



# Improving Catch Estimation Methods in Sparsely Sampled, Mixed Stock Fisheries.

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UCSC :: CSTAR :: SWFSC :: NMFS

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## Diagnostic Tutorial

**Request:** As a diagnostic template, for each sampled stratum compare the posterior predictive distributions at the 68th, 95th, and 99th percentiles with the current observed species proportions (create fully stratified versions of tables 2 and 3 in the Grunloh et al. methods documentation). With each row, include sample sizes and associated landing weights with a graphical display to highlight problems and outliers (circle size proportional to landing weights).

**Rationale:** The Team provided broad-scale summary metrics (e.g., MSE and DIC) for evaluating the goodness-of-fit of the different model forms and structures. Fine-scale diagnostics are needed to help identify aspects of the data that are not adequately addressed by the different models. The diagnostic template will provide a mechanism for fine-scale exploration of goodness-of-fit.

**Response:** The following slides show the requested diagnostic plot and demonstrate how to maneuver as well as interpret them.



## Diagnostic Tutorial

## Beta-Binomial Model

$$y_{ijklm\eta} \sim \text{Beta-Binomial}\left(\mu_{jklm\eta}, \sigma_{jklm\eta}^2\right)$$

$$\mu_{jklm\eta} = n \logit^{-1}(\theta_{jklm\eta})$$

$$\sigma_{jklm\eta}^2 = \mu_{jklm\eta} \left(1 - \frac{\mu_{jklm\eta}}{n}\right) \left(1 + (n-1) \rho\right)$$

$$\theta_{jklm\eta} = \beta_0 + \beta_j^{(s)} + \beta_k^{(p)} + \beta_l^{(g)} + \beta_{mn}^{(t)}$$

$y_{ijklm\eta}$ :  $i^{\text{th}}$  sample of the  $j^{\text{th}}$  species' integer weight, in the  $k^{\text{th}}$  port, caught with the  $l^{\text{th}}$  gear, in the  $\eta^{\text{th}}$  quarter, of year  $m$ , for a particular market category.

$j \in \{1, \dots, J\}$  Species

$k \in \{1, \dots, K\}$  Ports

$l \in \{1, \dots, L\}$  Gears

$m \in \{1, \dots, M\}$  Years

$\eta \in \{1, \dots, H\}$  Quarters





## Diagnostic Tutorial

	M4
DIC	38721
WAIC	38725

← click

Text underlined in green links to the appropriate diagnostics for all species and stratum.

(M4)

$$\beta_{m\eta}^{(t)} = \beta_{m\eta}^{(y:q)}$$

$$\beta_{m\eta}^{(y:q)} \sim N(0, v)$$

- species-port-gear-year-qtr,  
species-gear-year,  
species-year
- disaggregated\*.csv,  
gearYearSpp\*.csv,  
yearSpp\*.csv
- marginal plots by species



## Diagnostic Tutorial

## MAD Diagnostic

Let  $\ell_i$  be the landings in stratum  $i$ ,  $\mathcal{O}_{ij}$  be the observed predictive accuracy of species  $j$  in stratum  $i$ , and  $\mathfrak{N}$  be the nominal level of prediction for a particular model run. The Mean Absolute Deviation (MAD) for species  $j$  in stratum  $i$  is

$$\text{MAD}_{ij} = \frac{\ell_i}{\sum_i \ell_i} |\mathcal{O}_{ij} - \mathfrak{N}|.$$

- Low MAD scores occur when  $\ell_i$  is low -or-  $|\mathcal{O}_{ij} - \mathfrak{N}|$  is small.
- High MAD scores occur when  $\ell_i$  is large and  $|\mathcal{O}_{ij} - \mathfrak{N}|$  is large.
- Thus high MAD scores represent important mistakes, and low MAD scores represent either unimportant mistakes, or important correctness :)



## Stratum Plots

We show predictive accuracy at three levels of stratification:

- species-port-gear-year-qtr is fully disaggregated predictions.
- species-gear-year marginalizes over port and quarter; showing marginalized predictions by species, gear, and year.
- species-year marginalizes over port, quarter, and gear; showing marginalized predictions by species and year.

In each run's directory (here is M4's) disaggregated\*.csv, gearYearSpp\*.csv, yearSpp\*.csv are csv versions of these images.

## Introduction

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## Time Model

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## Prior Model

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## Interaction Model

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## Time Block

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## Correlation

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## Diagnostic Tutorial

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BDG	9
BRG	326
CRS	50
ERK	323
MNT	108
MRO	138
OSF	29
HKL	110
NET	6
TWL	867
1978	124
1979	102
1980	271
1981	237
1982	249
Q1	162
Q2	289
Q3	340
Q4	192

margCNRY



- Marginal Plots condition on a single species (CNRY here).
- For a particular species, each row conditions on a single stratum and marginalizes over all other strata.
- Use:
  - Sort species by MAD score.
  - Given a particular species, explore margins via marginal plots.
  - Explore within the margins via the previously described stratum plots.

**Request:** Provide a summary table of species sample sizes in each market category by time block.

**Rationale:** The requested information will assist in understanding where there are gaps in the available data that the model is filling in by means of its pooling structure.

