Spatial prediction of fisheries bycatch

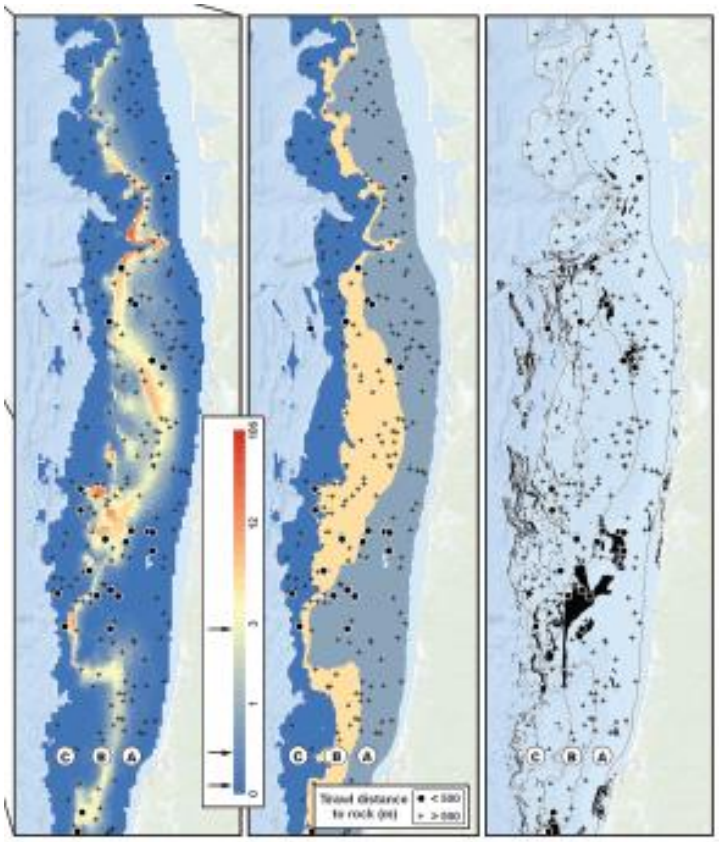
Brian Stock, Eric Ward, Tomo Eguchi
SIO/UCSD, NWFSC, SWFSC

Alfaro-Shigueto et al. 2011

Growing interest in spatial models

Spatial semiparametric models improve estimates of species abundance and distribution

Andrew Olaf Shelton, James T. Thorson, Eric J. Ward, and Blake E. Feist



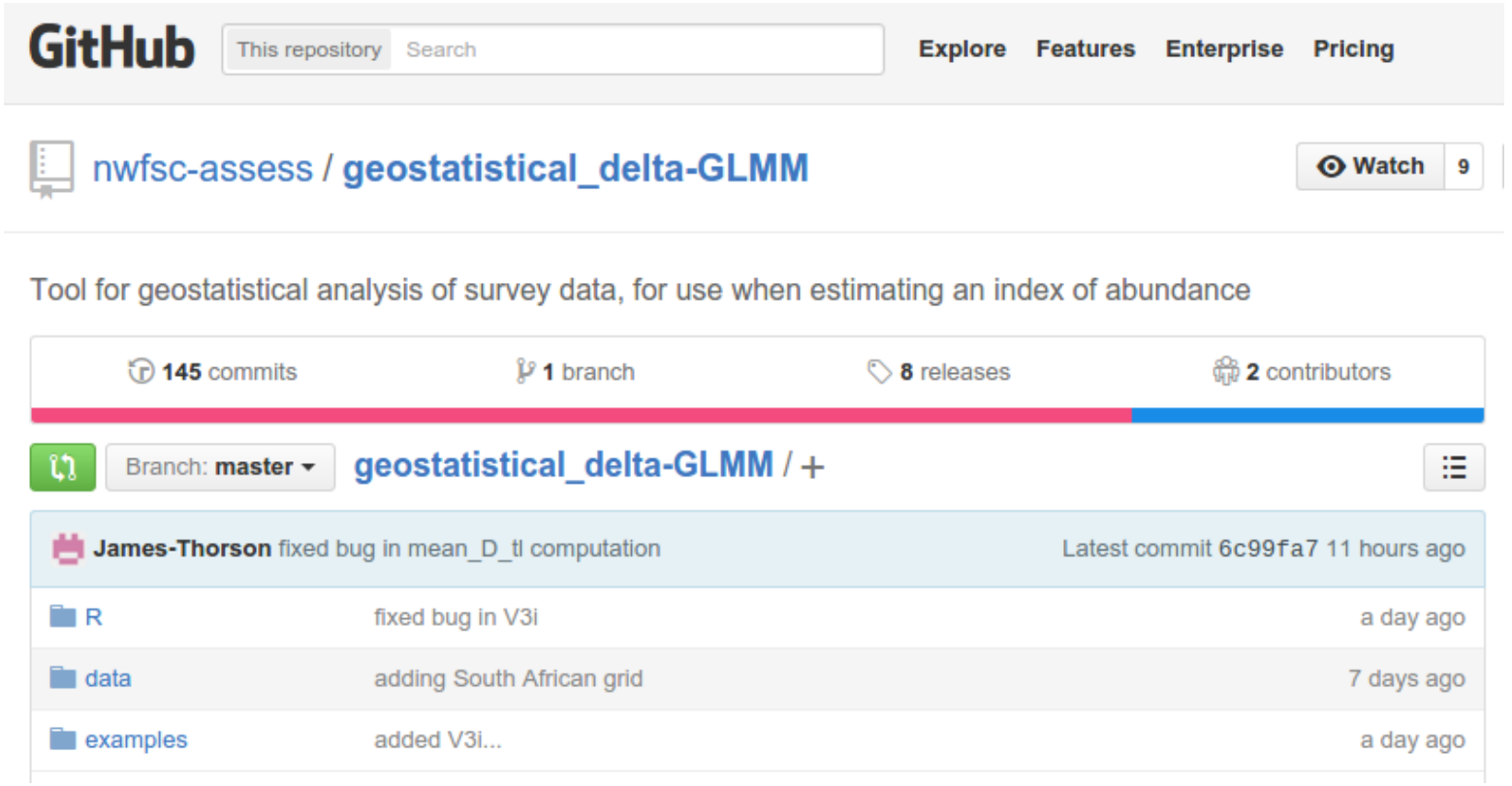
Yields abundance estimates that are:

- More precise
- More biologically reasonable
  - Extreme catch events
  - Sampling locations

Shelton et al. (2014)

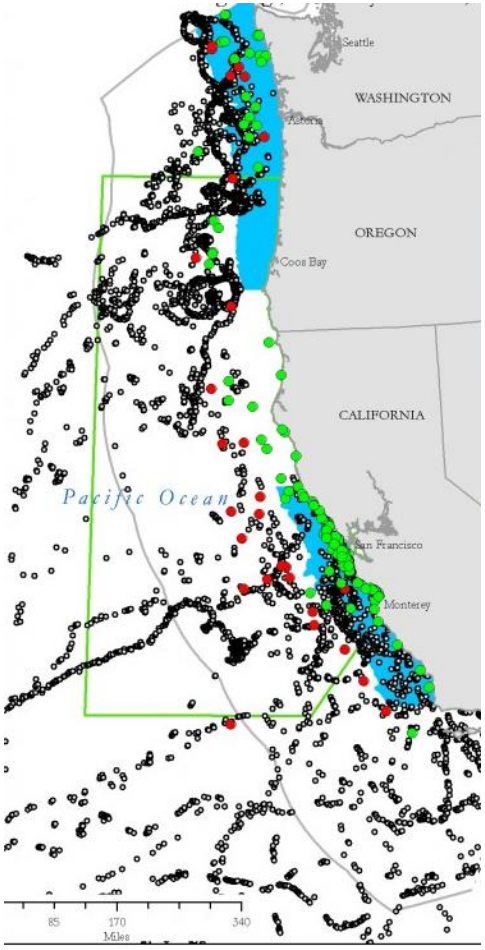
Growing interest in spatial models

Used by NWFSC assessment team



Motivation

Static management



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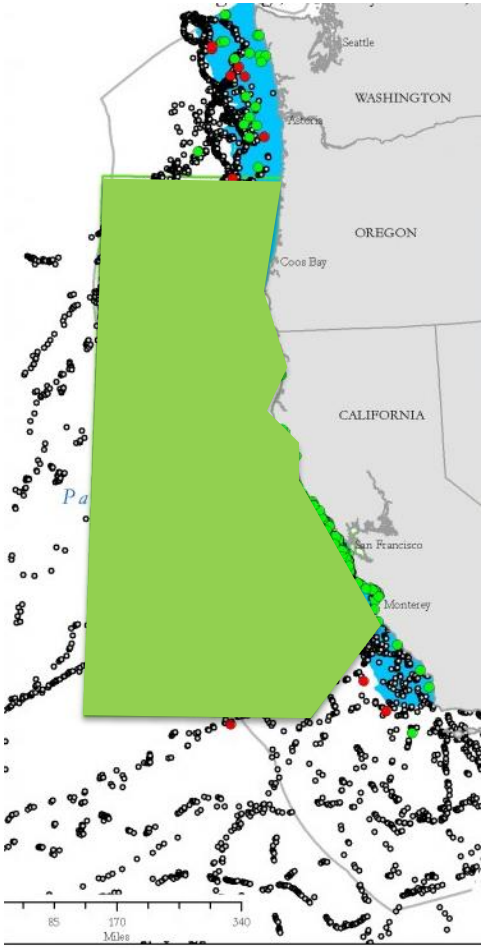

Motivation

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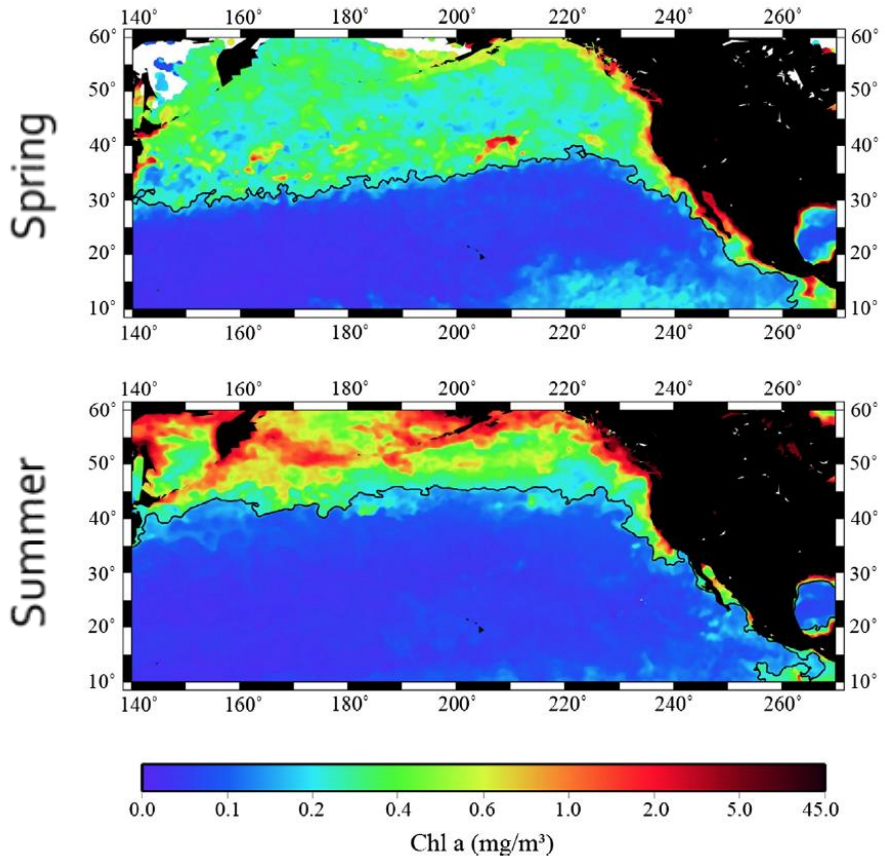
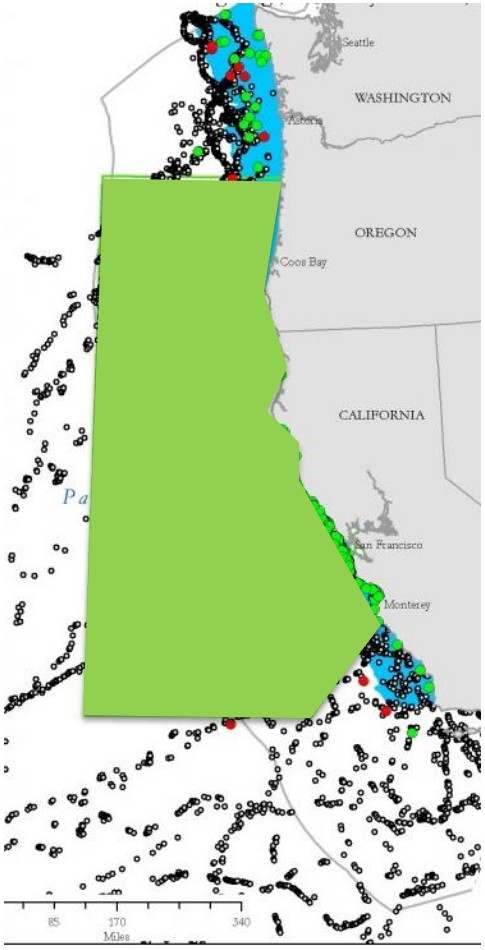


