

Spatial prediction of fisheries bycatch

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

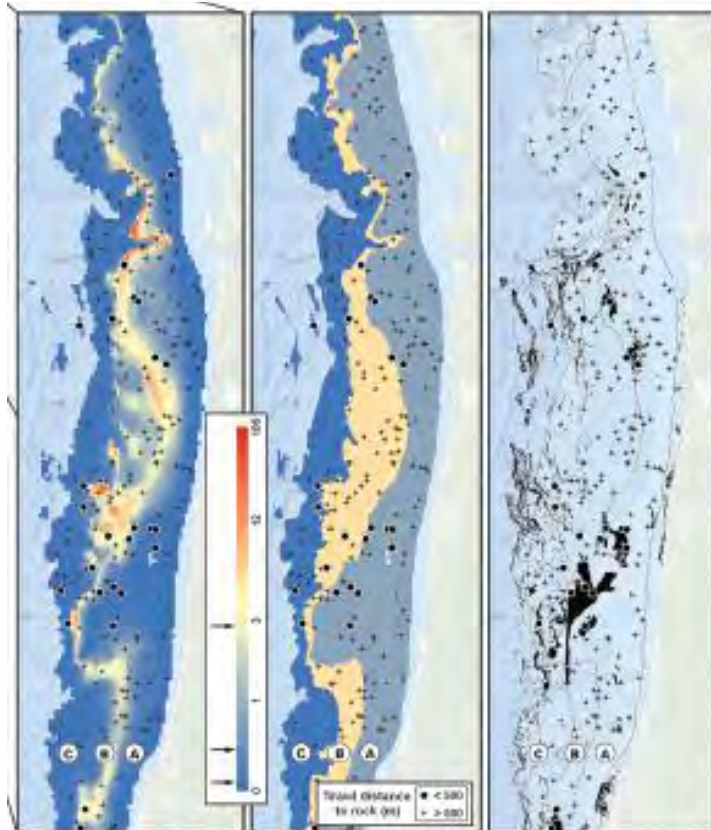


Alfaro-Shigueto et al. 2011

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

Growing interest in spatial models

Used by NWFSC assessment team

The screenshot shows the GitHub interface for the repository `nwfsc-assess / geostatistical_delta-GLMM`. At the top, the GitHub logo is on the left, followed by a search bar containing "This repository" and "Search". Navigation links for "Explore", "Features", "Enterprise", and "Pricing" are on the right. Below the repository name, there is a "Watch" button and a count of "9" watchers. A description of the tool is provided: "Tool for geostatistical analysis of survey data, for use when estimating an index of abundance". A progress bar shows the repository's activity, with a red segment for commits and a blue segment for releases. Below the progress bar, the current branch is "master", and the repository name is repeated with a plus sign for more options. A list of recent commits is shown, including a fix for a bug in the `mean_D_til` computation by James-Thorson, and updates to the `R`, `data`, and `examples` directories.

GitHub This repository Search Explore Features Enterprise Pricing

nwfsc-assess / **geostatistical_delta-GLMM** Watch 9

Tool for geostatistical analysis of survey data, for use when estimating an index of abundance

145 commits 1 branch 8 releases 2 contributors

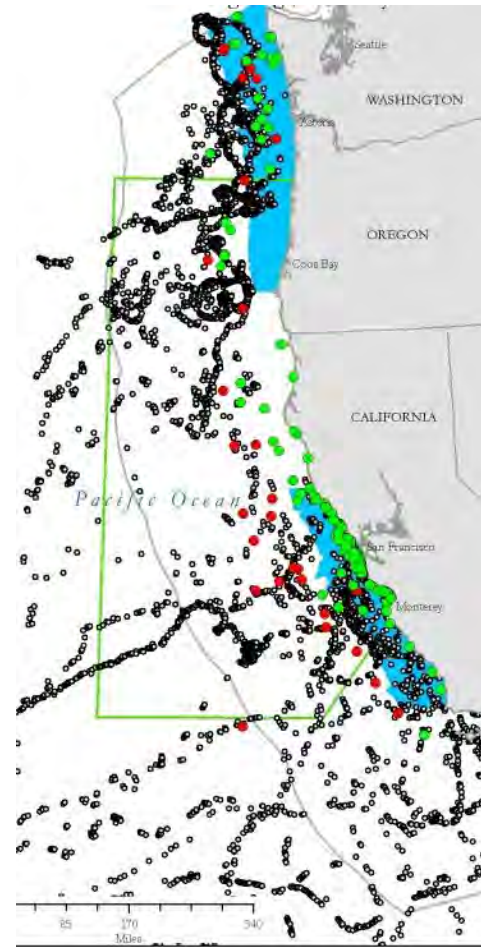
Branch: master **geostatistical_delta-GLMM** / +

James-Thorson fixed bug in `mean_D_til` computation Latest commit 6c99fa7 11 hours ago

R	fixed bug in V3i	a day ago
data	adding South African grid	7 days ago
examples	added V3i...	a day ago