**Response:** The following slides show tables of total sample sizes and the frequency of occurrence by species within each sample (across all years, gears, ports and quarters within a time period) for the three rockfish market categories that we focus on in the presentation, as well as elasmobranchs and flatfish. Supplementary excel files include data summaries and pivot tables that can be used to review the same information for all other market categories, as well as these and other market categories at higher levels of stratification (year, port complex, gear, quarter) to address specific questions or concerns.

## Introduction

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## Correlation

This table shows the total number of samples for Market Category 250 (Unspecified rockfish) in five major time periods. The sparseness of some species in the sample data (e.g., bronzespotted rockfish in the 1978-1982 period, when just one was encountered) directly relates to the challenges and poor diagnostics in the fits for such rare species.

These tables show the total number of samples for Market Category 253 (Boccaccio) and 269 (Widow rockfish), with the frequency of occurrence of all other rockfish species in each sample, in five major time periods.

Market Category 253: Bocaccio						
	1978-82	1983-90	1991-99	2000-09	2010-17	
Total Samples	224	44	718	171	310	
ARRA	4	5	2			
BANK	39	19	53	2	1	
BCAC	207	37	709	170	310	
BLGL	9	9	10			
BLUR	6			2		
BRNZ				2		
BRWN	1		2			
CLPR	187	34	113	8	14	
CNRY	21	4	1			1
CWCD	6	1	15			
DBRK	4	6	8			
EGLS	2					2
FLAG	1	1				
GBLC	3					
GSPT	16	1	9	1		
GSRK	17	3	7			1
KLPG	1					
LCOD	17	1	2			
LSPN						1
MISC	2					
MKRF				1		
OLIVE	5		4			
OWFS				1		
PDAB	1					1
PNKR	1	2				
POP				1		
PTRL				1		
RDBD	2	5	2			
REX						1
REX	1					
RSTN				3		
SABL	3					
SBLY	9		2		1	
SHRP		1	2			
SLGR			7	1		
SNOS	27	12	18			
SPKL	5	1	6			
SSPN	6	2	1			
STAR				1		
STRK	12	2	3			3
TIGR	1					
URCK				1		
VRML	4		2			
WDWQ	51	5	23			1
YTRK	19	1	19			

Market Category 269: Widow rockfish						
	1978-82	1983-90	1991-99	2000-09	2010-17	198
Total Samples	132	497	514	150	198	
ARRA			1			
BANK		5	29	3		
BCAC	6	13	5	2		1
BLCK	1	1				
BLGL		2	7	2		
BLUR			2			
BRNZ			1			
CLPR	4	19	18		1	
CMEL		1				
CNRY	2	3				
CWCD			1			
DBRK	1	3	6			
EGLS						1
GSPT		1	2			
GSRK	1	2				
LCOD			2			
MISC			1			
OLVE			1			
POP						1
POP	1	1				
RDBD					1	
REX						1
SBLY		1	2			
SHRP		3	1			
SLGR		1				
SNOS		1			1	
SPKL	2	3	30	1		3
SQRS			2			
STRK		3	4			
VRML		1				
WDOW	130	494	489	148		195

## Introduction

## Time Model

A 5x5 grid of 25 small circles, arranged in five rows and five columns.

## Prior Model

A 5x5 grid of 25 small circles, arranged in five rows and five columns.

## Interaction Model

A 5x5 grid of 25 small circles, arranged in five rows and five columns.

### Time Block

A 5x5 grid of 25 small circles, arranged in five rows and five columns.

### Correlation

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Moving beyond rockfish into flatfish and elasmobranch (primarily skates) market categories, these tables shows the total number of samples and frequency of occurrence by species for the largest flatfish (table on left) and elasmobranch (table on right) market categories. Flatfish species composition data have only been collected since 2002, and elasmobranchs since 2009, so all years are combined here (and information at higher stratification levels, including more sparsely sampled market categories, are available in the excel file).

## Introduction

## Time Model

## Prior Model

#### Interaction Model

## Time Block

## Correlation

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	147 Longnose skate	152 spiny dogfish	175 unspecifi ed skate	177 176 big skate	Californi a skate
Total samples	374	12	32	70	3
BSKT	19		5	70	
CSKT	3		4		2
CSRK					
DSRK		12			
LSKT	372		21		5
PTRL	1				
RATF					
RTSK	5		5		1
SPSK	9		3		
SSKT			1		
SSPN	1				
URAY					
USKT	3		4		



**Request:** Redo the modeling of the early time block without southern CA ports. Explore spatially and temporally (i.e., alternative time blocks).

**Rationale:** The available dataset does not have any sample data in the early time block from the southern CA ports. It was unclear how this lack of data influenced the model results. The requested analysis will clarify the situation.

**Response:** All of the model runs and plots from this point forward only model ports north of point conception.

**Request:** The diagnostic template should be developed for each of the sensitivity runs (vary across a range of plausible time models and priors and limit to the top 2-3 market categories).

**Rationale:** Application of the diagnostics across a wide range of models will form a test of how well the diagnostics illustrate whether the models capture important structural features that are thought to be embedded in the data.