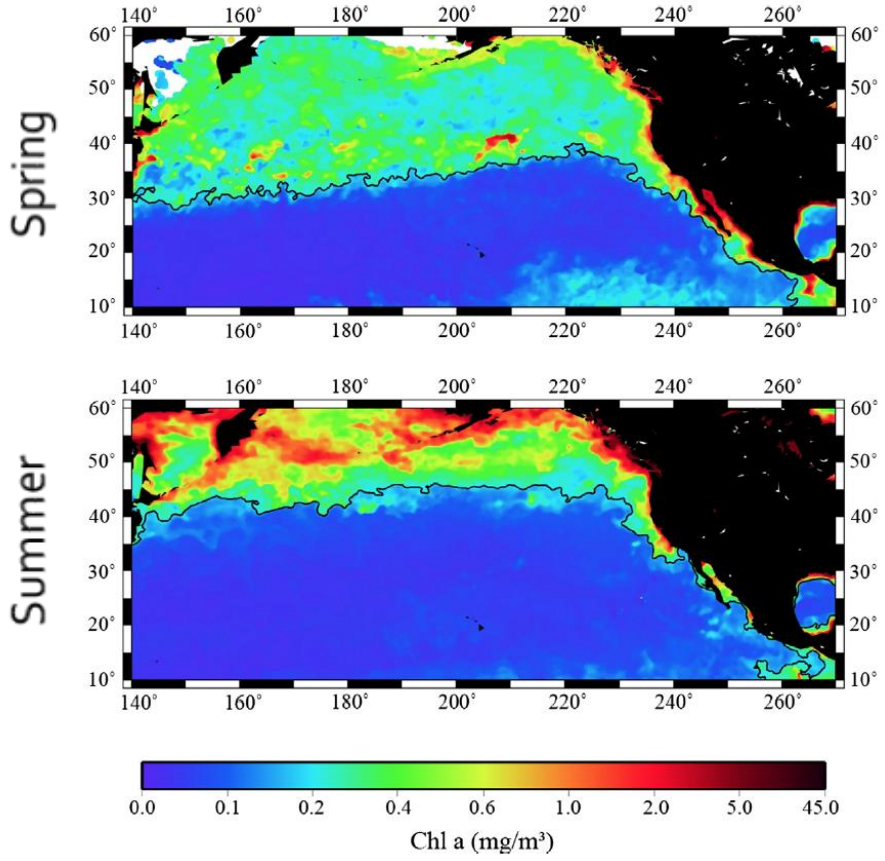
Static management

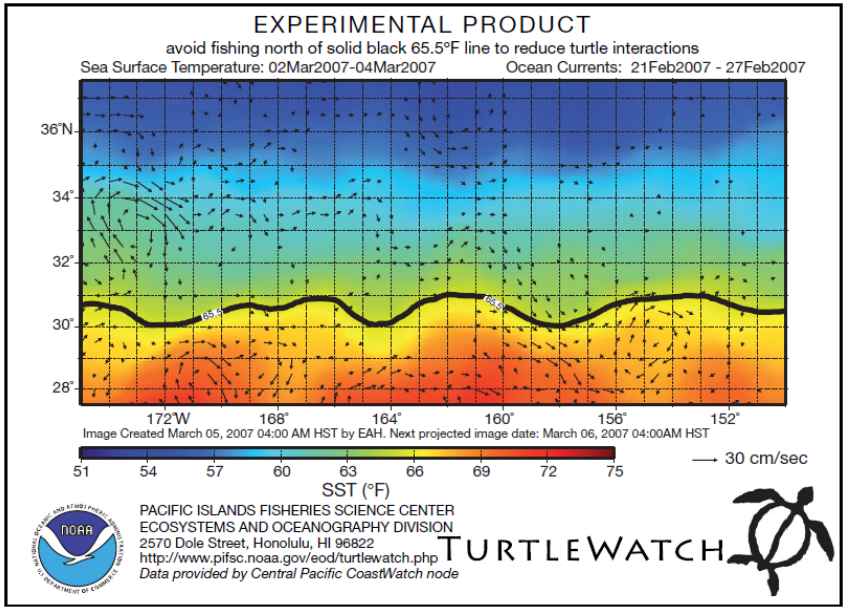


Polovina et al. 2015

Motivation

Dynamic management





PIFSC

Polovina et al. 2015

Research Questions

1. How well can we predict fisheries bycatch in space and time?

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Pr(some bycatch)

Binomial

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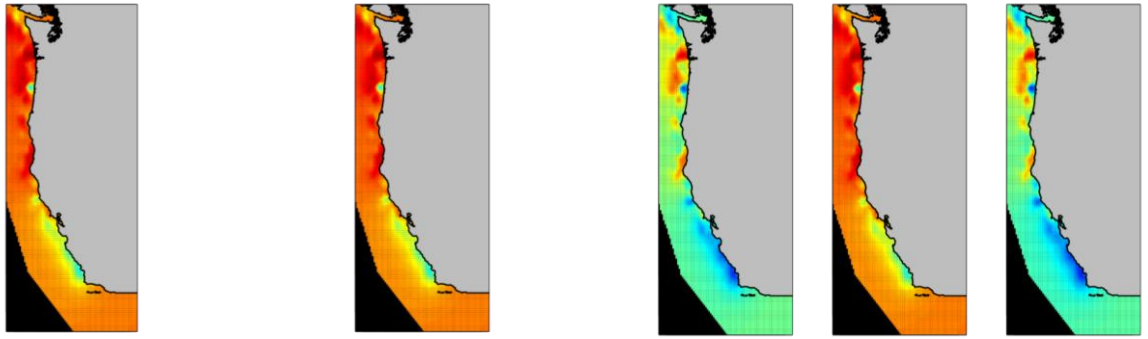
1. How well can we predict fisheries bycatch in space and time?

Pr(some bycatch)	**Binomial**
E(bycatch | some bycatch)	**Positive**

Research Questions

2. What *type* of spatial model best predicts bycatch?



1) Shared 2) Constant 3) Multiple years

Parametric
- INLA-SPDE
- GAM

Non-parametric
- Random Forest
- SVM

Research Questions

3. Does the answer depend on *species traits*?



Habitat:	Benthic	Benthic	Benthic
Movement:	Med	Low	Low
Bycatch Rate:	29%	18%	0.3%



Habitat:	Pelagic	Pelagic	Pelagic
Movement:	High	High	High
Bycatch Rate:	89%	0.15%	0.18%

Research Questions

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West Coast Groundfish

Binomial

Positive

~ sst +
depth +
distance to rocky substrate +
size of rocky patch +
in Rockfish Conservation Area +
gear type +
predicted occurrence (survey) +
spatial field

Hawaii Longline

Binomial

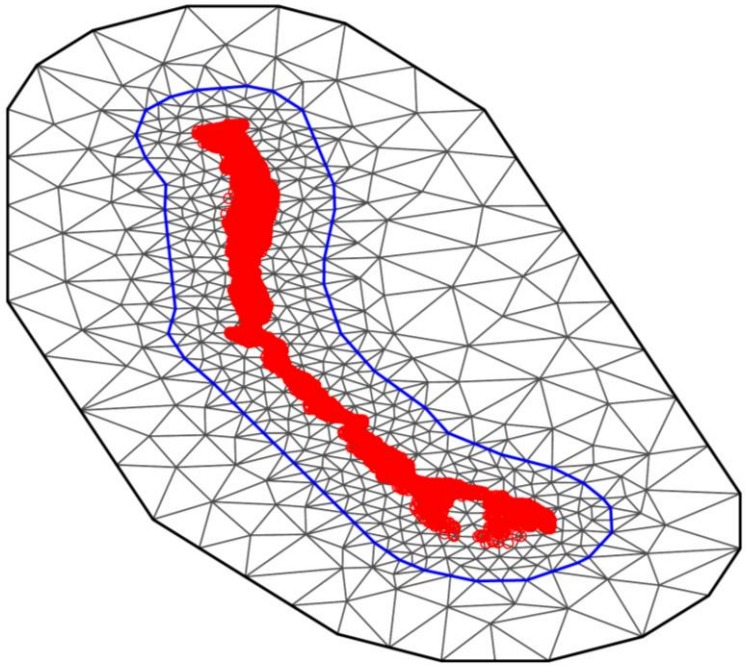
Positive

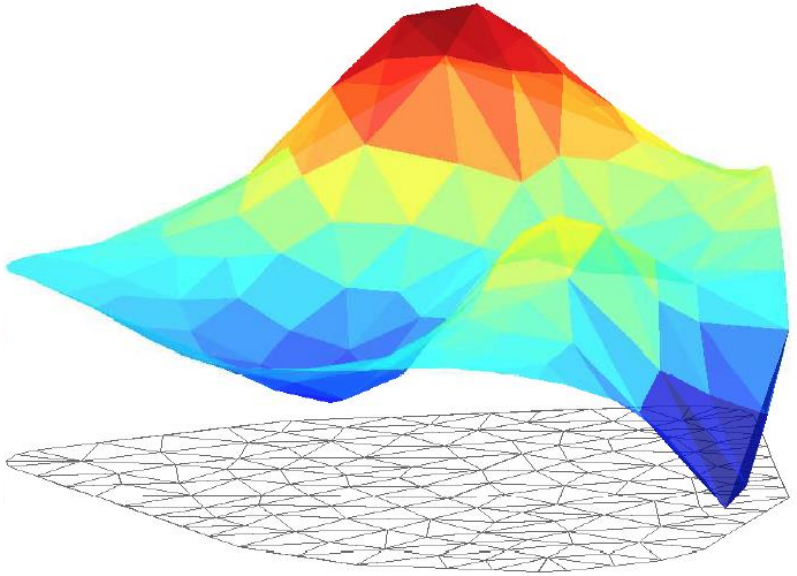
~ sst (observed) +
target +
spatial field