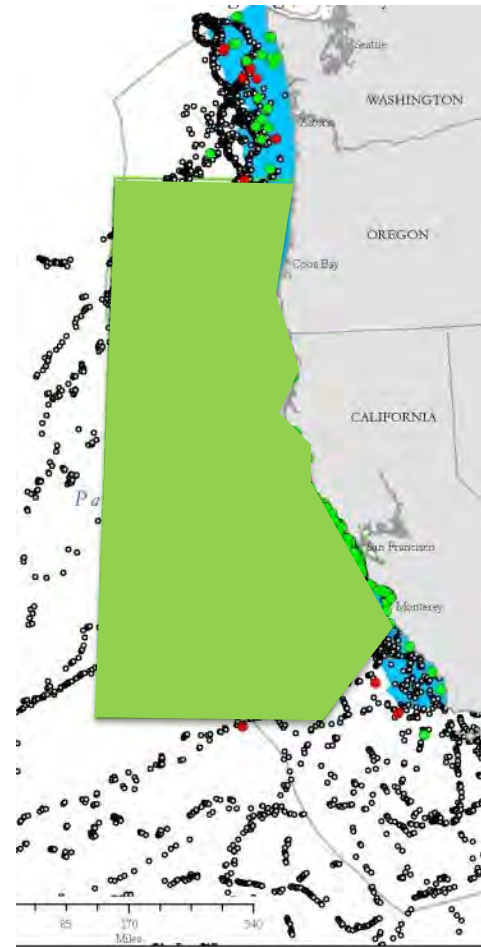
Motivation

Static management



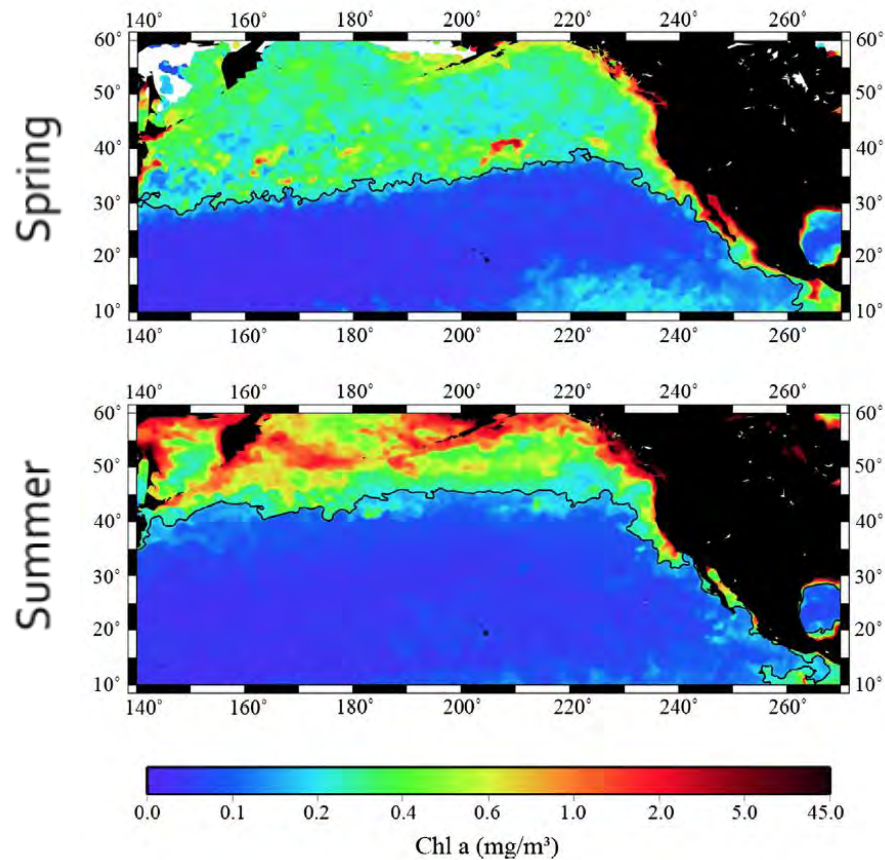
Motivation

Static management

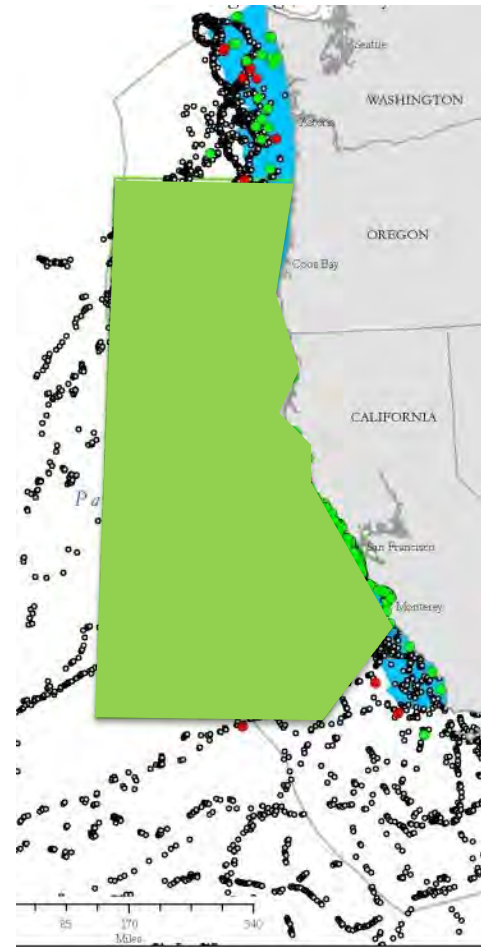


Motivation

Dynamic management

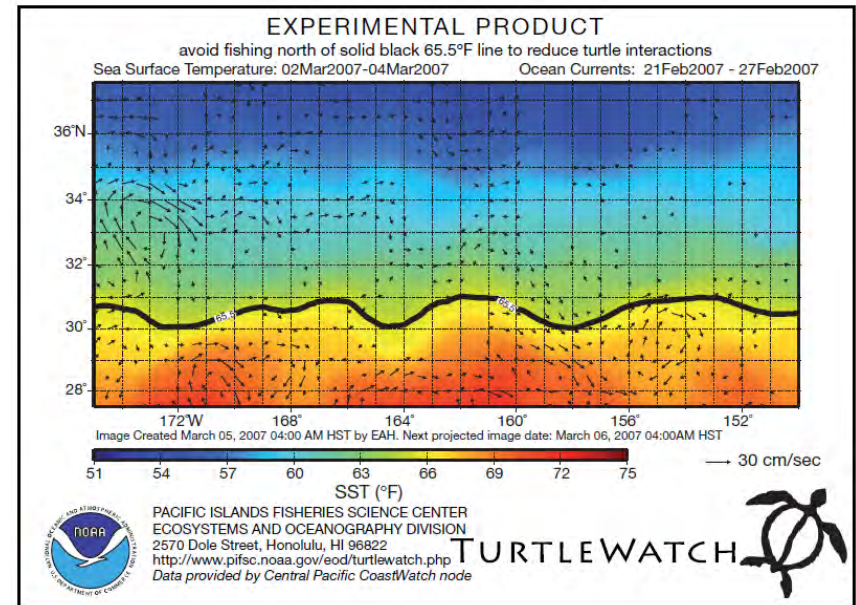
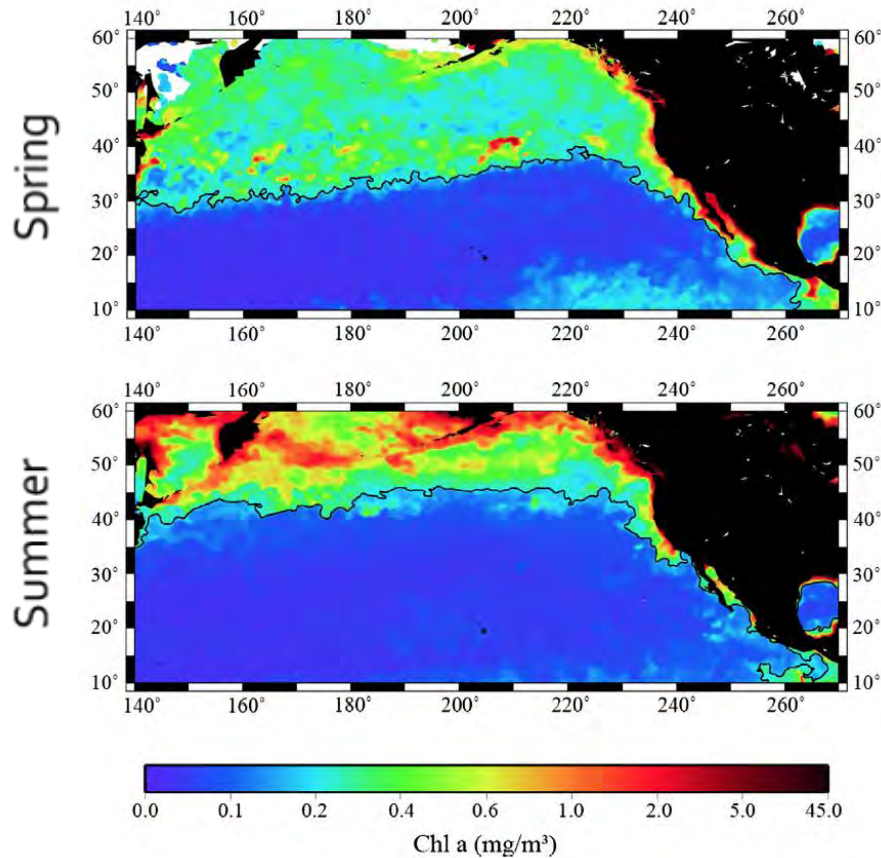


Static management



Motivation

Dynamic management



PIFSC

Research Questions

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

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Pr(some bycatch)

Binomial

Research Questions

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

$\Pr(\text{some bycatch})$

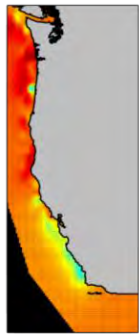
Binomial

$E(\text{bycatch} \mid \text{some bycatch})$

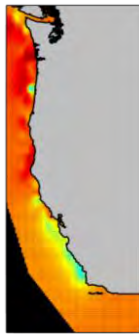
Positive

Research Questions

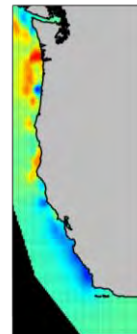
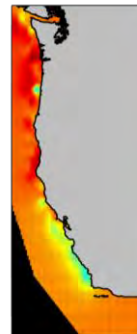
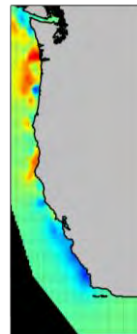
2. What *type* of spatial model best predicts bycatch?



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

Movement: Med

Bycatch Rate: 29%



Habitat: Benthic

Movement: Low

Bycatch Rate: 18%



Habitat: Benthic

Movement: Low

Bycatch Rate: 0.3%



Habitat: Pelagic

Movement: High

Bycatch Rate: 89%



Habitat: Pelagic

Movement: High

Bycatch Rate: 0.15%



Habitat: Pelagic

Movement: High

Bycatch Rate: 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

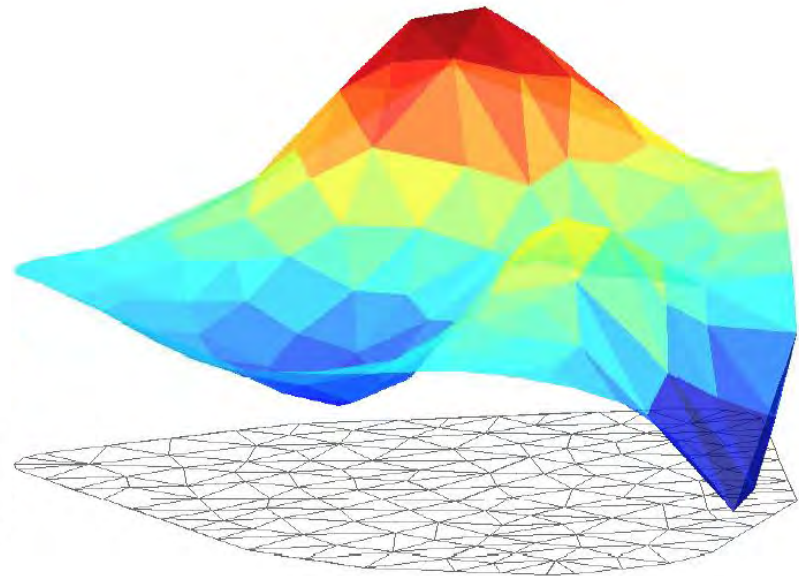
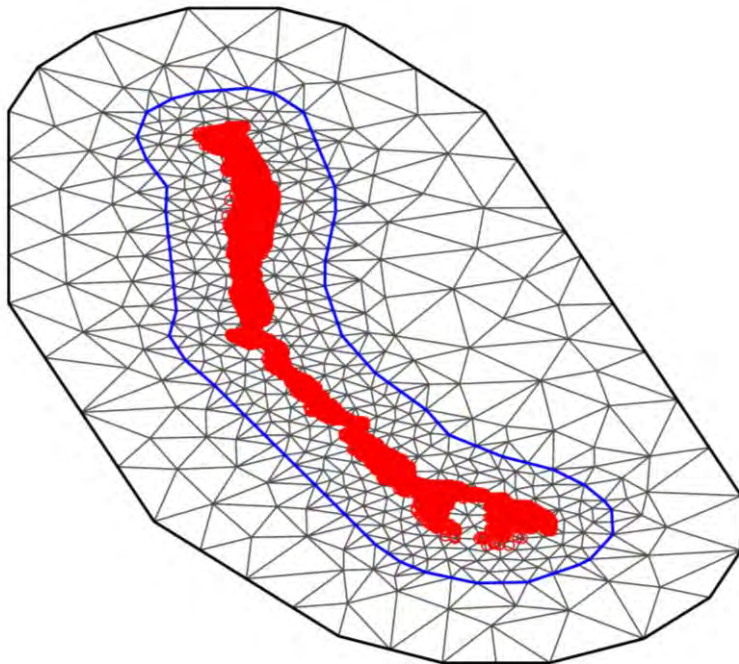
Positive