**Response:** The following slides show the requested diagnostic plots as applied to models across a range of time models and prior choices.

# Time Models

(M1)

$$\beta_{mn}^{(t)} = \beta_m^{(y)} + \beta_n^{(q)}$$

$$\beta_m^{(y)} \sim N(0, 32^2)$$

$$\beta_{\eta}^{(q)} \sim N(0, 32^2)$$

(M2)

$$\beta_{m\eta}^{(t)} = \beta_m^{(y)} + \beta_\eta^{(q)}$$

$$\beta_m^{(y)} \sim N(0, v^{(y)})$$

$$\beta_{\eta}^{(q)} \sim N(0, v^{(q)})$$

(M3)

$$\beta_{m\eta}^{(t)} = \beta_m^{(y)} + \beta_\eta^{(q)} + \beta_{m\eta}^{(y:q)}$$

$$\beta_m^{(y)} \sim N(0, v^{(y)})$$

$$\beta_{\eta}^{(q)} \sim N(0, v^{(q)})$$

$$\beta_{m\eta}^{(y:q)} \sim N(0, v)$$

(M4)

$$\beta_{m\eta}^{(t)} = \beta_{m\eta}^{(y:q)}$$

$$\beta_{m\eta}^{(y:q)} \sim N(0, v)$$

(M5)

$$\beta_{m\eta}^{(t)} = \beta_{m\eta}^{(y:q)}$$

$$\beta_{m\eta}^{(y:q)} \sim N(0, v_\eta)$$

(M6)

$$\beta_{m\eta}^{(t)} = \beta_{m\eta}^{(y:q)}$$

$$\beta_{m\eta}^{(y:q)} \sim N(0, v_m)$$

Introduction

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Time Model

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Prior Model

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Interaction Model

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Time Block

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Correlation

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MCAT 250

	M1	M2	M3	M4	M5	M6
$\Delta$ DIC	6448.98	0.33	0	4.45	9.3	7.42
$\Delta$ WAIC	6421.5	0.37	0	4.52	8.25	6.55

Introduction

## Time Model

## Prior Model

## Interaction Model

## Time Block

## Correlation

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A 5x5 grid of 25 small circles, arranged in five rows and five columns.

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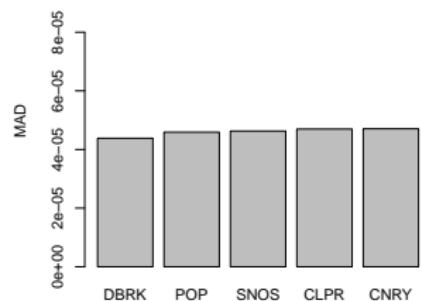
MCAT 250

M2

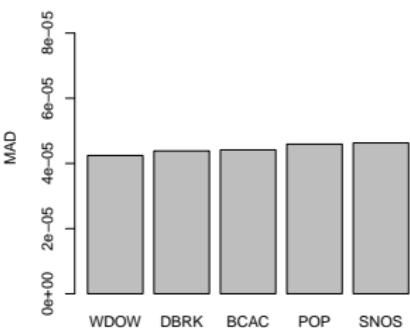
M3

M4

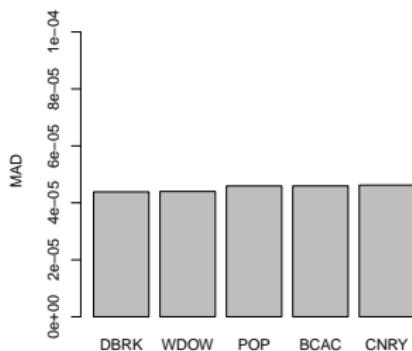
### MAD Ordered by Species



### MAD Ordered by Species



### MAD Ordered by Species



## Combined

## Introduction

## Time Model

## Prior Model

## Interaction Model

### Time Block

## Correlation

A 4x5 grid of 20 small circles, arranged in four rows and five columns.