Spatial field: INLA-SPDE

Spatial Partial Differential Equation

- Discrete approximation of continuous spatial fields





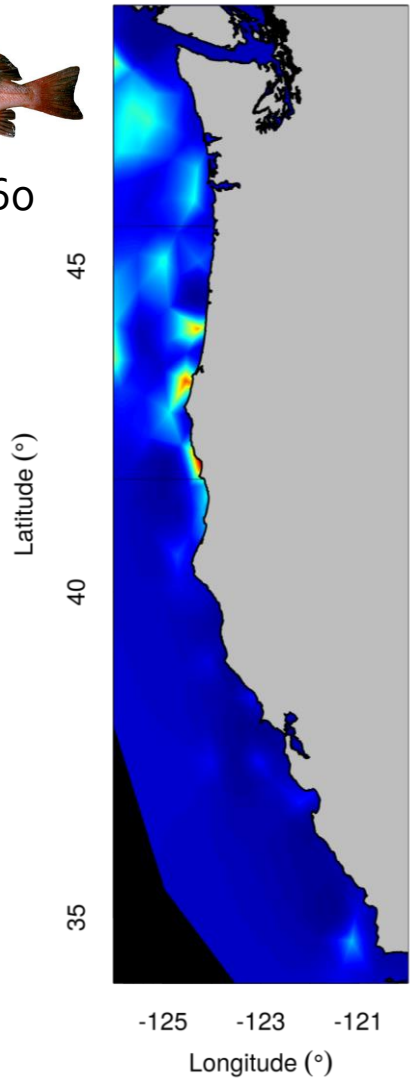
Results: Shared model

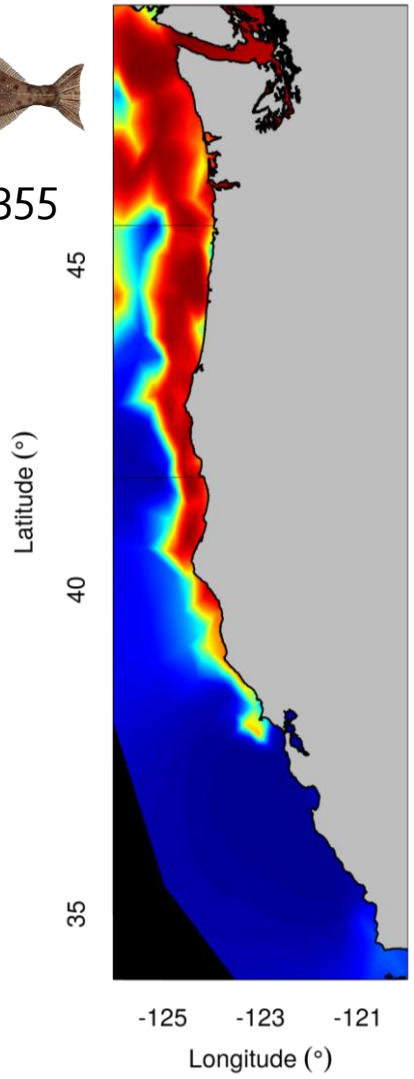
Binomial

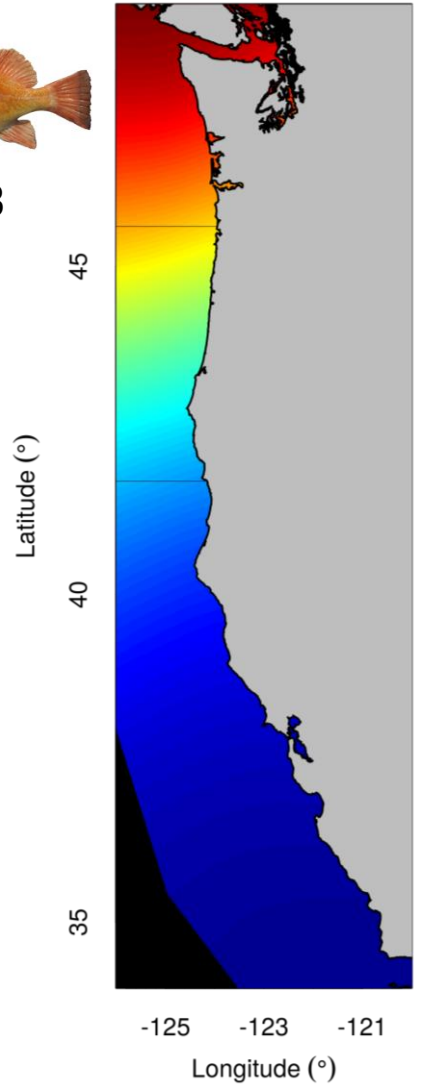
N = 7,660

N = 12,355

N = 143

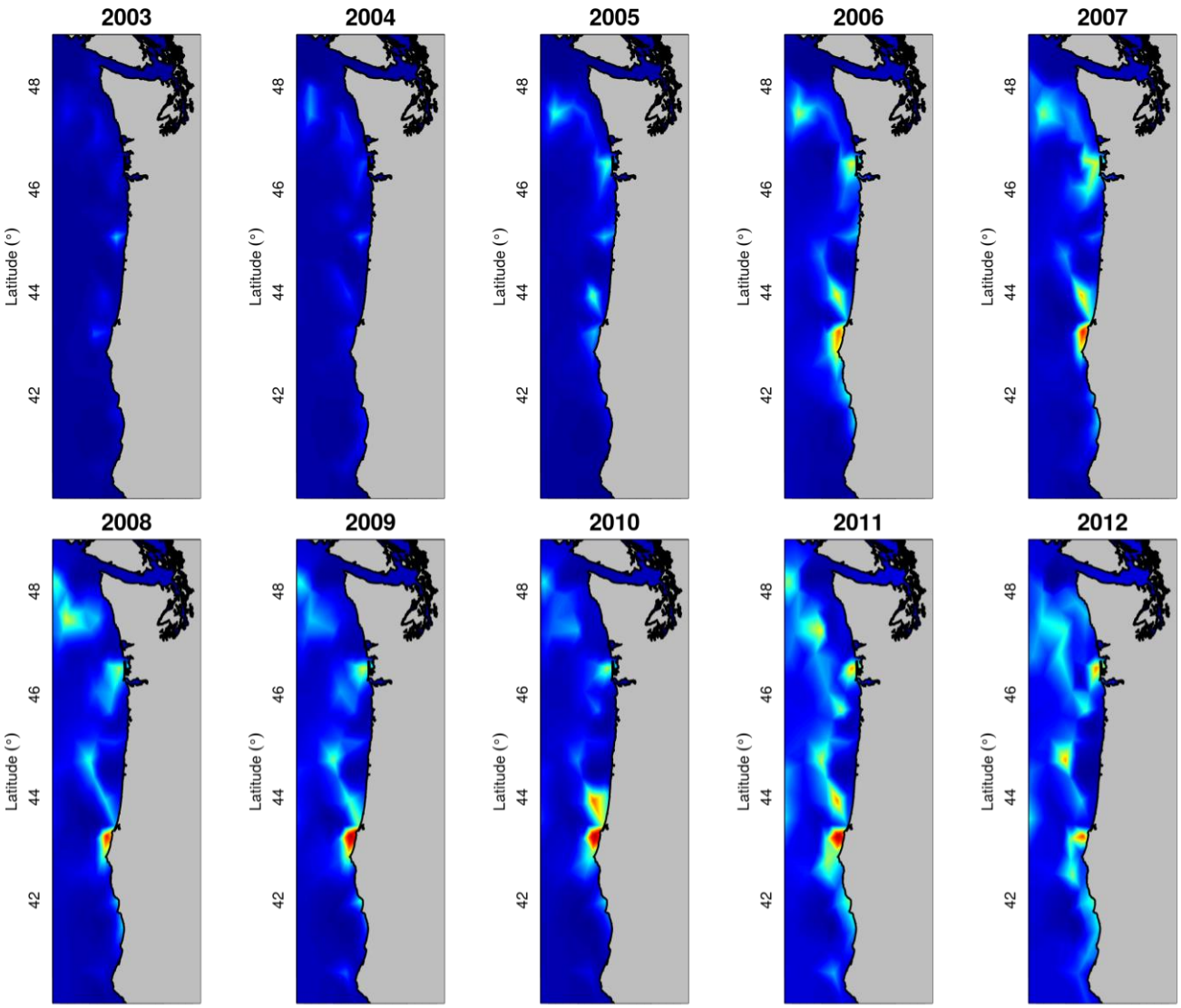






Results: Multiple years

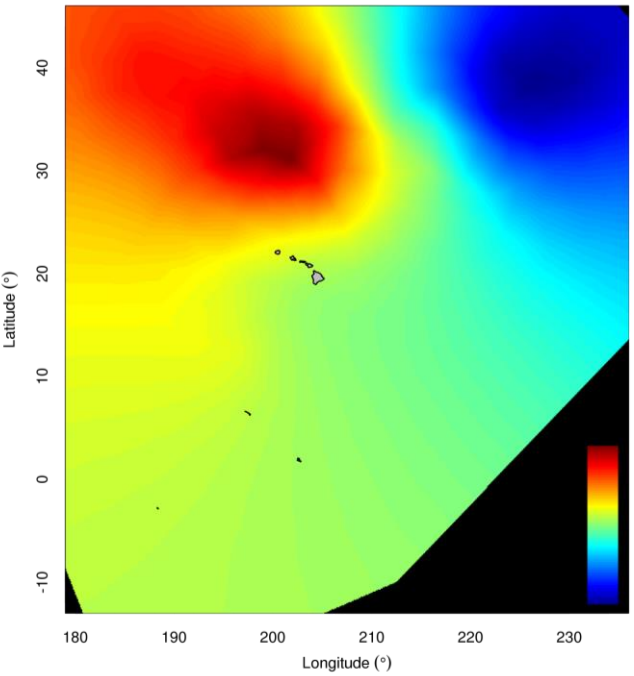