~ sst (observed) +
target +
spatial field

Spatial field: INLA-SPDE

Spatial Partial Differential Equation

- Discrete approximation of continuous spatial fields

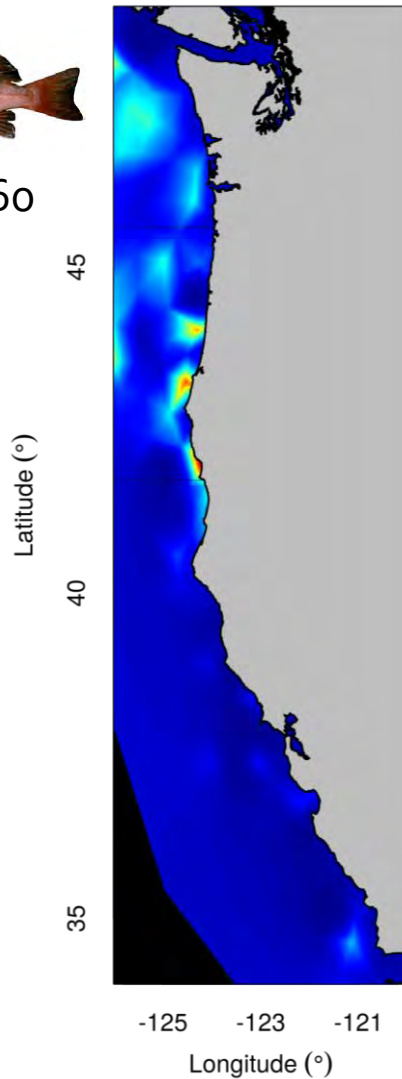


Results: Shared model

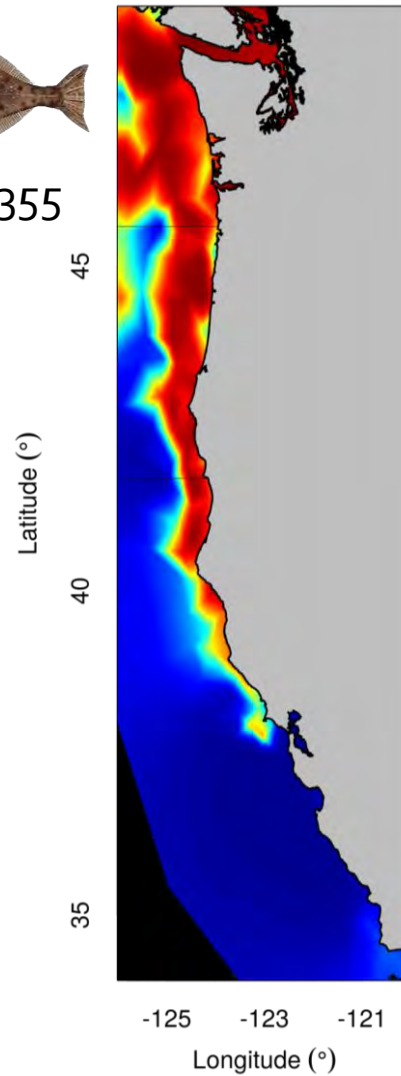
Binomial



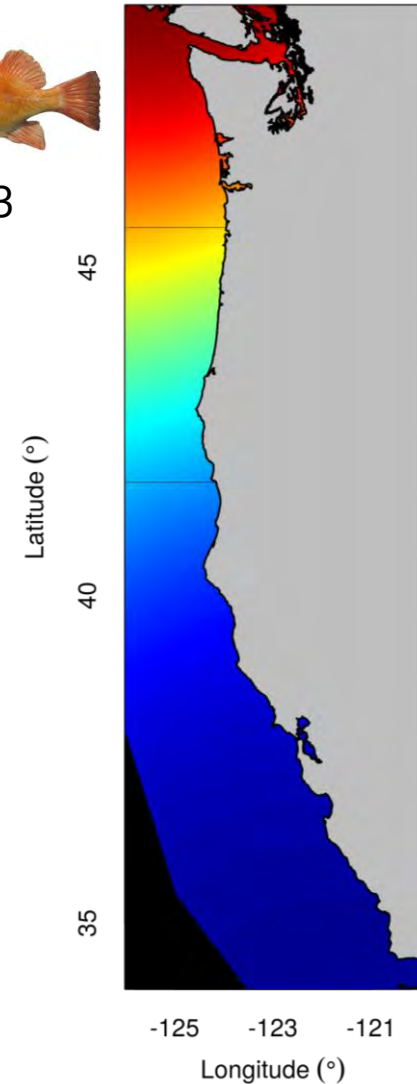
N = 7,660



N = 12,355

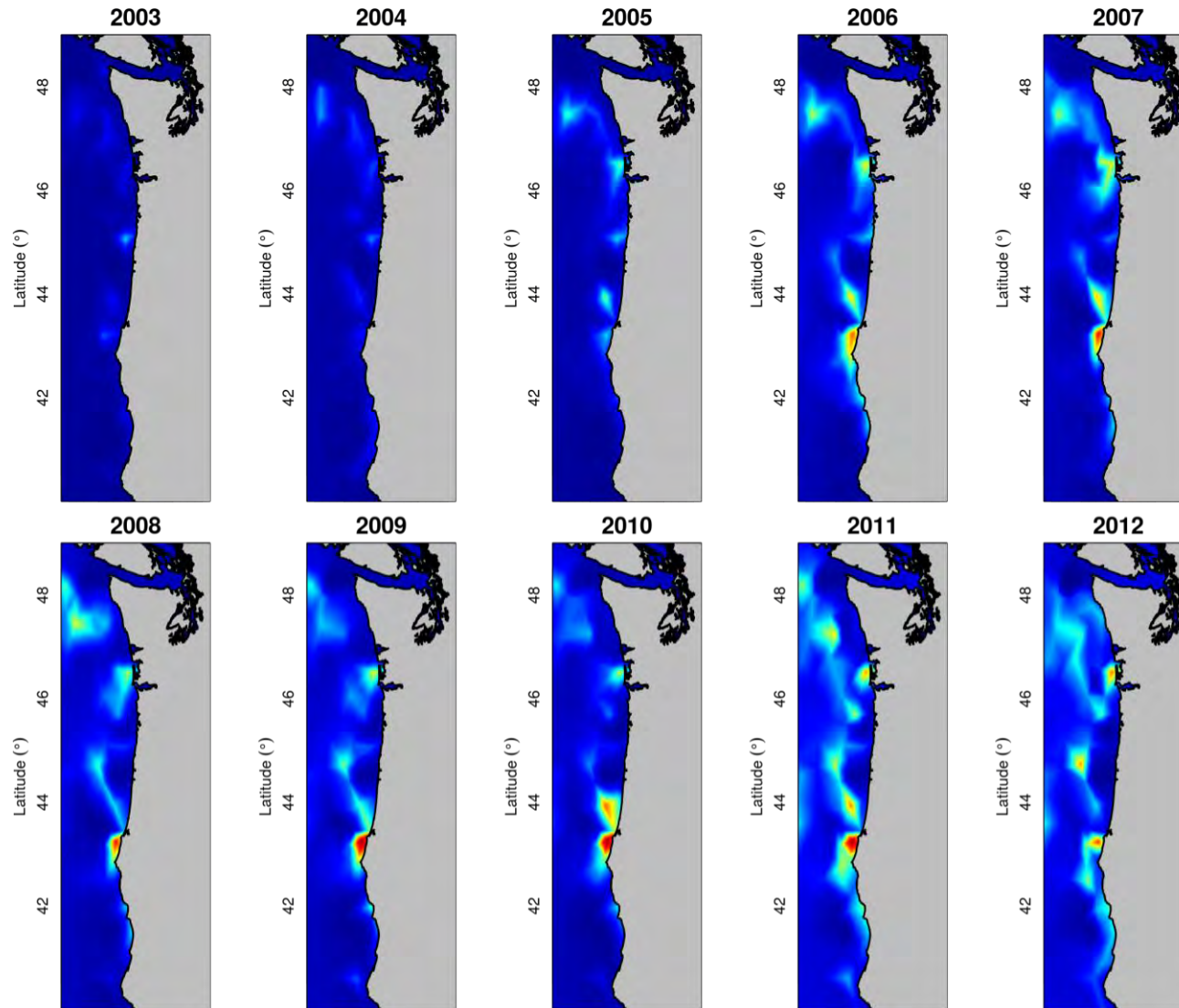


N = 143



Results: Multiple years

Binomial

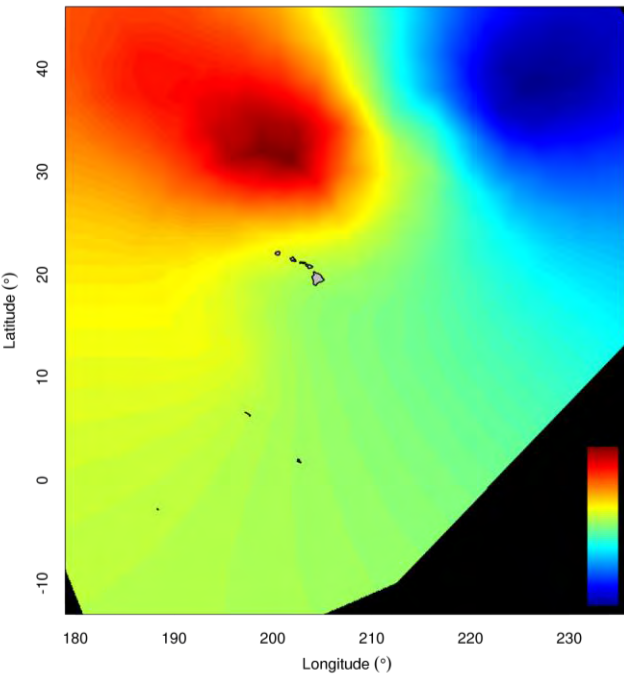


Results: Shared model

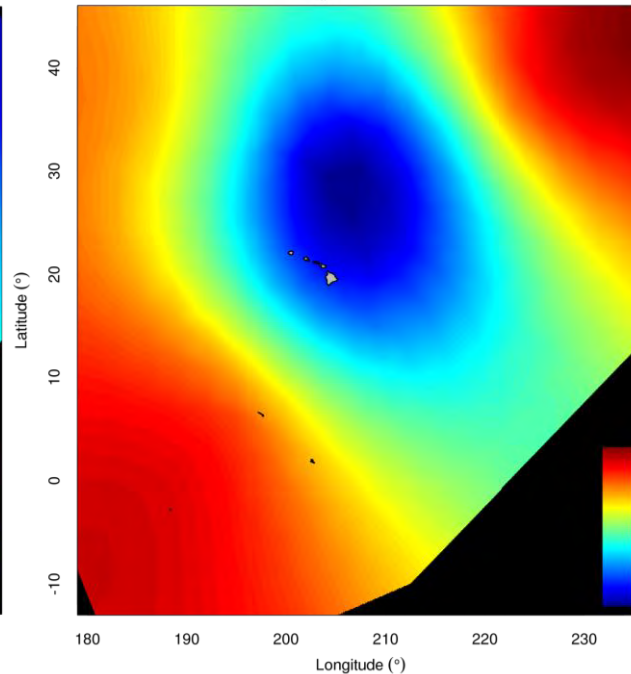
Binomial



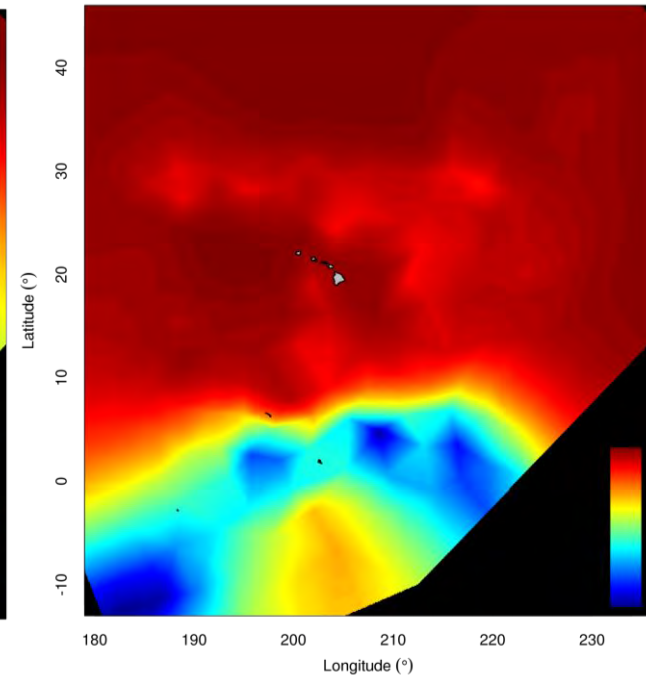
N = 97



N = 111



N = 55,703

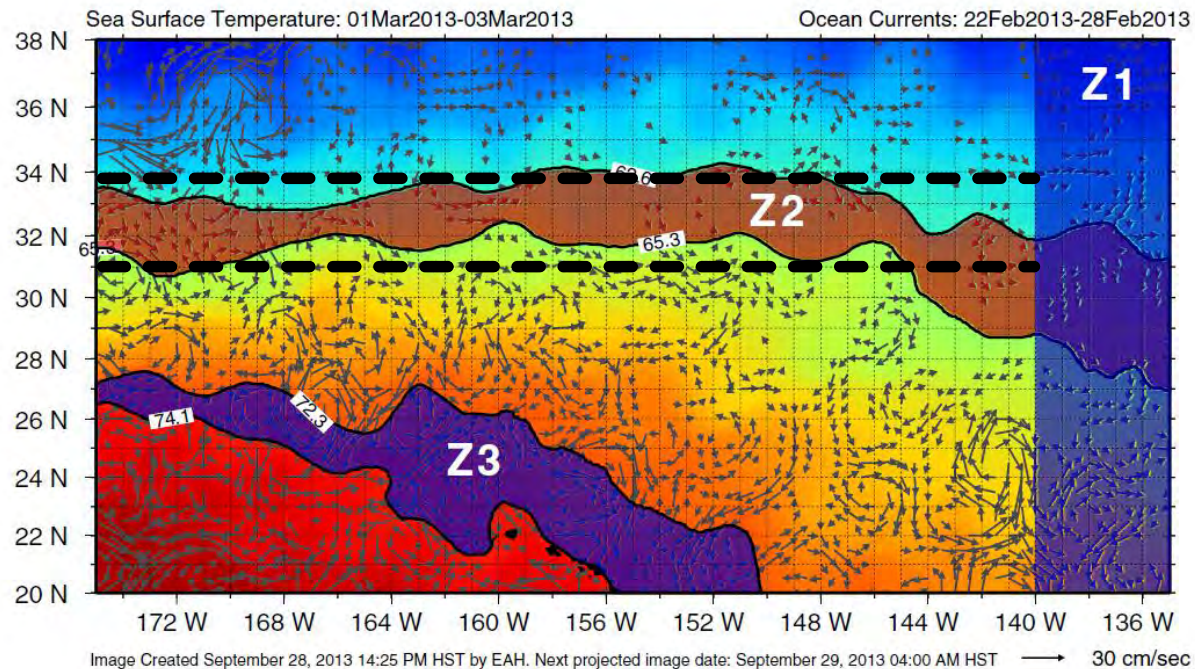
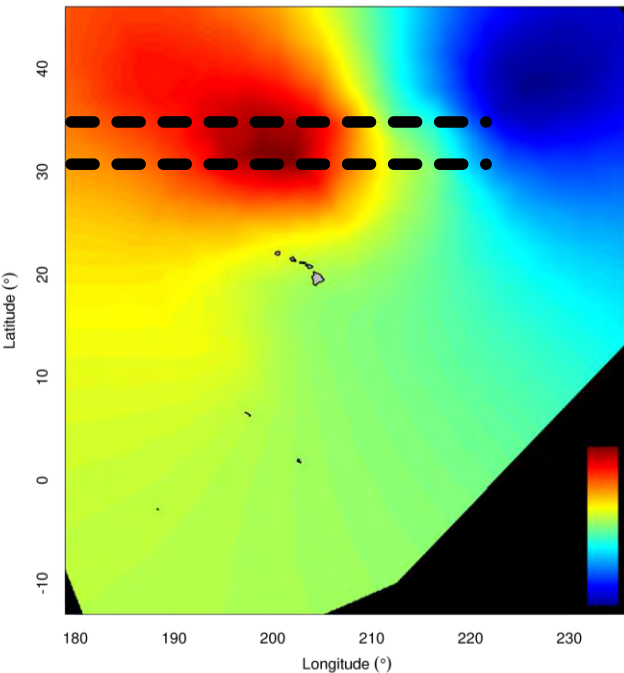