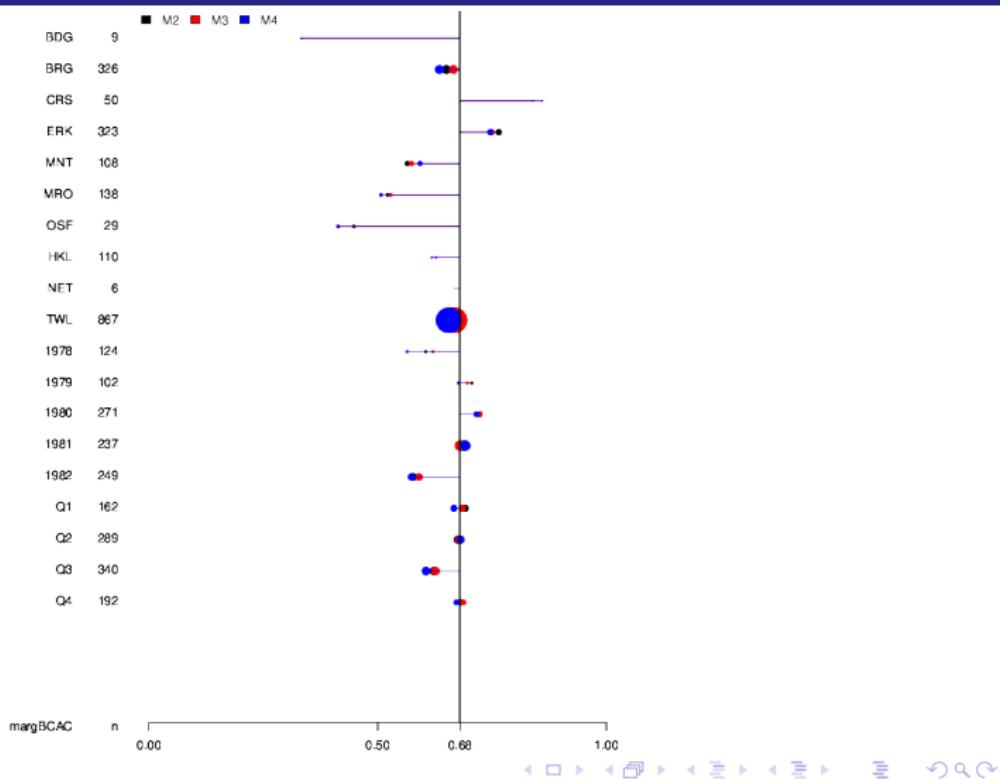
A 4x6 grid of 24 small circles, arranged in four rows and six columns.

A 4x3 grid of 12 small circles, arranged in four rows and three columns.

A 4x3 grid of 12 small circles, arranged in four rows and three columns.

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MCAT 250



Introduction

## Time Model

## Prior Model

## Interaction Model

### Time Block

## Correlation

A 4x5 grid of 20 small circles, arranged in four rows and five columns.

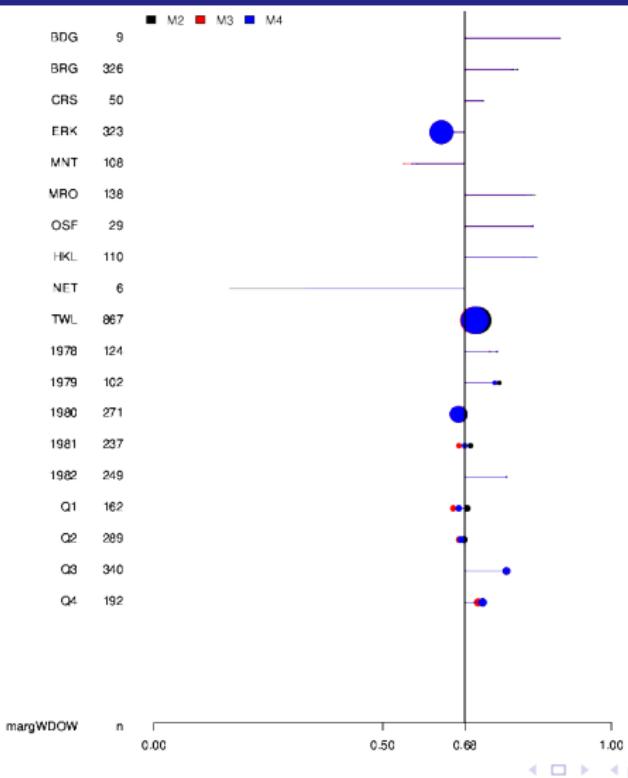
A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x6 grid of 24 small circles, arranged in four rows and six columns.

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MCAT 250



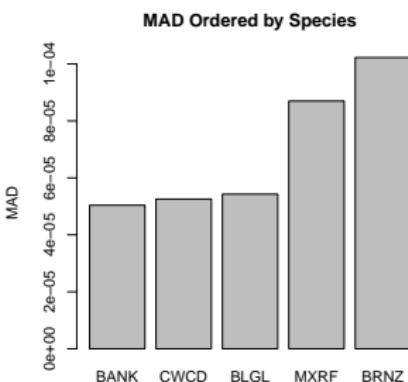
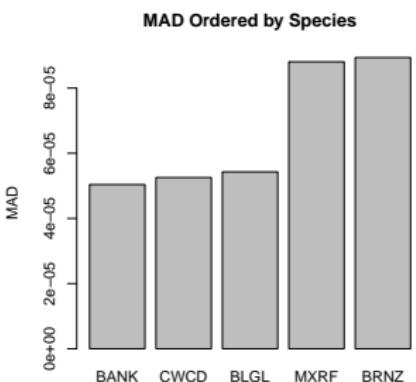
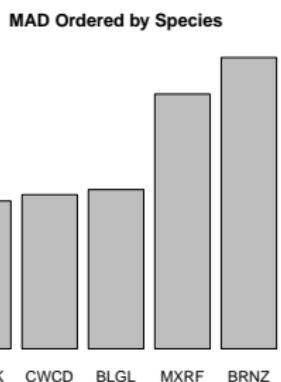