Binomial



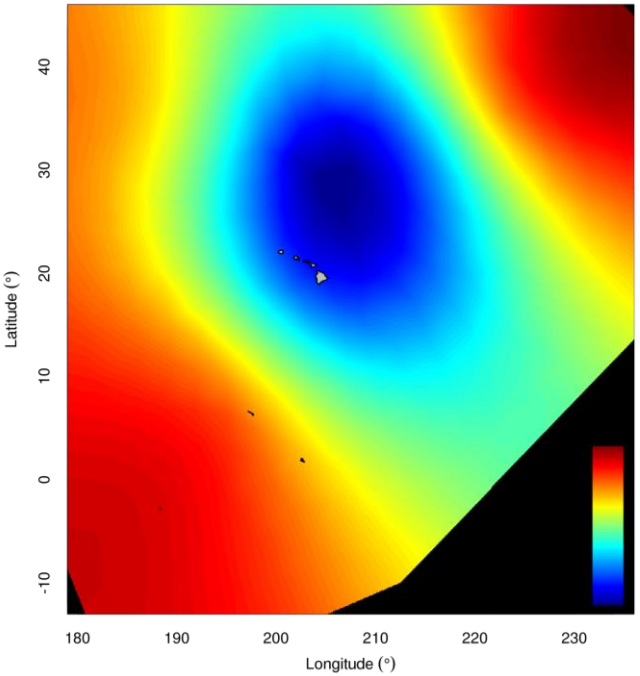
Results: Shared model

Binomial

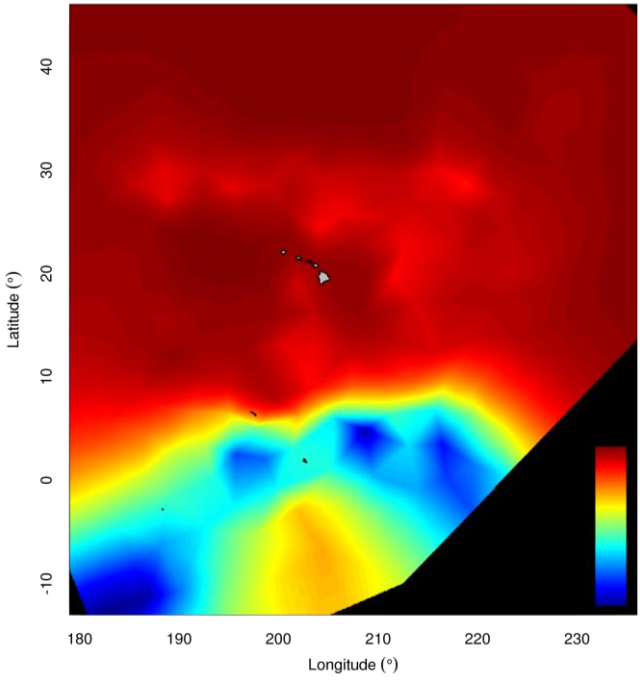
N = 97



N = 111



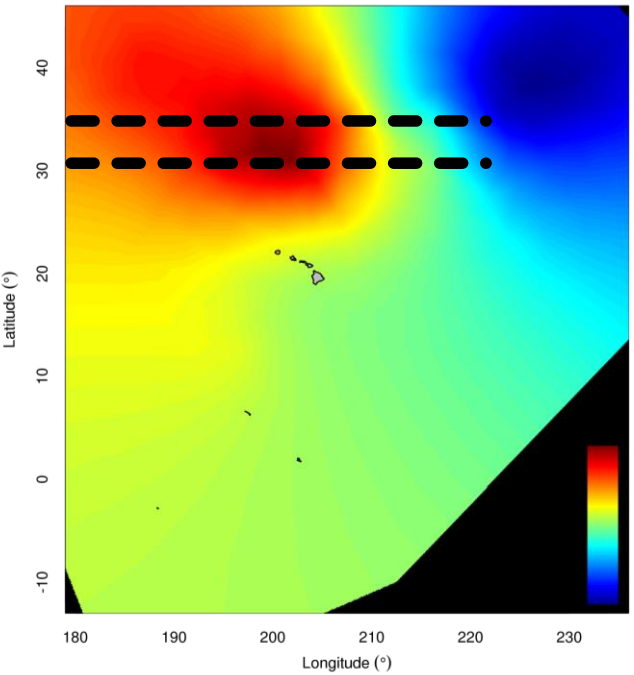
N = 55,703

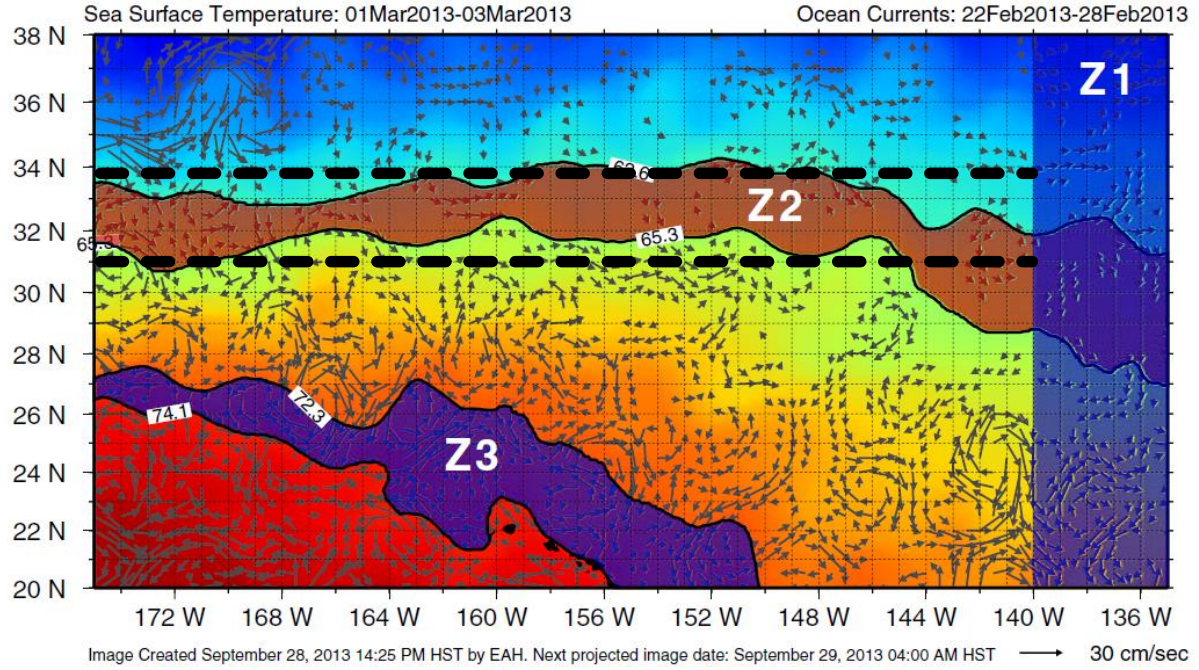


Results: Shared model

Binomial

N = 97



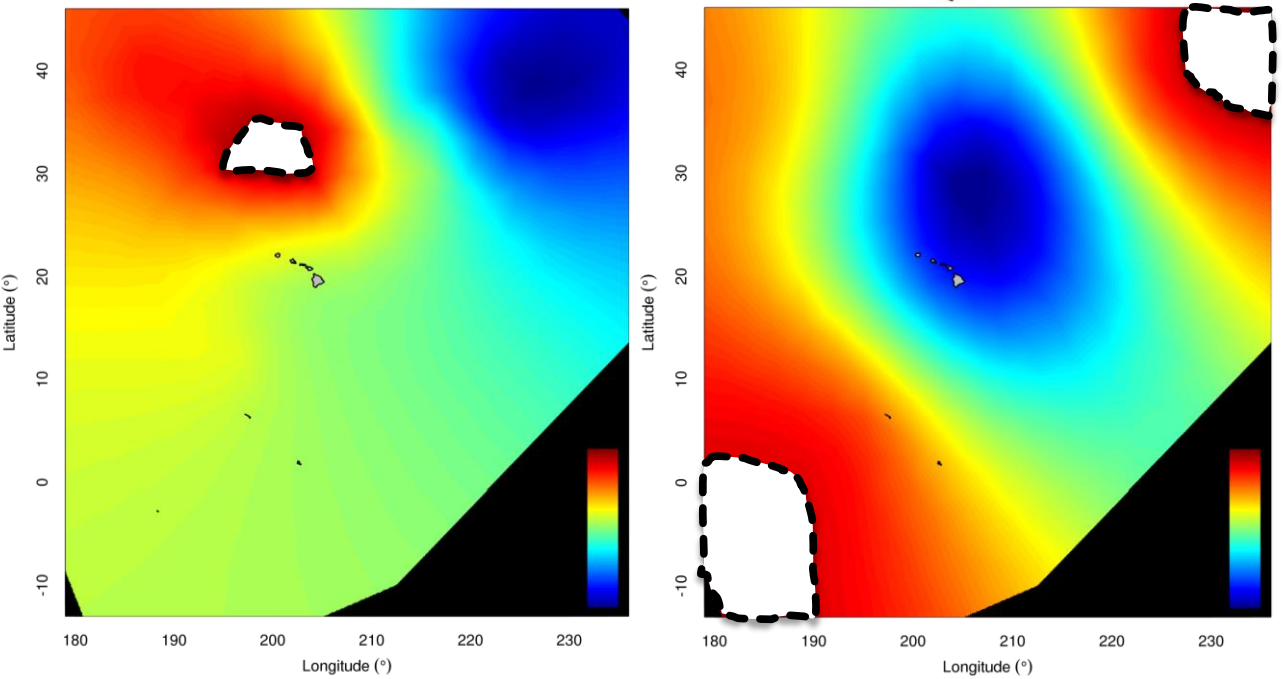


Results: Shared model

Binomial

N = 97

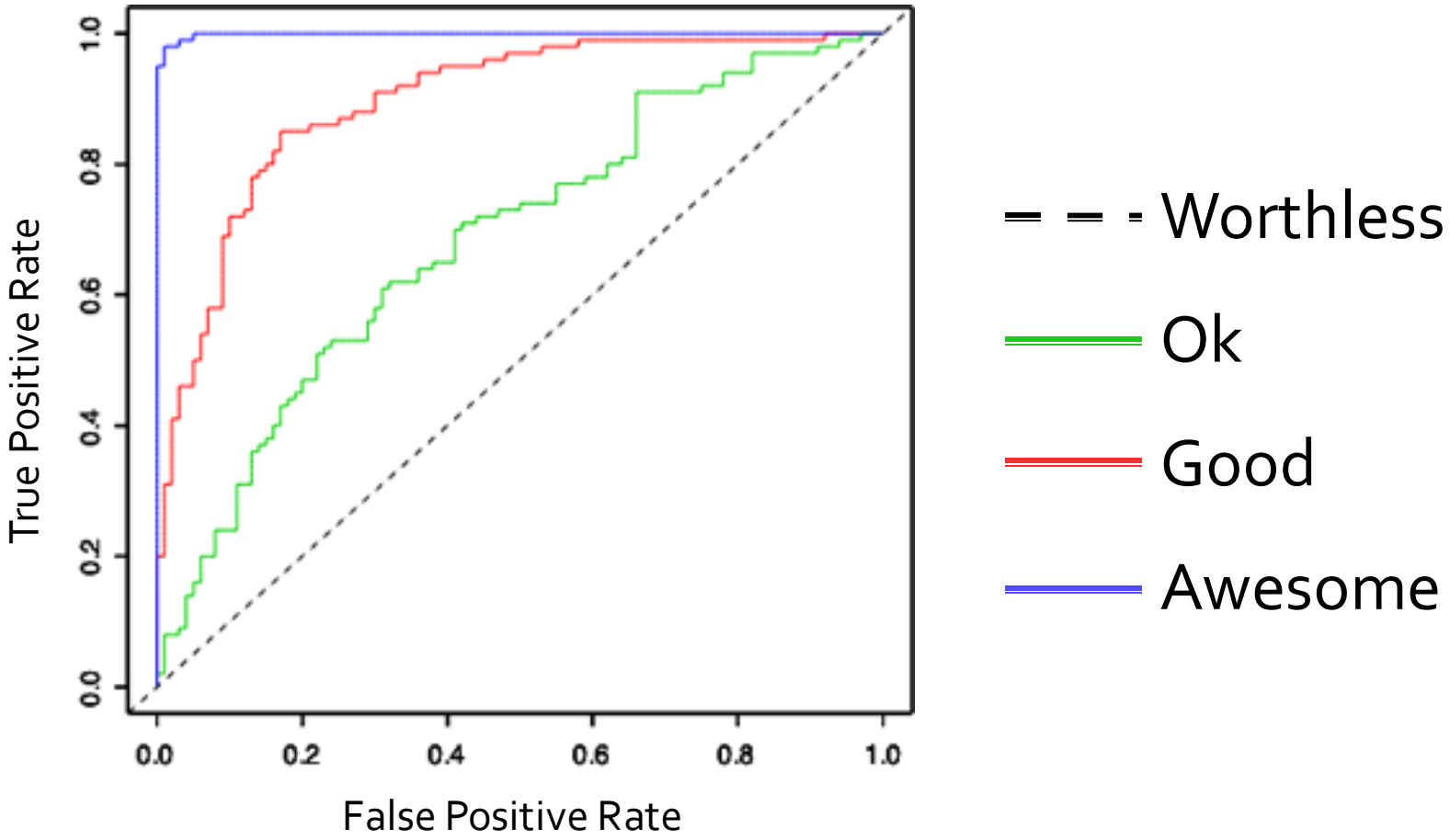
N = 111



So what?