Results: Shared model

Binomial



N = 97

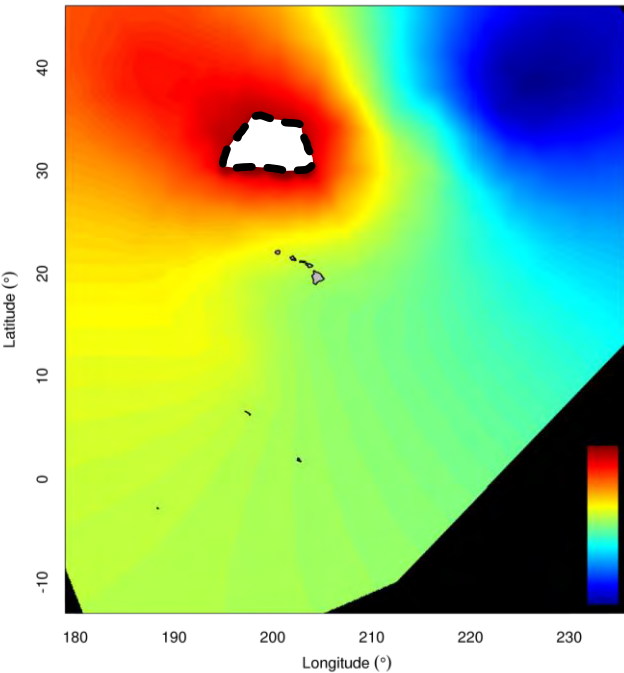


Results: Shared model

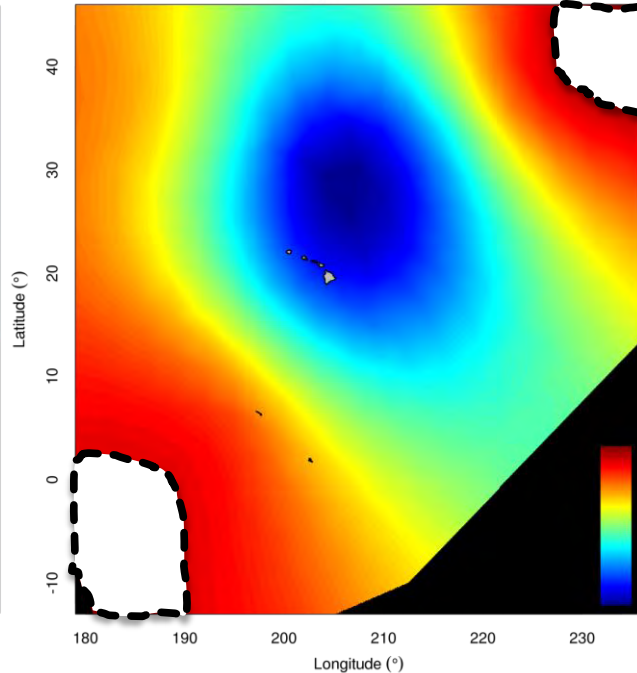
Binomial



N = 97



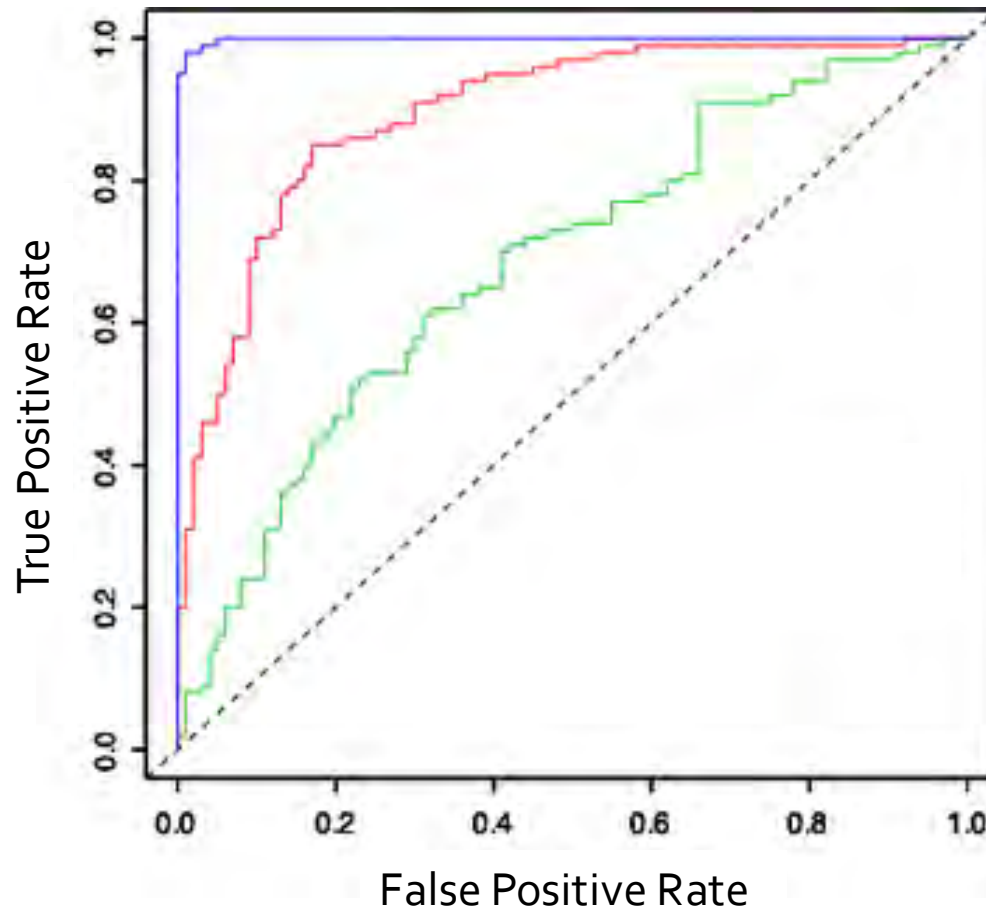
N = 111



So what?

Results: ROC

Binomial



--- Worthless

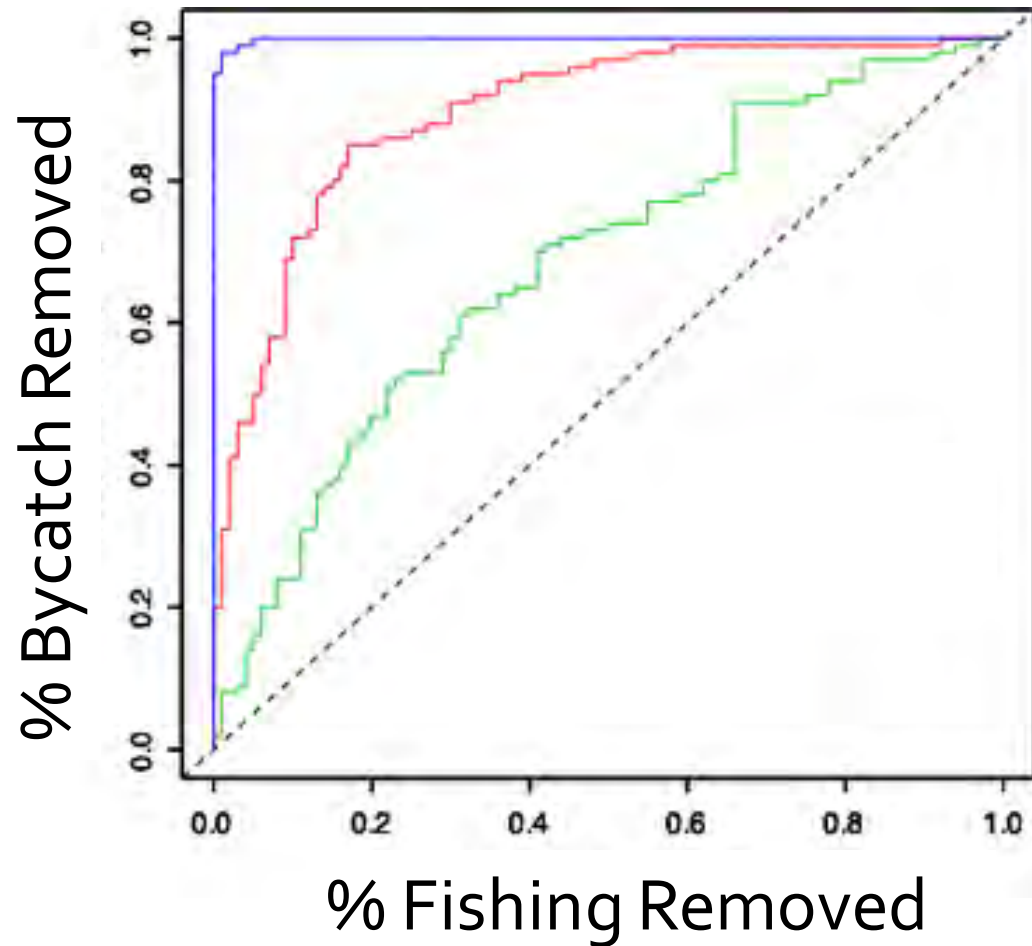
— Ok

— Good

— Awesome

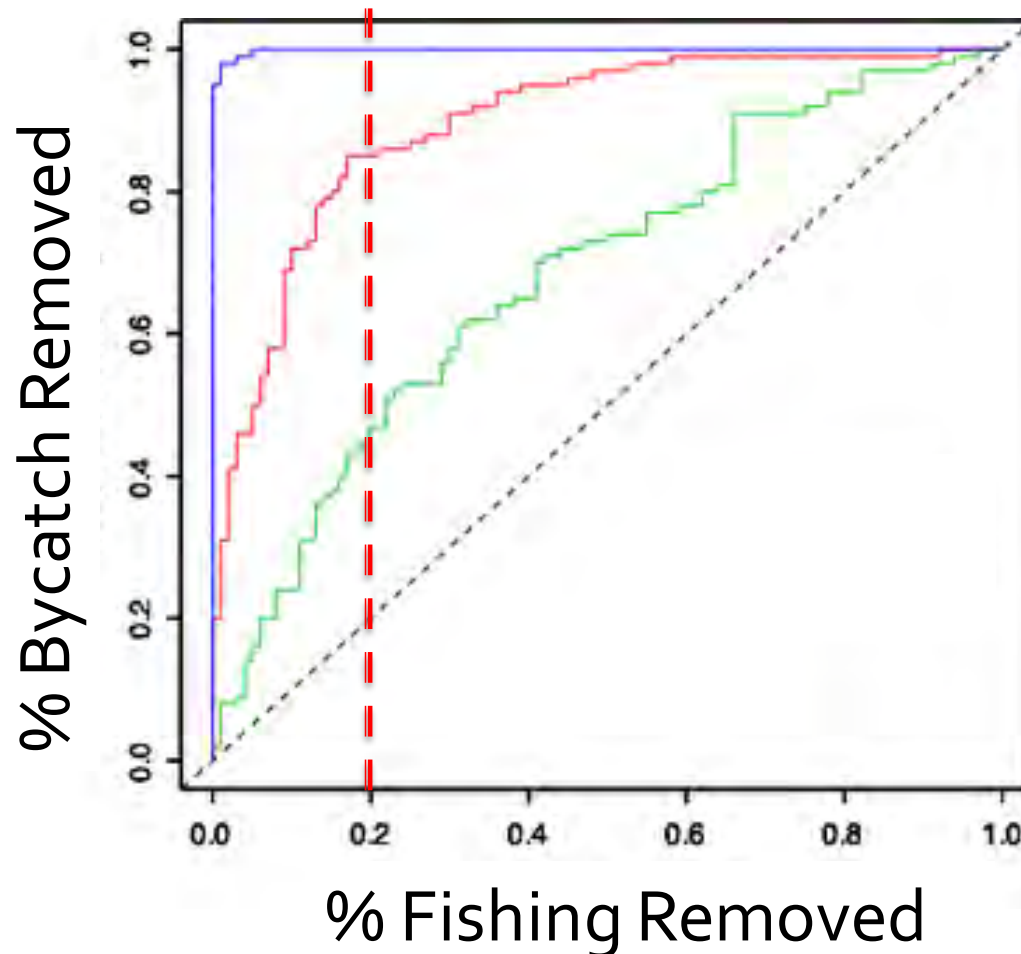
Results: ROC

Binomial



Results: ROC

Binomial



Eliminate 20% of fishing

Reduction in bycatch:

— — — 20%

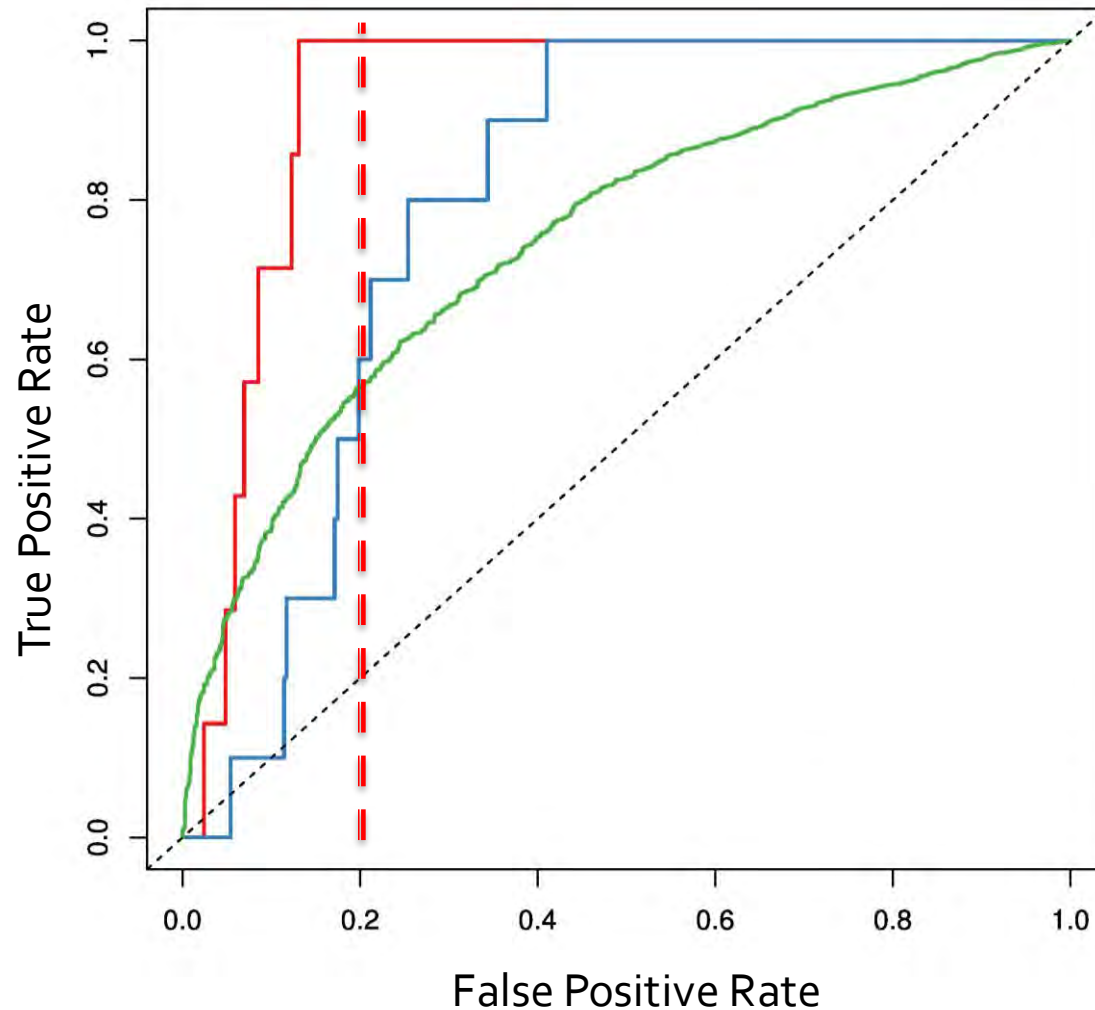
— 45%

— 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)

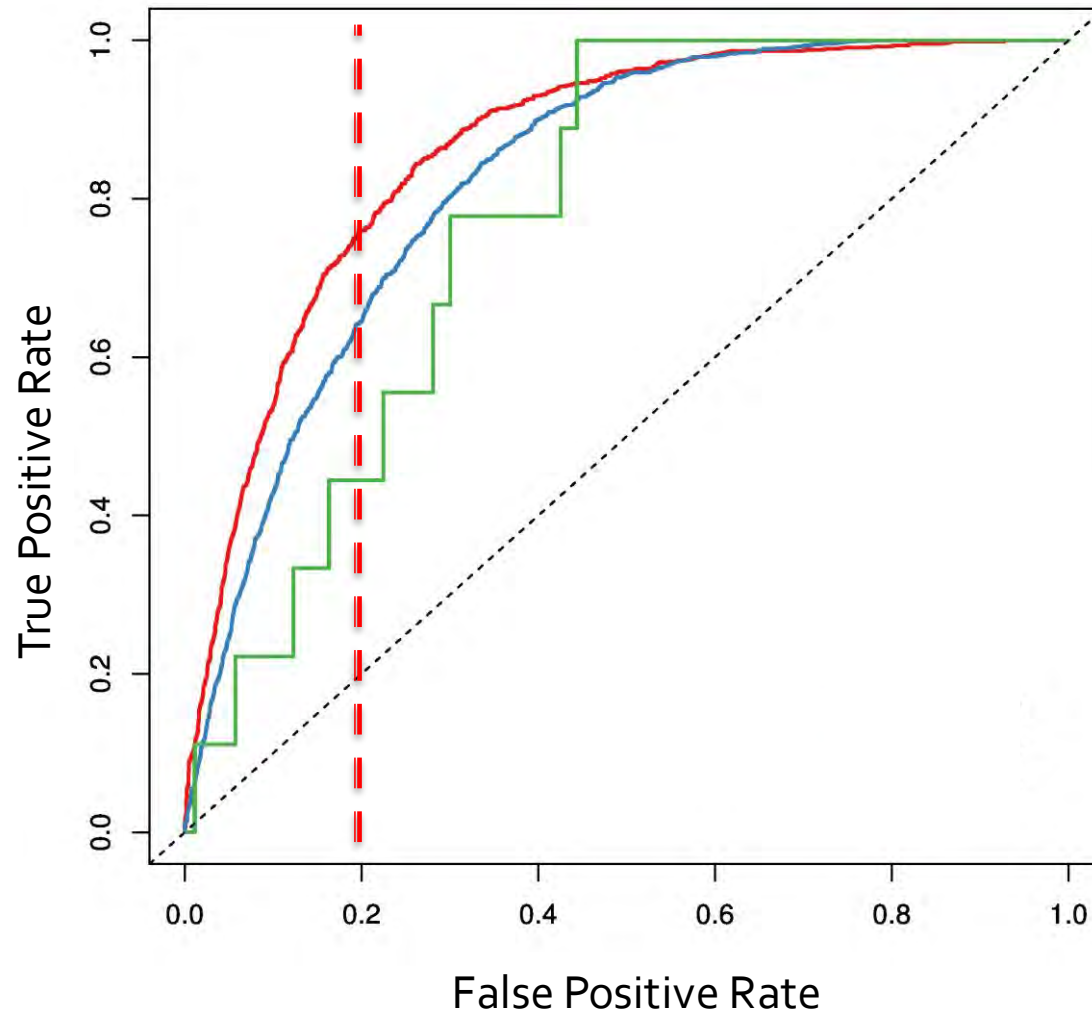
Binomial

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

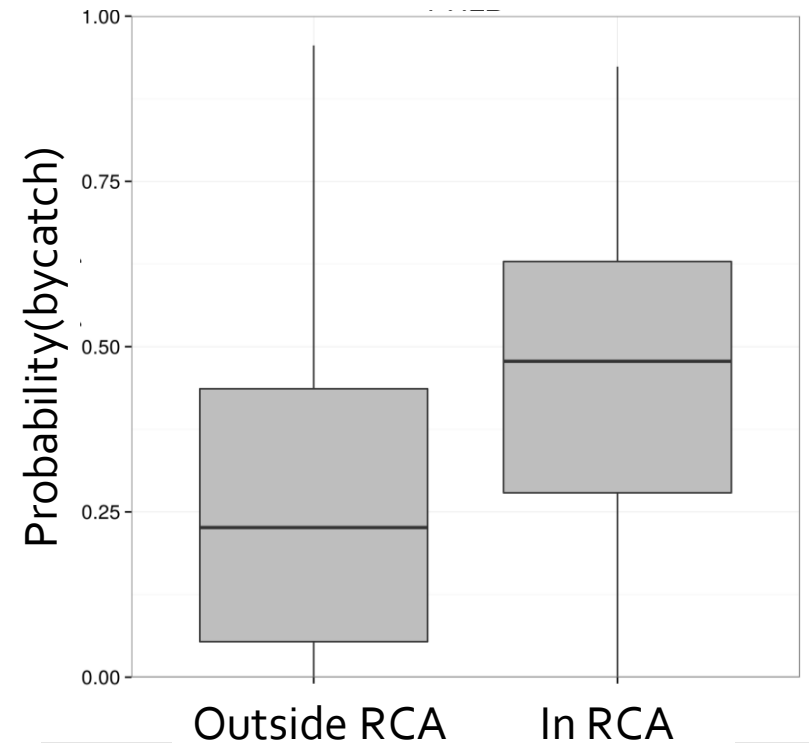
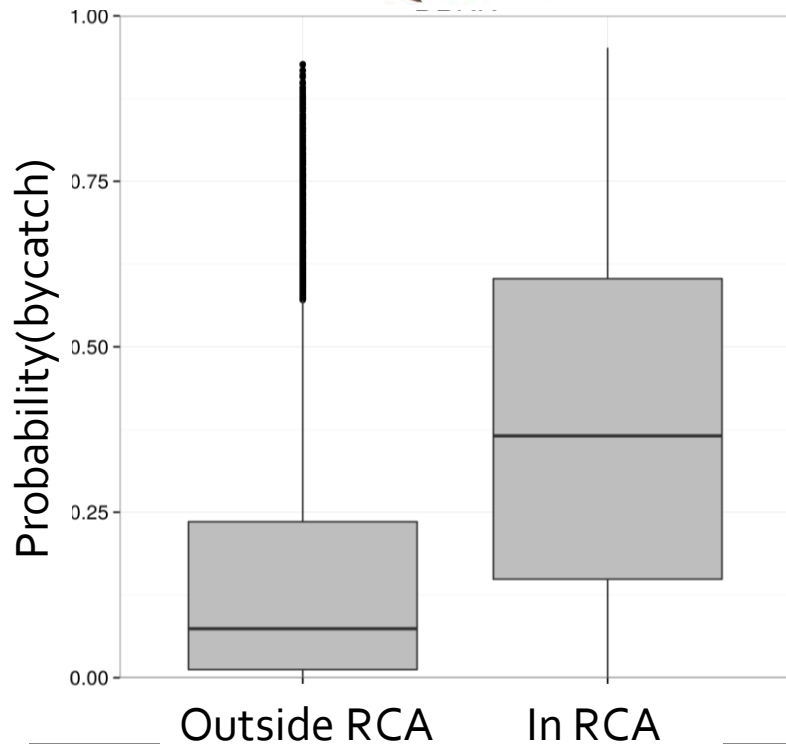
- 1994-2014
- 70,297 sets
- 3.2 million records



Results: RCAs

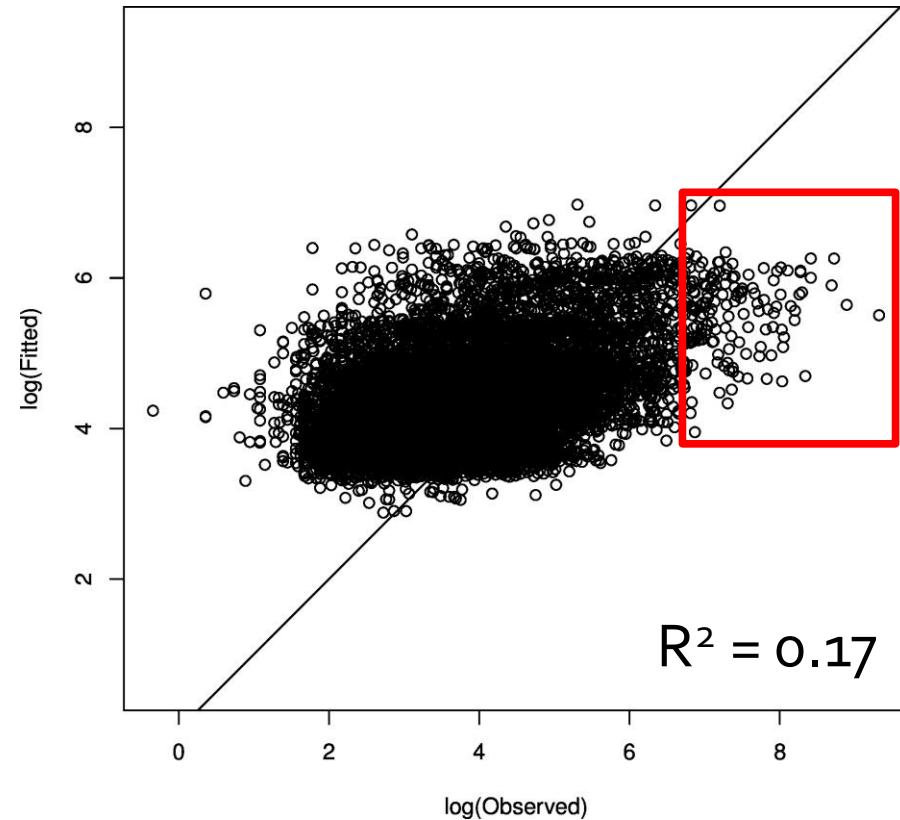
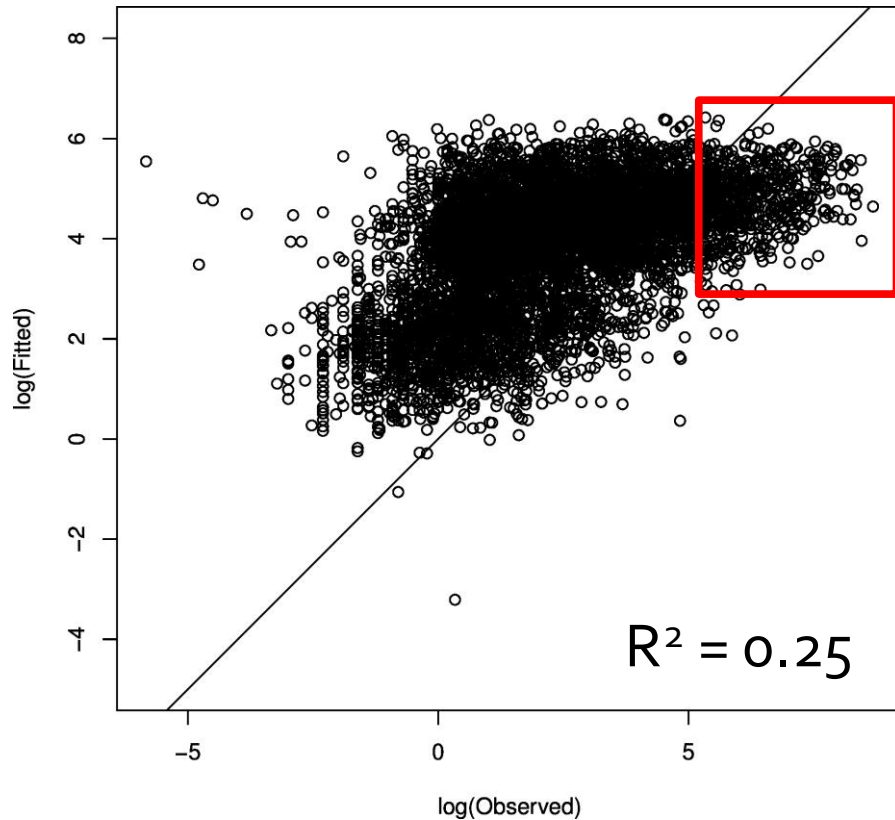
Binomial