MCAT 250

M2

M3

M4



## Combined

Introduction

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Time Model

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Prior Model

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Interaction Model

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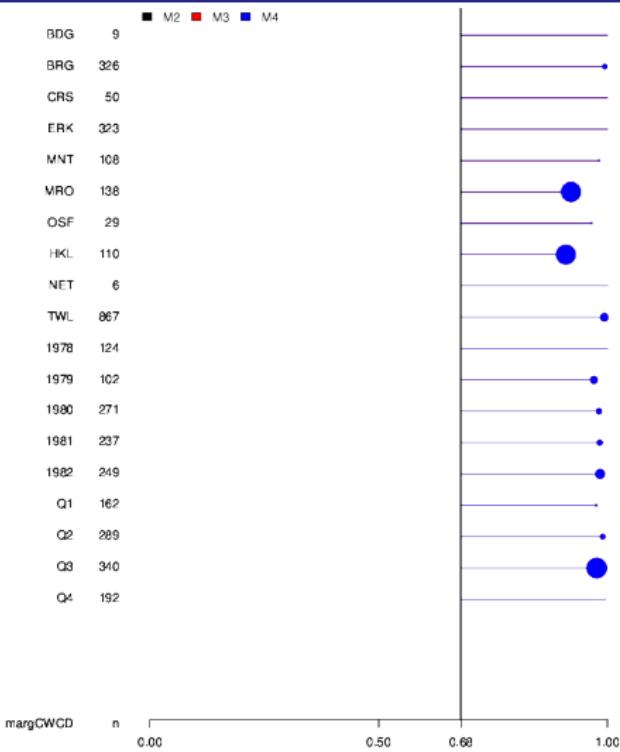
Time Block

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Correlation

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## MCAT 250



## Introduction

## Prior Model

A 5x5 grid of 25 small circles, arranged in five rows and five columns.

## Interaction Model

A 5x5 grid of 25 small circles, arranged in five rows and five columns.

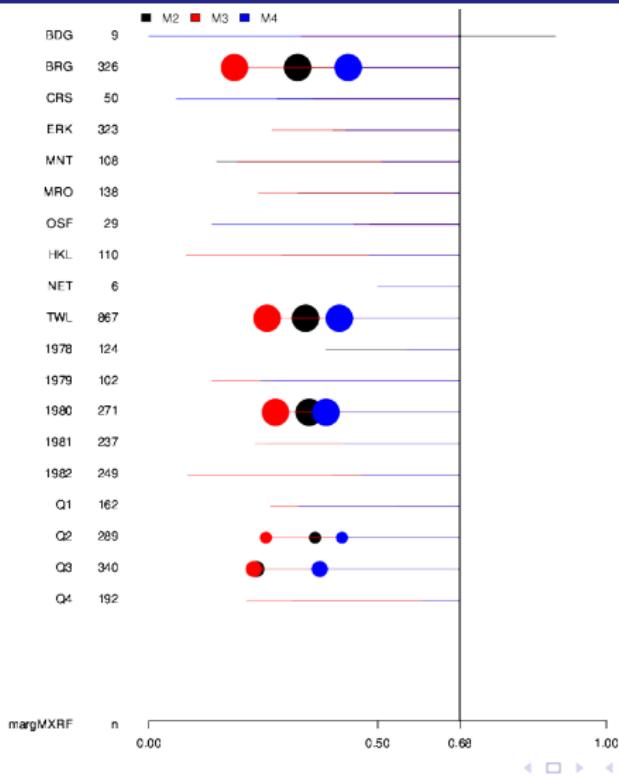
### Time Block

A 5x5 grid of 25 small circles, arranged in five rows and five columns.

## Correlation

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MCAT 250



Introduction

## Time Model

## Prior Model

## Interaction Model

## Time Block

## Correlation

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A 4x6 grid of 24 small circles, arranged in four rows and six columns.

A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

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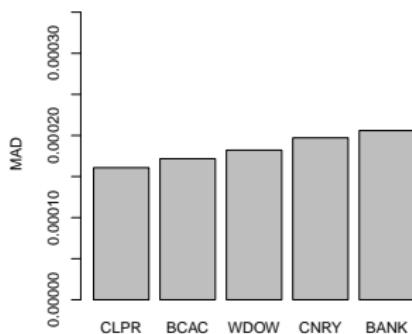
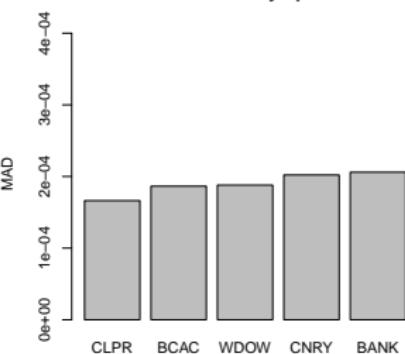
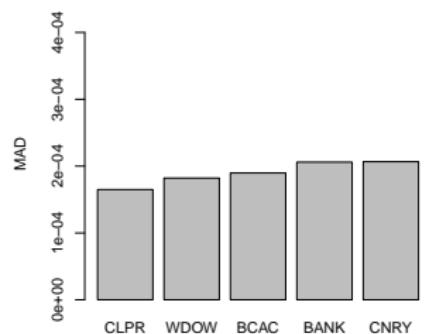
MCAT 253

	M1	M2	M3	M4	M5	M6
$\Delta$ DIC	1409.81	0.09	0.1	0.07	0.05	0
$\Delta$ WAIC	1391.66	0.16	0.18	0	0.13	0.08

M4

M5

M6



## Combined

Introduction

## Time Model

## Prior Model

## Interaction Model

## Time Block

## Correlation

A 4x5 grid of 20 small circles, arranged in four rows and five columns.

