ ecological interactions with a deployed tidal energy device: an observational pilot study. Ocean & Coastal Management 99: 31-38.

Jacques DA, Horne JK (2014) Scaling of spatial and temporal biological variability at marine renewable energy sites. Proceedings of the 2nd Marine Energy Technology Symposium. April 15-18, Seattle, WA.

Staines G, Zydlewski GB, Viehman H, Shen H, McCleave J (2015) Changes in vertical fish distributions near a hydrokinetic device in Cobscook Bay, Maine, USA. Proceedings of the 11th European Wave and Tidal Energy Conference. September 6-11 2015. Nantes, France.

Vieser JD (2014) Collaborative research on finfish, their distribution, and diversity in Cobscook Bay, Maine. Orono: the University of Maine. 135 pp.

Viehman H (2016) Hydroacoustic analysis of the effects of a tidal power turbine on fishes. Orono: the University of Maine. 151 pp.

Viehman H, Zydlewski GB, McCleave J, Staines G (2015) Using acoustics to understand fish presence and vertical distribution in a tidally dynamic region targeted for energy extraction. Estuaries and Coasts 38(Suppl 1): S215-S226.

Presenter

Pacific Northwest NATIONAL LABORATORY
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- Ann Bull, Chief Emeritus, Environmental Sciences Section, Pacific Region Office
  - Bureau of Ocean Energy Management
    - EMF Environmental Effects & Risk

BOEM Bureau of Ocean Energy Management

ACADIA UNIVERSITY

EMF Environmental Effects & Risk

Ann Scarborough Bull, Ph.D.

Speaking by request for
Bureau of Ocean Energy Management
Pacific OCS Region

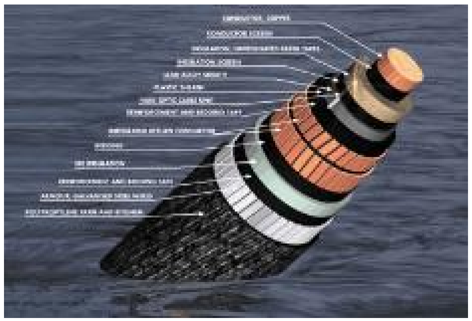
Tethys Annex IV Environmental Webinar
January 18, 2017

Moving Electricity from Offshore to Onshore is a Common Global Technology

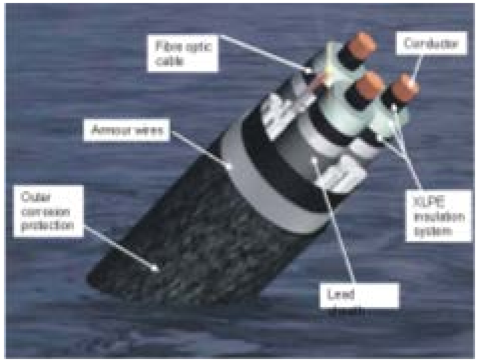
Accomplished via Power Transmission Cables

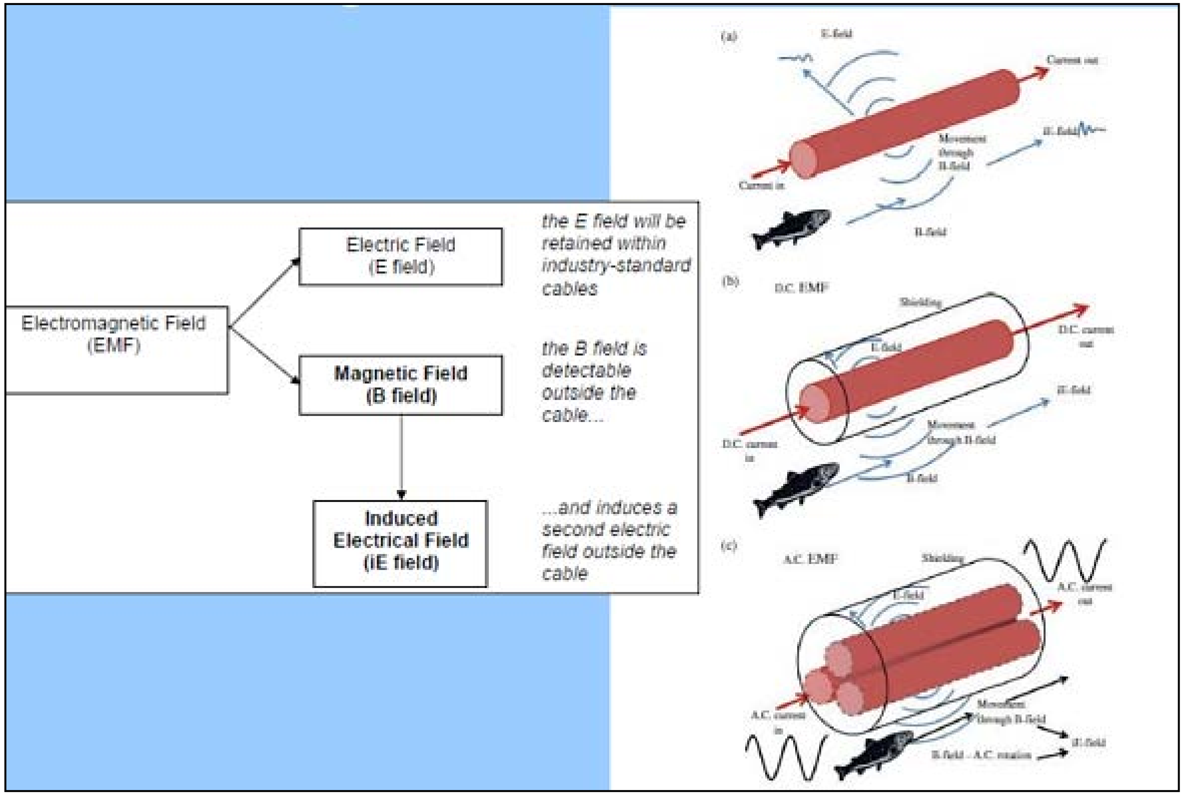
Defining Electromagnetic Fields for AC and DC Power Cables

