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# Analysis and interpretation of acoustic array data: estimating horizontal movement

Martin W. Pedersen, Kevin Weng

26 November 2012

PFRP PI meeting

University of Hawaii at Manoa

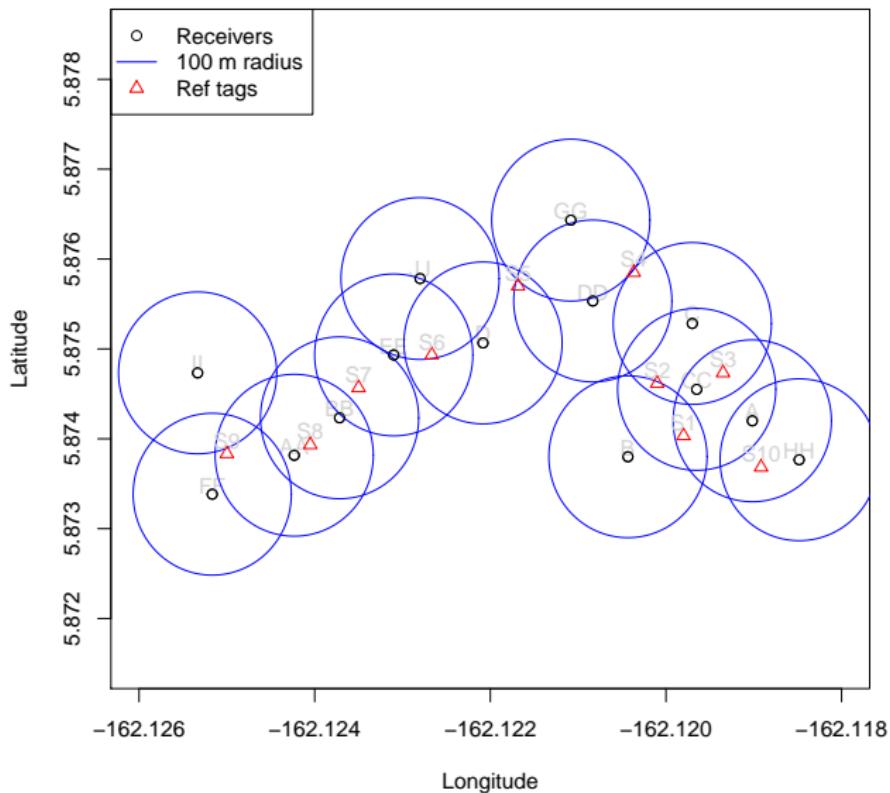


# Equipment for acoustic data collection



*Photo credit: Vemco.*

# Example: Palmyra rubble pile array



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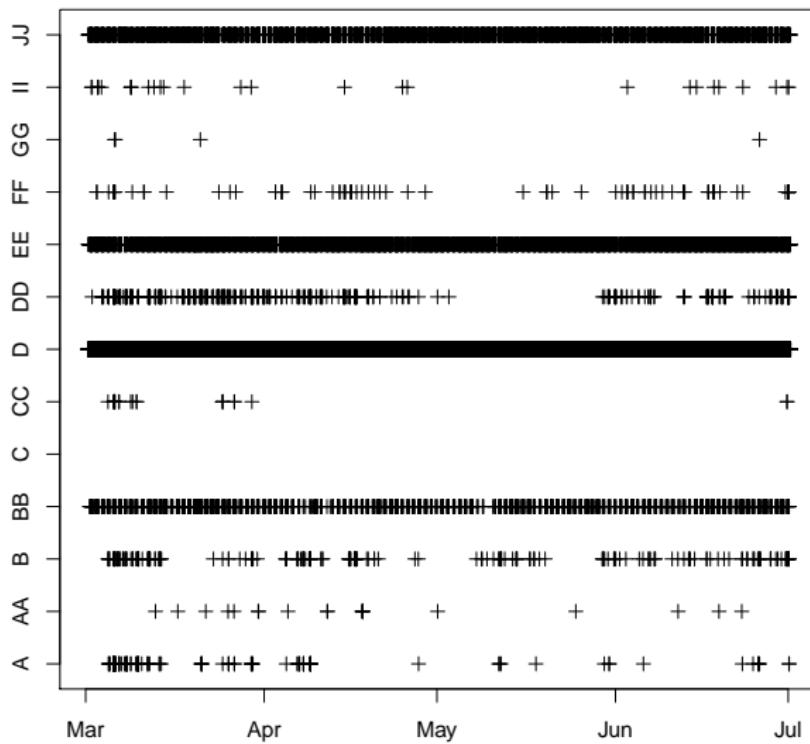
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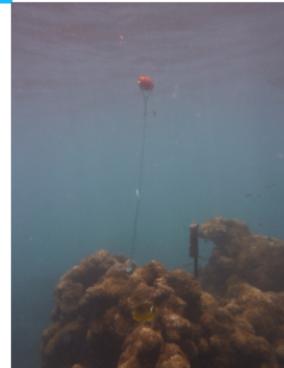
# Acoustic array data