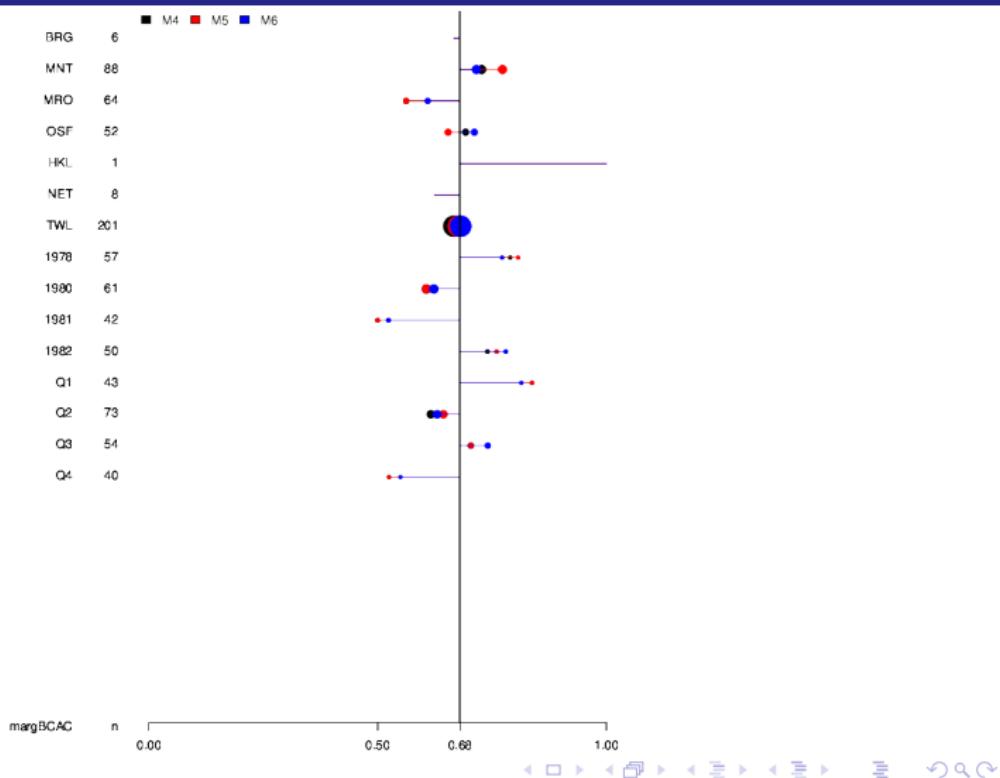
A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x6 grid of 24 small circles, arranged in four rows and six columns.

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MCAT 253



Introduction

## Time Model

### Prior Model

## Interaction Model

### Time Block

## Correlation

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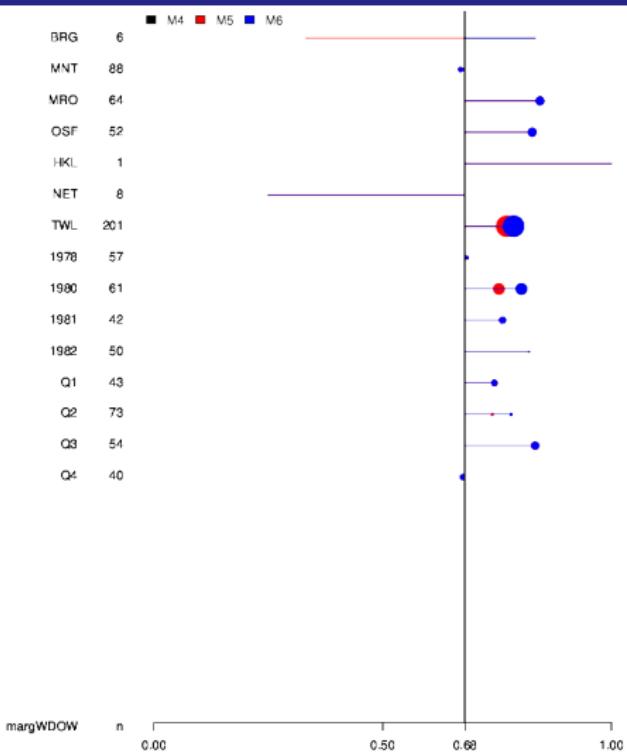
A 4x6 grid of 24 small circles, arranged in four rows and six columns.

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A 4x6 grid of 24 small circles, arranged in four rows and six columns.

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MCAT 253



A 4x4 grid of 16 small circles, arranged in four rows and four columns.