DC Cable



AC Cable

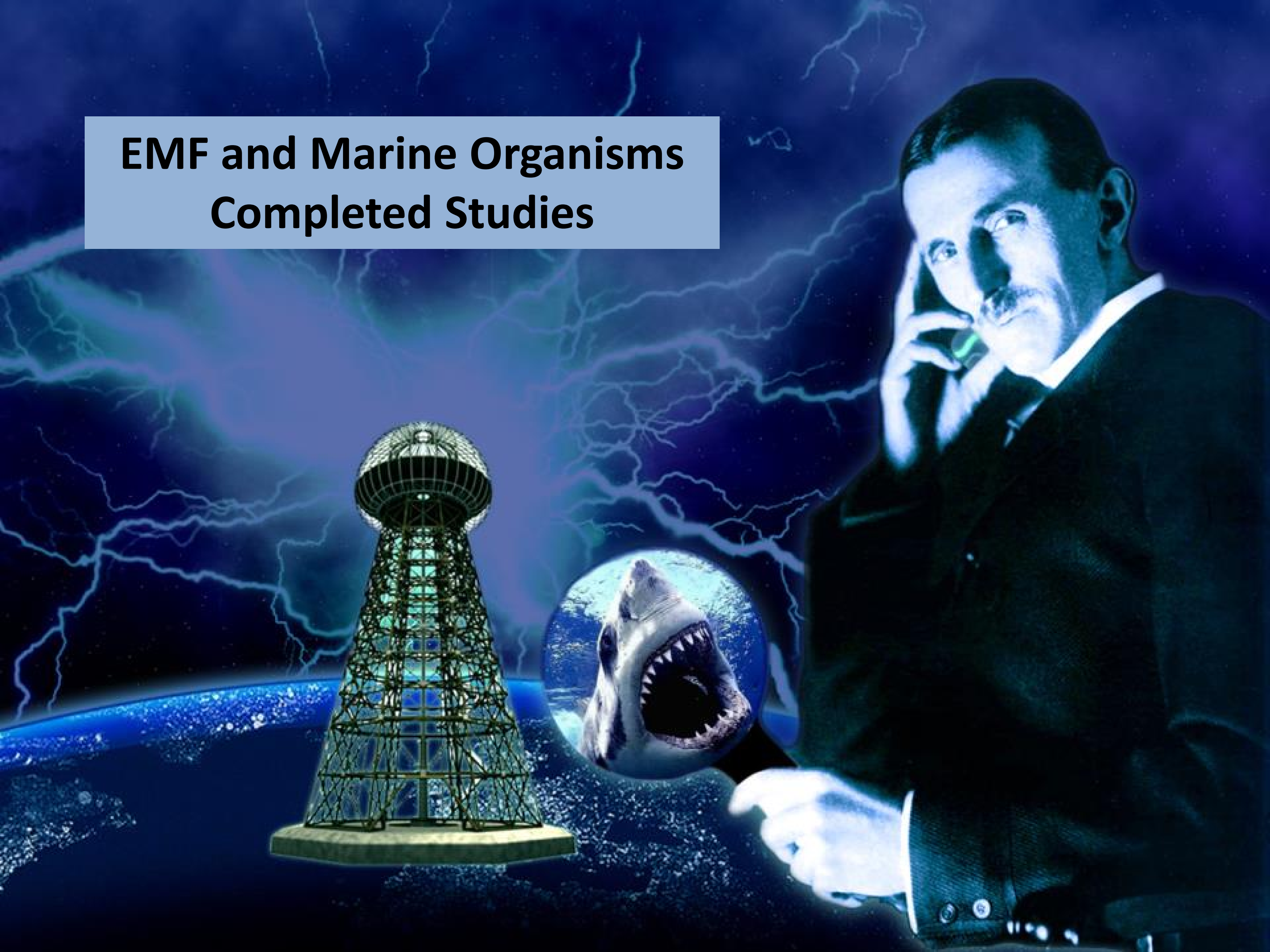




DC

AC

Gill et al. 2009


EMF and Marine Organisms
Completed Studies

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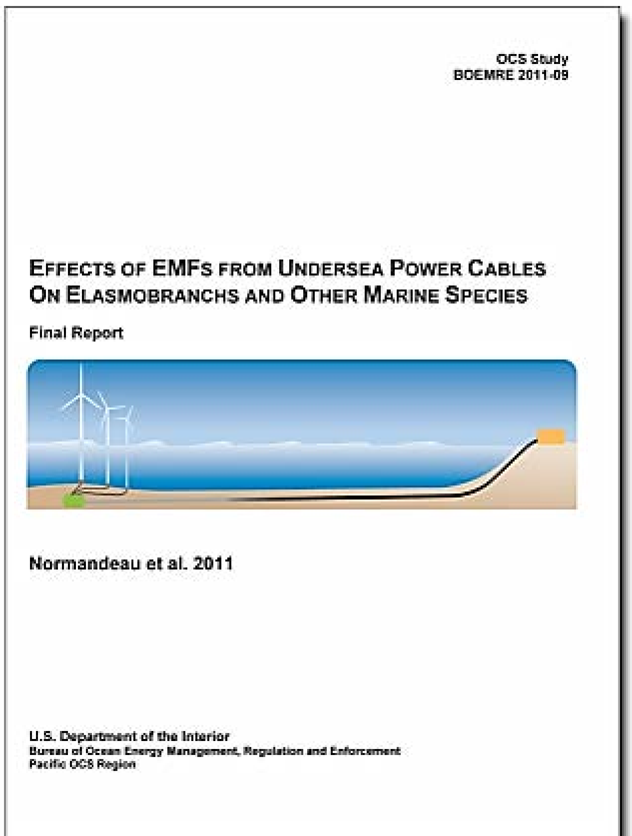
Some Completed Studies Related to EMF

https://tethys.pnnl.gov/stressor/emf

- Effects of EMFs from Undersea Power Cables on Elasmobranchs and Other Marine Species
  www.data.boem.gov/PI/PDFImages/ESPIS/4/5115.pdf
- Effects of Electromagnetic Fields on Fish and Invertebrates
  http://www.pnl.gov/main/publications/external/technical_reports/PNNL-22154.pdf
  http://www.pnl.gov/main/publications/external/technical_reports/PNNL-22154.pdf
  http://www.pnl.gov/main/publications/external/technical_reports/PNNL-22154.pdf
- Sensitive Fish Response to EMF from Sub-Sea Electric Cables
  https://www.thecrownestate.co.uk/media/5924/km-ex-pc-emf-032009-cowrie-20-electromagnetic-fields-emf-phase-2.pdf
- Sub-sea Power Cables and the Migration Behaviour of the European Eel
  https://tethys.pnnl.gov/publications/sub-sea-power-cables-and-migration-behaviour-european-eel
- Renewable Energy *in situ* Power Cable Observation http://www.boem.gov/2016-008/
- Annex IV State of the Science http://tethys.pnnl.gov/publications/state-of-the-science-2016

Effects of EMFs from Undersea Power Cables on Elasmobranchs and Other Marine Species

What does the literature say about EMF? Can the anticipated EMF fit a model?


OCS Study
BOEMRE 2011-09

EFFECTS OF EMFS FROM UNDERSEA POWER CABLES
ON ELASMOBRANCHS AND OTHER MARINE SPECIES

Final Report

Normandeau et al. 2011

U.S. Department of the Interior
Bureau of Ocean Energy Management, Regulation and Enforcement
Pacific OCS Region

Objectives:

- Describe and quantify predicted EMF from power cables connected to offshore renewable energy projects.
- Compile information on sensitive marine species that have the potential for exposure effects.
- Understand sensitive marine species and the potential effects of exposure to EMF from offshore power cables.

Normandeau et al. 2011

Some Findings from Literature Study

- Anticipated EMFs from power cables can be modeled easily if specific information is available:
  - Cable design
  - Anticipated burial depth and layout
  - Magnetic permeability of the sheathing
  - Anticipated electrical loading range

- Behavioral responses to and some effects from electro- or magnetic fields are known for a few species; extrapolation to many other species or to population impacts is speculative.

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Effects of Electromagnetic Fields on Fish and Invertebrates

What do laboratory experiments say?

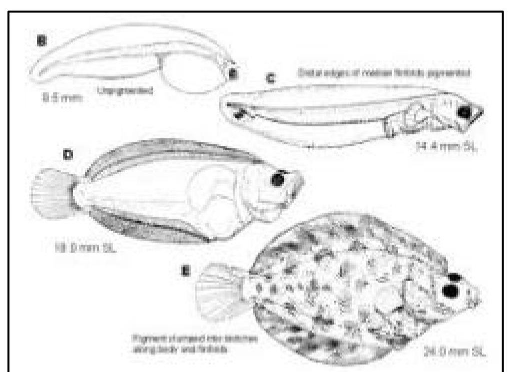
Objectives:

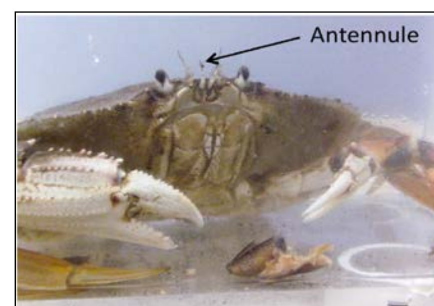
- Describe and quantify predicted EMF from power cables connected to offshore renewable energy projects.
- Compile information on sensitive marine species that have the potential for exposure effects.
- Understand sensitive marine species and the potential effects of exposure to EMF from offshore power cables.
- Perform experiments under tightly controlled conditions in the laboratory.

Schultz et al. 2010
Wilson and Woodruff 2011
Woodruff et al. 2013

Some Findings from the Laboratory Studies

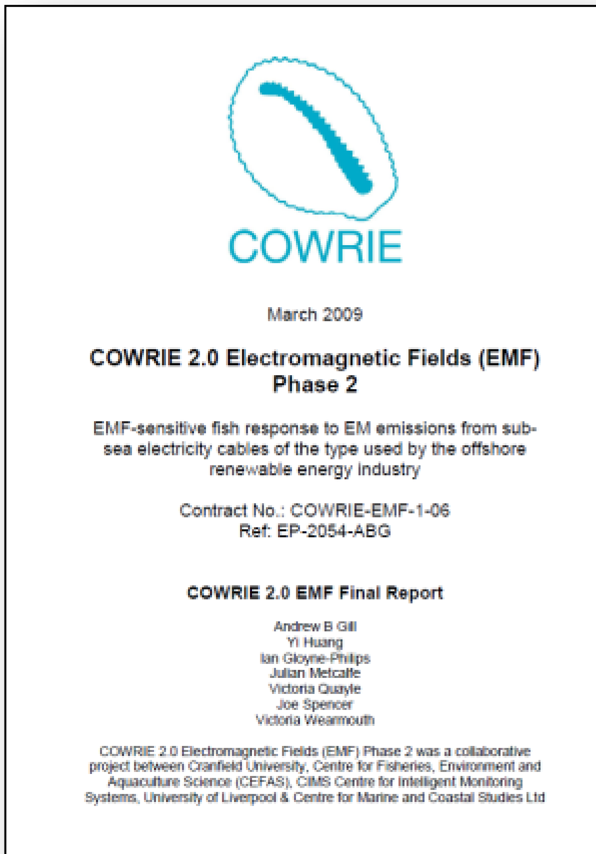
- Little evidence to indicate distinct or extreme behavioral responses in the presence of elevated EMF at 3 mT (3000 µT) for the species tested.
- Several developmental and physiological responses were observed in the fish exposures, although most were not statistically significant.
- Several movement and activity responses were observed in the crab experiments.
- There may be possible developmental and behavioral responses to even small environmental effects; however, further replication is needed in the laboratory as well as field verification.