Tag ID: 46894, # data: 32173



# Sources of transmission error

- ▶ Time of day.
- ▶ Water movement (swells, currents).
- ▶ Water column stratification (thermocline etc.).
- ▶ Time since deployment (biofouling).
- ▶ Bottom topography (signal blocking).



# Horizontal movements

## Current approaches

- ▶ Kernel estimation.
- ▶ Local polynomial regression.

**Advantages:** Quick way to get an overview of data.

**Drawbacks:** No biological interpretation, no account for errors or uncertainties in data.

# State-space model (SSM)

A model with two components:

- ▶ Process model (describing movement).
- ▶ Observation model (describing data collection).

Appealing model because it describes the mechanisms underlying the data.

## Review

### State-space models of individual animal movement

Toby A. Patterson<sup>1,2</sup>, Len Thomas<sup>3</sup>, Chris Wilcox<sup>1</sup>, Otso Ovaskainen<sup>4</sup> and Jason Matthiopoulos<sup>5,3</sup>

<sup>1</sup>Commonwealth Industrial and Scientific Research Association (CSIRO) Marine and Atmospheric Research, GPO Box 1538, Hobart, Tasmania 7001, Australia

<sup>2</sup>Antarctic Wildlife Research Unit, School of Zoology, University of Tasmania, PO Box 252-05 Hobart, Tasmania 7001, Australia

<sup>3</sup>Centre for Research in Environmental and Ecological Modelling, University of St Andrews, The Observatory, Buchanan Gardens, St Andrews, Fife, KY16 8LB, UK

<sup>4</sup>National Institute of Health Research Group, Department of Biological and Environmental Sciences, University of Helsinki, PO Box 65 (Viikkiinranta 1), FI-00014, Finland

<sup>5</sup>National Environmental Research Council (NERC) Sea Mammal Research Unit, Gatty Marine Laboratory,

University of St Andrews, St Andrews, Fife, KY16 8LB, UK



## REVIEW AND SYNTHESIS

*Ecology Letters*, (2008) 11: 1338–1350

doi: 10.1111/j.1461-0248.2008.01249.x

### Understanding movement data and movement processes: current and emerging directions

#### Abstract

Animal movement has been the focus on much theoretical and empirical work in ecology over the last 25 years. By studying the causes and consequences of individual movement, ecologists have gained greater insight into the behavior of individuals and the spatial dynamics of populations at increasingly higher levels of organization. In particular, ecologists have focused on the interaction between individuals and their environment in an effort to understand future impacts from habitat loss and climate change. Tools to examine this interaction have included: fractal analysis, first passage time, Lévy flights, multi-behavioral analysis, hidden markov models, and state-space models. Concurrent with the development of movement models has been an increase in the sophistication and availability of hierarchical bayesian models. In this review we bring these two threads together by using hierarchical structures as a framework for reviewing

Patterson et al. 2008 TREE,

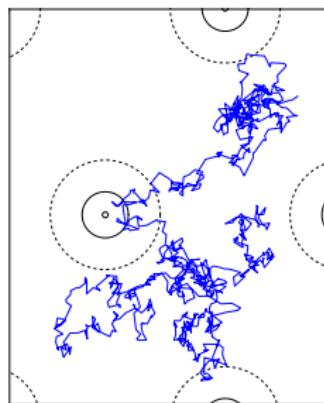
Schick et al. 2008 Ecol. Lett.

