

Spatial prediction of fisheries bycatch

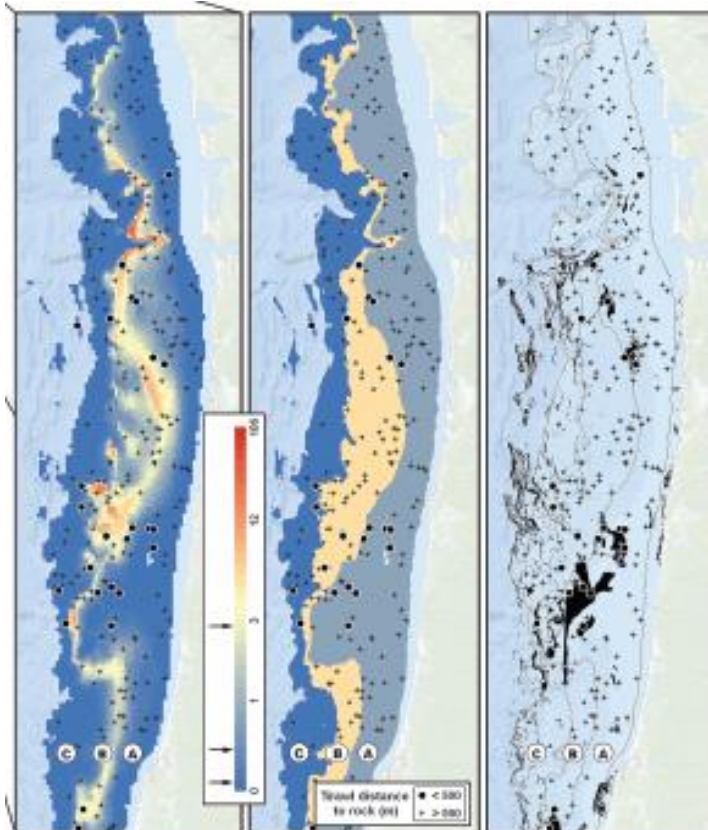
Brian Stock, Eric Ward, Tomo Eguchi
SIO/UCSD, NWFSC, SWFSC



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

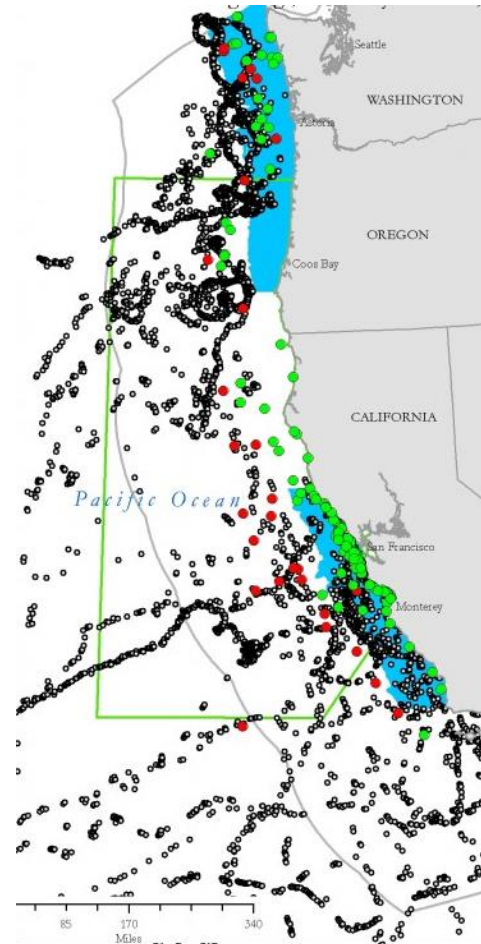
Used by NWFSC assessment team

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 labeled 'This repository' and 'Search'. To the right are navigation links: 'Explore', 'Features', 'Enterprise', and 'Pricing'. Below the navigation bar, the repository name is displayed with a 'Watch' button showing 9 subscribers. A description reads: 'Tool for geostatistical analysis of survey data, for use when estimating an index of abundance'. A summary bar shows '145 commits', '1 branch', '8 releases', and '2 contributors'. The current branch is 'master'. A commit history table is visible below.

Commit Message	Time Ago
James-Thorson fixed bug in mean_D_tl 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

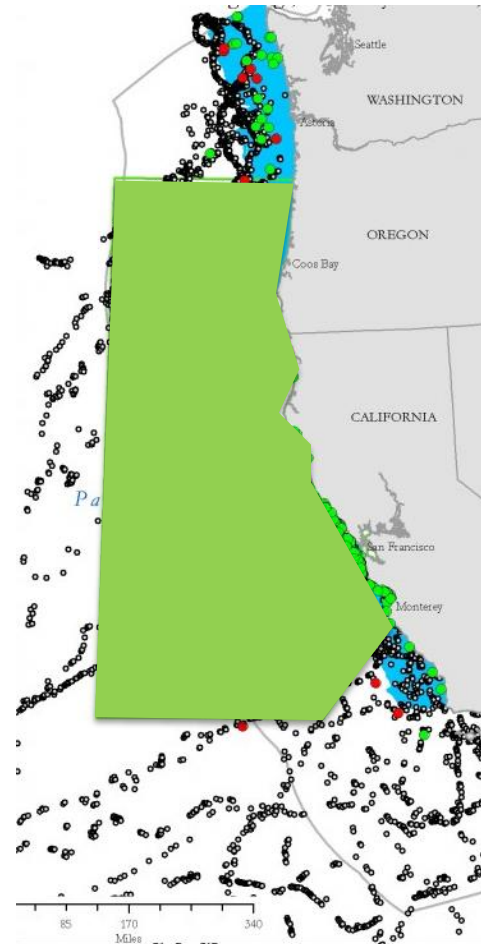
Motivation

Static management



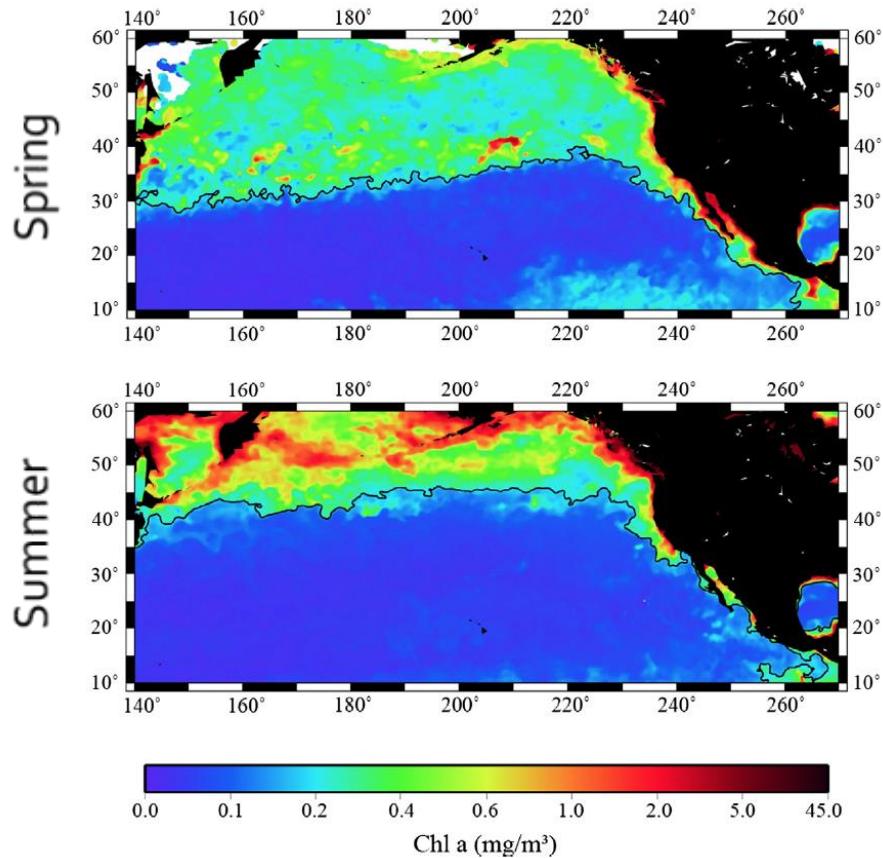
Motivation

Static management

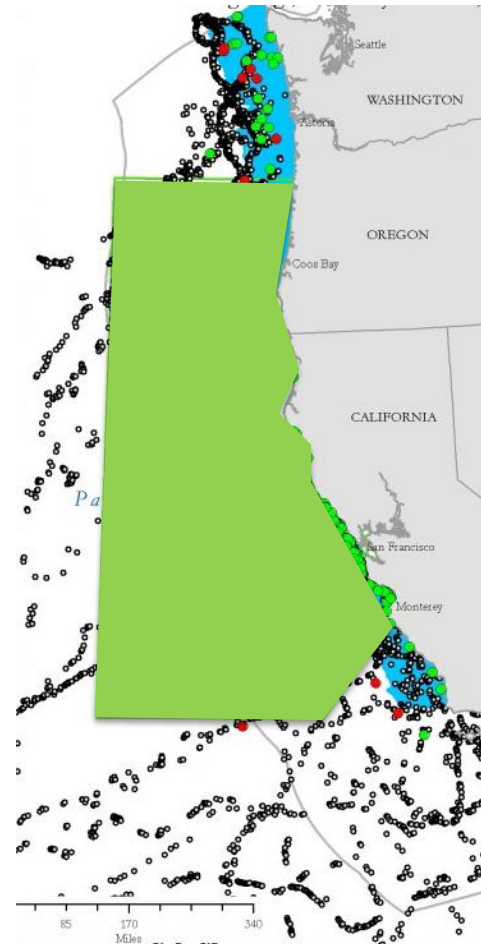


Motivation

Dynamic management

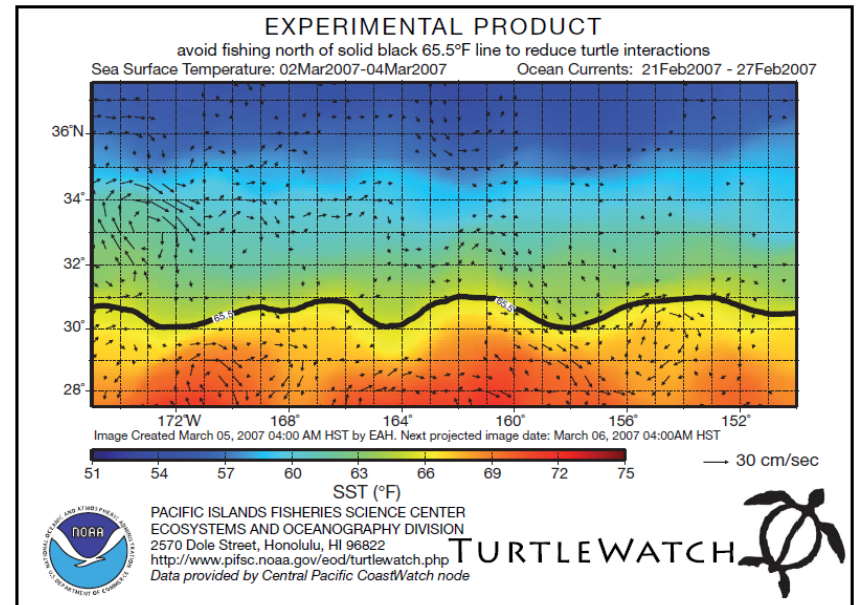
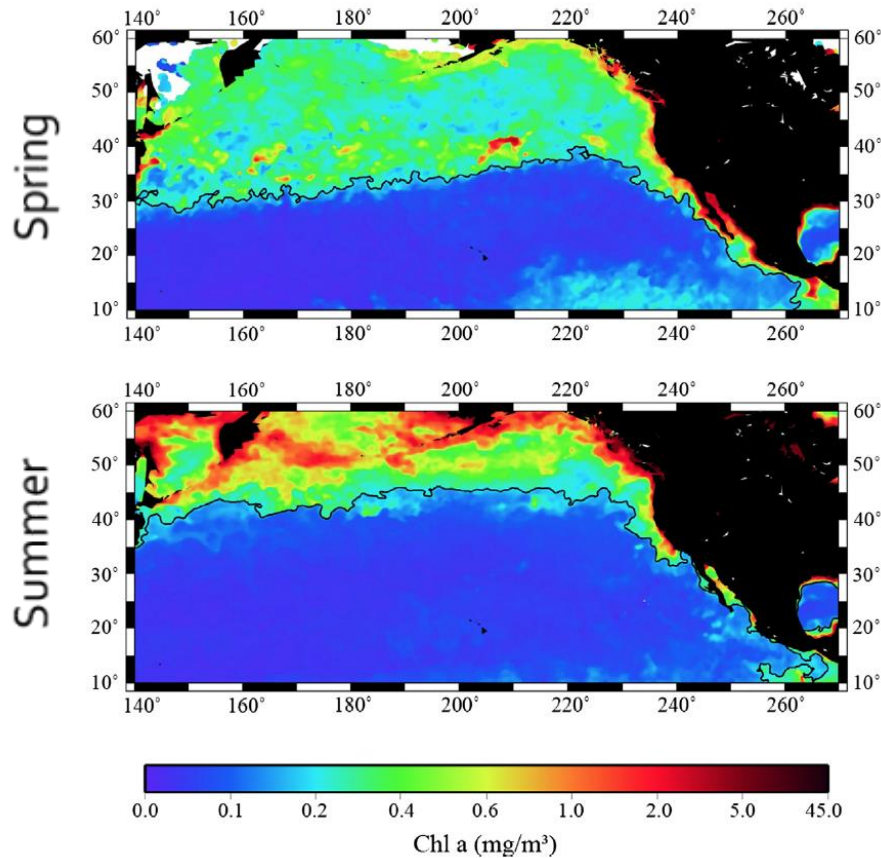


Static management



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?