EMF-Sensitive Fish Response to EM Emissions from Subsea Electricity Cables of the Type Used by the Offshore Renewable Energy Industry

What does a mesocosm study say?



COWRIE

March 2009

COWRIE 2.0 Electromagnetic Fields (EMF) Phase 2

EMF-sensitive fish response to EM emissions from sub-sea electricity cables of the type used by the offshore renewable energy industry

Contract No.: COWRIE-EMF-1-06
Ref: EP-2054-ABG

COWRIE 2.0 EMF Final Report

Andrew B Gill
Yi Huang
Ian Gloyne-Philips
Julian Metcalfe
Victoria Quayle
Joe Spencer
Victoria Wearmouth

COWRIE 2.0 Electromagnetic Fields (EMF) Phase 2 was a collaborative project between Cranfield University, Centre for Fisheries, Environment and Aquaculture Science (CEFAS), CIMS Centre for Intelligent Monitoring Systems, University of Liverpool & Centre for Marine and Coastal Studies Ltd

Objectives:

Determine response of electromagnetically sensitive organisms to anthropogenic EMF.

- Test if electromagnetically (EM) sensitive organisms respond to anthropogenic EMFs expected from offshore wind farms.
- Conduct the study under *in situ* controlled coastal conditions to improve its applicability to the actual offshore situation.
- Create a mesocosm experiment to mimic the EMF type and magnitude generated by offshore wind farms.

Gill et al. 2009

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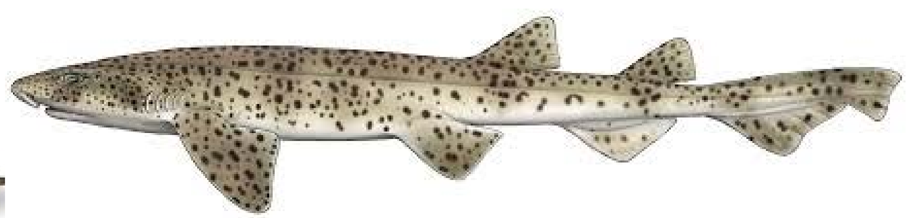
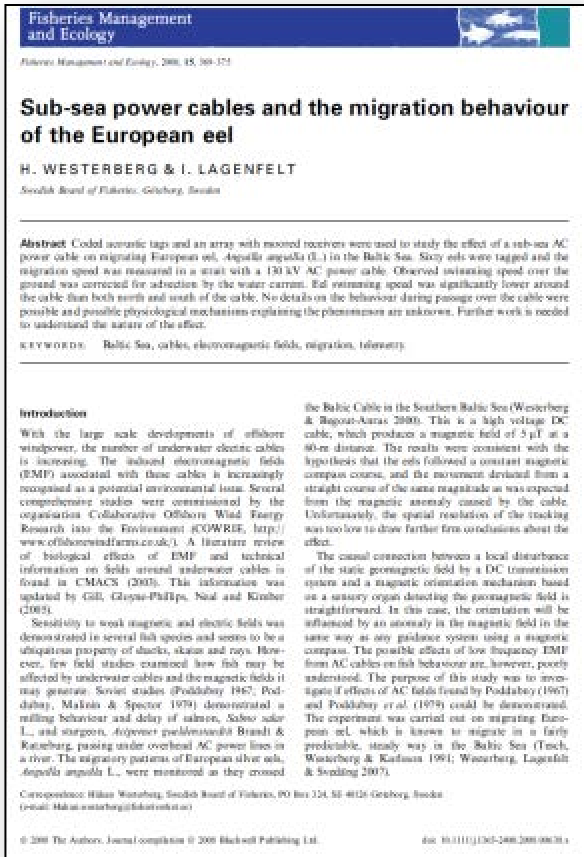
Some Findings from Mesocosm Study

- There is no evidence from the study to suggest any positive or negative effect on elasmobranchs from the encountered EMF.
- The benthic elasmobranchs species did respond to the presence of EMF emitted by the sub-sea cable.
- Target monitoring would be considerably cheaper than a catch-all comprehensive fishery survey to determine changes in numbers, demographics of populations, and recruitment.
- The use of large-scale mesocosms (40m x 5m) with replicate studies and the inclusion of a control are a feasible way of understanding environmental effects at a scale appropriate to the marine renewable energy sector.



Sub-sea Power Cables and the Migration Behaviour of the European Eel

What does a migration study say?



Fisheries Management and Ecology

Fisheries Management and Ecology, 2008, 15, 369–375

Sub-sea power cables and the migration behaviour of the European eel

H. WESTERBERG & I. LAGENFELT

Swedish Board of Fisheries, Göteborg, Sweden

Abstract Coded acoustic tags and an array with moored receivers were used to study the effect of a sub-sea AC power cable on migrating European eel, *Anguilla anguilla* (L.) in the Baltic Sea. Sixty eels were tagged and the migration speed was measured in a strait with a 130 kV AC power cable. Observed swimming speed over the ground was corrected for advection by the water current. Eel swimming speed was significantly lower around the cable than both north and south of the cable. No details on the behaviour during passage over the cable were possible and possible physiological mechanisms explaining the phenomenon are unknown. Further work is needed to understand the nature of the effect.

KEYWORDS: Baltic Sea, cables, electromagnetic fields, migration, telemetry.

Introduction

With the large scale developments of offshore windpower, the number of underwater electric cables is increasing. The induced electromagnetic fields (EMF) associated with these cables is increasingly recognised as a potential environmental issue. Several comprehensive studies were commissioned by the organisation Collaborative Offshore Wind Energy Research into the Environment (COWRIE, http://www.offshorewindfarms.co.uk/). A literature review of biological effects of EMF and technical information on fields around underwater cables is found in CMACS (2003). This information was updated by Gill, Gloyne-Phillips, Neal and Kimber (2005).

Sensitivity to weak magnetic and electric fields was demonstrated in several fish species and seems to be a ubiquitous property of sharks, skates and rays. However, few field studies examined how fish may be affected by underwater cables and the magnetic fields it may generate. Soviet studies (Poddubny 1967; Poddubny, Malinin & Spector 1979) demonstrated a milling behaviour and delay of salmon, *Salmo salar* L., and sturgeon, *Acipenser gueldenstaedtii* Brandt & Ratzeburg, passing under overhead AC power lines in a river. The migratory patterns of European silver eels, *Anguilla anguilla* L., were monitored as they crossed the Baltic Cable in the Southern Baltic Sea (Westerberg & Begout-Anras 2000). This is a high voltage DC cable, which produces a magnetic field of 5 μT at a 60-m distance. The results were consistent with the hypothesis that the eels followed a constant magnetic compass course, and the movement deviated from a straight course of the same magnitude as was expected from the magnetic anomaly caused by the cable. Unfortunately, the spatial resolution of the tracking was too low to draw further firm conclusions about the effect.

The causal connection between a local disturbance of the static geomagnetic field by a DC transmission system and a magnetic orientation mechanism based on a sensory organ detecting the geomagnetic field is straightforward. In this case, the orientation will be influenced by an anomaly in the magnetic field in the same way as any guidance system using a magnetic compass. The possible effects of low frequency EMF from AC cables on fish behaviour are, however, poorly understood. The purpose of this study was to investigate if effects of AC fields found by Poddubny (1967) and Poddubny *et al.* (1979) could be demonstrated. The experiment was carried out on migrating European eel, which is known to migrate in a fairly predictable, steady way in the Baltic Sea (Tesch, Westerberg & Karlsson 1991; Westerberg, Lagenfelt & Svedäng 2007).