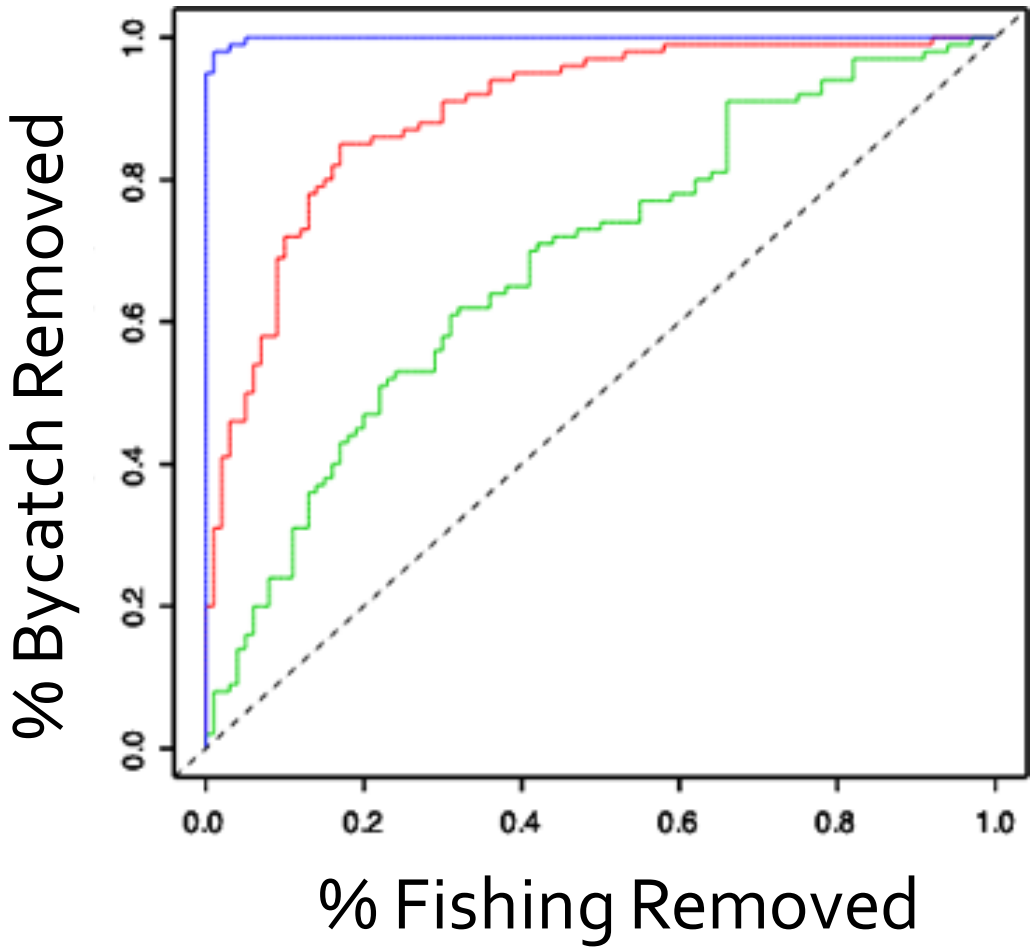
Results: ROC

Binomial



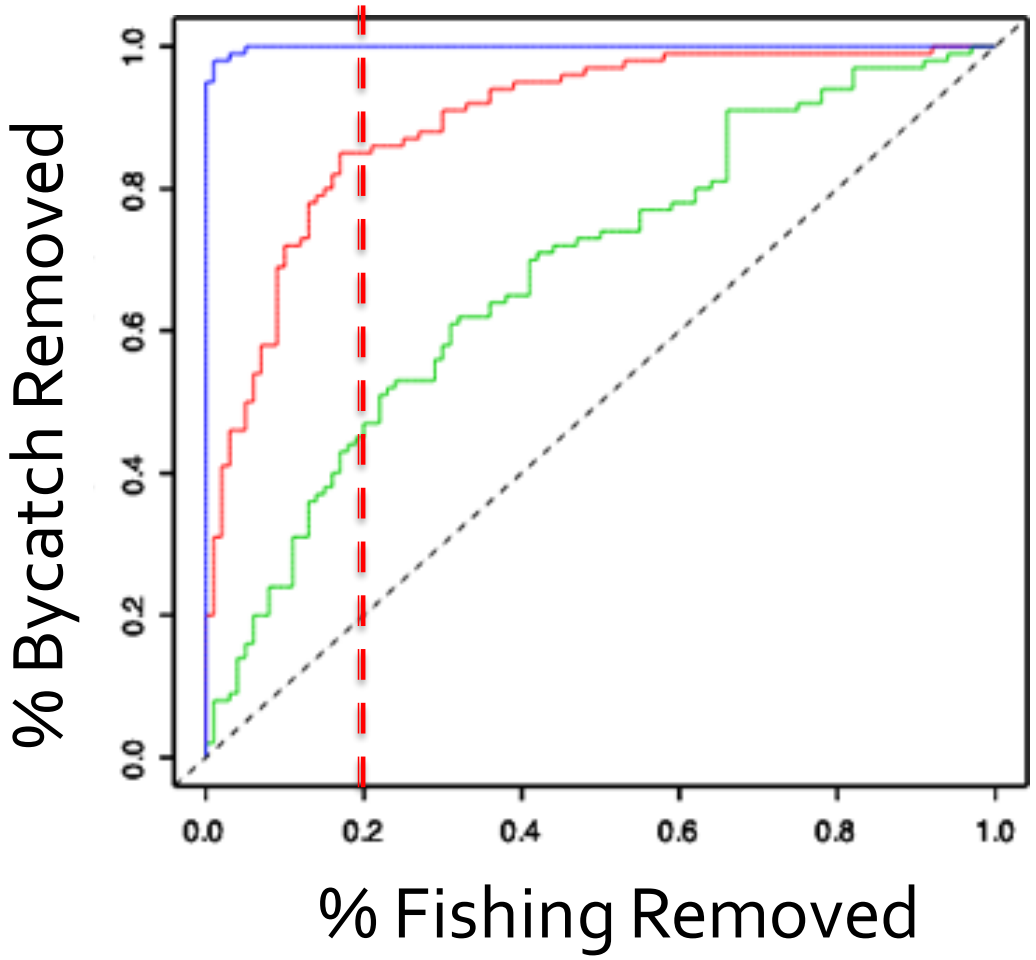
Results: ROC

Binomial



Results: ROC

Binomial



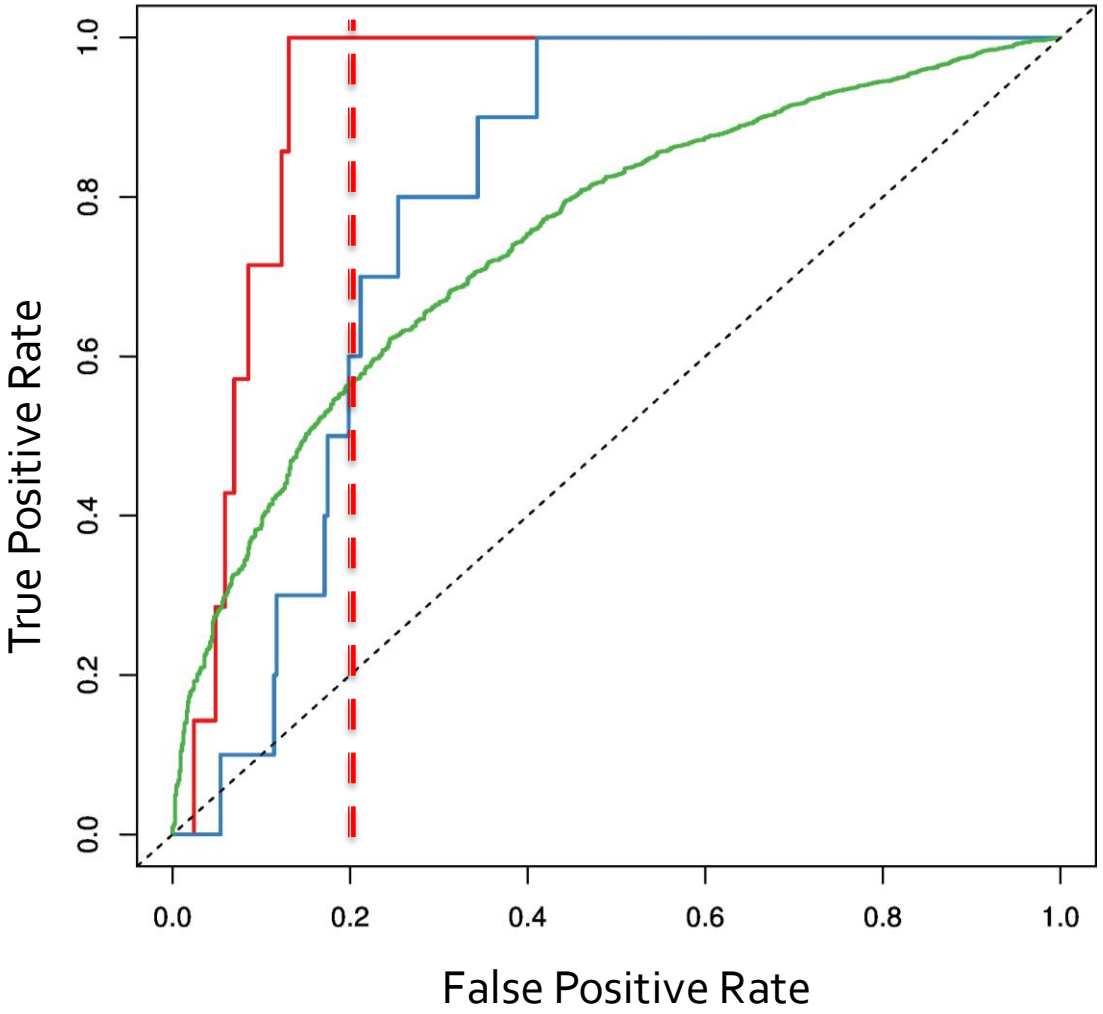
Eliminate 20% of fishing

Reduction in bycatch:

- 20%
- 45%
- 85%
- 100%

Results: ROC

Binomial



Eliminate 20% of fishing

Reduction in bycatch:

100%

60%

55%

Conclusions

1. How well can we predict fisheries bycatch in space and time?

   Well enough to be useful for management

2. What *type* of spatial model best predicts bycatch?
3. Does the answer depend on *species traits*?

   Depends on amount of data and bycatch rate

Acknowledgements

SIO

- Brice Semmens

NWFSC

- Eric Ward
- Essential Fish Habitat (Blake Feist)
- West Coast Groundfish Observer Program (Jason Jannot)

SWFSC

- Tomo Eguchi

PIFSC

- Hawaii Longline Observer Program (Eric Forney)

Results (preliminary)

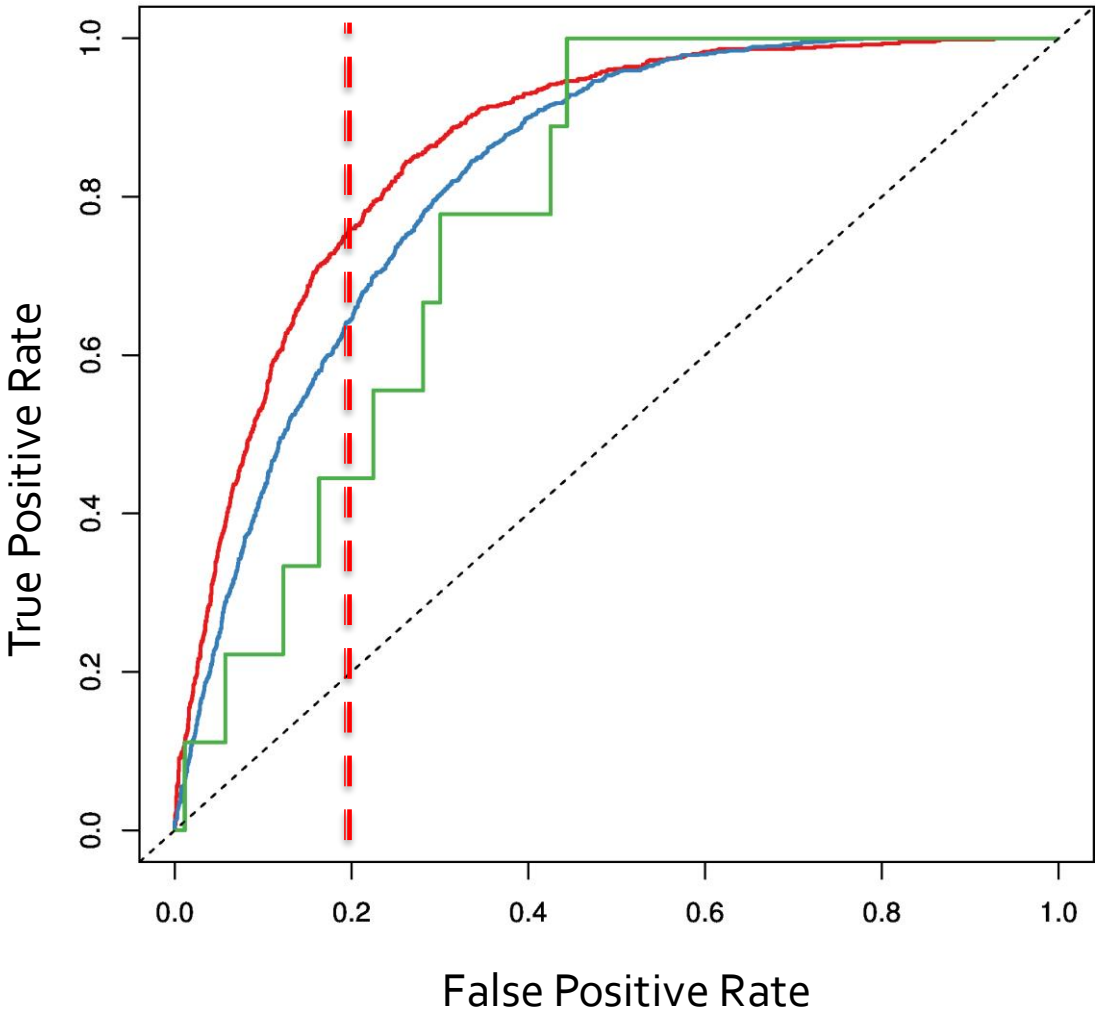
Binomial

Table 2. Probability of occurrence (binomial model, test data)

	DBRK (18%)		PHLB (28%)		YEYE (0.4%)		LOGG (0.15%)		LEATH (0.18%)		BLUE (89%)	
Method	AUC	F	AUC	F	AUC	F	AUC	F	AUC	F	AUC	F
INLA												
Shared	.843		.820		*.775*		*.923*		*.795*		.740	
Constant	.849		*.826*		.774		---		---		*.749*	
Fixed	*.863*		.790		.774		---		---		---	
AR	.862		.790		.774		---		---		.684	
GAM												
Null (GLM)	.799		.704		.762		.924		.797		.672	
Shared	.845		.818		.766		.931		**.847**		.739	
Constant	.851		.826		*.776*		.938		.820		.749	
Fixed	*.864*		*.848*		.653		*.947*		.677		*.762*	
Random Forest												
Constant	**.881**		**.874**		.743		.592		.627		.780	
SMOTE	.879		.871		**.794**		**.953**		.704		.781	
Downsample	.874		.869		.788		.946		*.836*		**.795**	

Results: ROC

Binomial



Eliminate 20% of fishing

Reduction in bycatch:

75%

65%

45%

Fisheries Observer Data

West Coast Groundfish

- 2002-2013
- 55,835 tows
- 1.7 million records

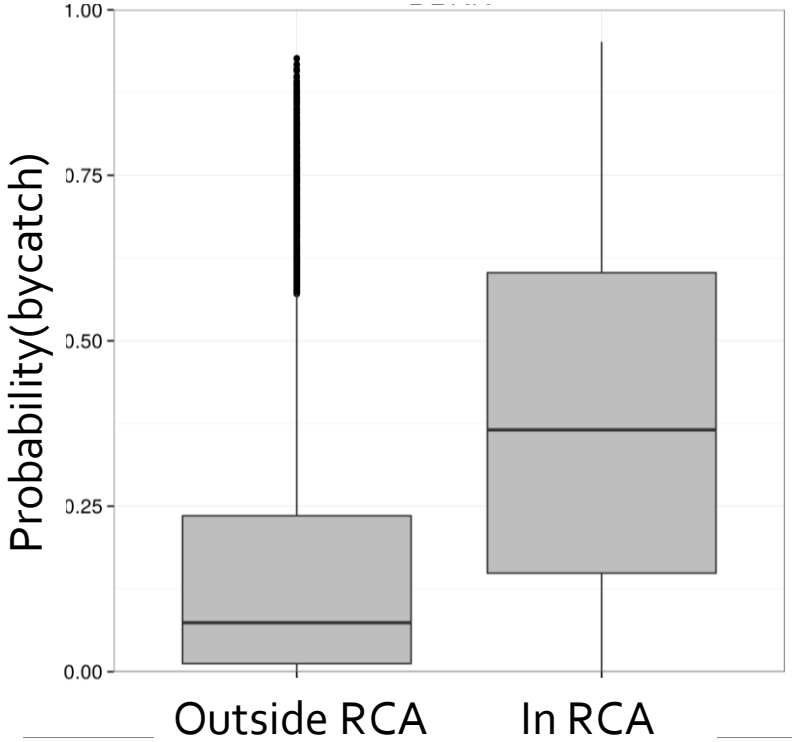
Hawaii Longline

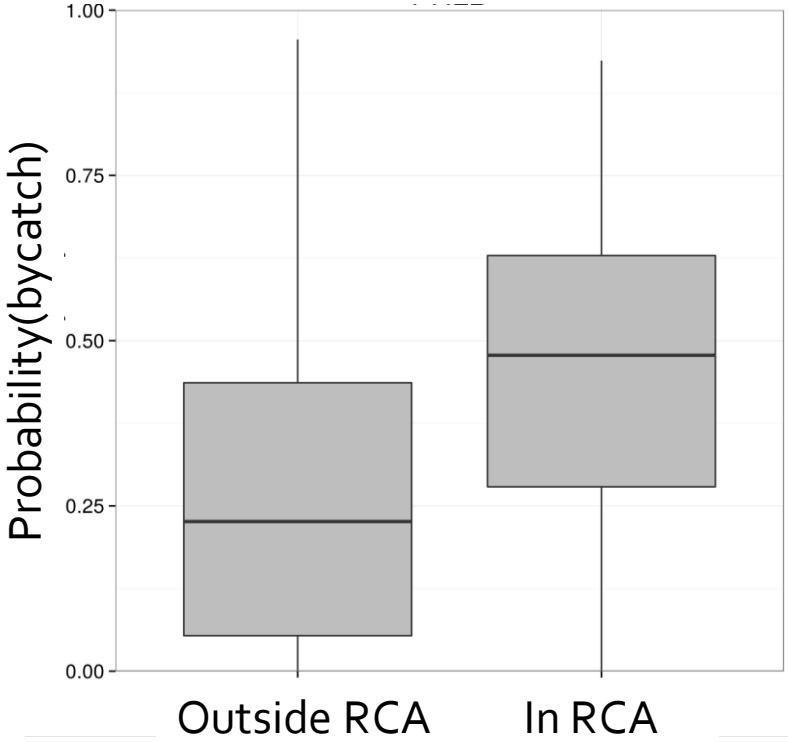
- 1994-2014
- 70,297 sets
- 3.2 million records