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

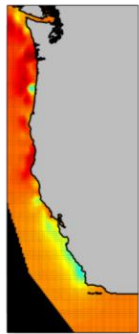
Binomial

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

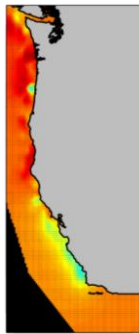
Positive

Research Questions

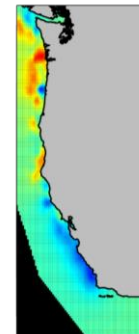
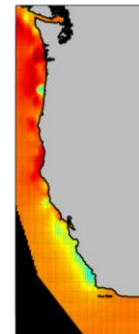
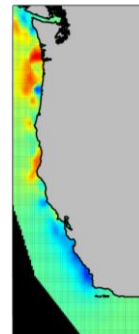
2. What *type* of spatial model best predicts bycatch?



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

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

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



Habitat: Benthic

Habitat: Benthic

Habitat: Benthic

Movement: Med

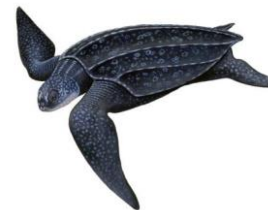
Movement: Low

Movement: Low

Bycatch Rate: 29%

Bycatch Rate: 18%

Bycatch Rate: 0.3%



Habitat: Pelagic

Habitat: Pelagic

Habitat: Pelagic

Movement: High

Movement: High

Movement: High

Bycatch Rate: 89%

Bycatch Rate: 0.15%

Bycatch Rate: 0.18%

Research Questions

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



Habitat: Benthic

Habitat: Benthic

Habitat: Benthic

Movement: Med

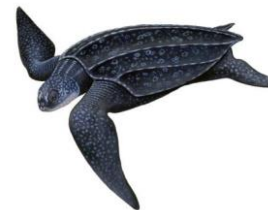
Movement: Low

Movement: Low

Bycatch Rate: 29%

Bycatch Rate: 18%

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Habitat: Pelagic

Habitat: Pelagic

Habitat: Pelagic

Movement: High

Movement: High

Movement: High

Bycatch Rate: 89%

Bycatch Rate: 0.15%

Bycatch Rate: 0.18%

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

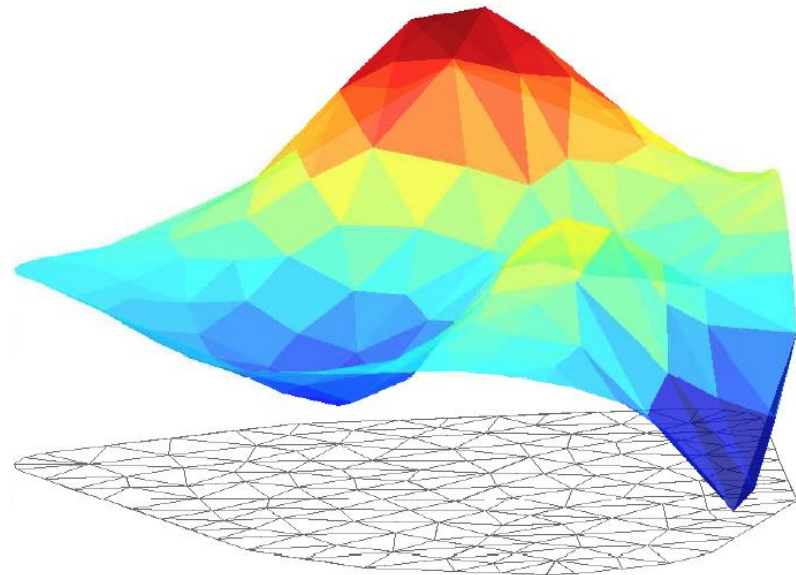
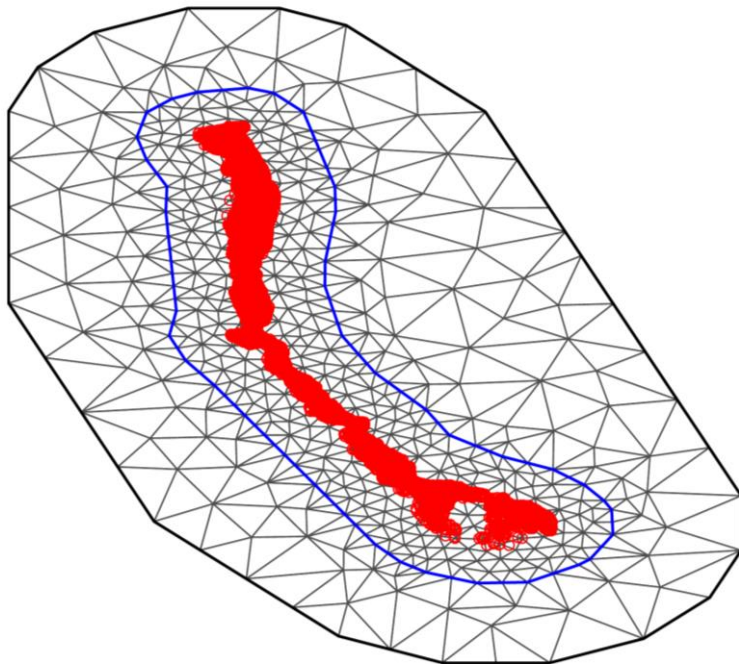
Positive