Correspondence: Håkan Westerberg, Swedish Board of Fisheries, PO Box 324, SE-40126 Göteborg, Sweden (e-mail: hakan.westerberg@fiskeriverket.se)

doi: 10.1111/j.1365-2400.2008.00630.x

Objectives:

- Investigate if the effects of 130 kV AC fields on fish behaviour could be demonstrated.
- Use acoustic tags and a receiver array to study the effect of a sub-sea AC cable on fish migration.
- Investigate possible effects of low-frequency EMF from AC cables on eel migration behaviour.

Westerberg and Lagenfelt 2008

Some Findings from the Eel Migration Study

- Eels swam slower crossing an unburied 130 kV AC cable during migration and slower speed was related to EMF.
- The effect of the cable on eels was small.
- There was no evidence that the cable was an obstruction to eel migration.
- The experimental technique using sonic tags in an array with fixed receivers is able to detect even small environmental effects.

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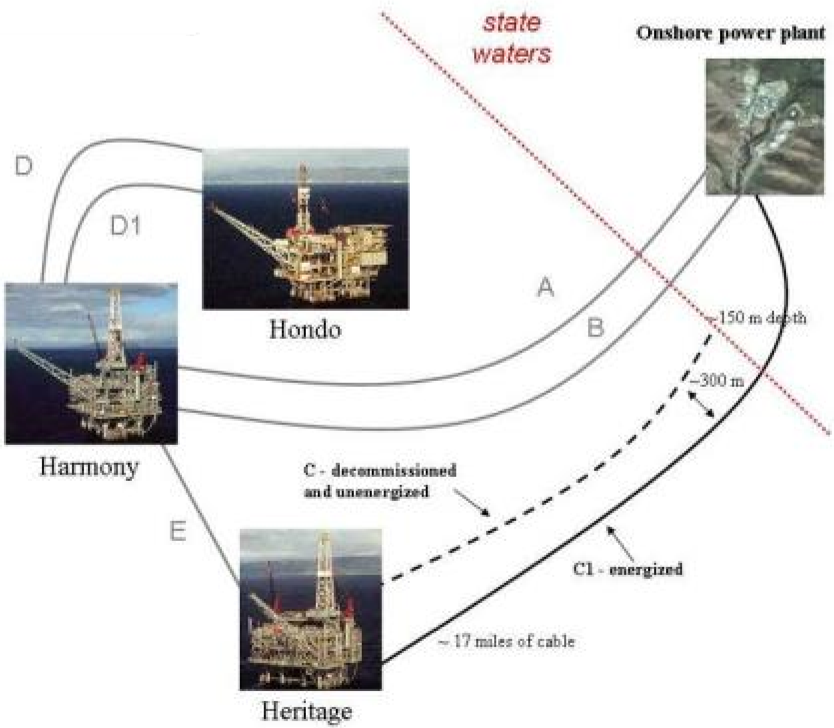
Renewable Energy *in situ* Power Cable Observation

What does an observational study say?



Identical 35 kV AC power cables carrying a usual load of 17 to 18 MW and occasionally as high as 26 MW

Objectives:

- Measure the strength, spatial extent, and variability of EMF along both energized and unenergized cables.
- Determine attraction/repulsion of fish and macroinvertebrates to the EMF from the power cables.
- Determine the effectiveness of the commonly proposed mitigation of cable burial.

Love et al. 2016

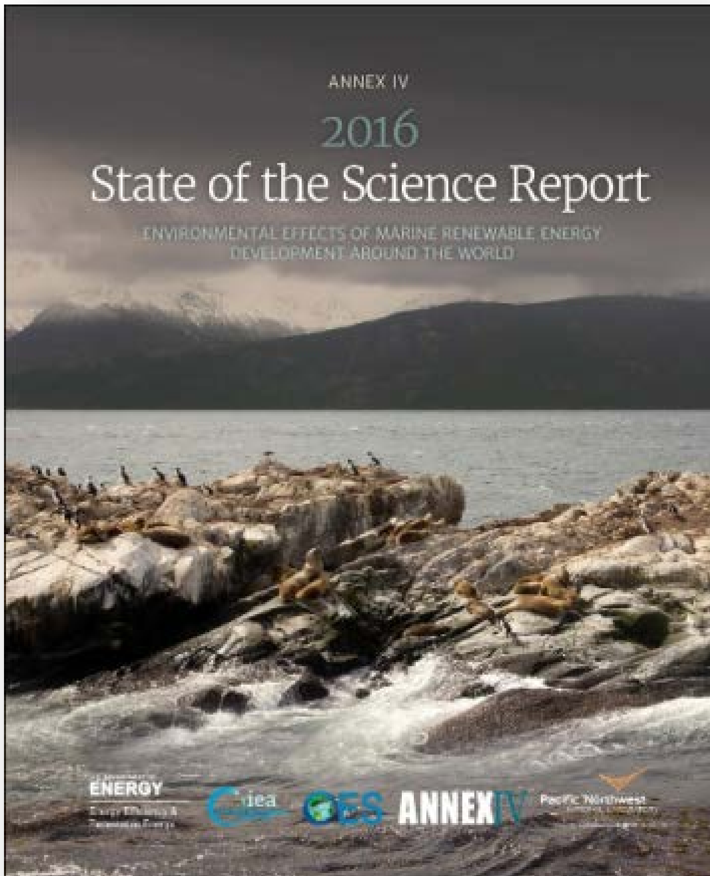
Some Findings from *in situ* Study

- No response (attraction/repulsion) from fish or macroinvertebrates to EMF from a 35 kV AC *in situ* power transmission cable.
- At a usual electricity load of 17 to 18 MW, and occasionally as high as 26 MW, the mean value EMF was 109-120 µT (~0.11 - 0.12 mT) directly on the 35 kV energized cable.
- Carrying no electricity load, the mean value EMF was 0.5 µT directly on the unenergized cable, which is approaching background value.
- The scalar magnitude of the magnetic field diminishes to background levels at 1m from the energized cable.
- Actual EMF measured on and away from the cables closely fit the model results found in Normandeau 2011 EMF study.
- Apparent lack of response would indicate burial is not always essential for biological reasons; however, burial could be used as mitigation to further decrease potential exposure.

2016 State of the Science Report

Environmental Effects of Marine Renewable Energy Development Around the World

What does a major literature update say about EMF?



Objectives:

- Summarize the state of the science of integrations and effects of marine renewable energy devices on the marine environment.
- Update and complement prior Annex IV reports.
- Present case studies that examine siting/permitting/consenting of marine renewables.

https://tethys.pnnl.gov/stressor/emf

EMF and Marine Organisms
Ongoing Studies

Some Ongoing Field Studies Testing EMF Effects at AC and DC Power Cables on the Seafloor

https://tethys.pnnl.gov/stressor/emf

- Electromagnetic Field Impacts on Elasmobranch and American Lobster Movement and Migration from Direct Current Cables
  http://www.boem.gov/EMF-Impacts-on-Elasmobranch-and-American-Lobster/

- Potential Impacts of Submarine Power Cables on Crab Harvest
  http://www.boem.gov/pc-14-02/

- Assessment of Potential Impact of Electromagnetic Fields (EMF) from Undersea Cable on Migratory Fish Behavior
  http://energy.gov/sites/prod/files/2014/04/f14/CX-011385.pdf

- Characterization of EMF Emissions from Submarine Cables and Monitoring for Potential Responses of Marine Species
  https://tethys.pnnl.gov/publications/characterization-emf-emissions-submarine-cables-and-monitoring-potential-responses

Electromagnetic Field Impacts on Elasmobranch and American Lobster Movement and Migration from Direct Current Cables

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Objectives:

Determine if animals sensitive to EMF will behave abnormally near a HVDC cable.

- Synthesize existing information that updates BOEM report 2011-09 .
- Design and execute a field survey plan that will detect statistically significant, very small effects of EMF from HVDC cables on marine species of concern.
- Develop a model to predict EMF, compare the model predictions with field measurements, and evaluate whether the model can be extrapolated to future higher capacity cables.