A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x6 grid of 24 small circles, arranged in four rows and six columns.

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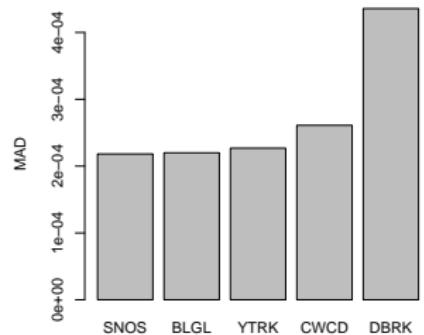
MCAT 253

M4

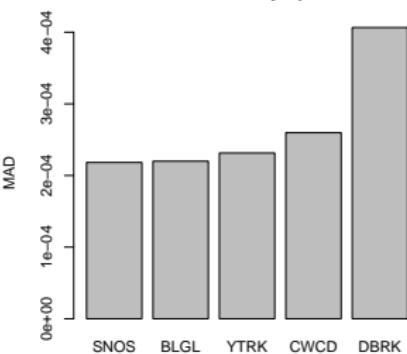
M5

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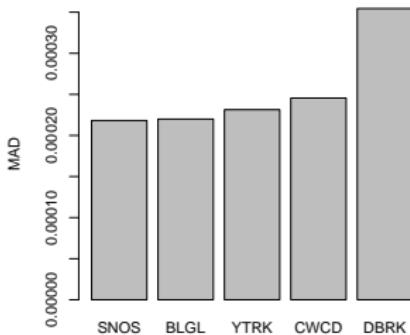
#### MAD Ordered by Species



### MAD Ordered by Species



#### MAD Ordered by Species



## Combined

## Introduction

## Time Model

## Prior Model

## Interaction Model

### Time Block

## Correlation

A 4x5 grid of 20 small circles, arranged in four rows and five columns.

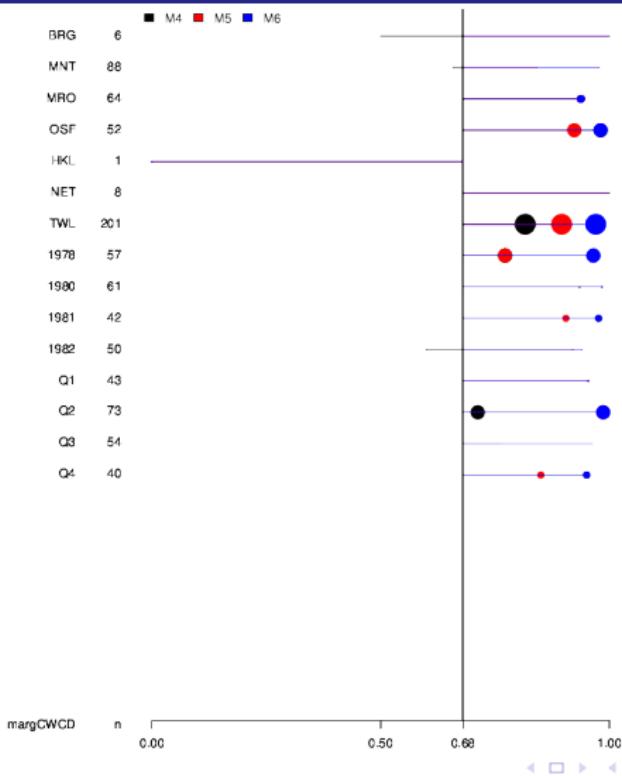
A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x6 grid of 24 small circles, arranged in four rows and six columns.

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MCAT 253



Introduction

## Time Model

## Prior Model

## Interaction Model

### Time Block

## Correlation

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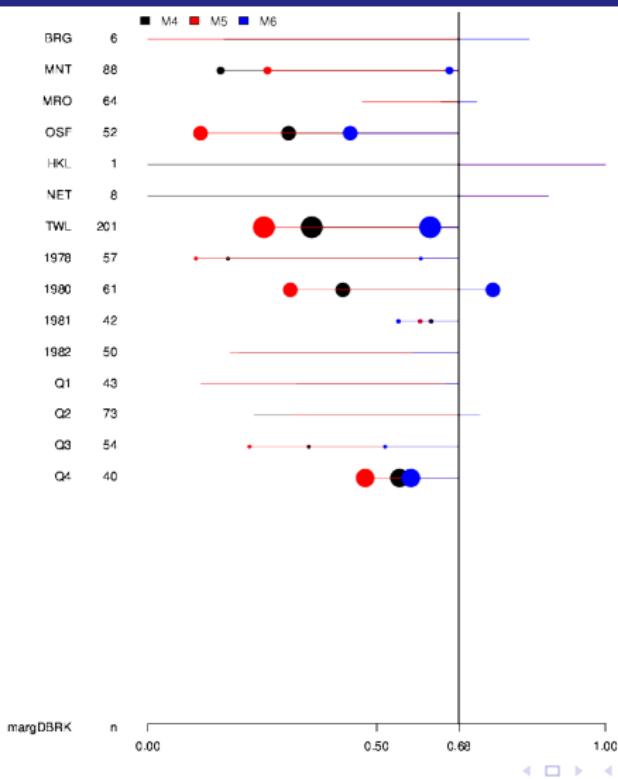
A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x4 grid of 16 small circles arranged in four rows and four columns.