11% of tows were in Rockfish Conservation Areas



Q: What about the positive model?

Positive

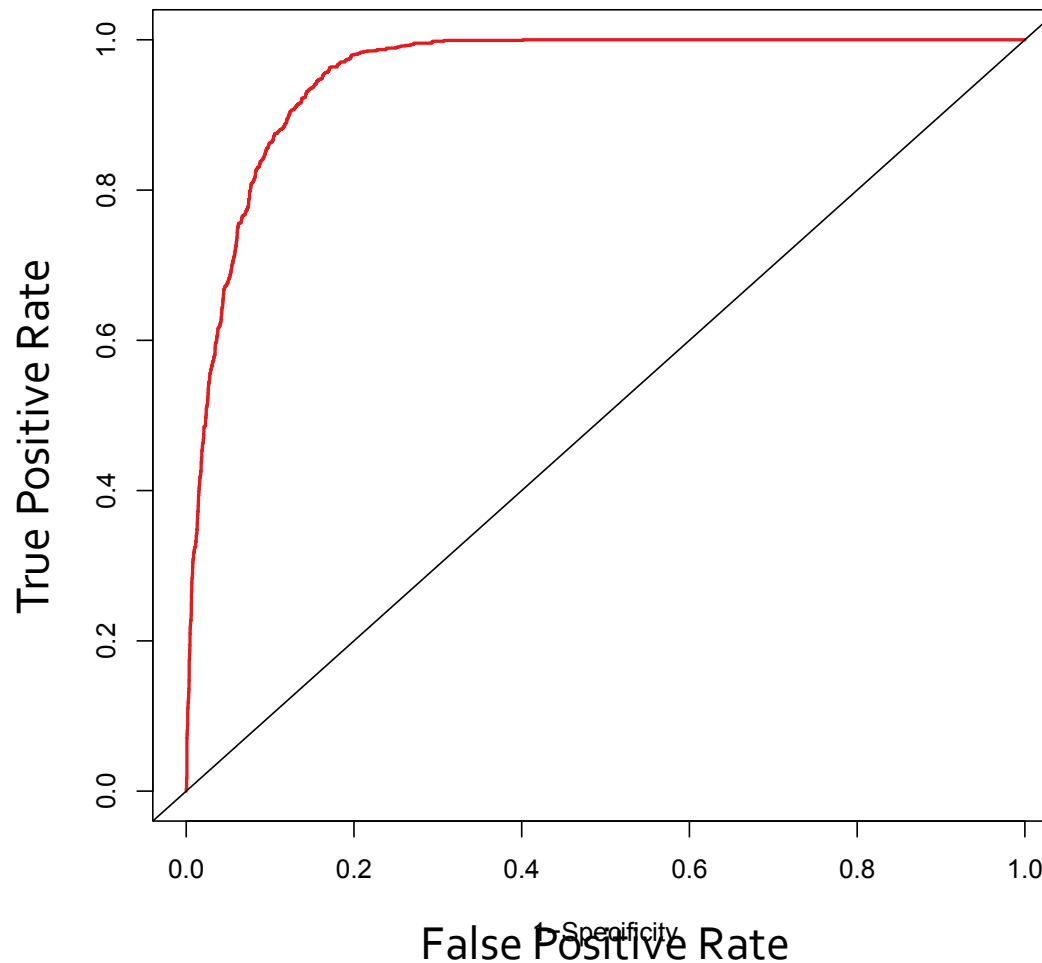


Q: What about effort?

Results: ROC (survey)

Binomial

ROC Curves: survey_DBRK_AR_binomial

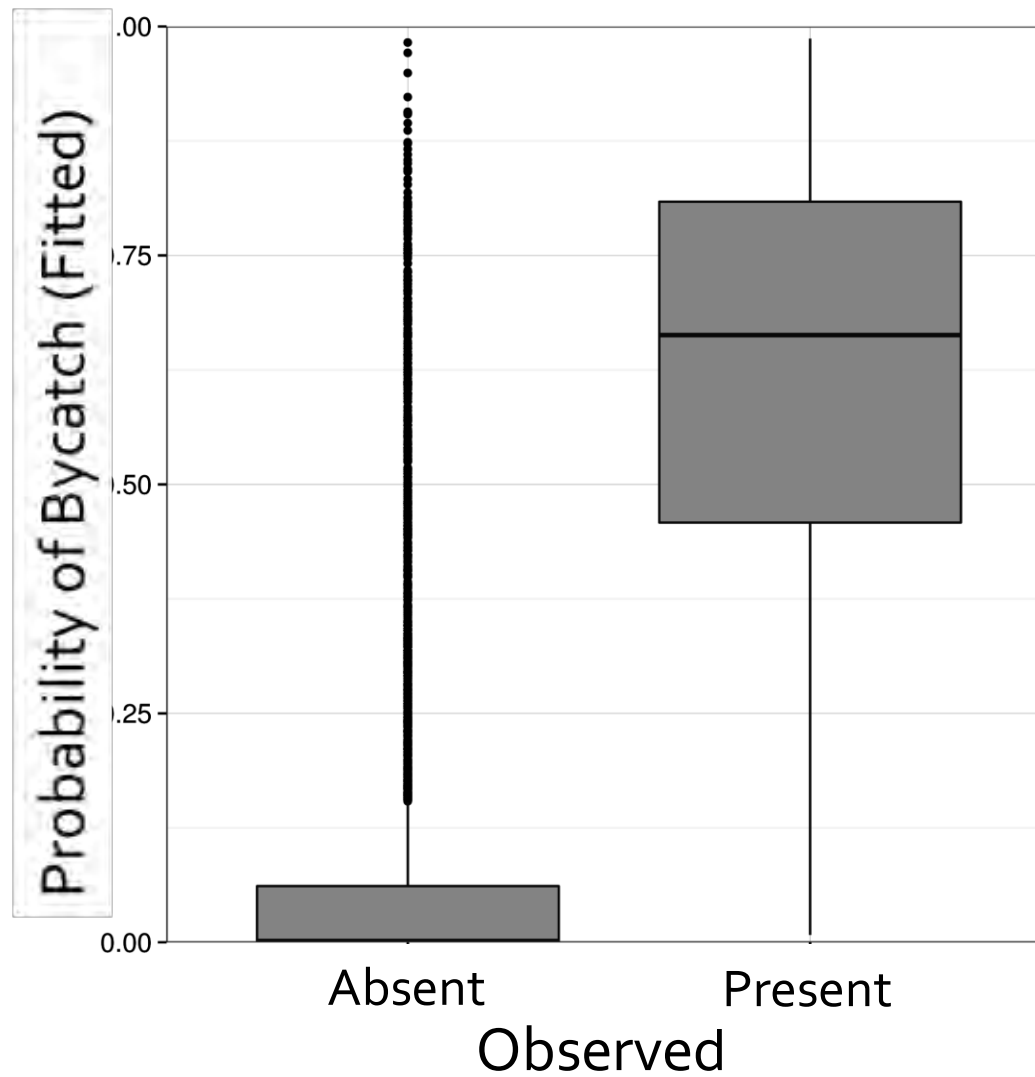


AUC = 0.955

Outstanding!