Electromagnetic Field Impacts on Elasmobranch and American Lobster Movement and Migration from Direct Current Cables

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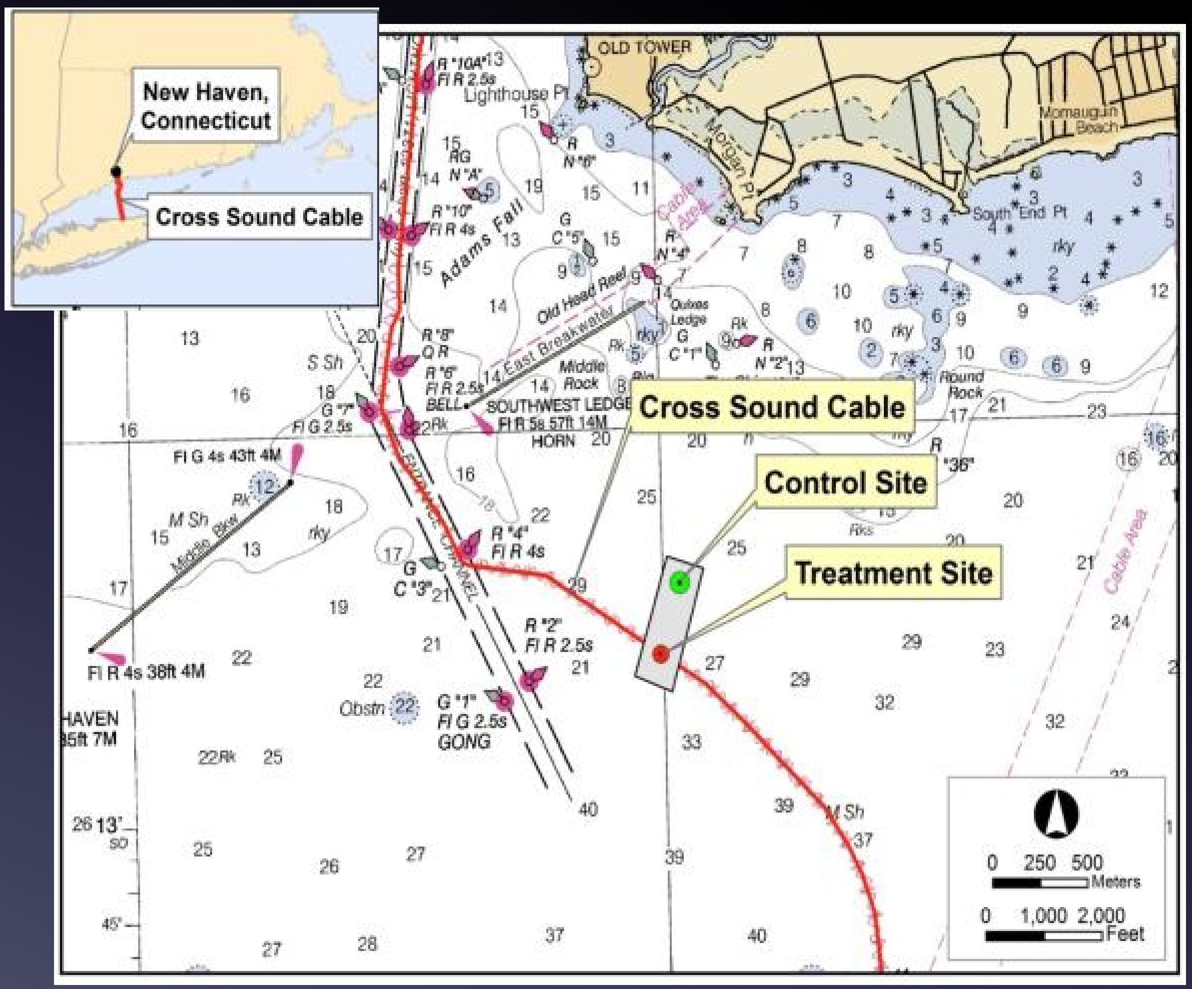

- Map cable EMF with high resolution “SEMLA” sensor, consisting of 3-axis electrode and fluxgate magnetometer.
- Situate submerged animal enclosures at high EMF location and at a nearby control site.
- Release 5 animals (lobsters or skates) into enclosure; record animal movement using acoustic tags on organisms and a hydrophone-based telemetry system.

Electromagnetic Field Impacts on Elasmobranch and American Lobster Movement and Migration from Direct Current Cables

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Deployment of Animal Enclosures and Electronics/Diving Platforms, August 2016

- Two enclosures: 1) “Treatment Site” on the Cross Sound Cable 2) “Control Site” (~ 360 meters from cable)
- Animal monitoring equipment housed on support platform moored at each location
- Divers assist with initial positioning of the submerged enclosure, and exchanging populations of test animals

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Potential Impacts of Submarine Power Cables on Crab Harvest

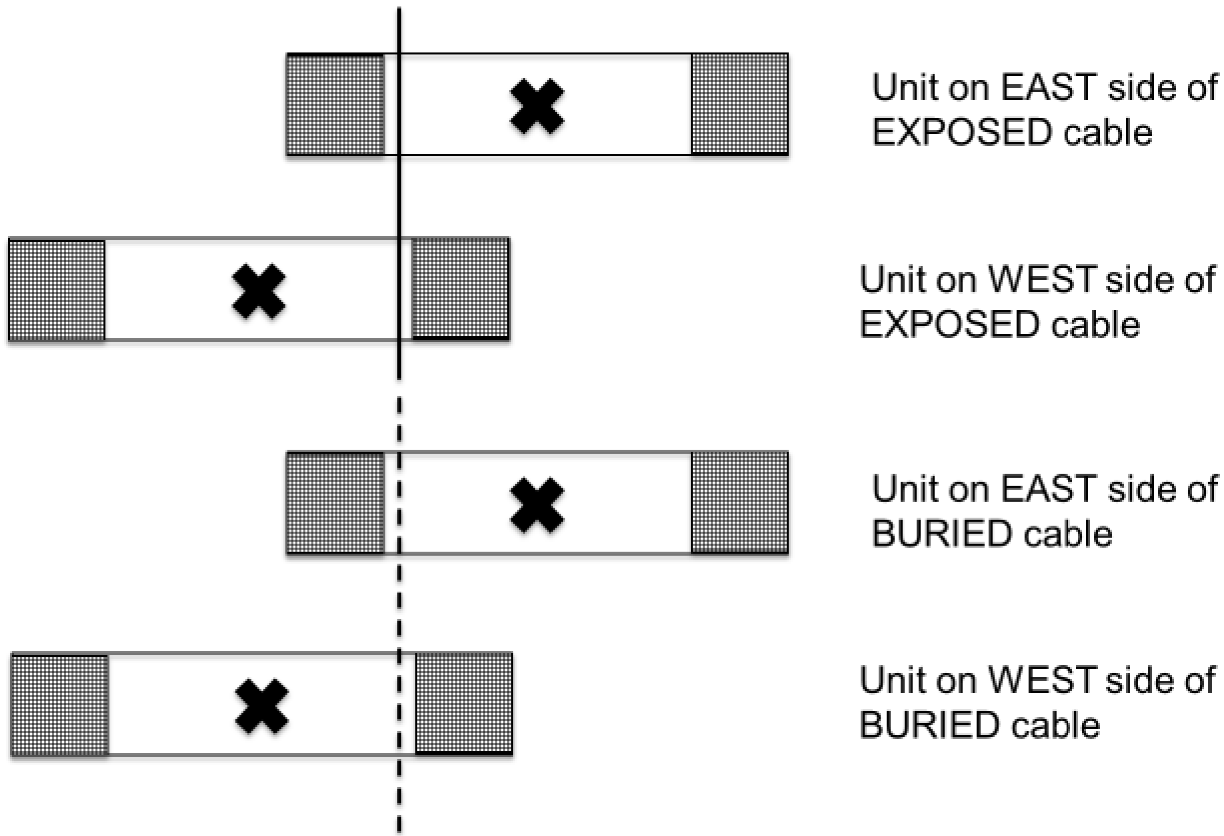
Will EMF from a power cable affect commercial crab harvest?

Objectives:

- Determine if rock crab and dungeness crab will cross a power cable and be caught in commercial baited traps.
- Expose rock crabs to 35 kV AC power cable with response choice in Santa Barbara Channel.
- Expose dungeness crabs to 69 kV AC power cables with response choice in Puget Sound.
- Determine likely impact on harvest for assessment documents and planning.