Results: RCAs

Binomial

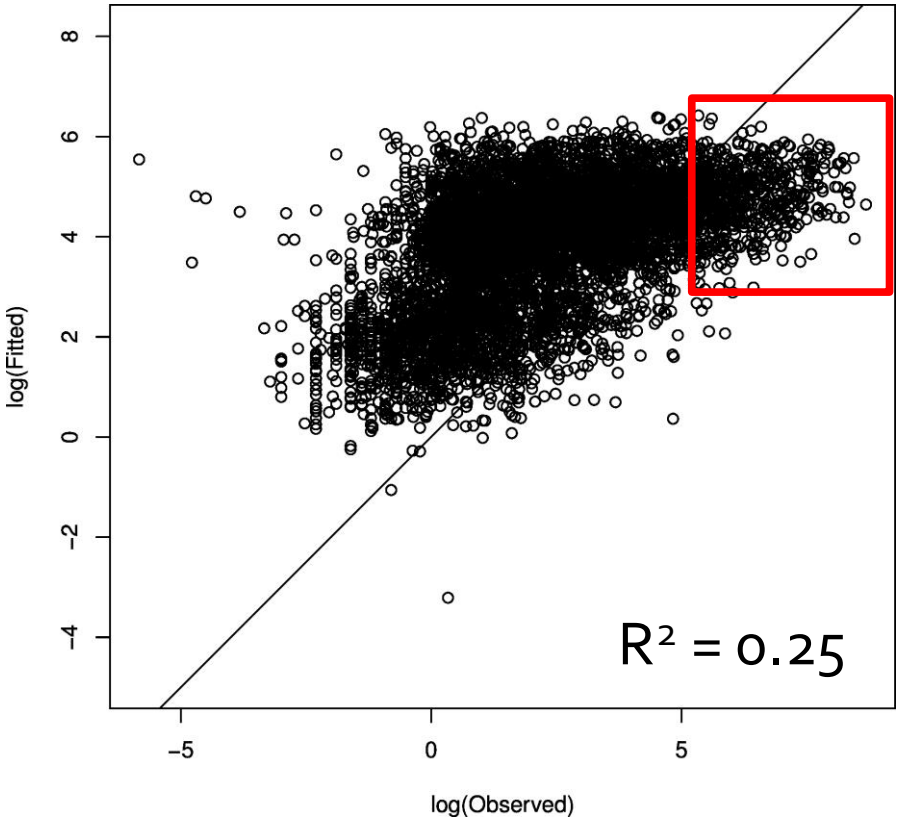
11% of tows were in Rockfish Conservation Areas

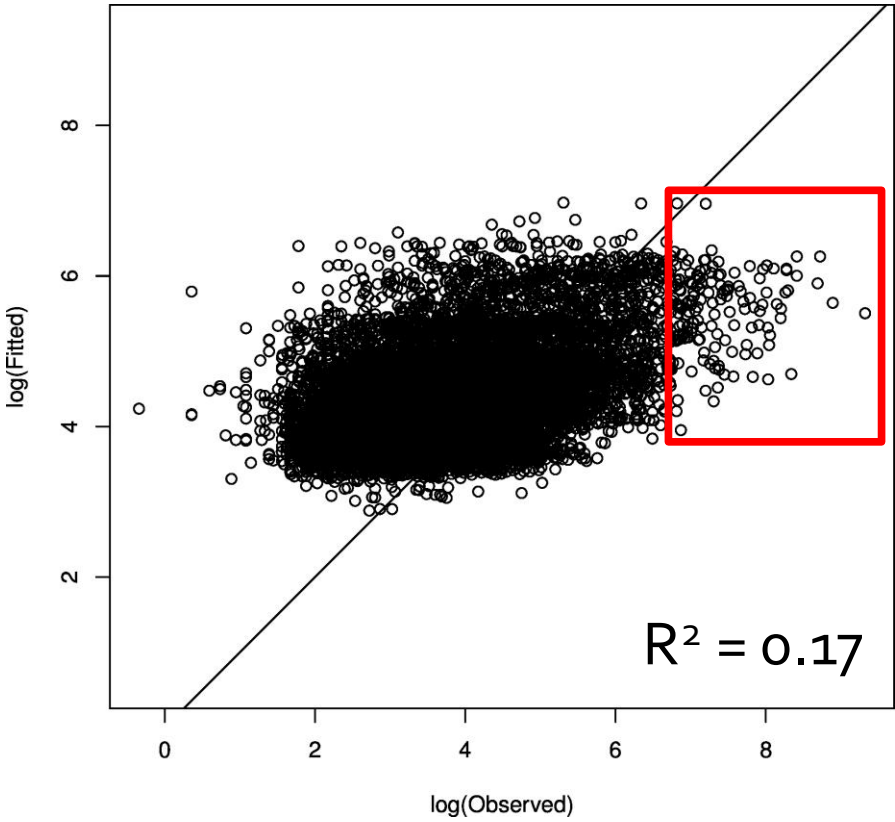




Q: What about the positive model?

Positive

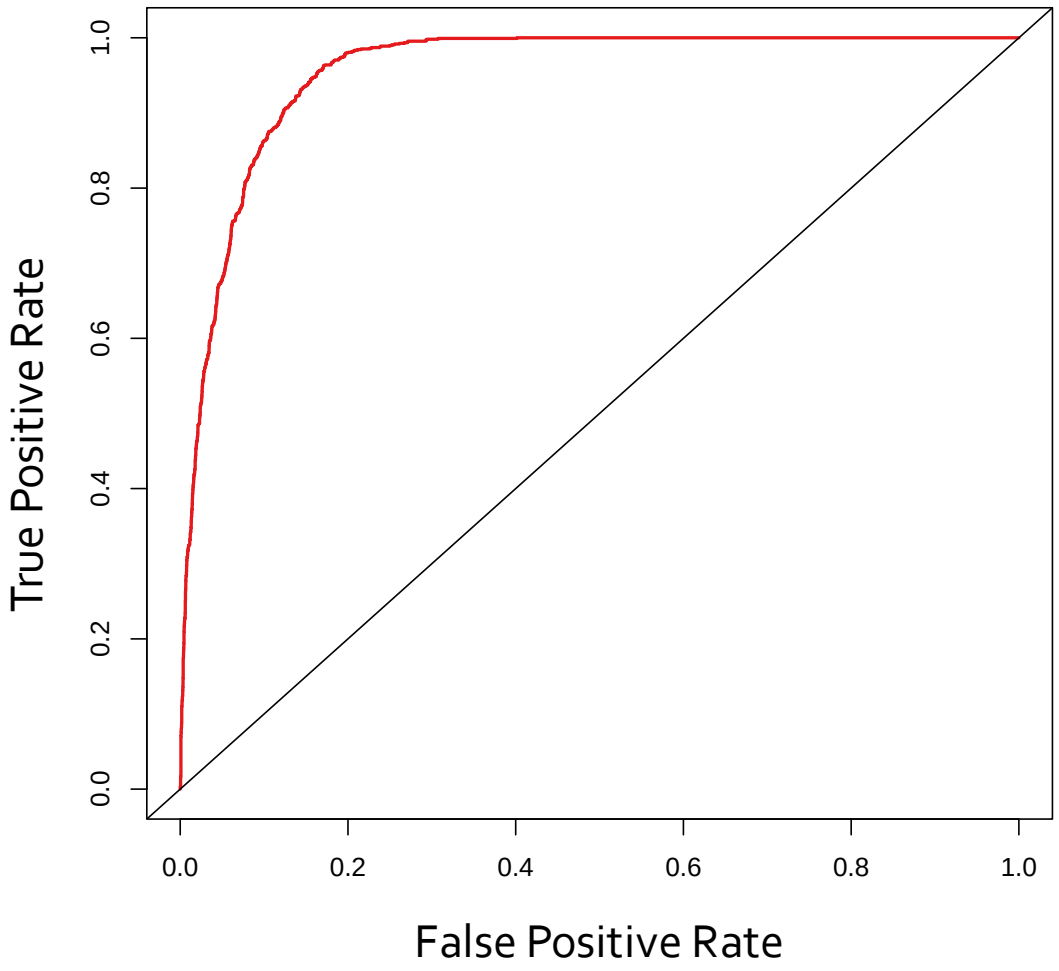




Q: What about effort?

Results: ROC (survey)

Binomial

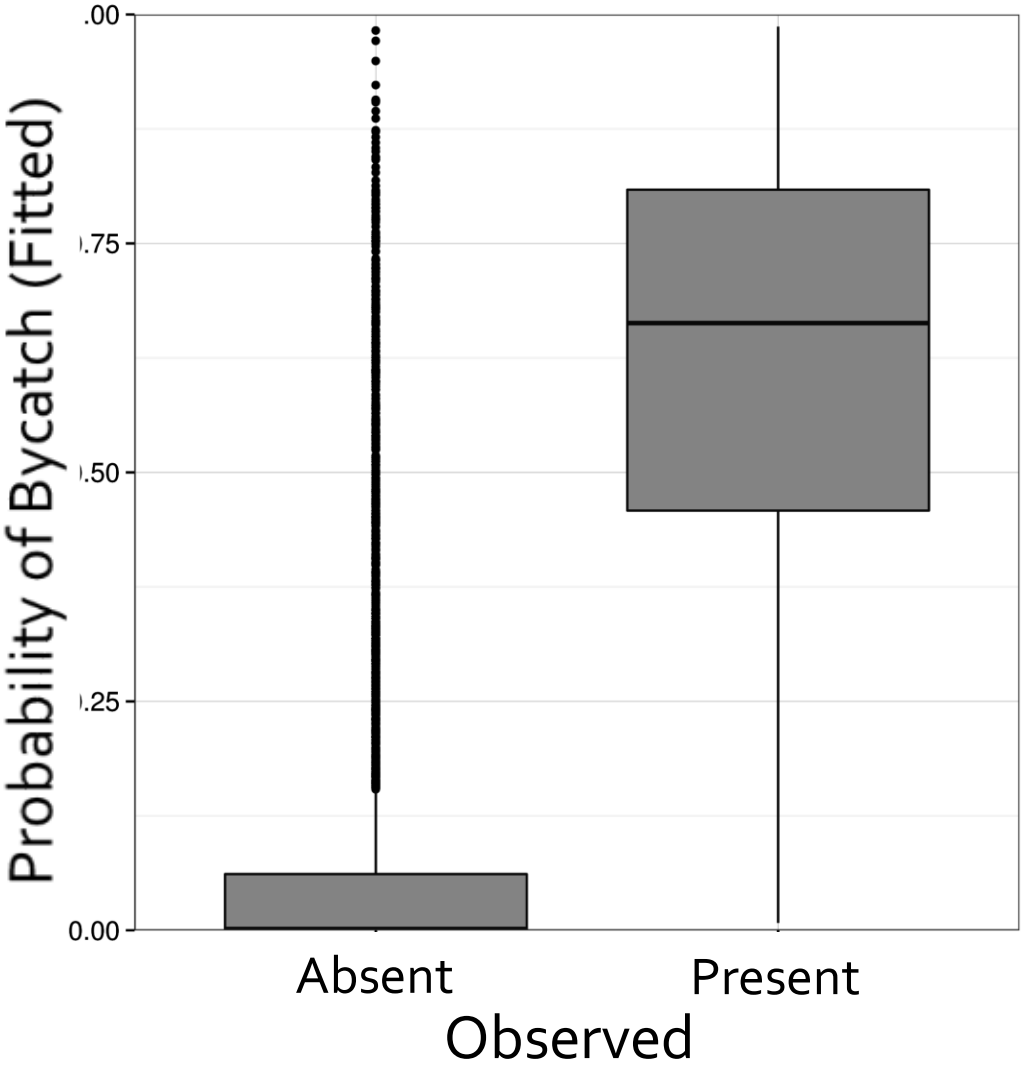


AUC = 0.955

Outstanding!