~ sst (observed) +
target +
spatial field

Spatial field: INLA-SPDE

Spatial Partial Differential Equation

- Discrete approximation of continuous spatial fields

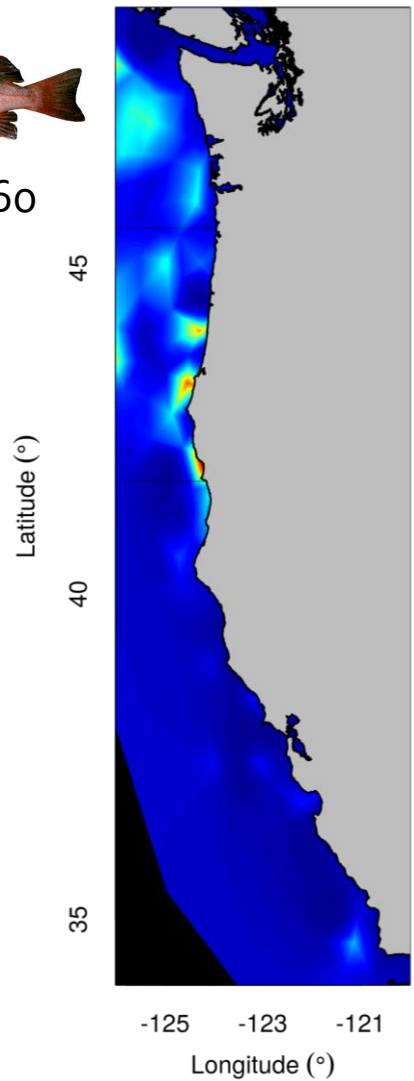


Results: Shared model

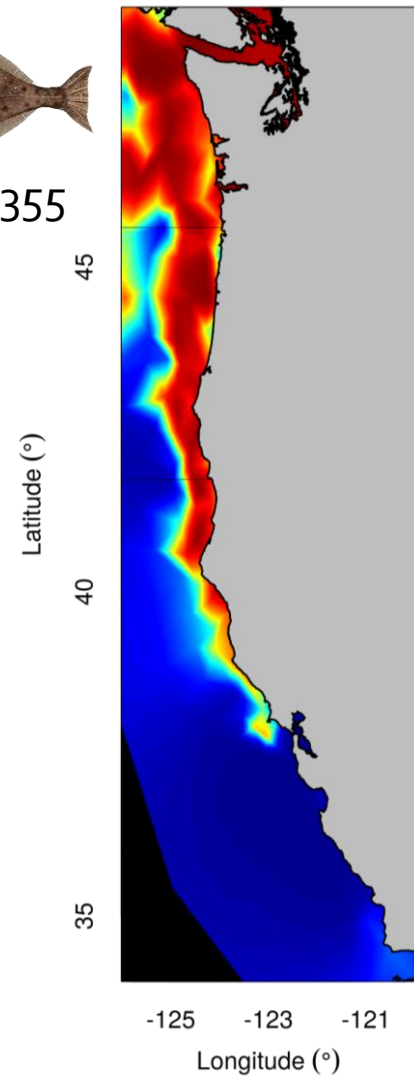
Binomial



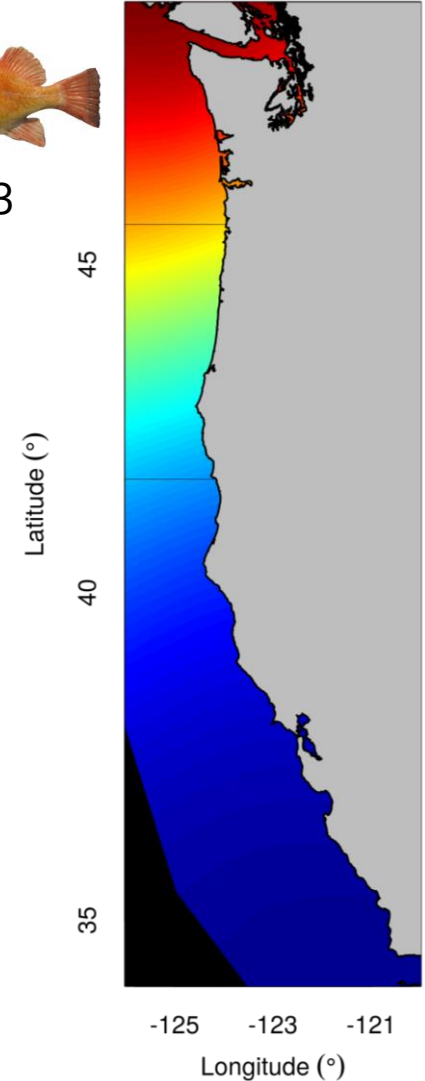
N = 7,660



N = 12,355

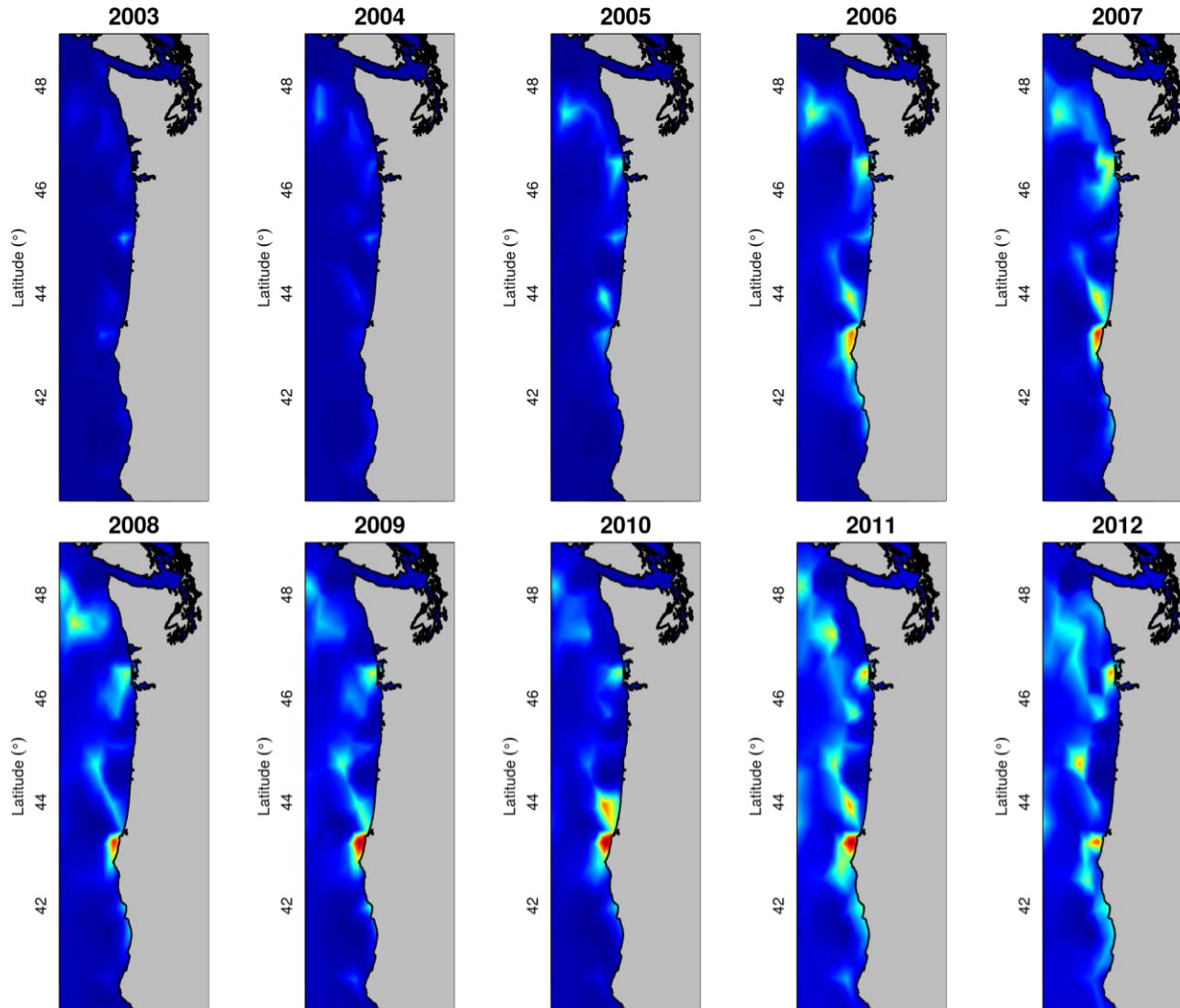


N = 143



Results: Multiple years

Binomial

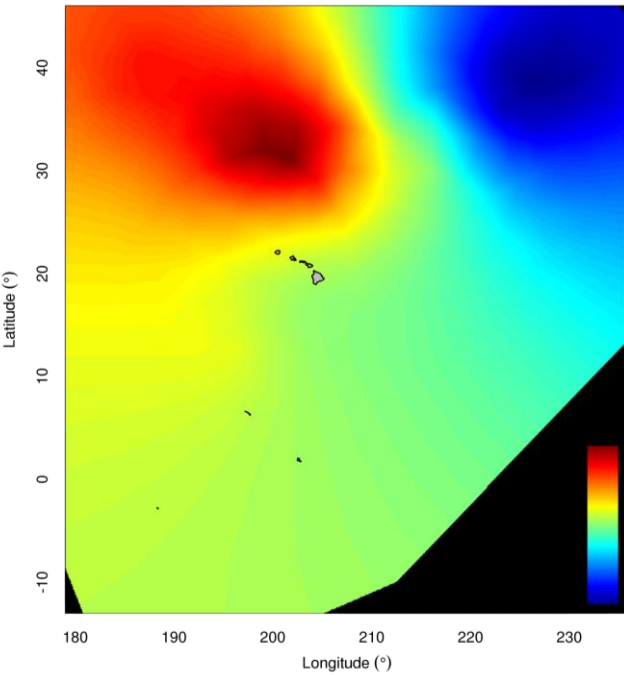


Results: Shared model

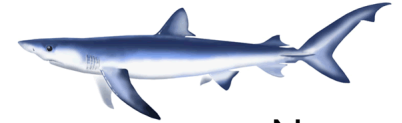
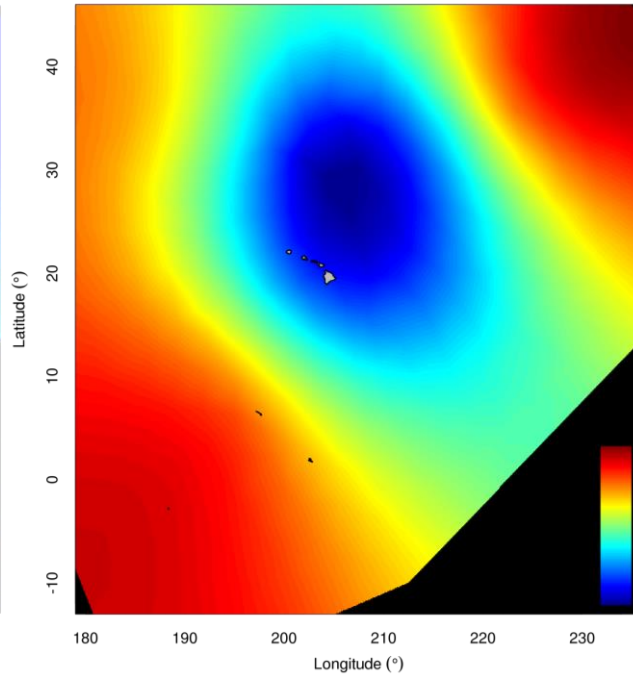
Binomial



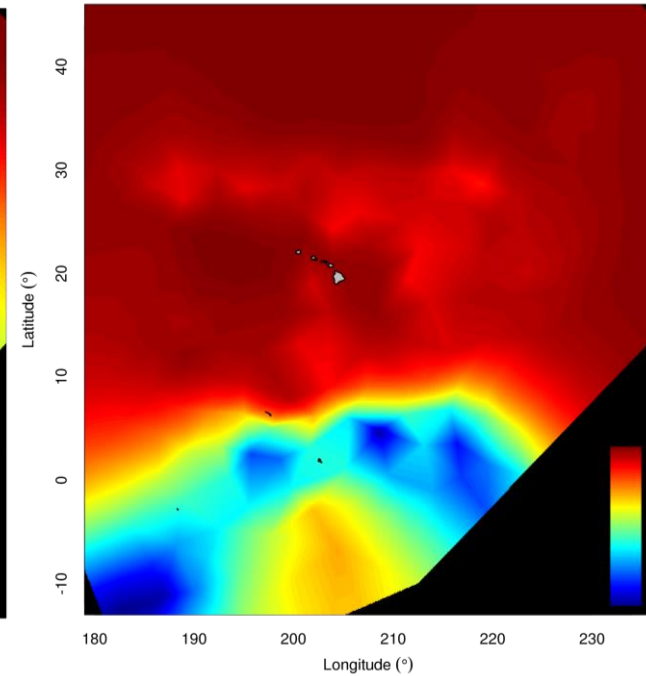
N = 97



N = 111



N = 55,703

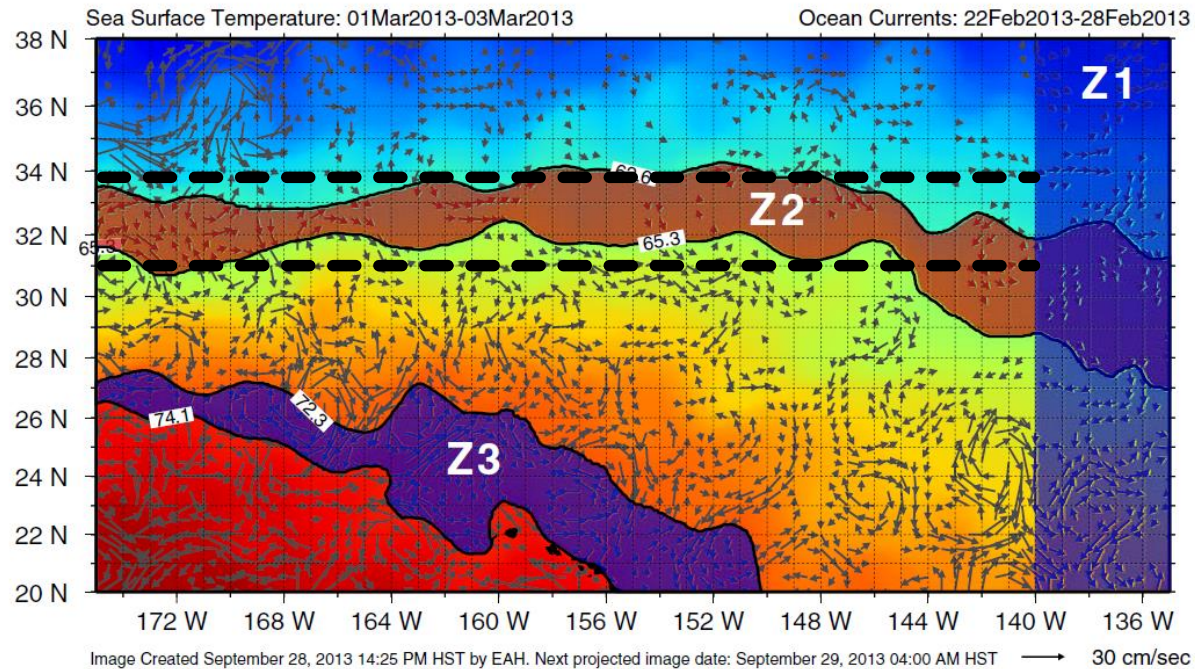
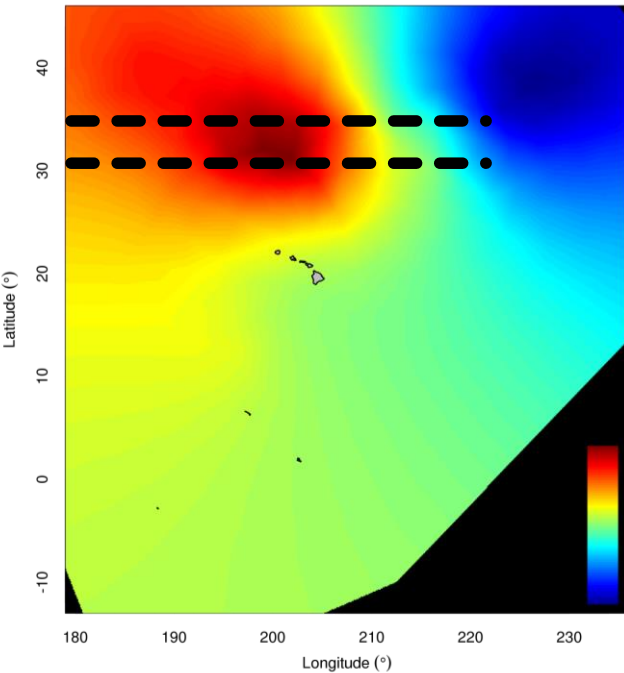