# Movement model

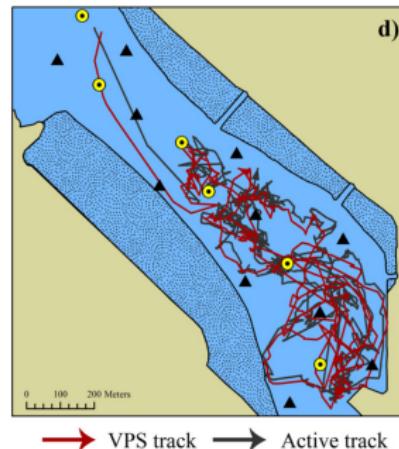
Simple random walk

$$x_t = x_{t-1} + e_t, \quad e_t \sim N(0, 2Dt).$$

The parameter  $D$  is related to the movement rate of the fish.



Simulated RW



Espinosa et al. 2011

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## Observation model

What do we observe and how does it relate to location?

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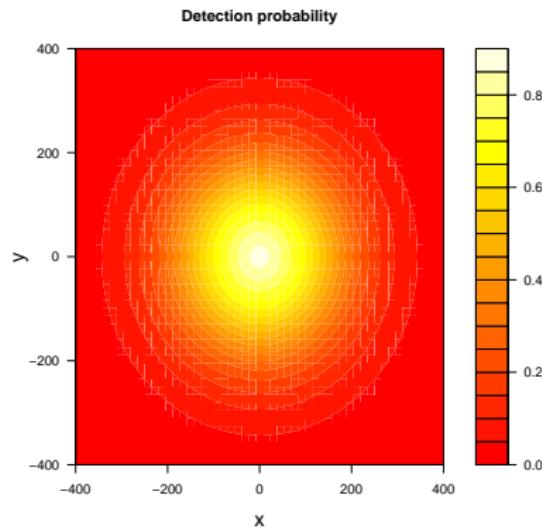
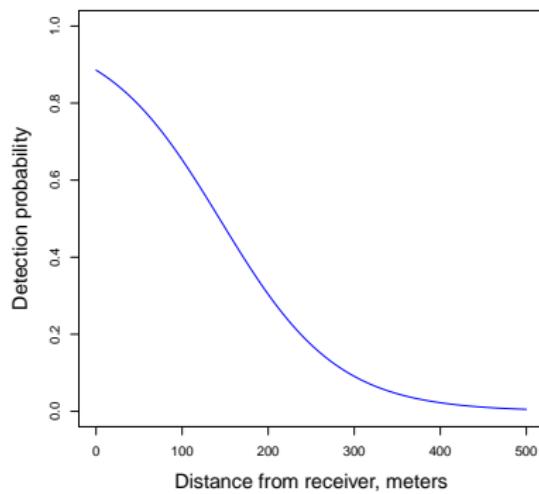
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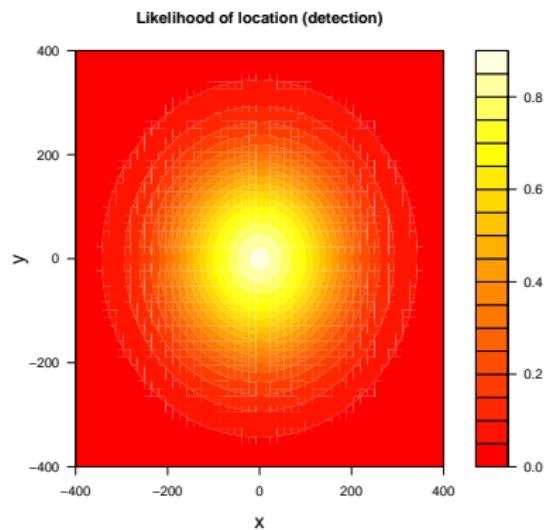
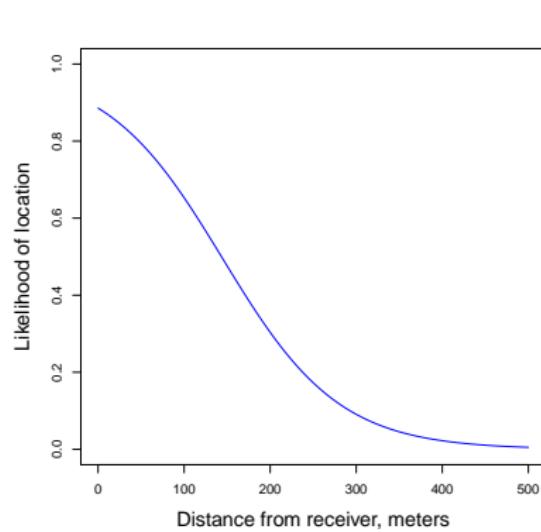
$$P = f(d)$$