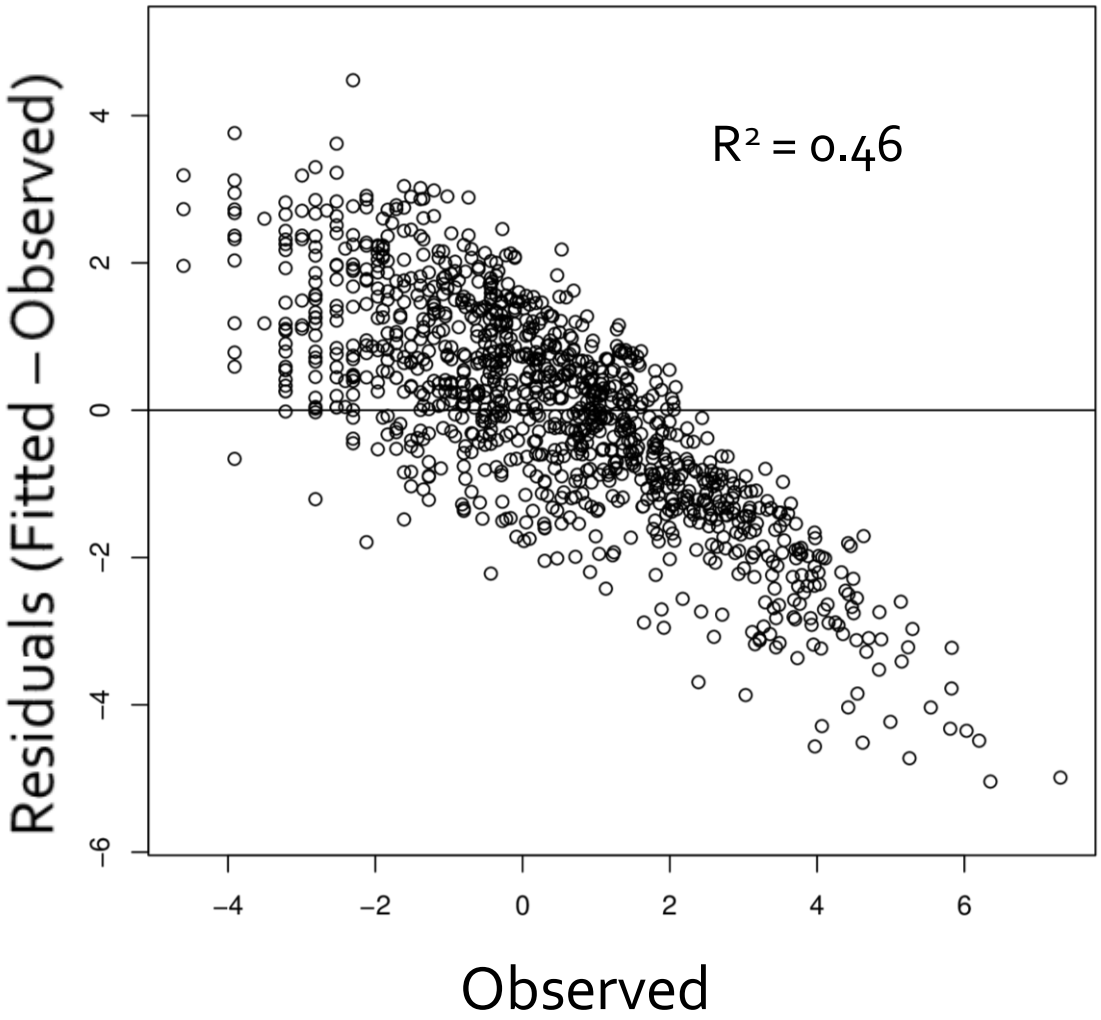
Proof of Concept

Binomial



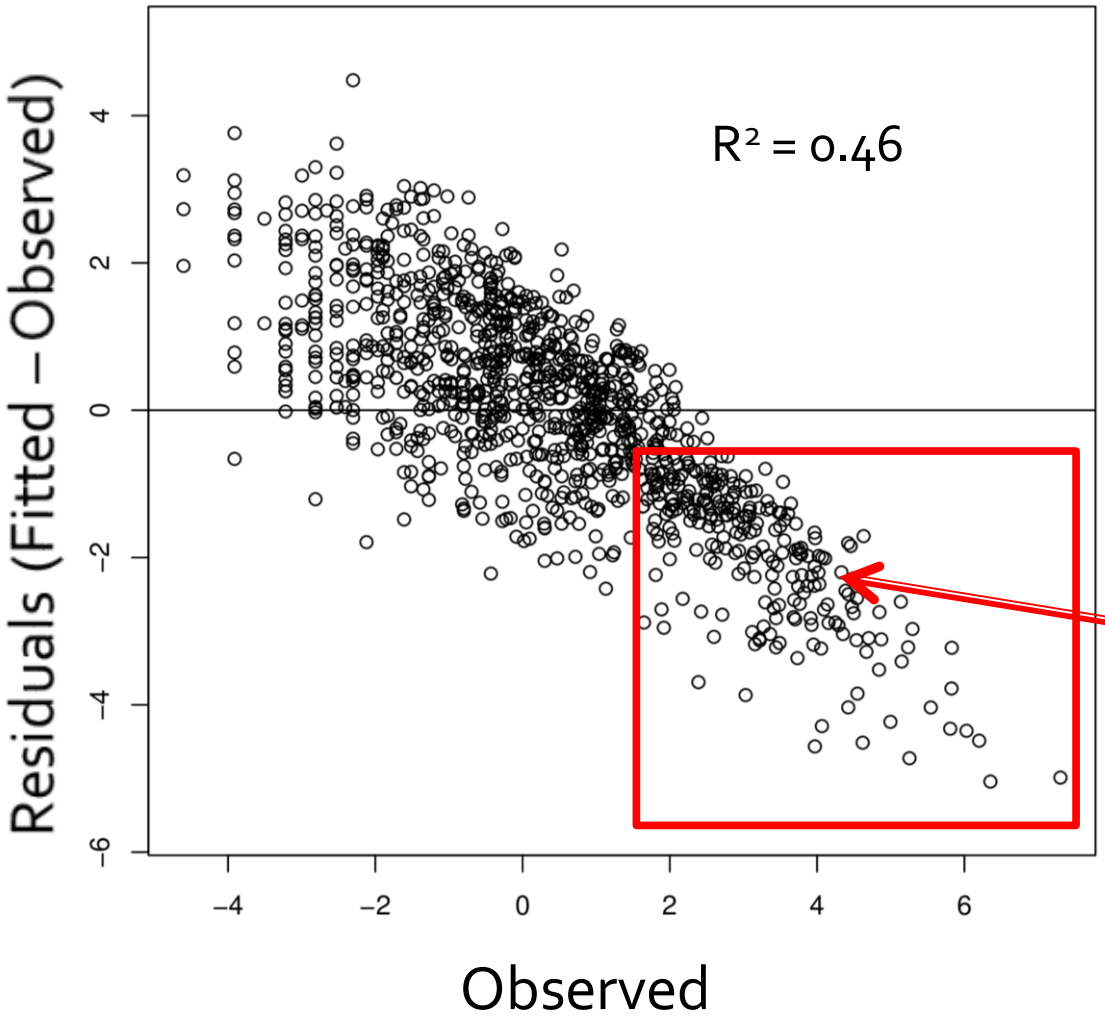
Proof of Concept

Positive



Proof of Concept

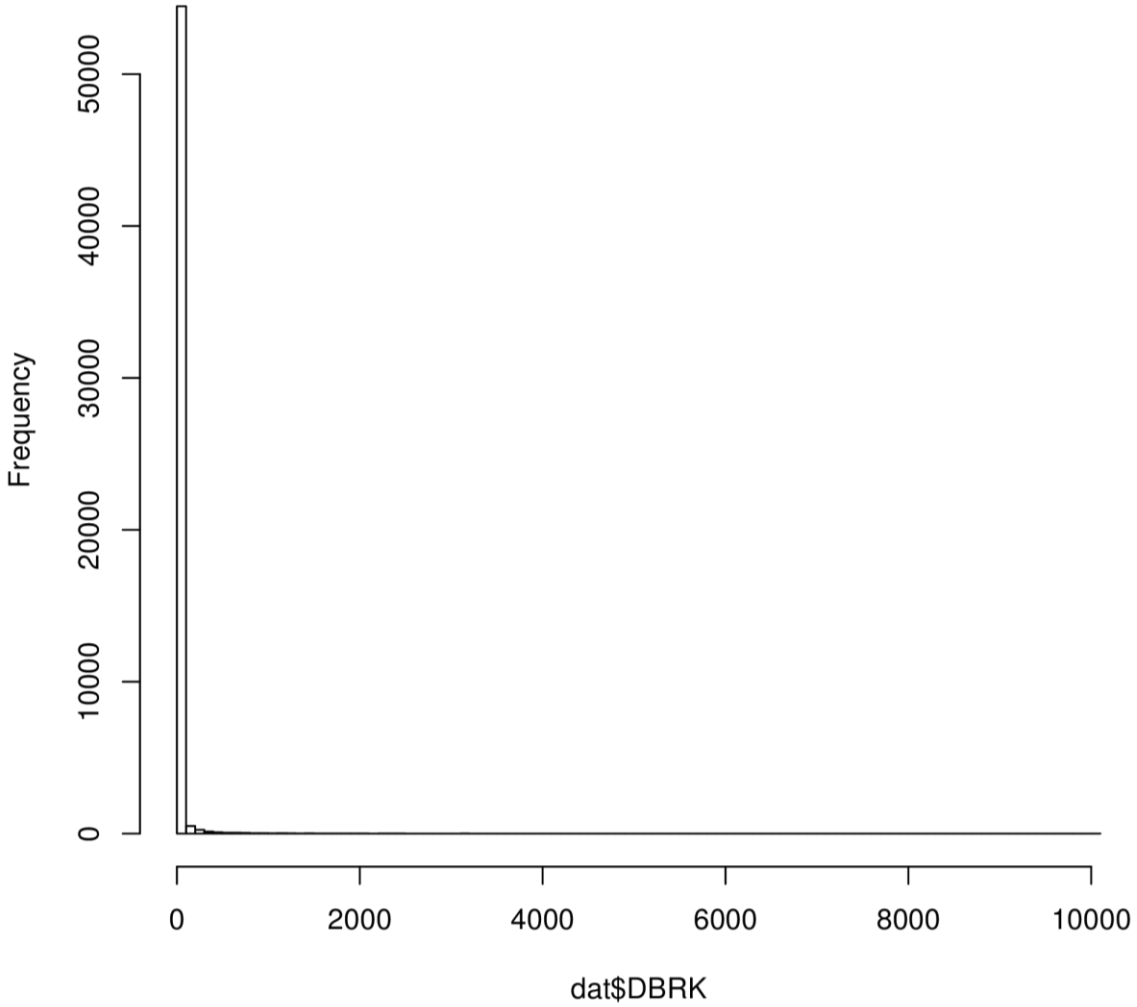
Positive



These extreme bycatch events are the most important to predict!

Proof of Concept

Positive



Proof of Concept

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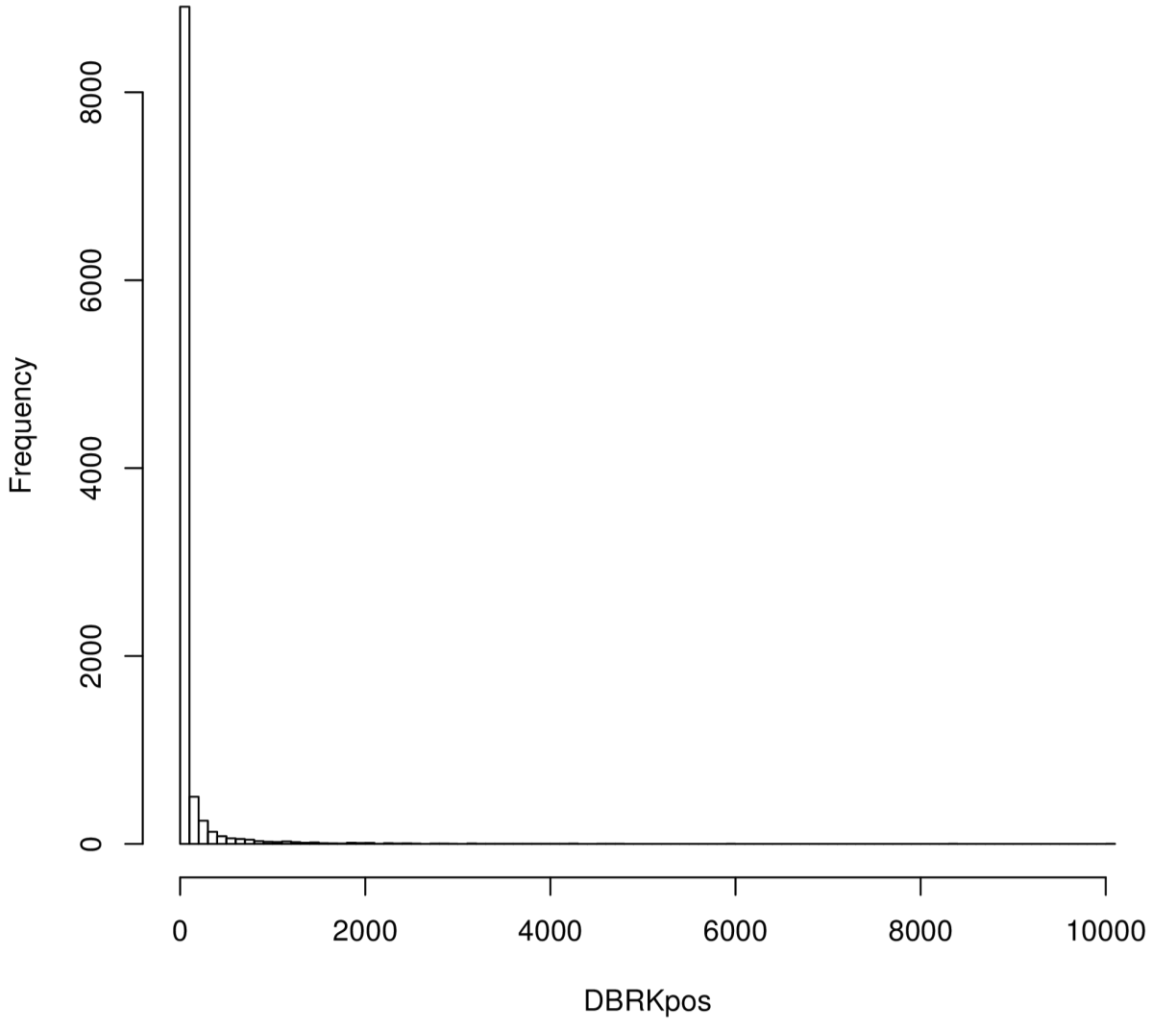