EXPERIMENTAL SET UP IN BOTH STUDY AREAS

12 units, 3 replicates of each of 4 test conditions, were randomly placed along the cable



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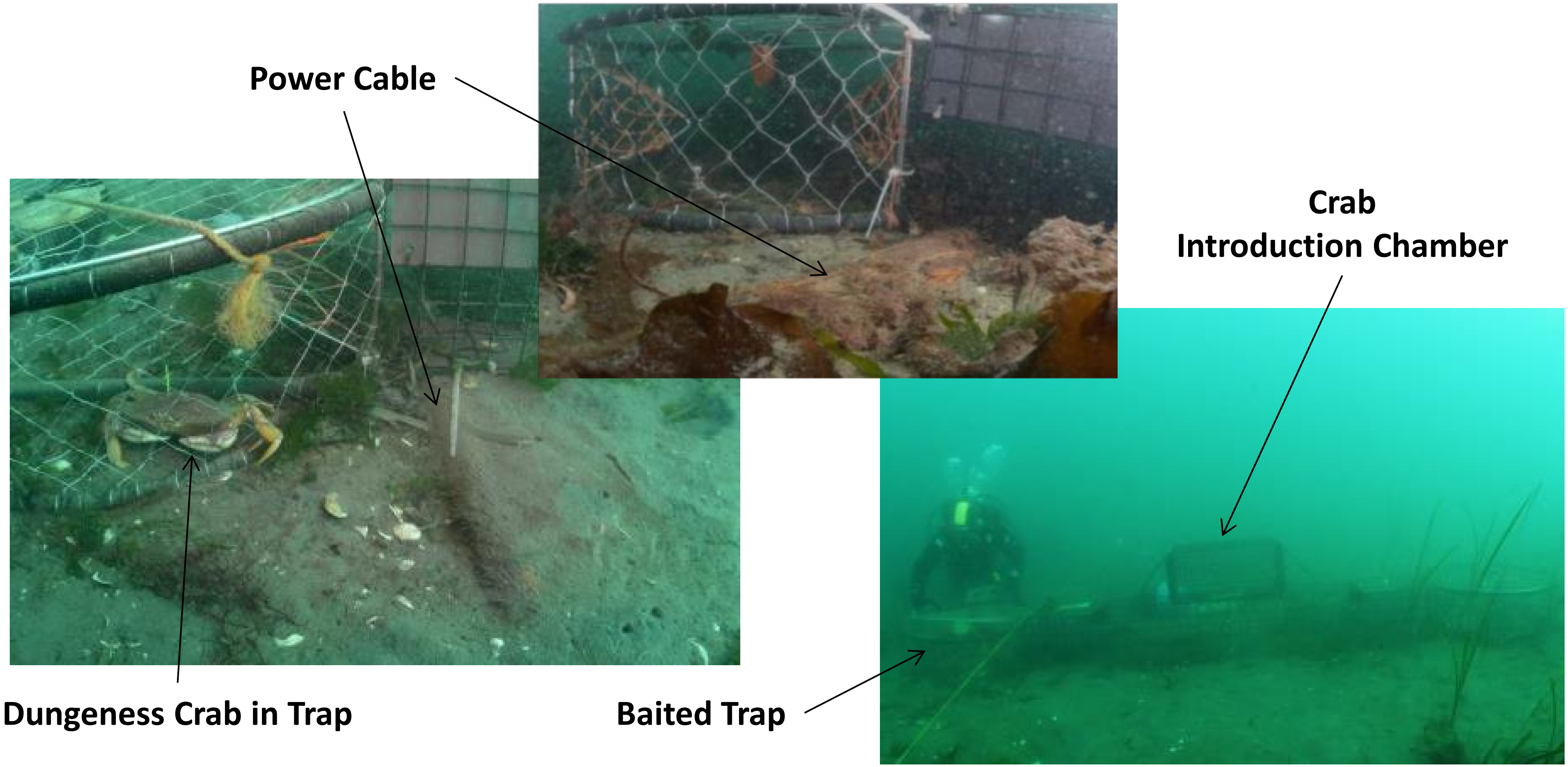
Crab Experimental Design for Puget Sound

Give crabs a choice to decide if they will cross an energized power cable in response to a baited commercial fishing trap



Preliminary Findings from Crab Harvest Study

Unpublished Results from Rock and Dungeness Crab Experiments

- Rock crabs will cross an unburied 35 kV AC power cable and Dungeness crabs will cross an unburied 69 kV AC power cable to enter baited commercial traps.
- Crabs tend to move into the current.
- Chemosensory response to bait in commercial traps is not impeded by energized power cables.

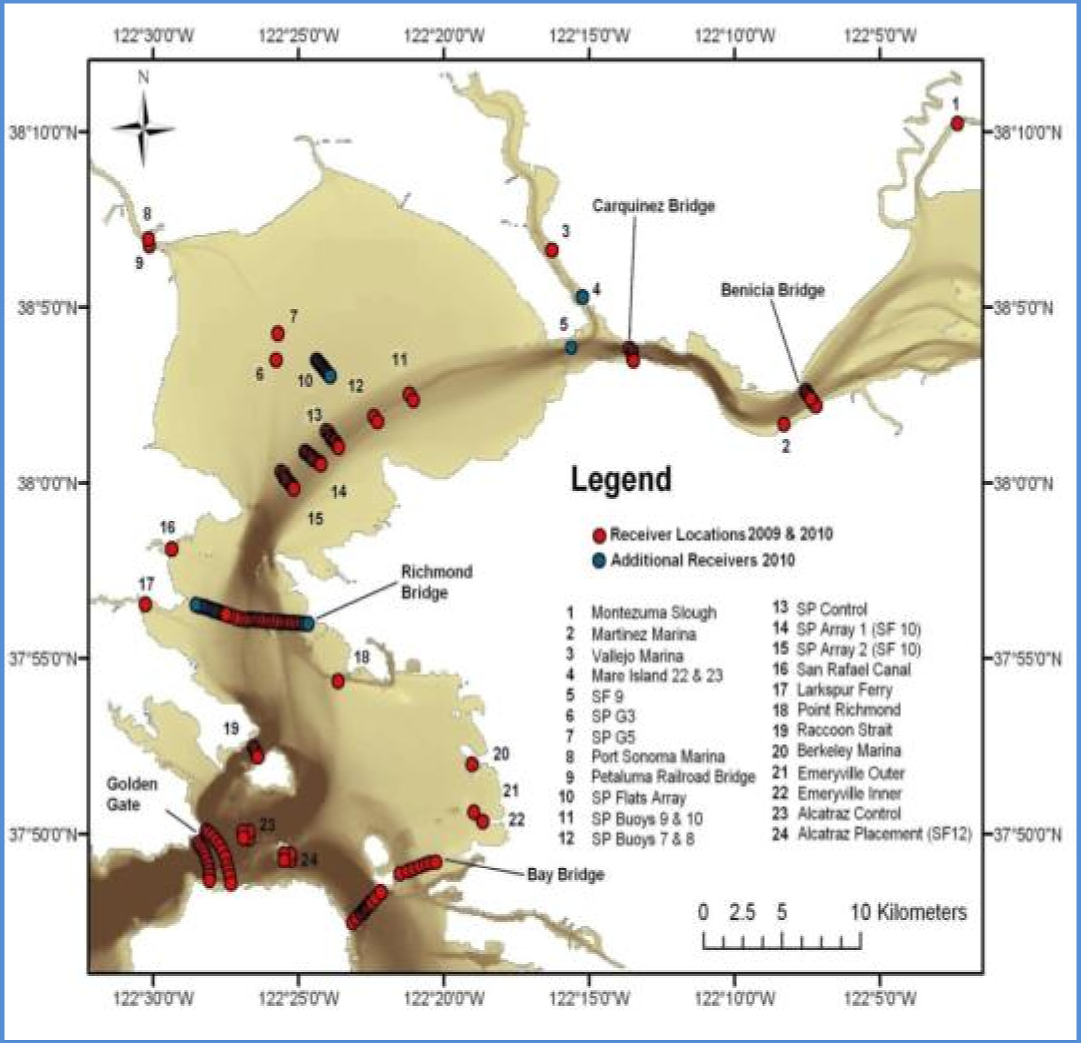
Assessment of Potential Impact of Electromagnetic Fields (EMF) from Undersea Cable on Migratory Fish Behavior

Wyman, Megan T.[1], A. Peter Klimley[1], and Robert Kavet[2]