# Observation model - presence information

Likelihood of location given detection.

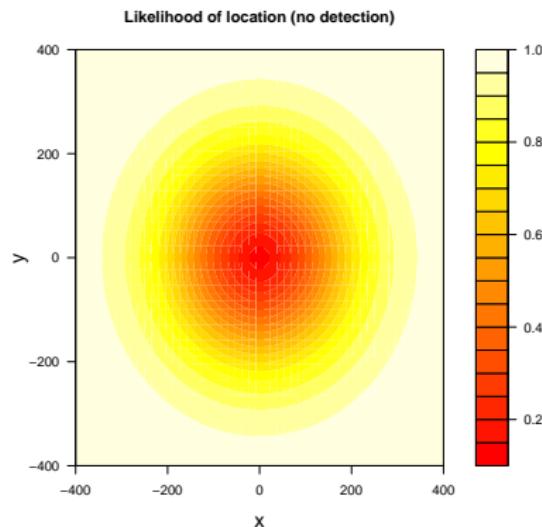
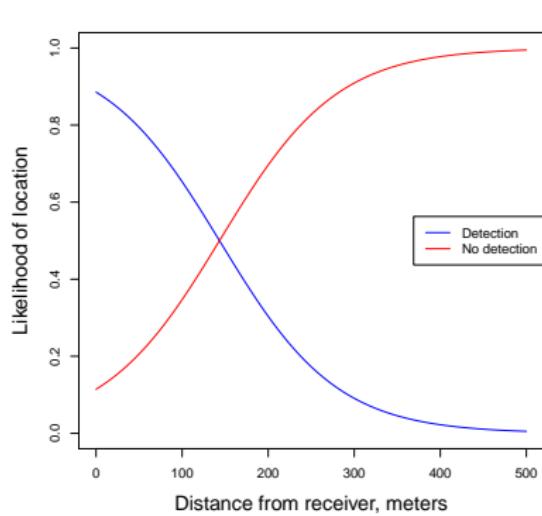
$$L \propto f(d)$$



# Observation model - absence information

Ping rate is known from manufacturer.

$$L \propto 1 - f(d)$$



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## Noise conditions

Use reference tag detection efficiency,  $z_t$ , as a proxy for noise conditions.

$$L_t \propto f(d, z_t)$$

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# Simulation study

## **Scenario 1** - constant noise conditions

- ▶ Check consistency of parameter estimates.
- ▶ Compare state-space model performance with other approaches.

## **Scenario 2** - varying noise conditions

- ▶ Compare results with and without using reference tag information.