Results: Shared model

Binomial



N = 97

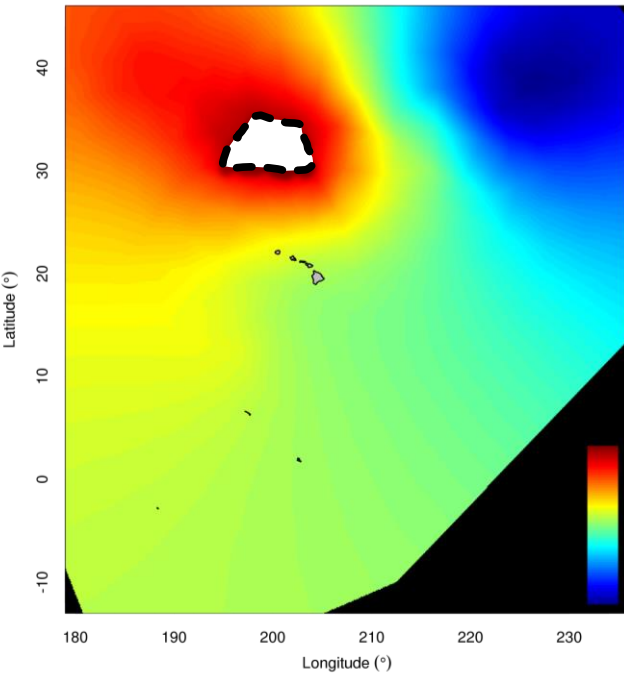


Results: Shared model

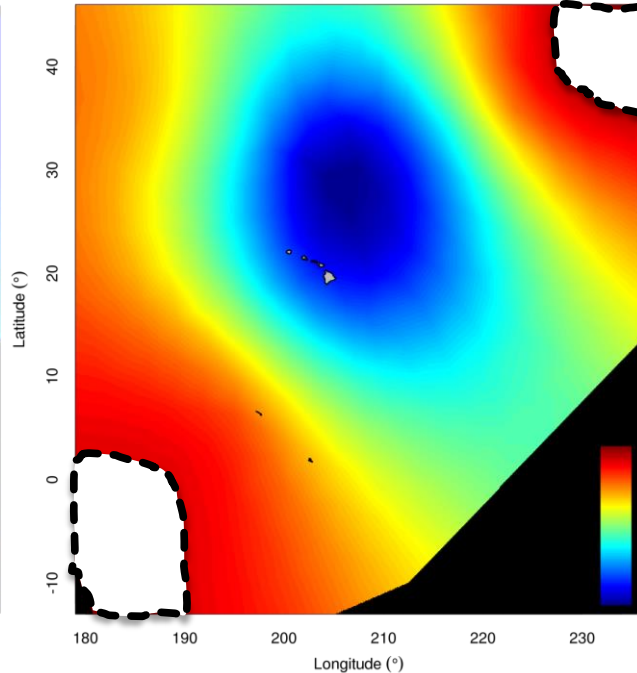
Binomial



N = 97



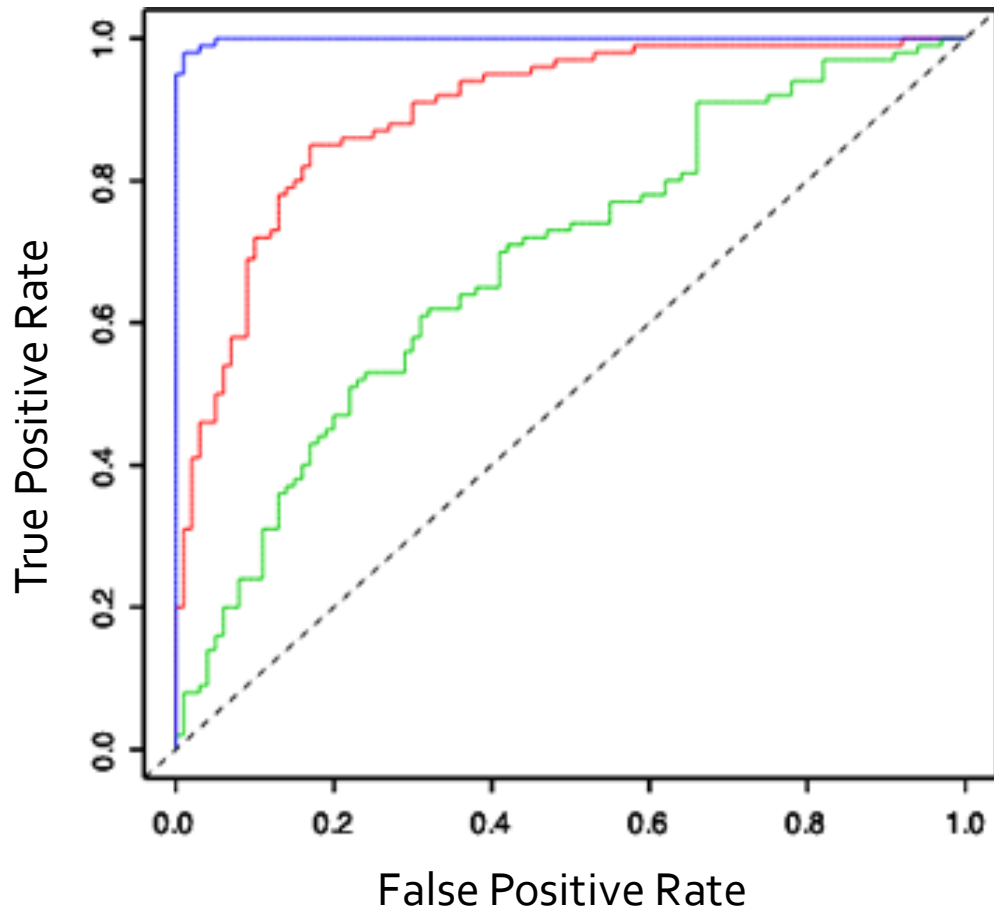
N = 111



So what?

Results: ROC

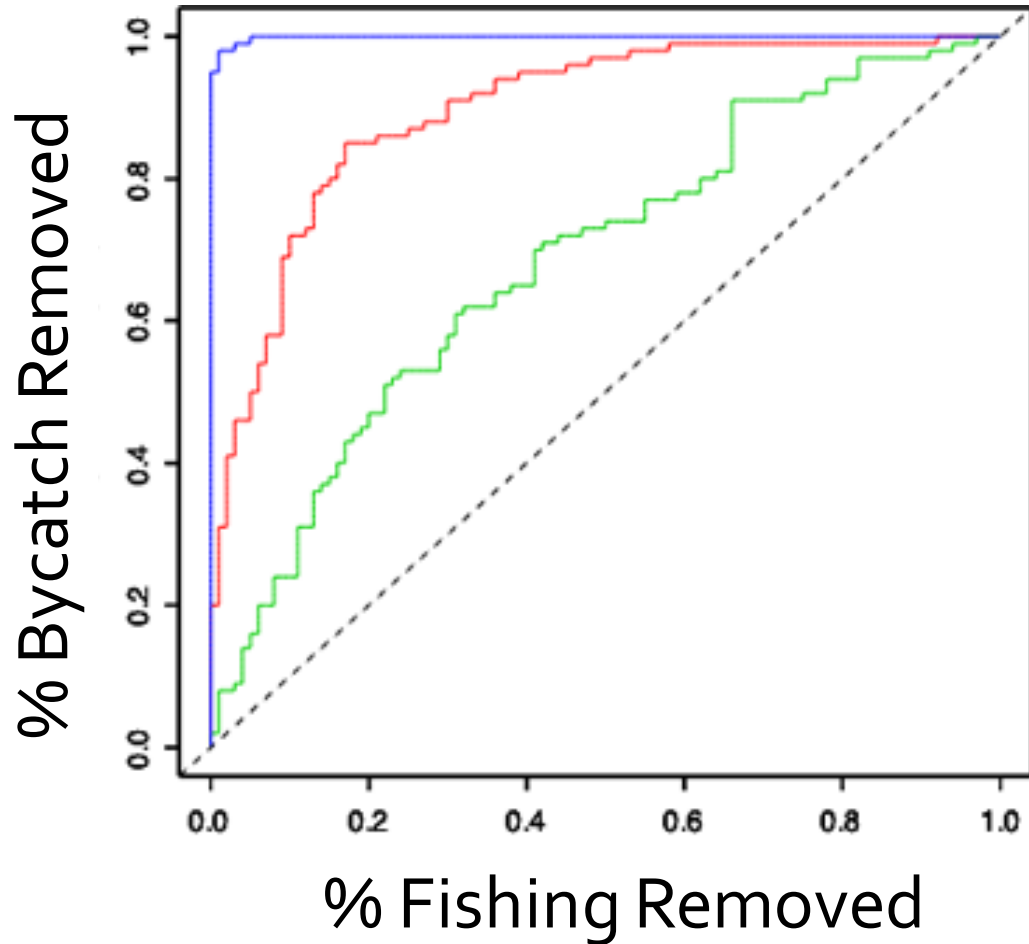
Binomial



- - - Worthless
- Ok
- Good
- Awesome

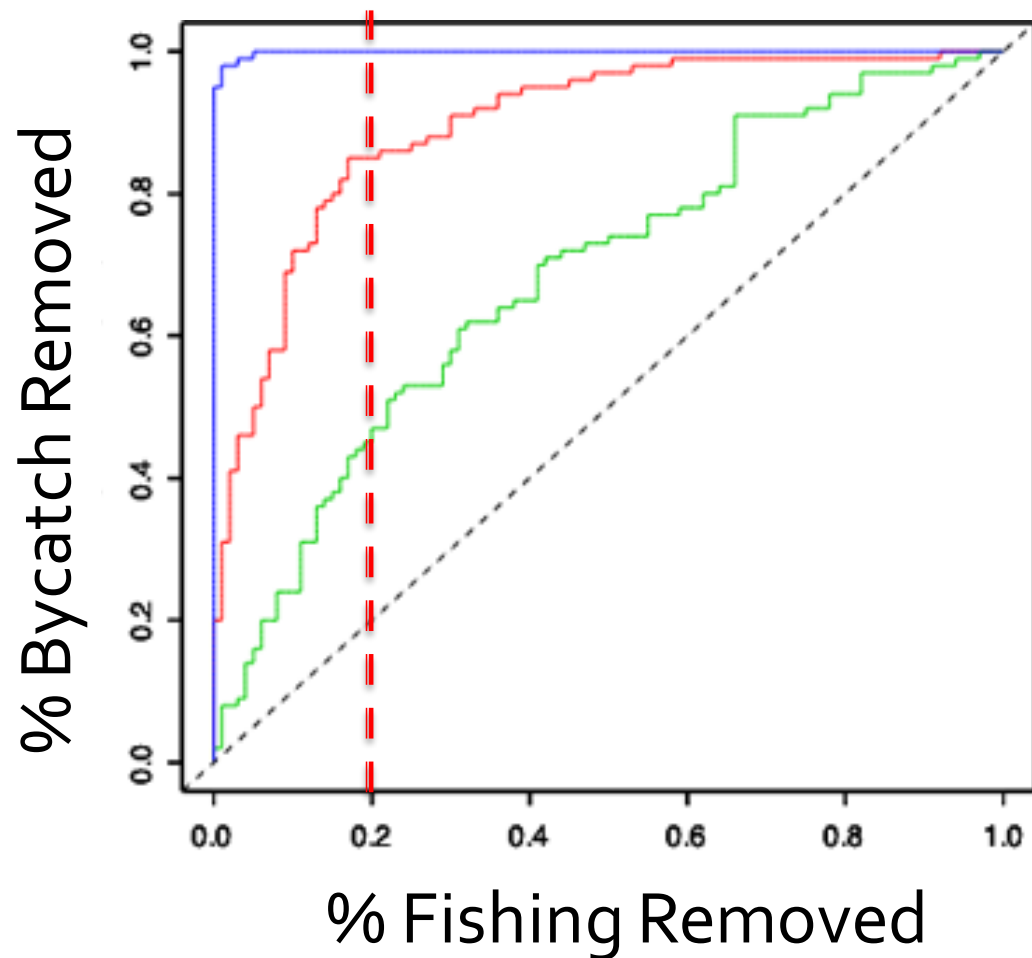
Results: ROC

Binomial



Results: ROC

Binomial



Eliminate 20% of fishing

Reduction in bycatch:

--- 20%

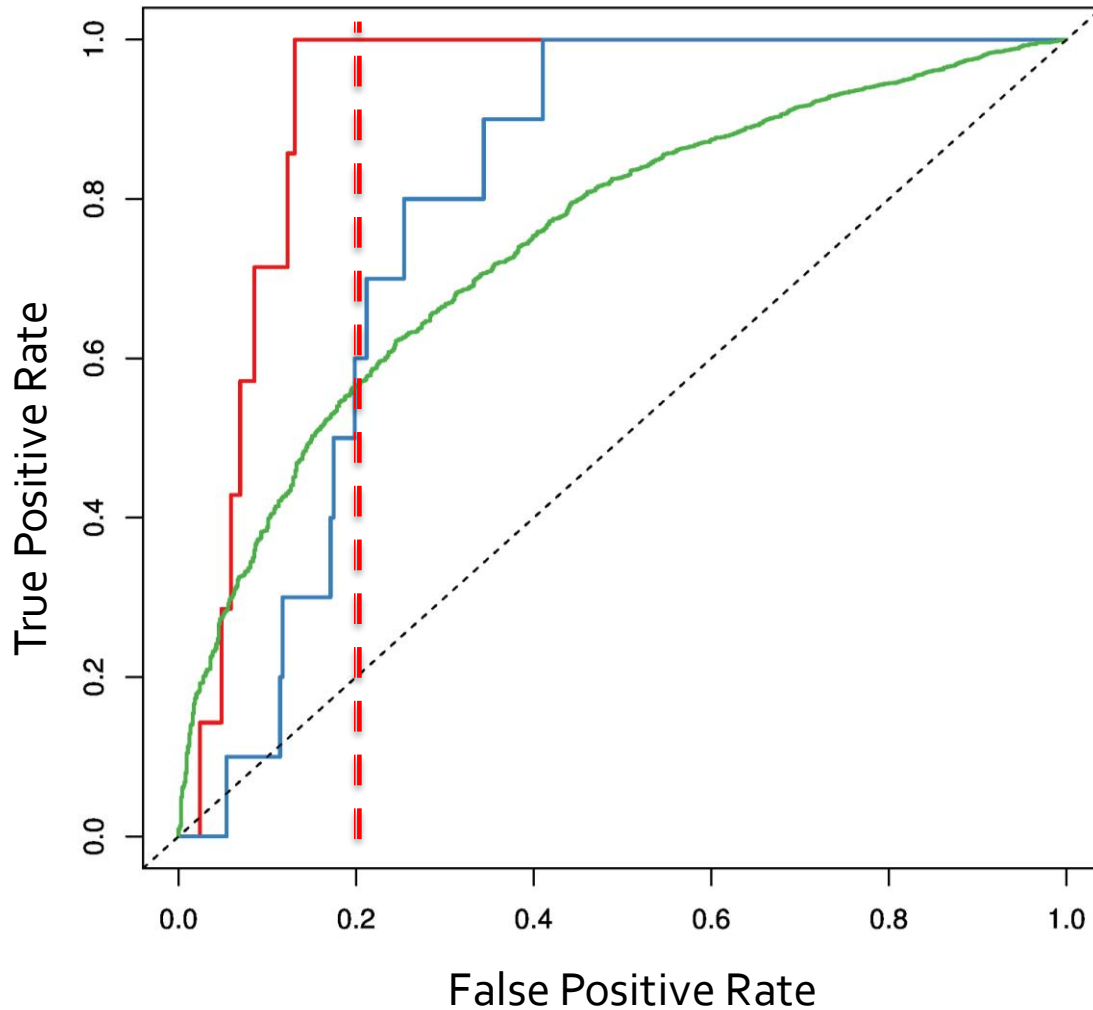
— 45%

— 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)

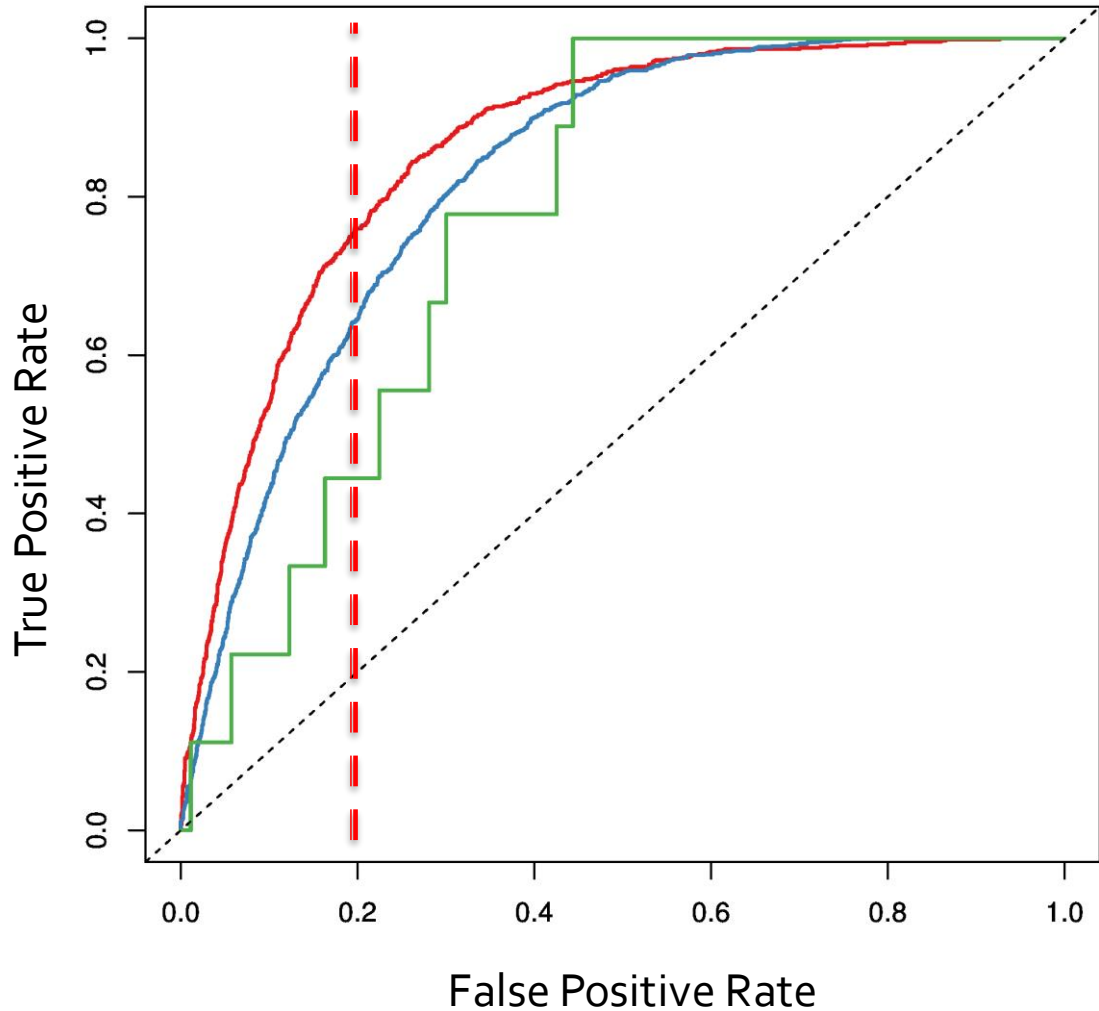
Binomial

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

Method	DBRK (18%)		PHLB (28%)		YEYE (0.4%)		LOGG (0.15%)		LEATH (0.18%)		BLUE (89%)	
	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

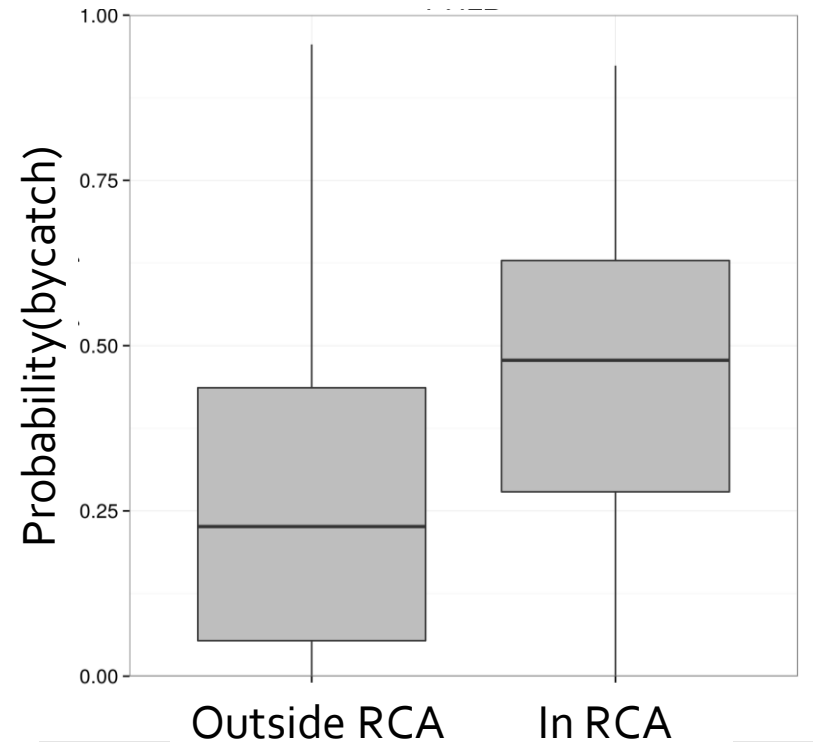
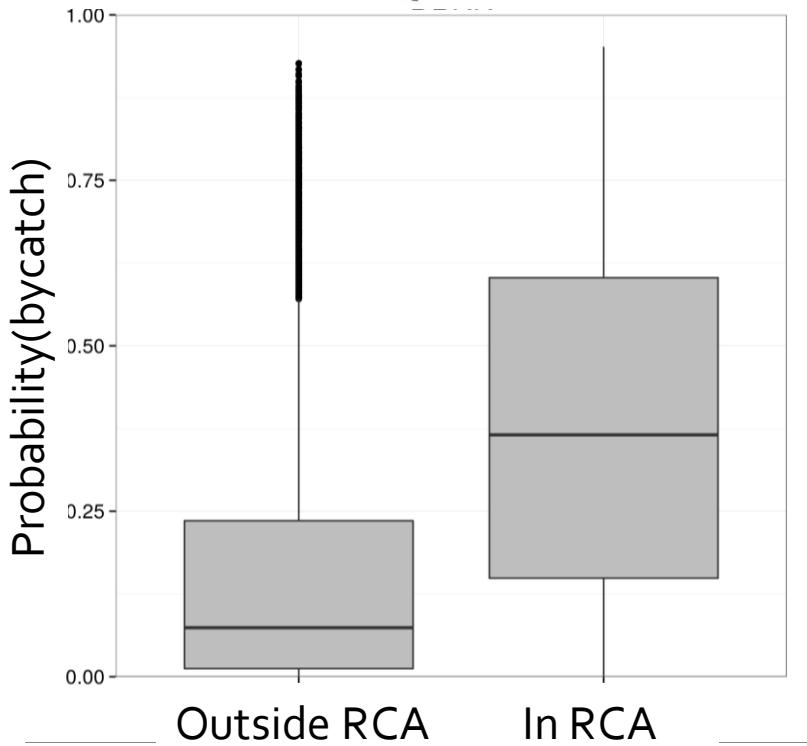
- 1994-2014
- 70,297 sets
- 3.2 million records