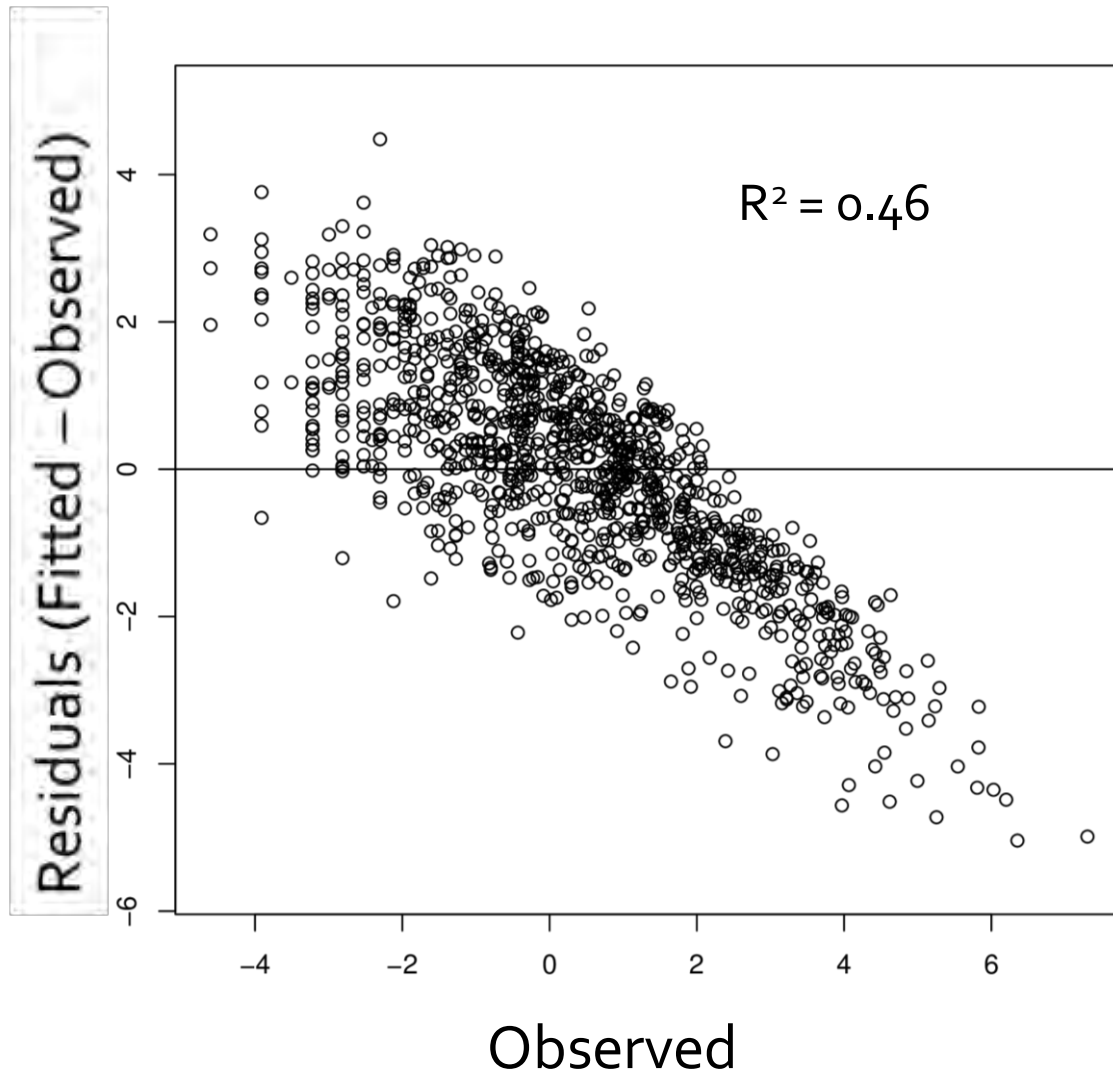
Proof of Concept

Binomial



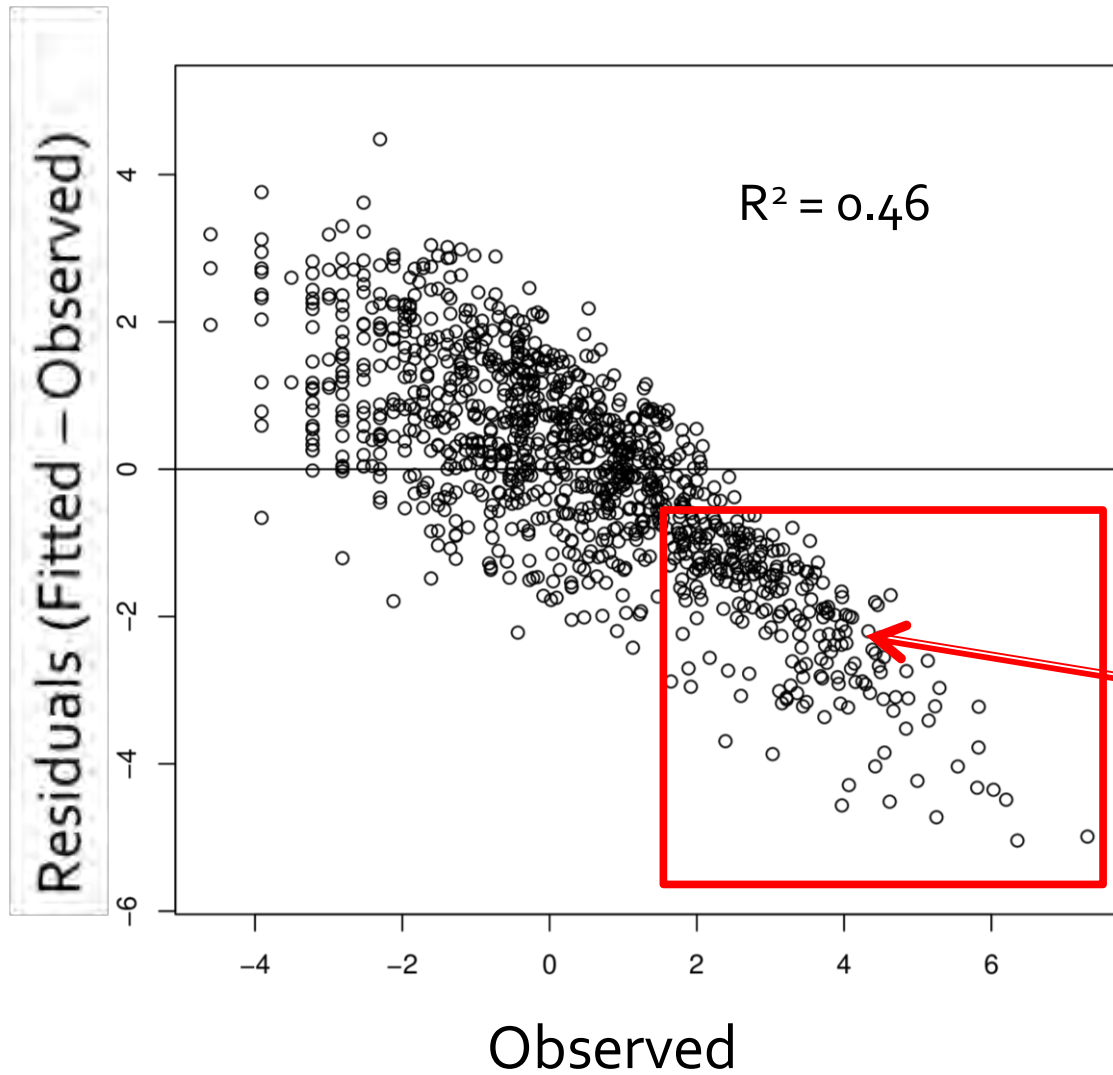
Proof of Concept

Positive



Proof of Concept

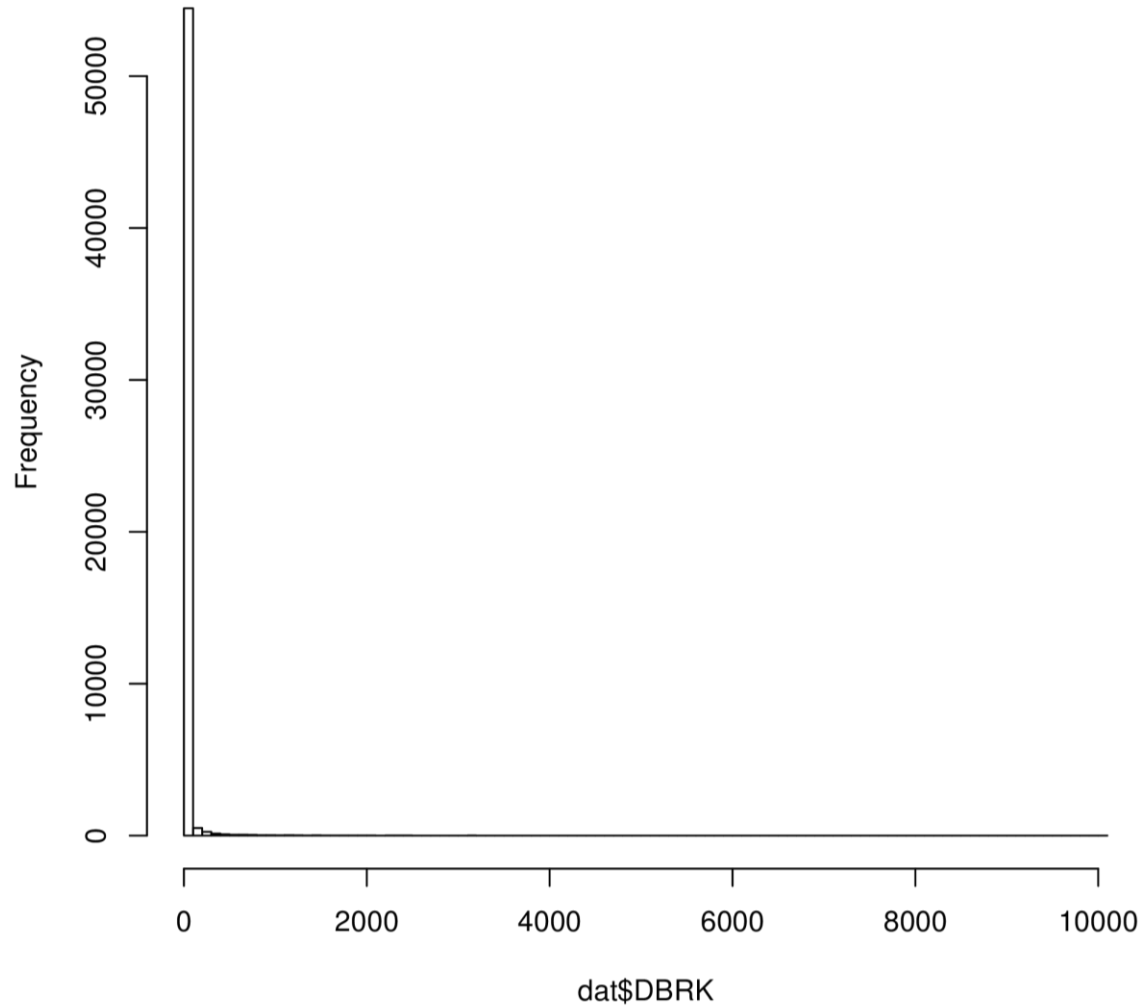
Positive



These extreme bycatch events are the most important to predict!