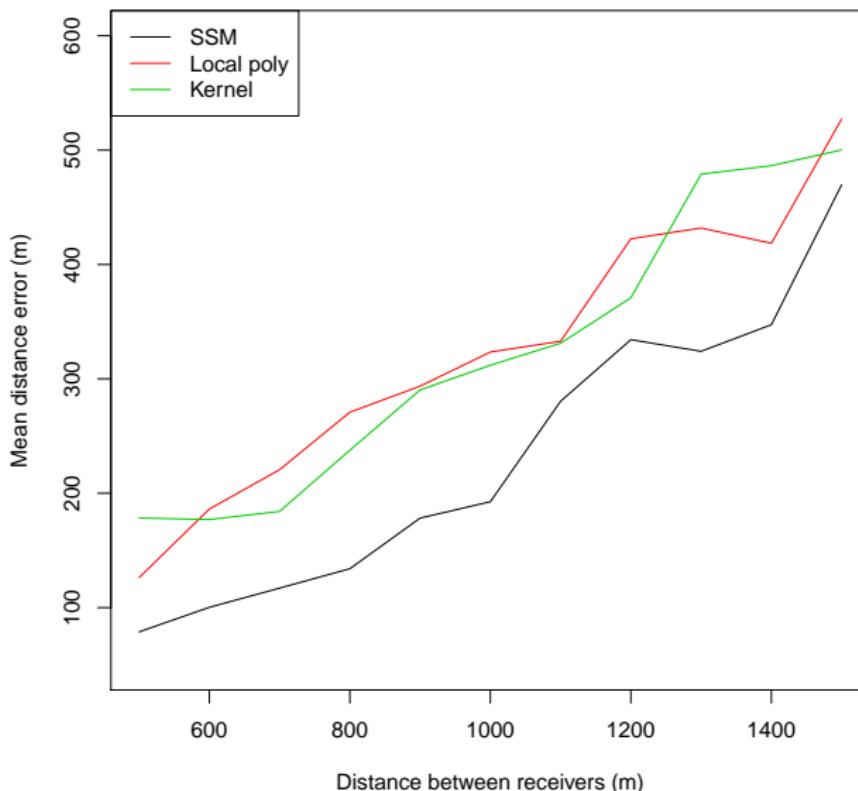
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# Comparing SSM with other approaches



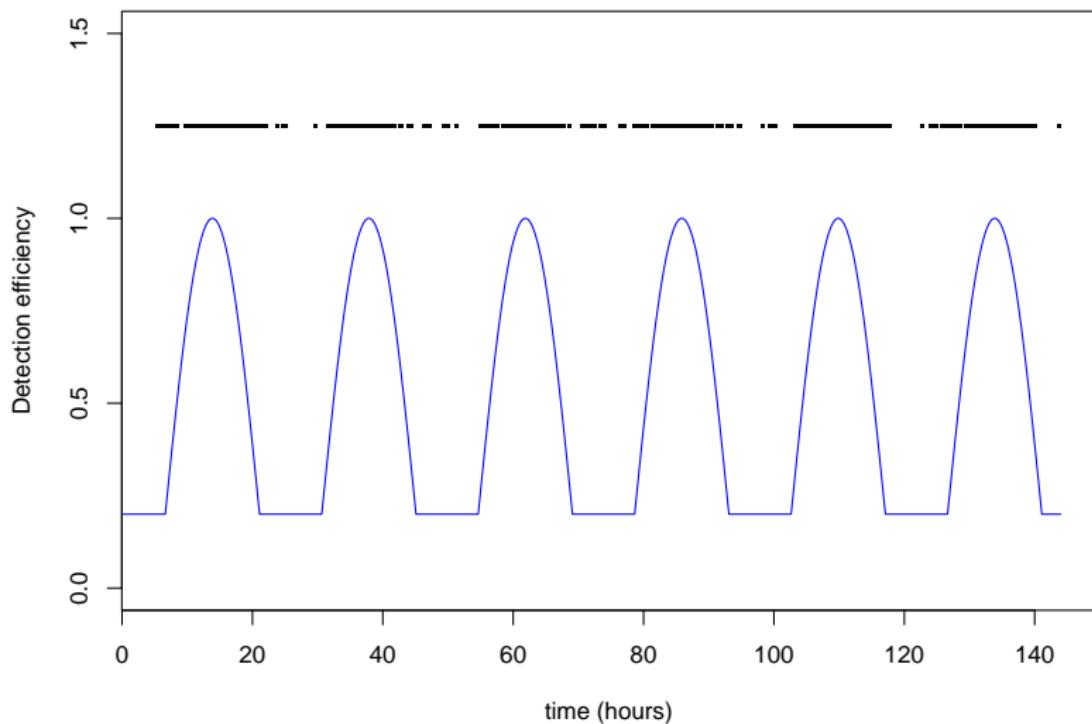
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## Covariate information from reference tag