Proof of Concept

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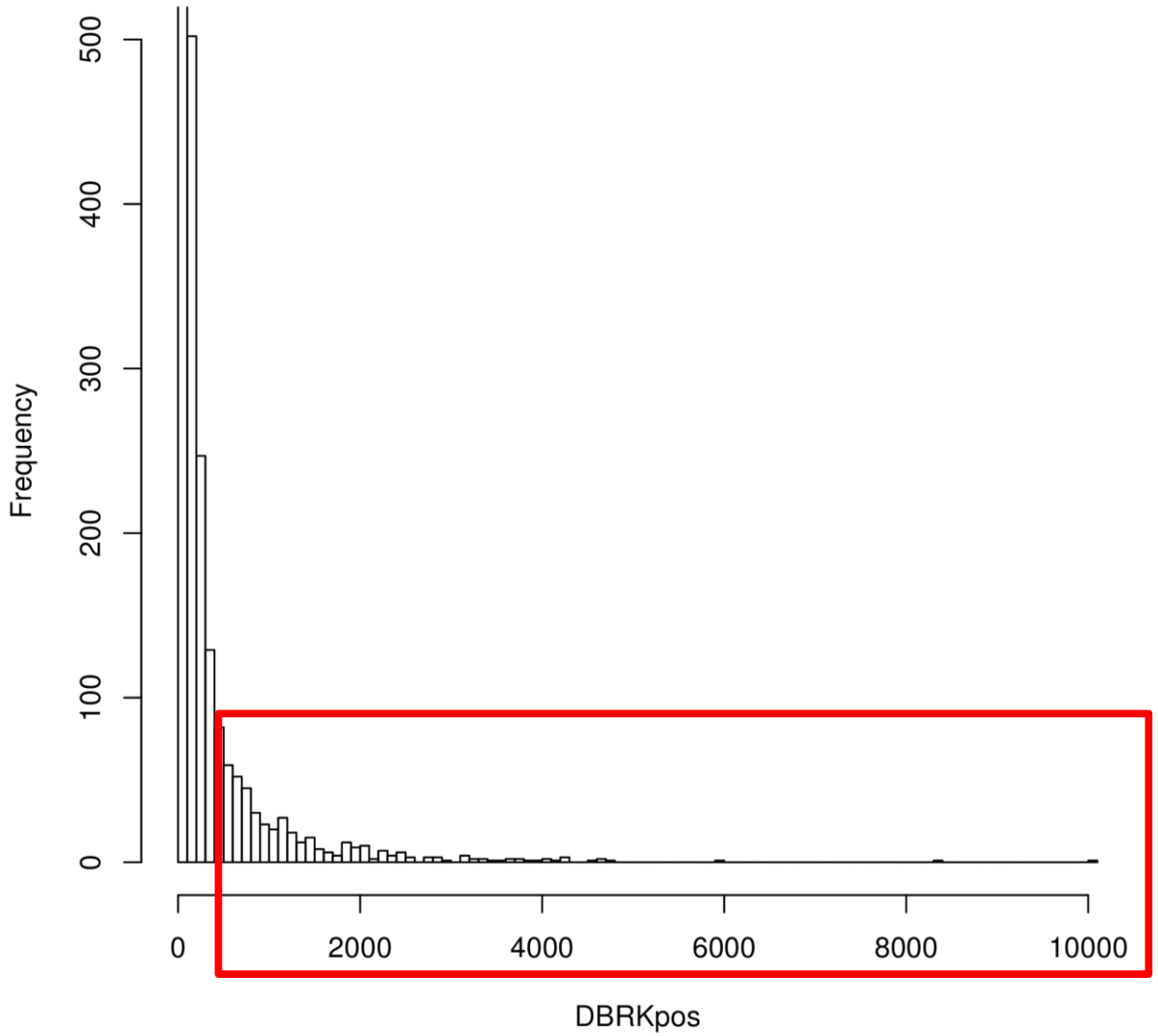
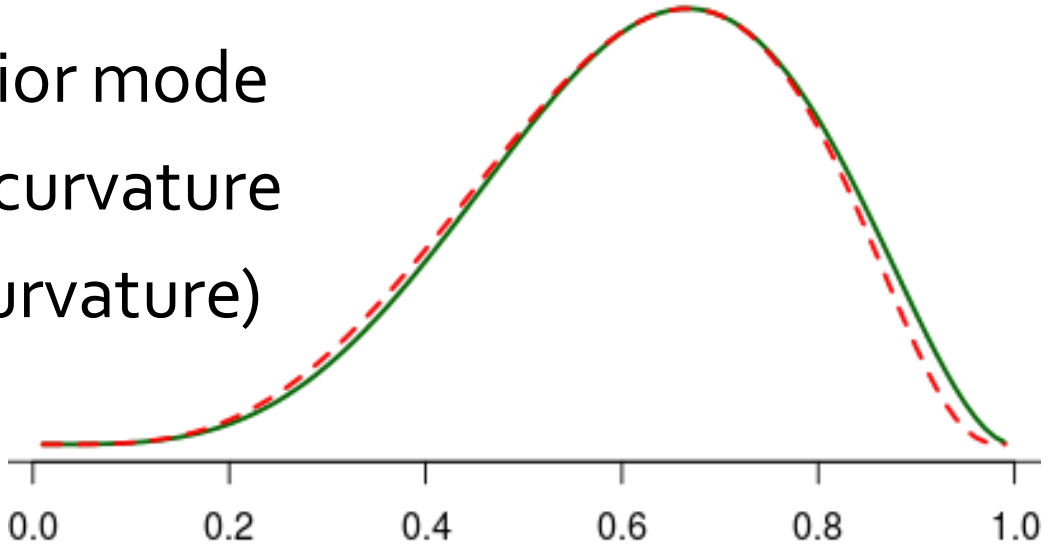


Spatial models: INLA-SPDE

Integrated Nested Laplace Approximation

- Alternative to MCMC for Bayesian inference
- *Much* faster

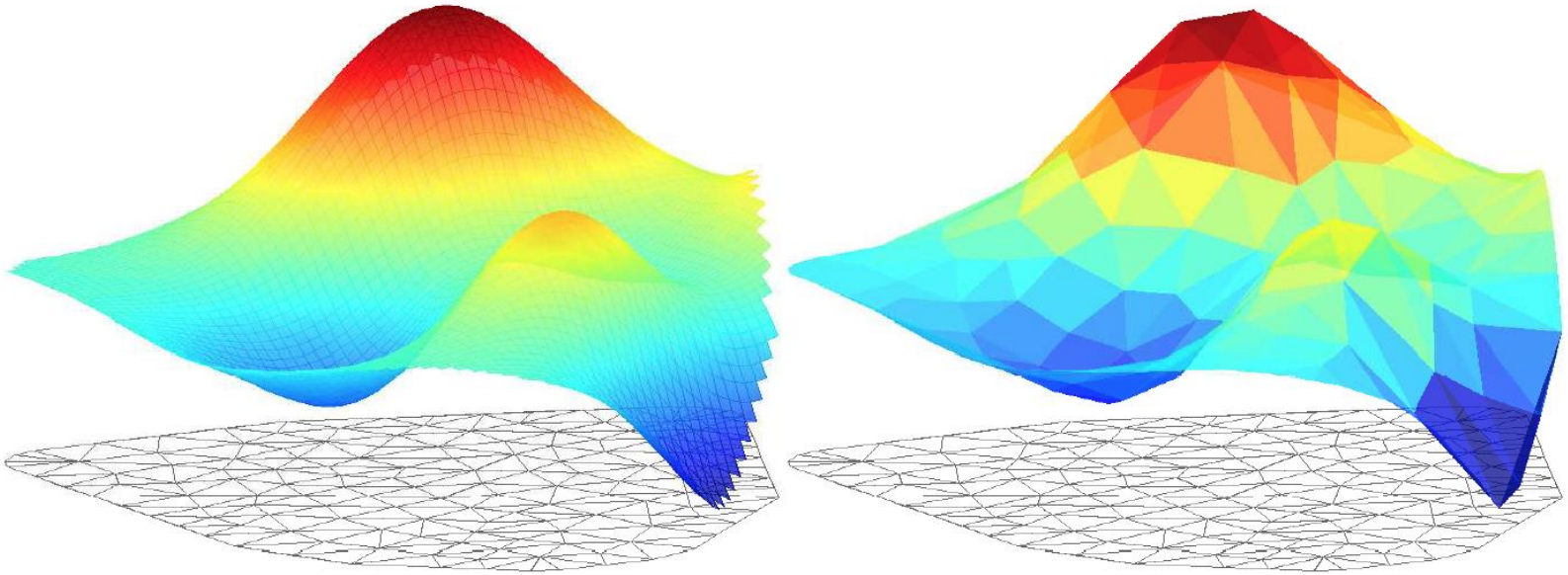
1. Find the posterior mode
2. Calculate local curvature
3. Use *N*(mode, curvature)



Spatial models: INLA-SPDE

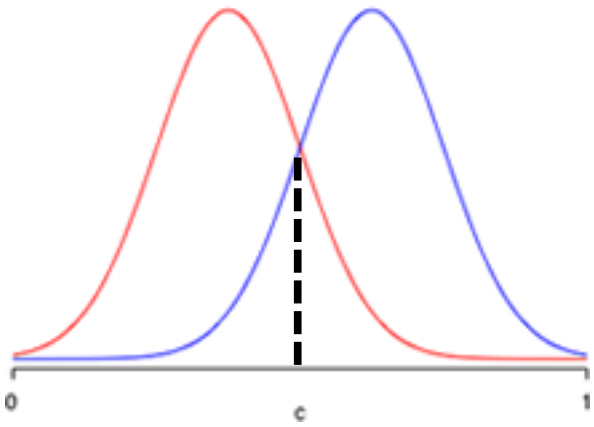
Spatial Partial Differential Equation

- Discrete approximation of continuous spatial fields



Preliminary results: ROC curves

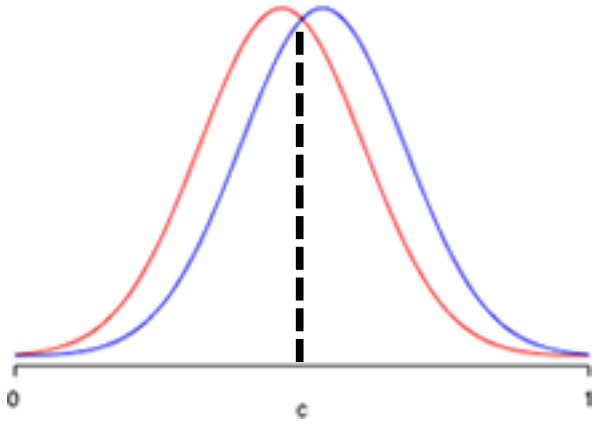
Good



False positive rate 0.30
True positive rate 0.70

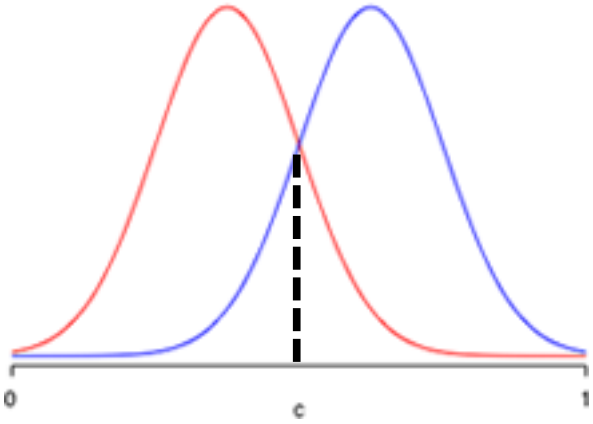
Preliminary results: ROC curves

Bad



False positive rate 0.48
True positive rate 0.52

Good



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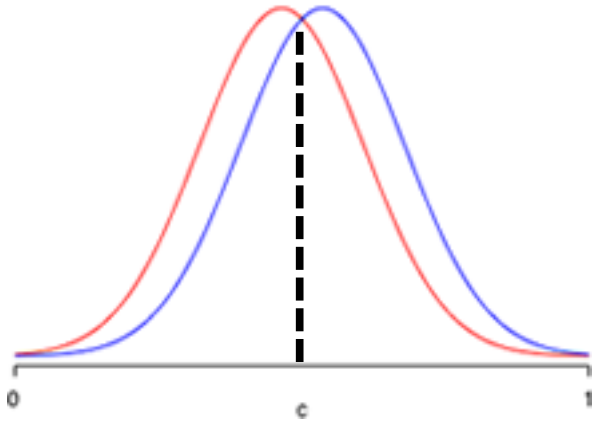
Preliminary results: ROC curves

This PDF was later amended to make the document 508 compliant.

Bad



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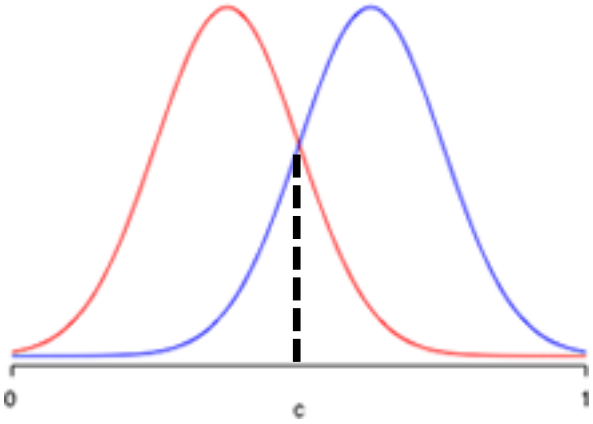

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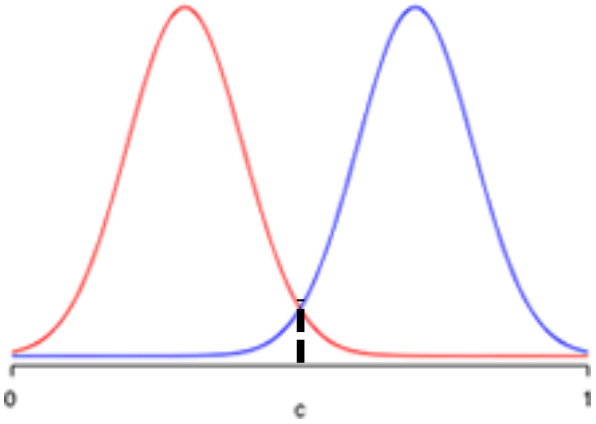
Great



False positive rate 0.05
True positive rate 0.95