Results: RCAs

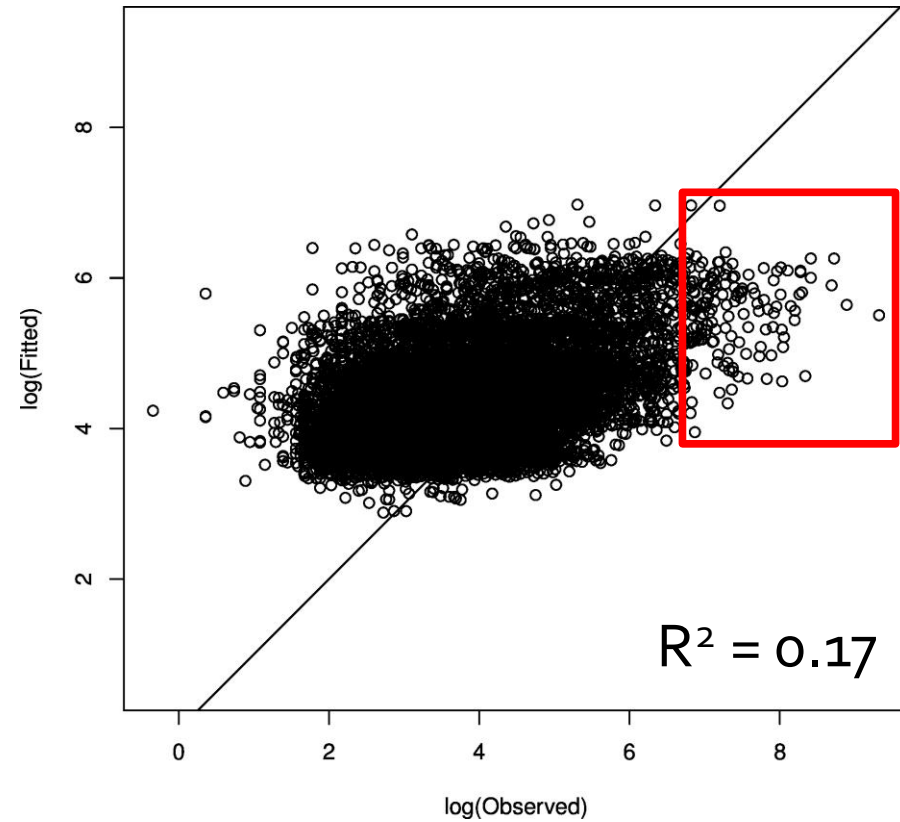
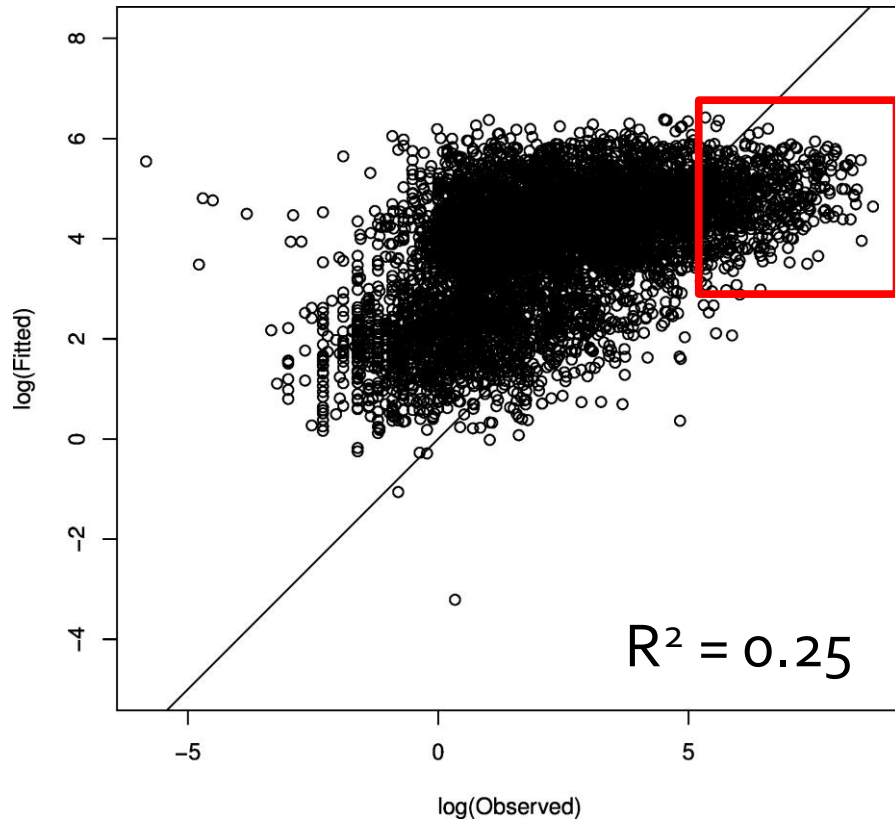
Binomial

11% of tows were in Rockfish Conservation Areas



Q: What about the positive model?

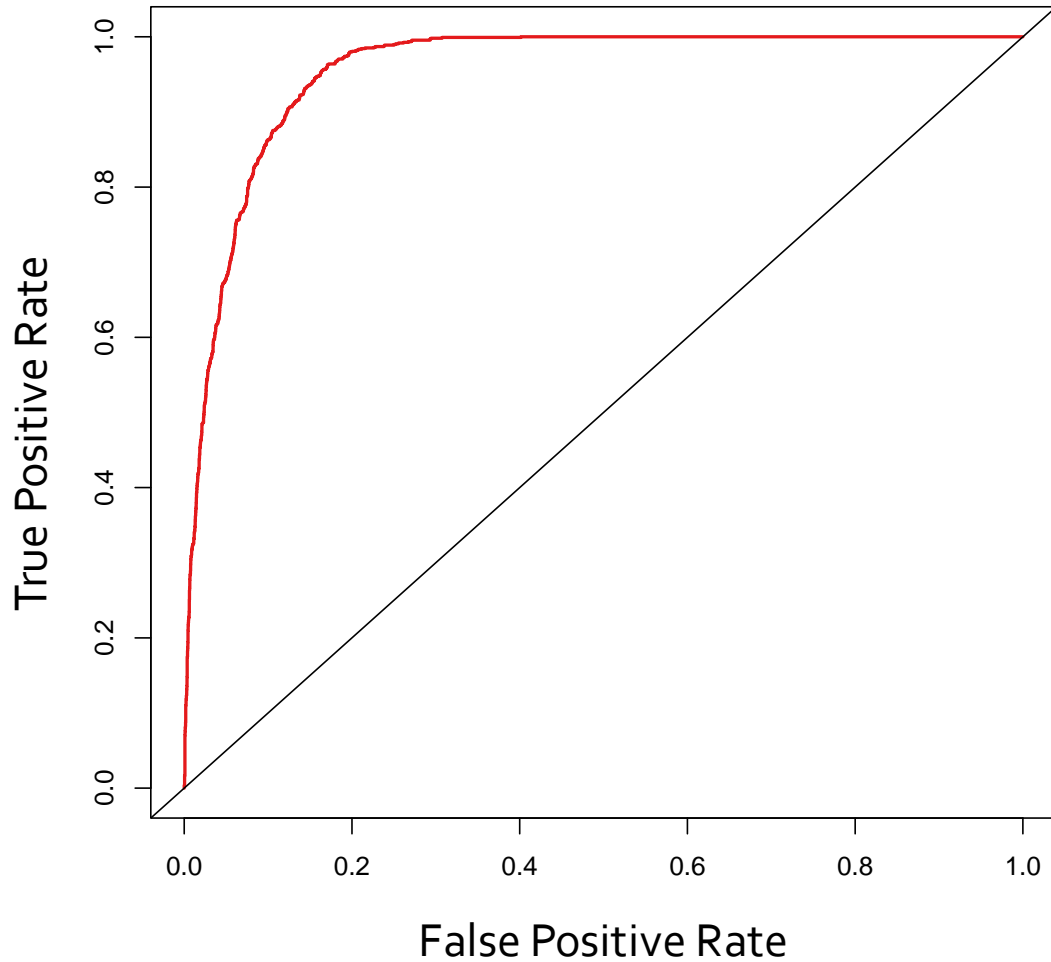
Positive



Q: What about effort?

Results: ROC (survey)

Binomial

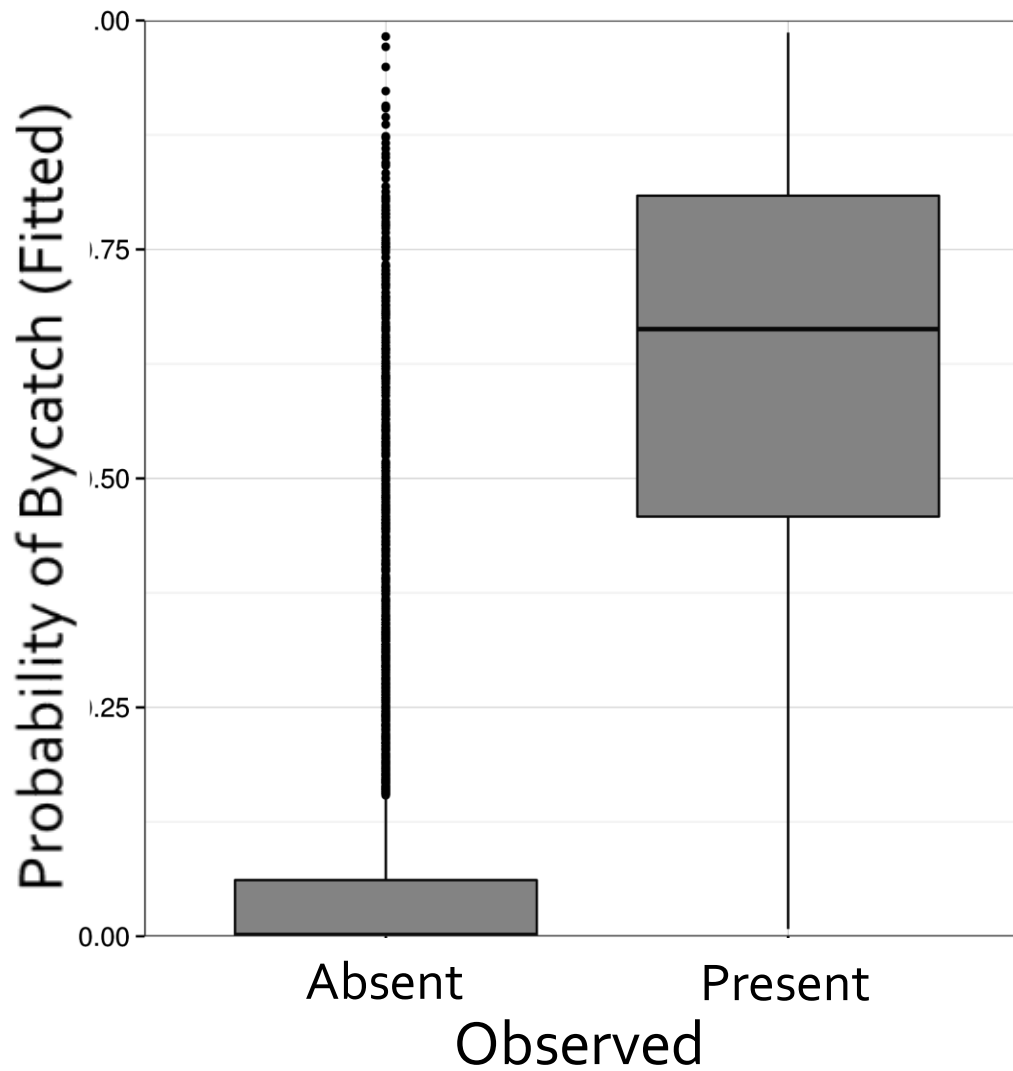


AUC = 0.955

Outstanding!