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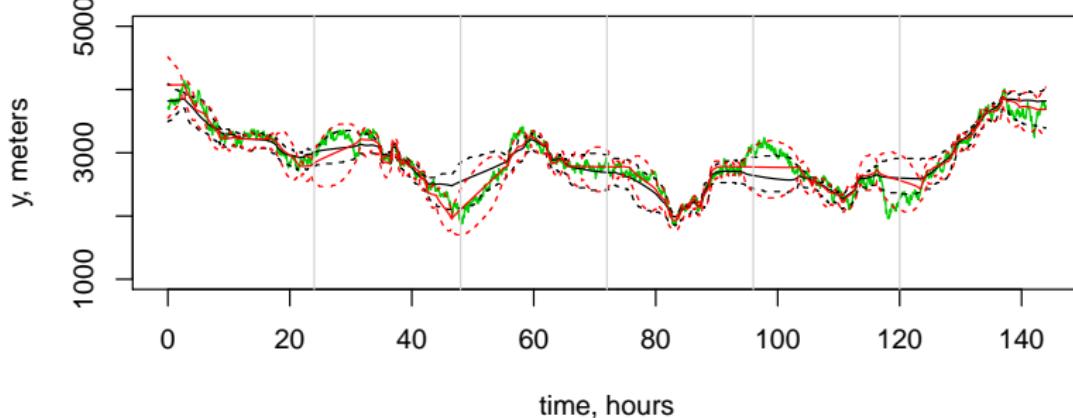
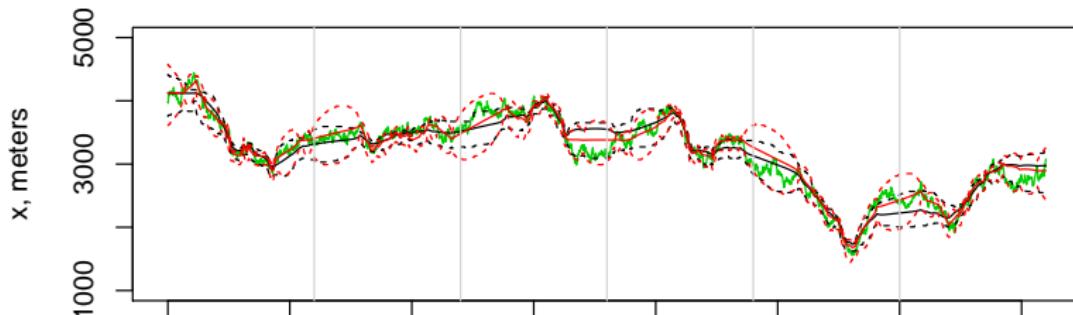
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## Movement estimation (500 m btw receivers)

■ True ■ SSM no cov. ■ SSM w cov. (dashed is 95% CI)