[1]University of California, Davis, Davis, California

[1]Electric Power Research Institute, Palo Alto, California

San Francisco Bay Perfect Site to Study EMF



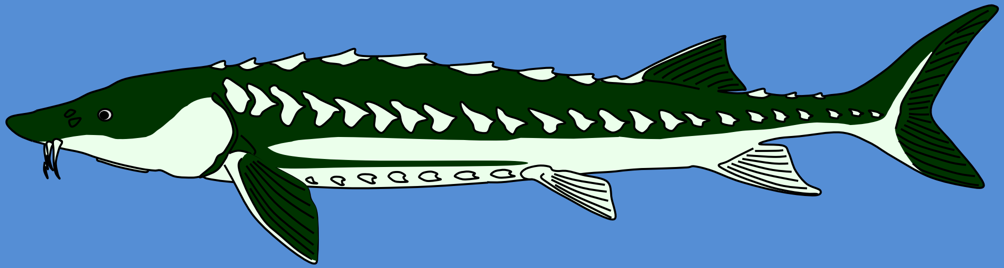
- High voltage, direct current Trans Bay Cable runs from Pittsburg through Suisun and San Pablo Bays, crosses San Francisco Bay, to San Francisco
- It is either parallel or perpendicular to the migratory pathways of green and white sturgeon, salmon, and steelhead smolts.
- Their movements have been well described by placing coded beacons on them and detecting their passage with an array of monitors (see red circles in map).

Methods

Electronic Tags and Monitors

- Tag detecting monitors (left)
- Smolt tags (right top)
- Moorings with acoustic releases (right bottom)

- Late-fall run Chinook smolts (top), and green sturgeon (bottom) with electronic tags were released before and after cable energized

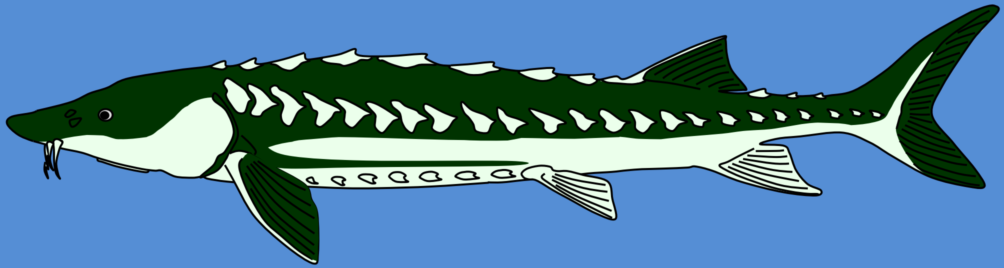


Tentative Results

- Chinook salmon and green sturgeon migrate through San Francisco Estuary and Bay despite large distortions in local magnetic fields

- Salmon smolts may be attracted to the cable after activation (more cable location crossings, more detections at Bay Bridge, high importance of distance to cable in predicting fish location)

- The smolts are not impeded from successfully migrating through the San Francisco Bay (similar proportions of successful exits, faster transit rates)



- Cable activity had opposite effects on outbound and inbound green sturgeon migrations: outbound migrations had significantly longer transit times while inbound migrations had significantly shorter migration times

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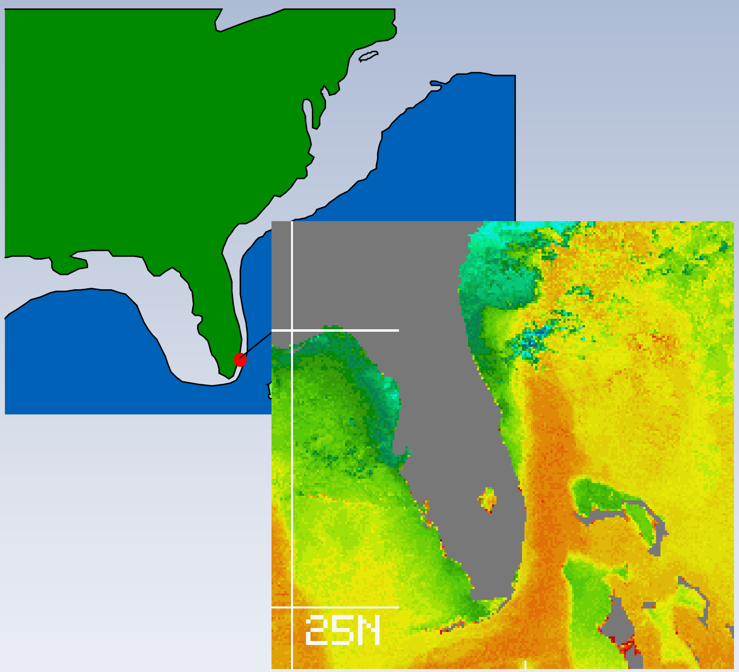
Characterization of EMF Emissions from Submerged Power Cables and Monitoring for Potential Responses of Marine Species

Manhar Dhanak,
Florida Atlantic University

Work Supported by the US Department of Energy

Location of EMF Surveys



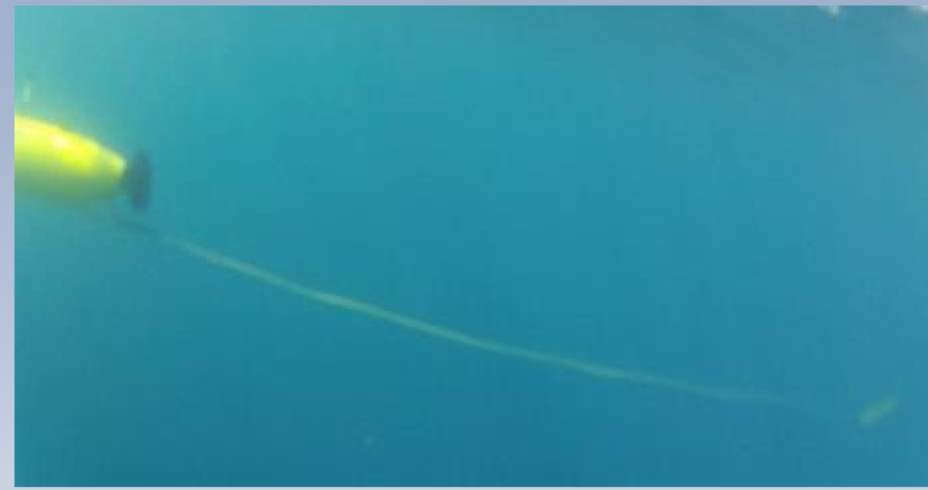
Naval Surface Warfare Center Carderock Division's
South Florida Ocean Measurement Facility