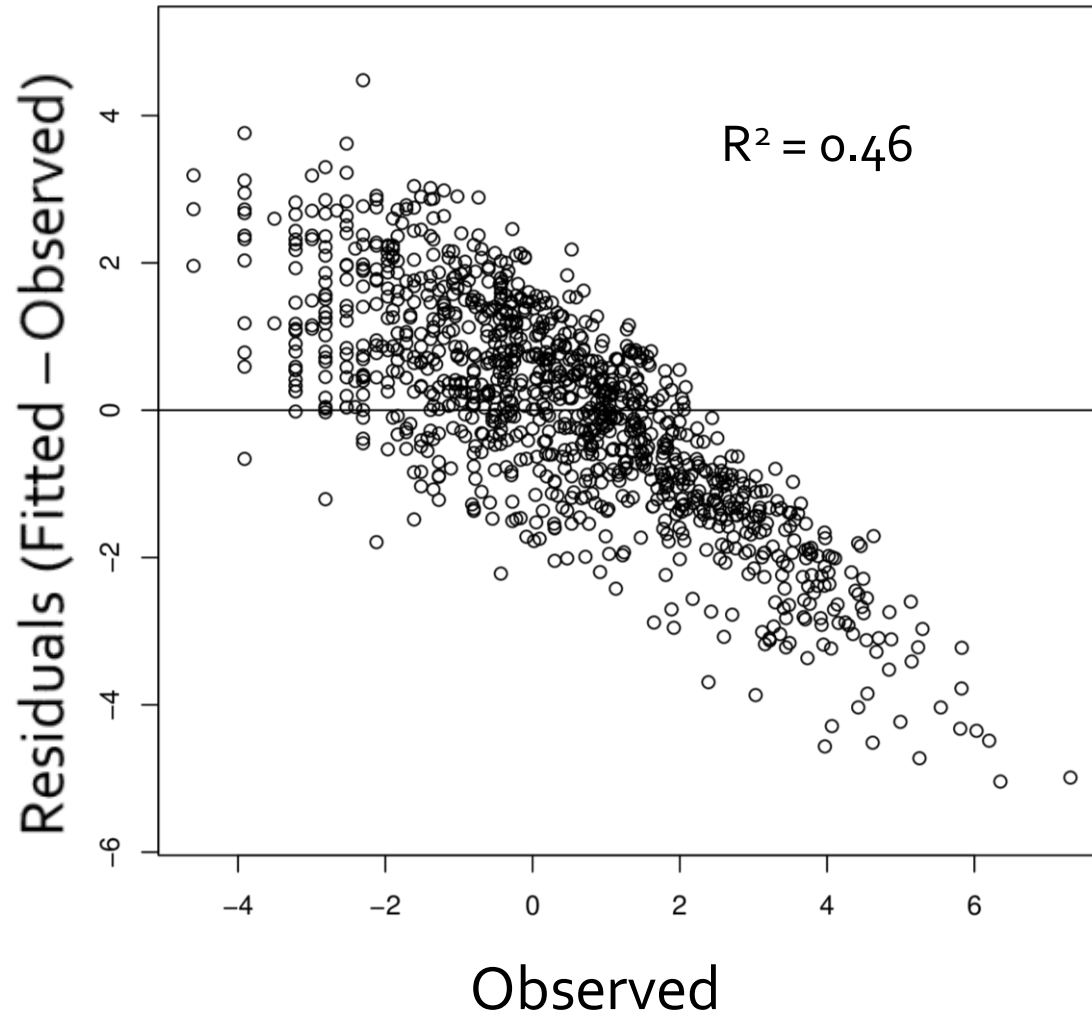
Proof of Concept

Binomial



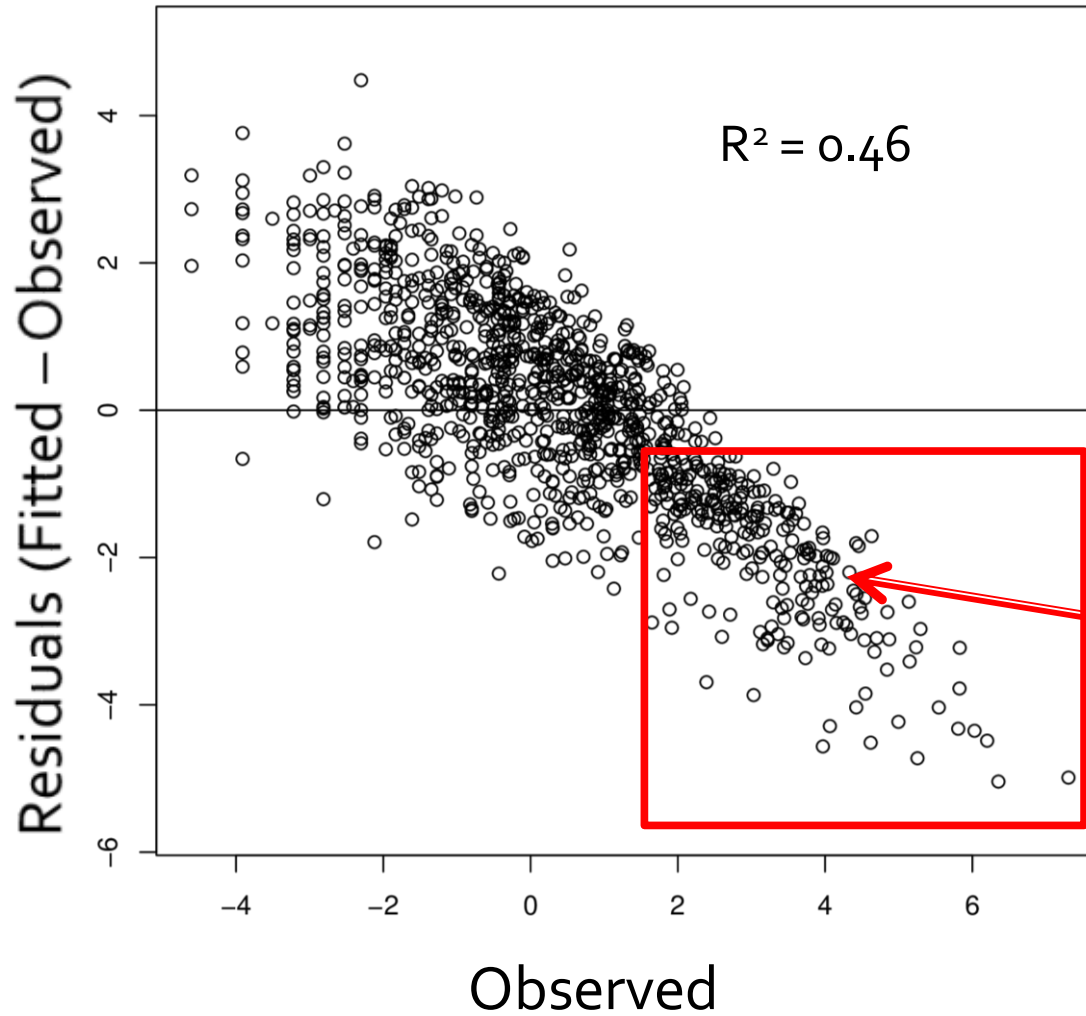
Proof of Concept

Positive



Proof of Concept

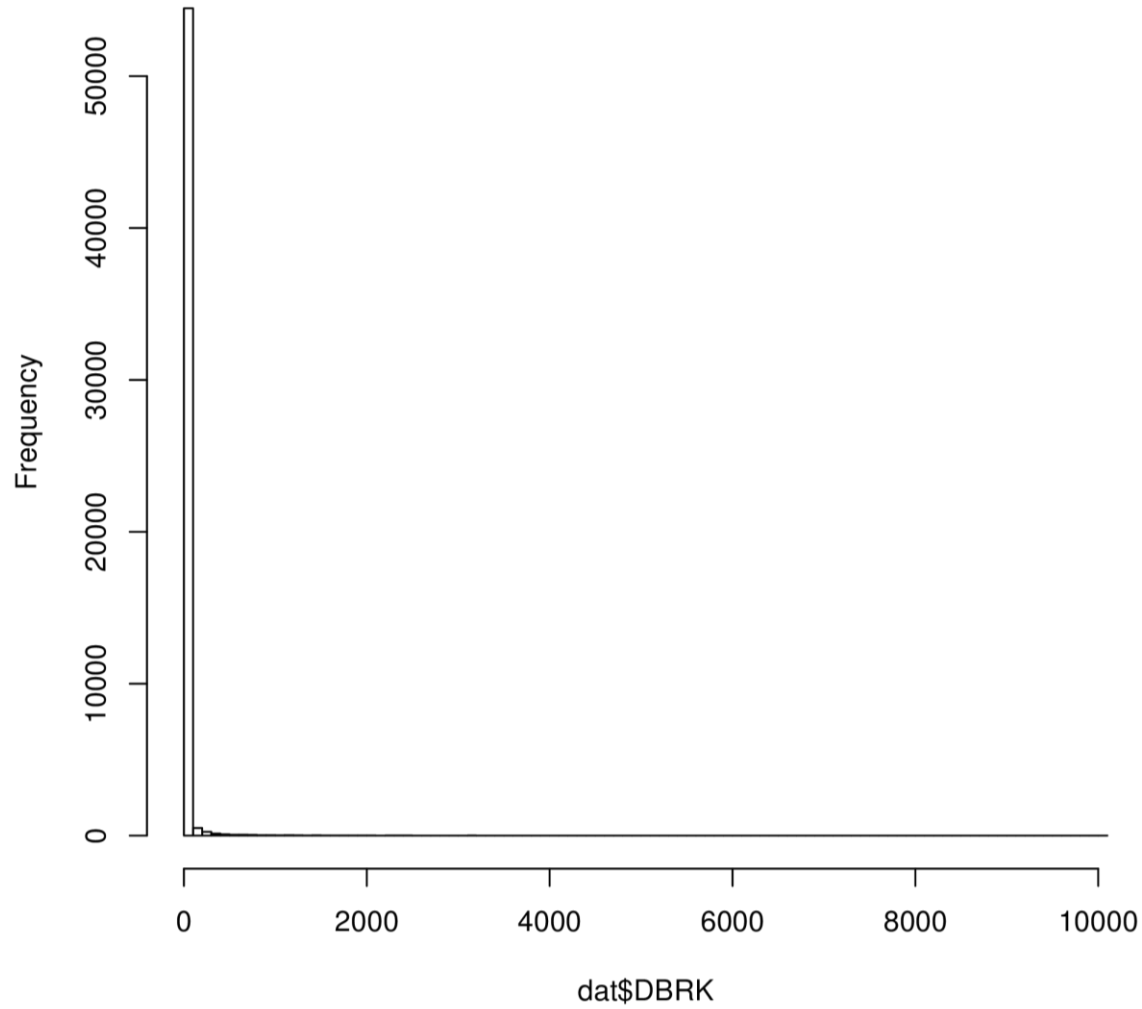
Positive



These extreme bycatch events are the most important to predict!