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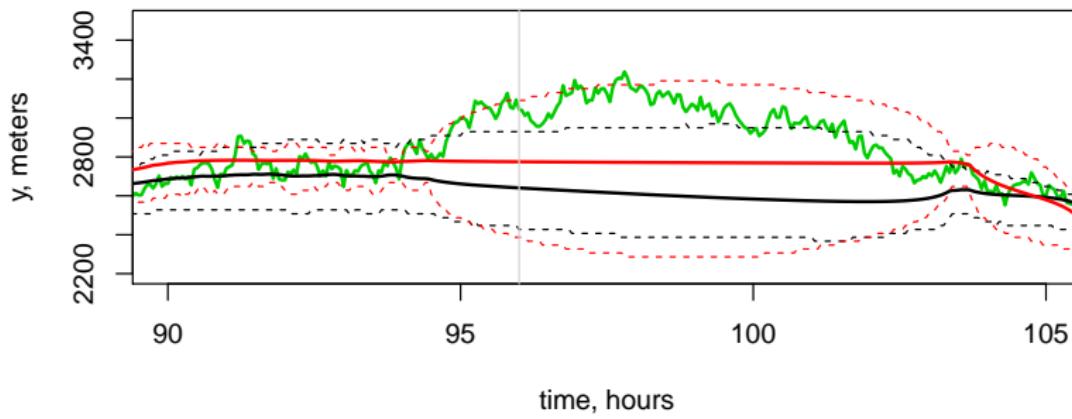
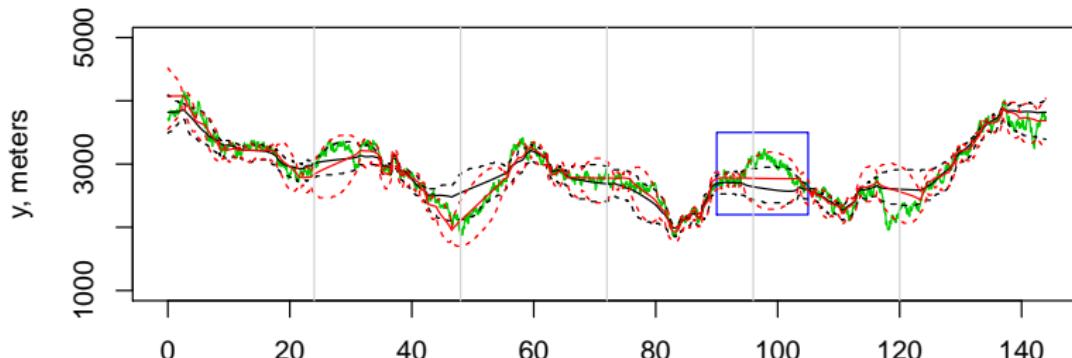
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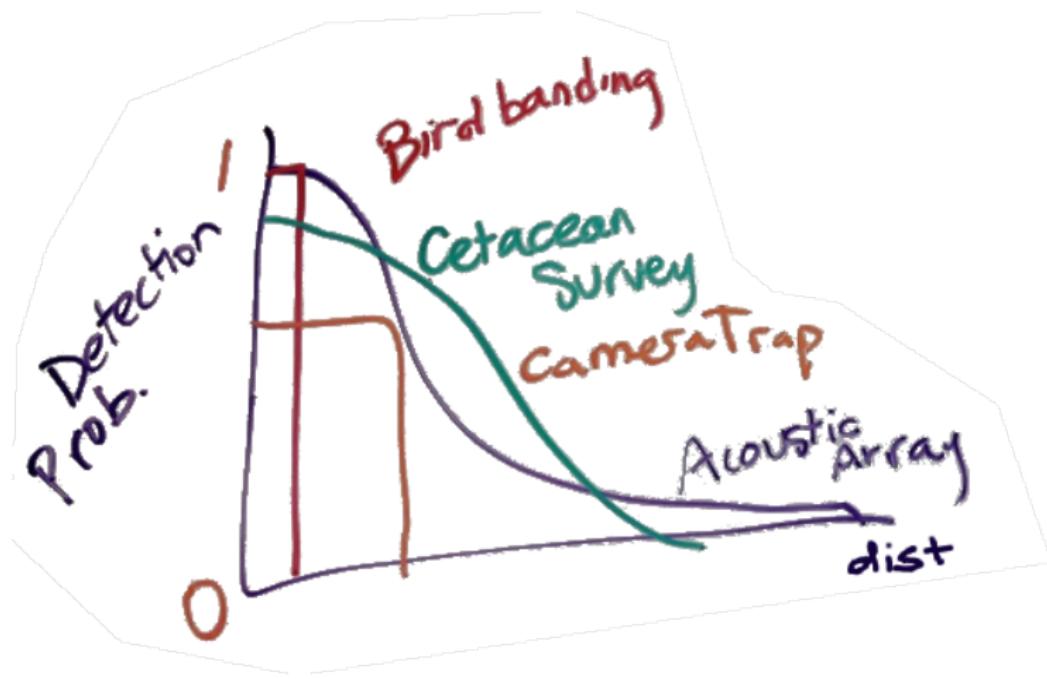
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## Future work

- ▶ Apply to real data.
- ▶ Develop guidelines for acoustic array design.
- ▶ Applications to other types of presence/absence data.

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- ▶ Apply to real data.
- ▶ Develop guidelines for acoustic array design.
- ▶ Applications to other types of presence/absence data.



# Thank you for listening!

**PFRP** Pelagic Fisheries Research Program  
*of the Joint Institute for Marine and Atmospheric Research (JIMAR)*

IN THE SCHOOL OF OCEAN AND EARTH SCIENCE AND TECHNOLOGY AT THE UNIVERSITY OF HAWAII AT MĀNOA