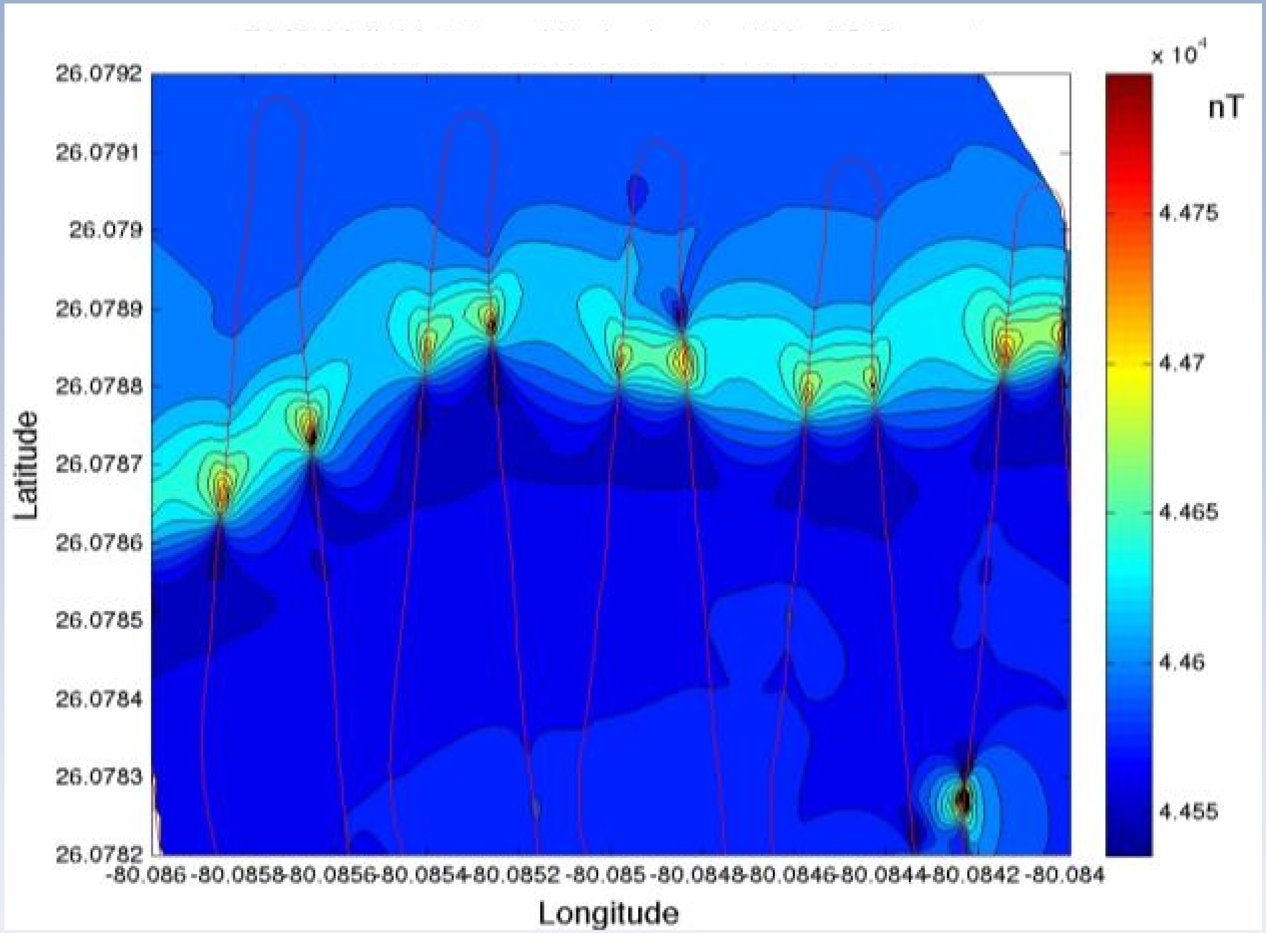
Objectives:

Characterize EMF emissions from subsea cables such as ones that may transmit power from offshore turbines to shore.

- Develop an AUV-based system for measuring and characterizing EMF levels in the water column.
- Determine the distribution and characteristics of the E and B field emissions in the region due to an energized submarine cable.
- Compare power cables in an energized and unenergized condition.
- Use results to compare with and help validate predictions from models.

AUV-towed magnetometer: Aerial view (top), and side views (right)





B-field at 2.2m altitude above a subsea cable energized with DC power. The lawn-mower pattern path of the AUV is superimposed on the contour map.

EMF and Environmental Risk

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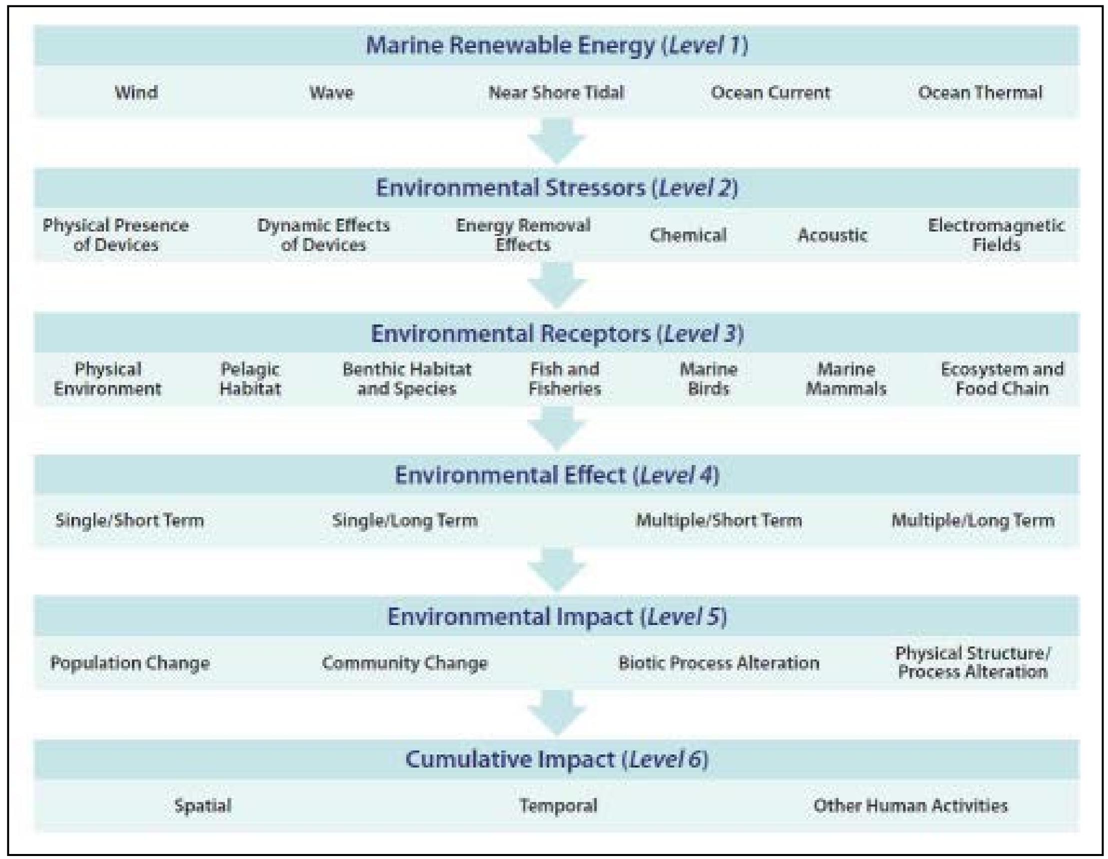
Uncertainty about Environmental Effects Increases Regulatory and Industry Risk

Confidence about Environmental Effects Stabilizes Risk

- Framework for consideration of environmental effects of marine renewable energy encompassing different scales.
- The reaction of an animal at level four does not indicate that the animal is adversely affected.
- Level five makes the key distinction between biological response of an animal (level four) and environmental impact.



Boehlert and Gill 2010

Bureau of Ocean Energy Management

Based on Results from the Completed and Ongoing Studies How Should We Perceive EMF Risk?

- There is no indication from scientific research that EMF from seafloor power cables is a significant risk to marine animals or their habitat, or that EMF from cables prevents movement within habitats.
- Research techniques are well understood and becoming standardized.
- Past and ongoing research likely provide an acceptable level of confidence about expected effects from EMF.
- Past and ongoing research suggest burial as a mitigation to further decrease exposure to and potential effects from EMF.

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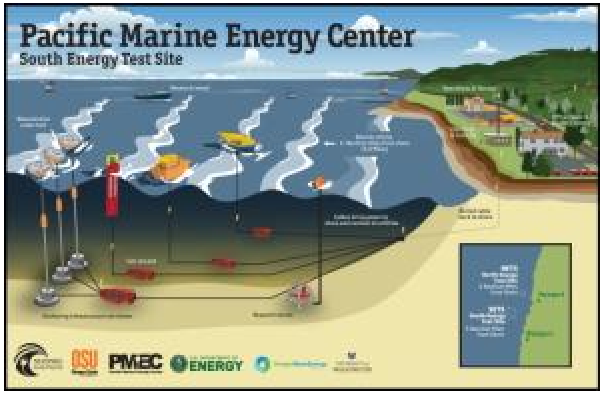
How Should We Treat EMF Risk?

- Based on scientific research data, EMF is a low-risk stressor.
- Commercial installations and test facilities can provide real-time opportunities for monitoring to provide additional data.
- Regulating agencies should move to higher priority interactions.



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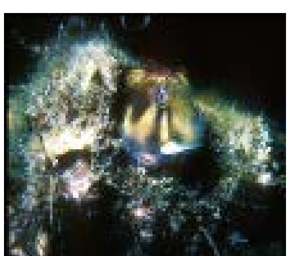

Questions & Answers

THANK YOU!

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- Recordings of presentations will be posted on Tethys at: **https://tethys.pnnl.gov/environmental-webinars?content=water**
  - Information on previous and upcoming Annex IV webinars

- The next Annex IV Environmental webinar is planned for March and will discuss our ability to understand fish interactions with turbines, using algorithms to detect fish from video.

- For those of you who are not on the webinar mailing list, visit **https://tethys.pnnl.gov/environmental-webinars**.

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OES ANNEX IV