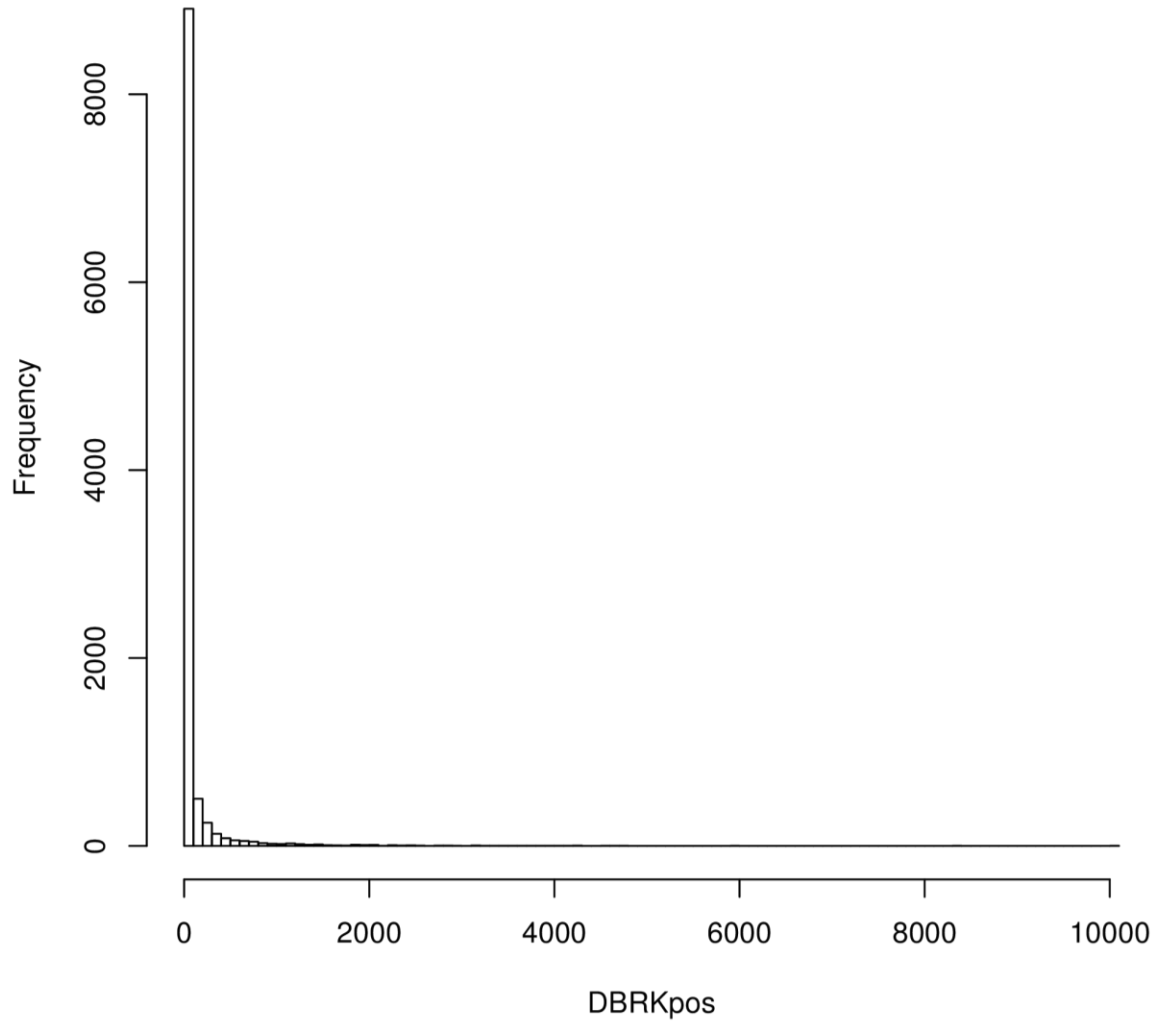
Proof of Concept

Positive



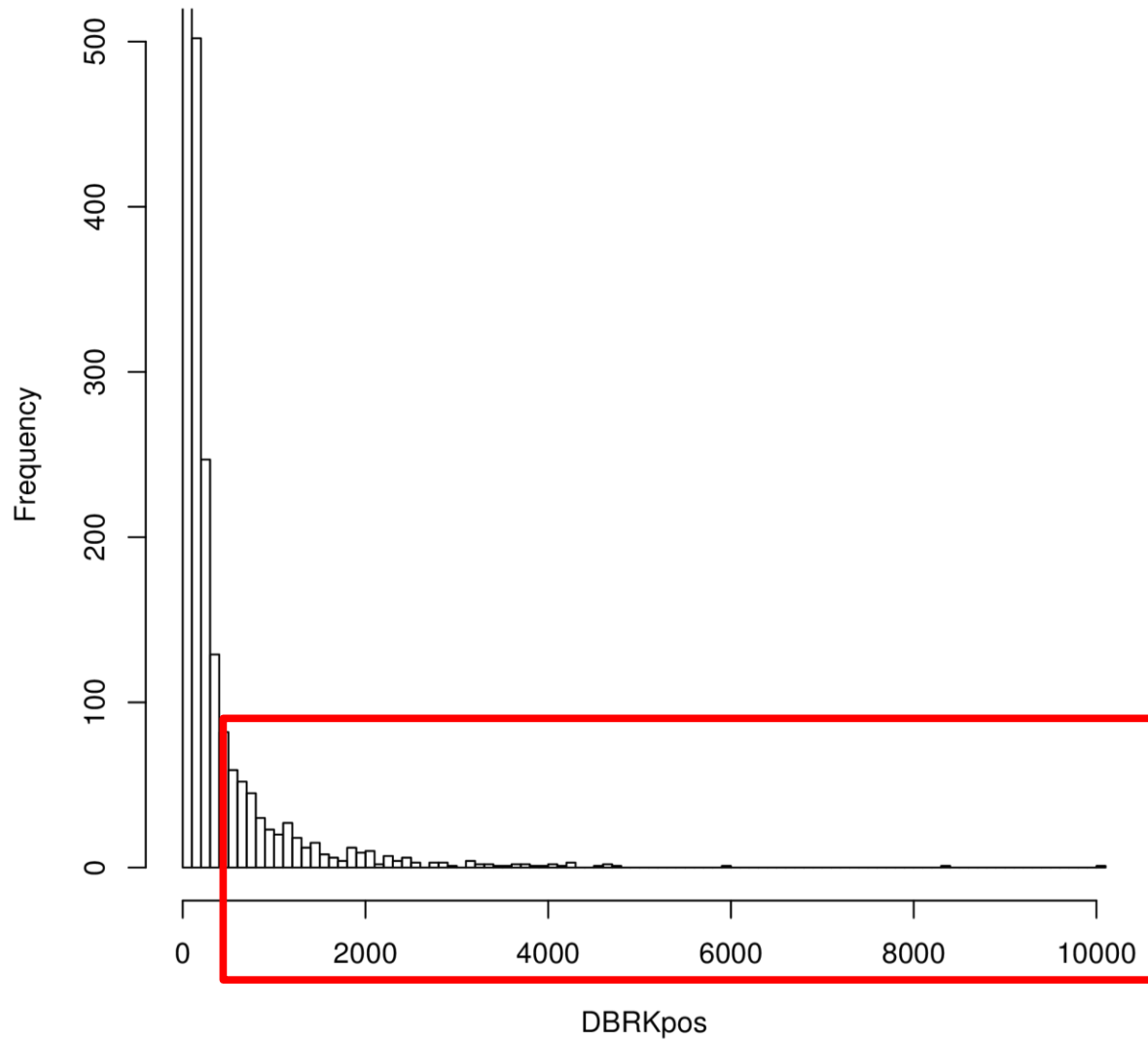
Proof of Concept

Positive



Proof of Concept

Positive

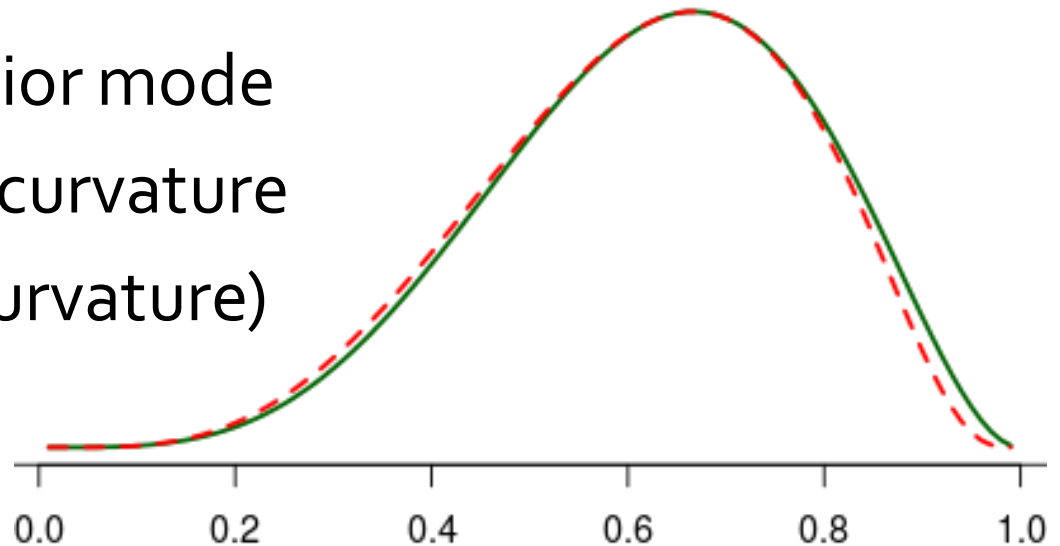


Spatial models: INLA-SPDE

Integrated Nested Laplace Approximation

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

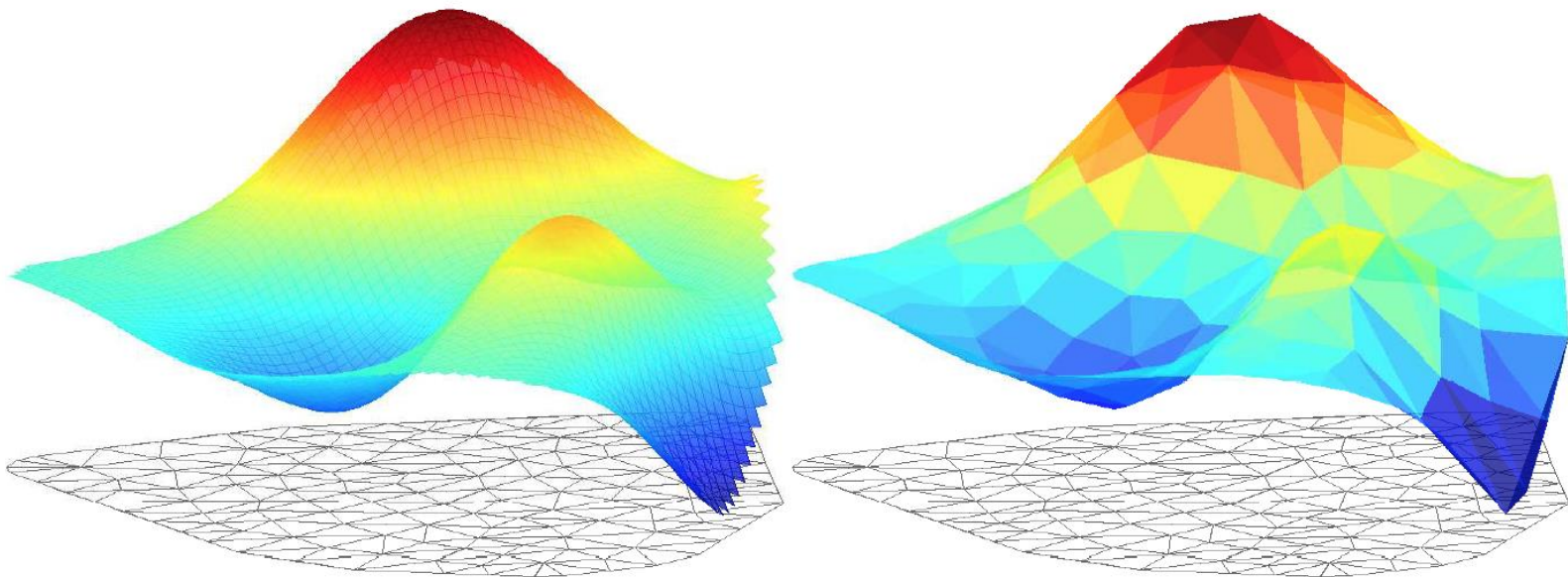
1. Find the posterior mode
2. Calculate local curvature
3. Use $N(\text{mode}, \text{curvature})$



Spatial models: INLA-SPDE

Spatial Partial Differential Equation

- Discrete approximation of continuous spatial fields



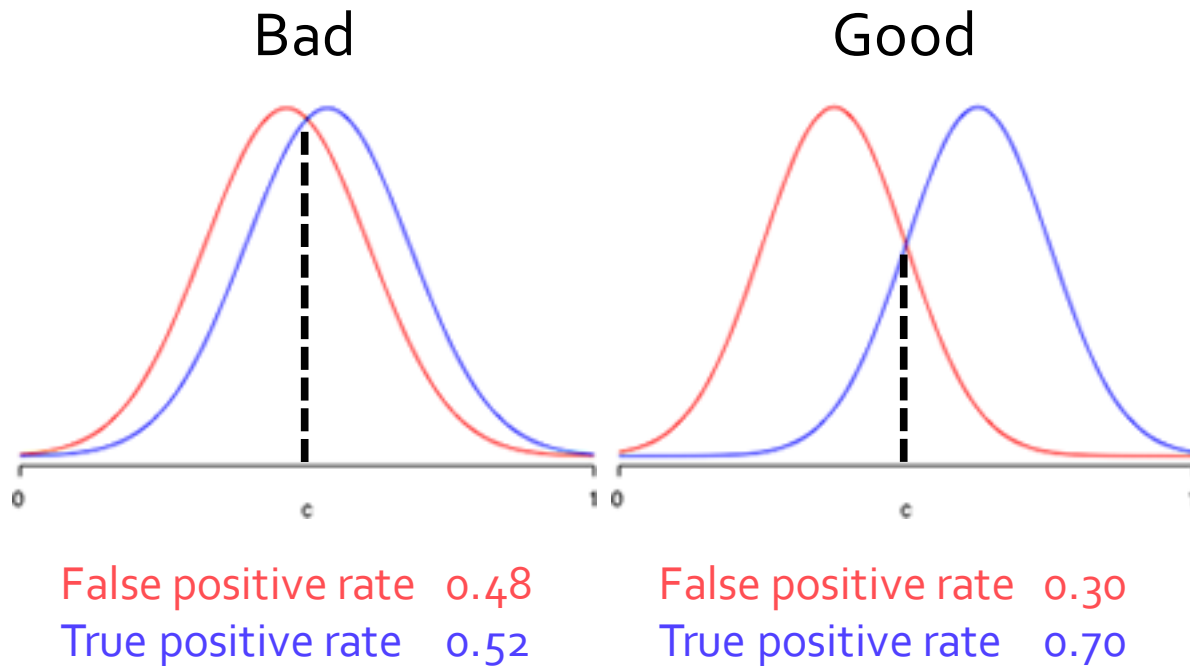
Preliminary results: ROC curves



False positive rate 0.30

True positive rate 0.70

Preliminary results: ROC curves



Preliminary results: ROC curves

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