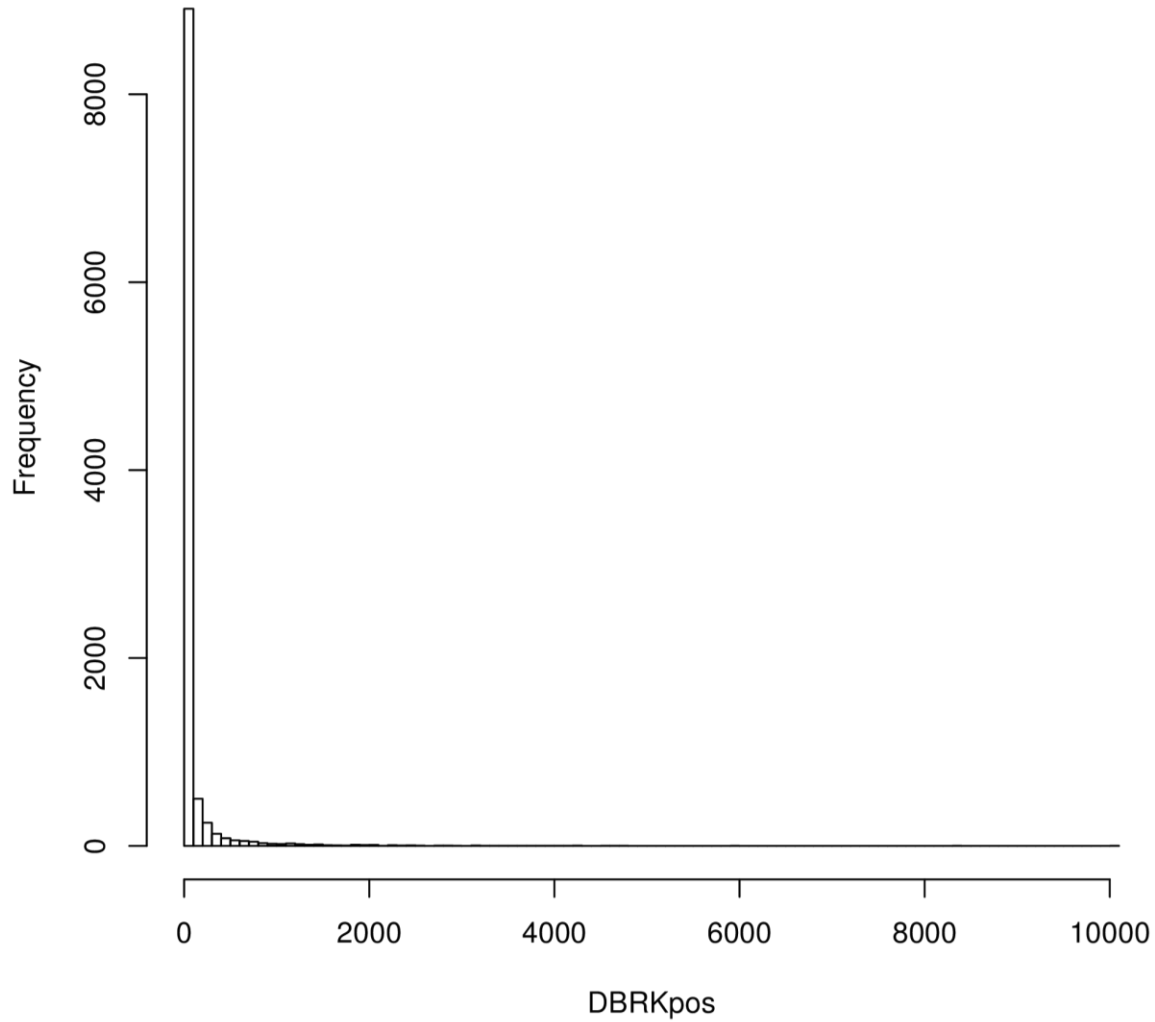
Proof of Concept

Positive



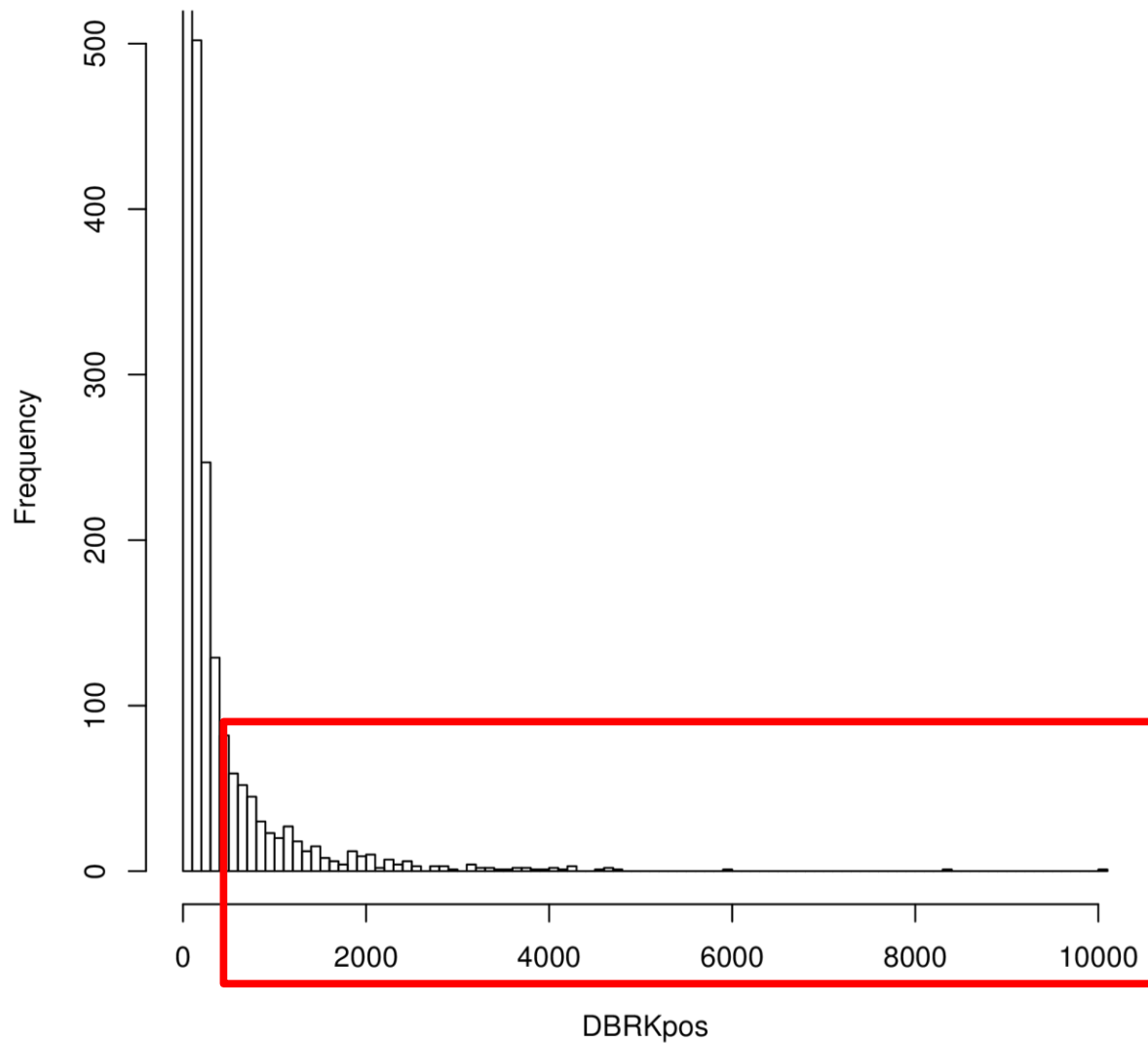
Proof of Concept

Positive



Proof of Concept

Positive

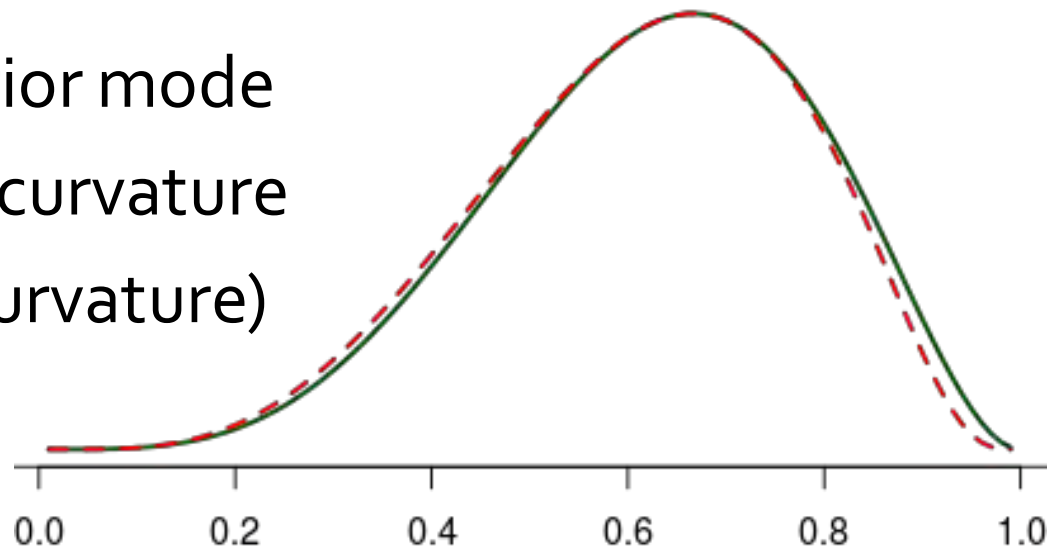


Spatial models: INLA-SPDE

Integrated Nested Laplace Approximation

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

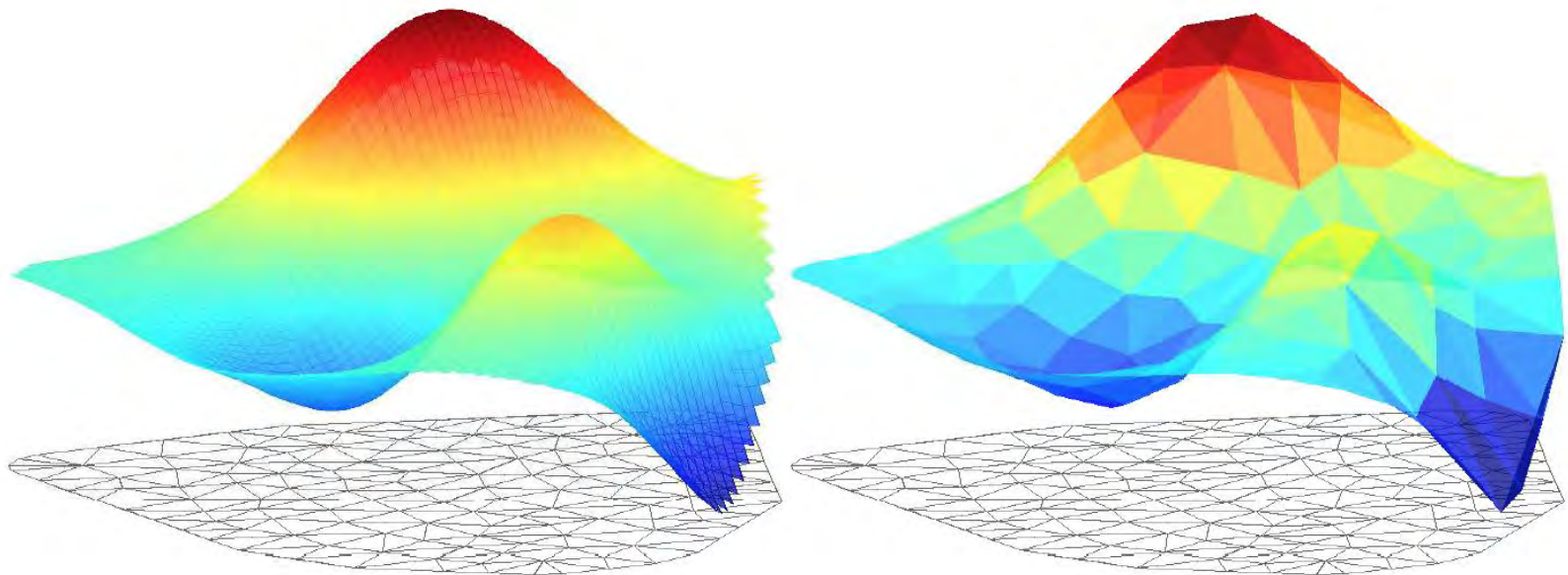
1. Find the posterior mode
2. Calculate local curvature
3. Use $N(\text{mode}, \text{curvature})$



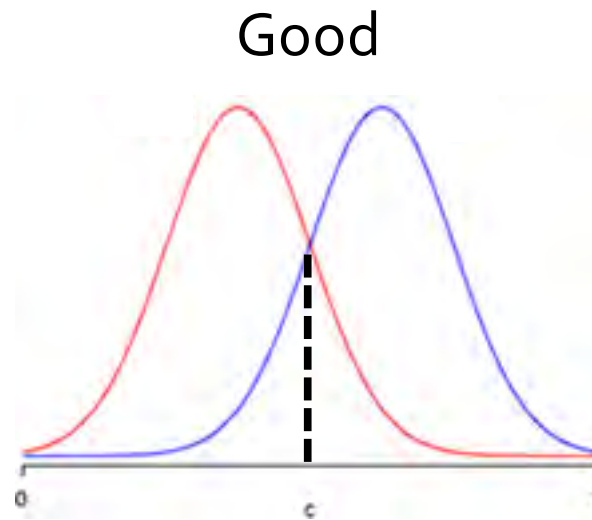
Spatial models: INLA-SPDE

Spatial Partial Differential Equation

- Discrete approximation of continuous spatial fields



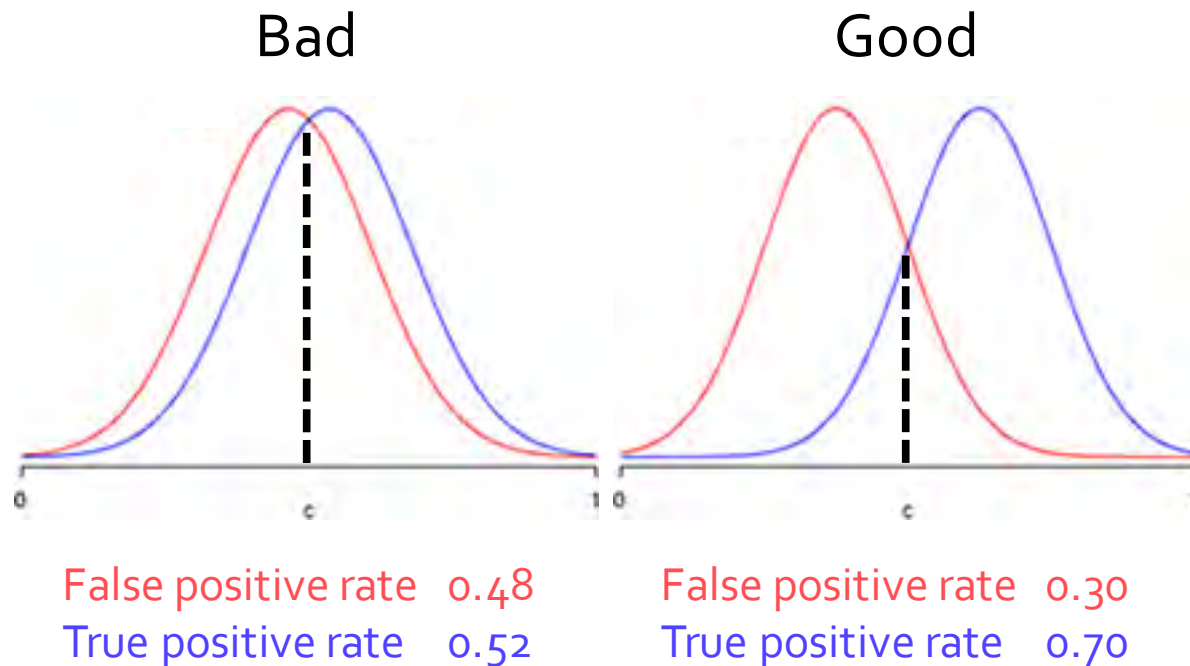
Preliminary results: ROC curves



False positive rate 0.30

True positive rate 0.70

Preliminary results: ROC curves



Preliminary results: ROC curves