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MCAT 253



Introduction

## Time Model

## Prior Model

## Interaction Model

## Time Block

## Correlation

A 4x6 grid of 24 small circles, arranged in four rows and six columns.

A 4x5 grid of circles. The top row has 2 circles. The second row has 5 circles. The third row has 5 circles. The bottom row has 1 circle on the left and 4 circles on the right.

A 4x6 grid of 24 small circles, arranged in four rows and six columns.

A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

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MCAT 269

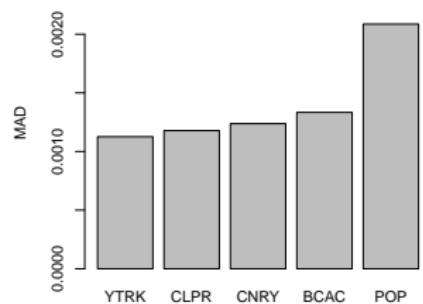
	M1	M2	M3	M4	M5	M6
$\Delta$ DIC	572.51	176.63	599.41	0.57	0	193.35
$\Delta$ WAIC	427.48	69.37	454.41	0.23	0	78.07

M4

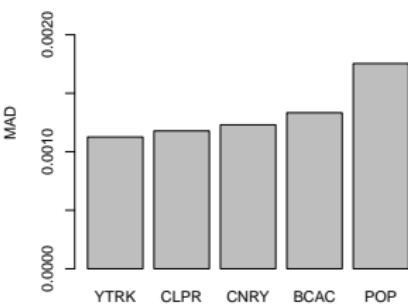
M5

M6

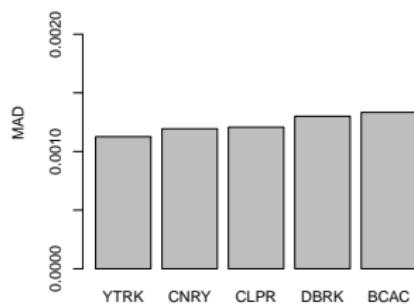
### MAD Ordered by Species



### MAD Ordered by Species



### MAD Ordered by Species



## Combined

## Introduction

## Time Model

## Prior Model

## Interaction Model

### Time Block

## Correlation

A 4x5 grid of 20 small circles, arranged in four rows and five columns.

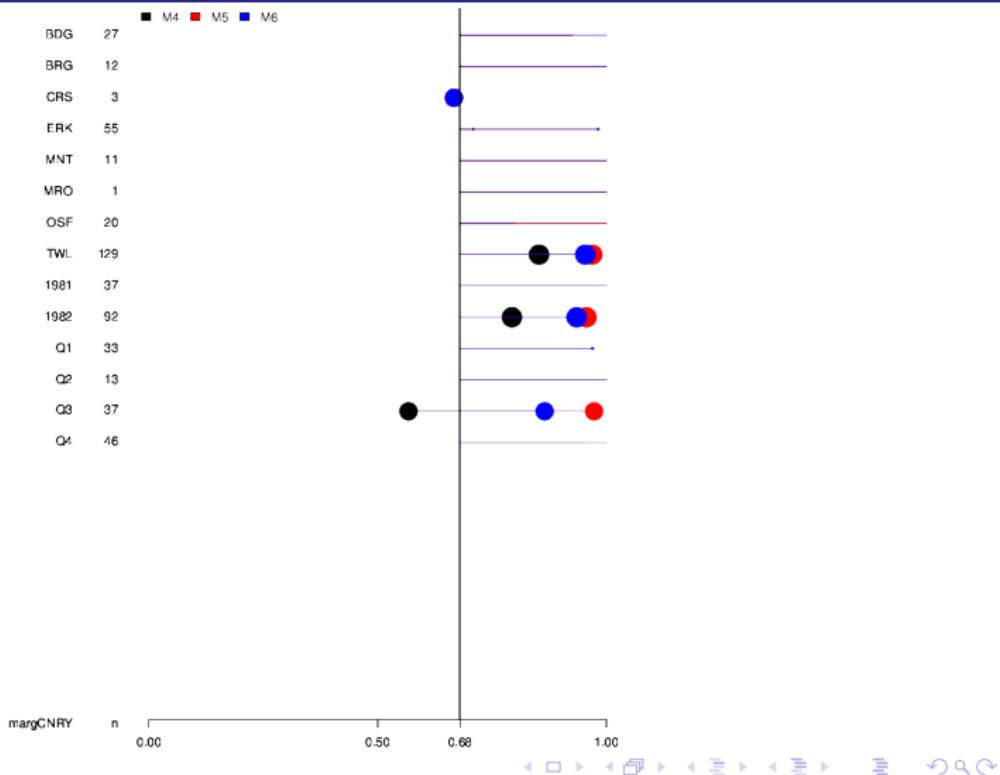
A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x3 grid of 12 small circles, arranged in four rows and three columns.

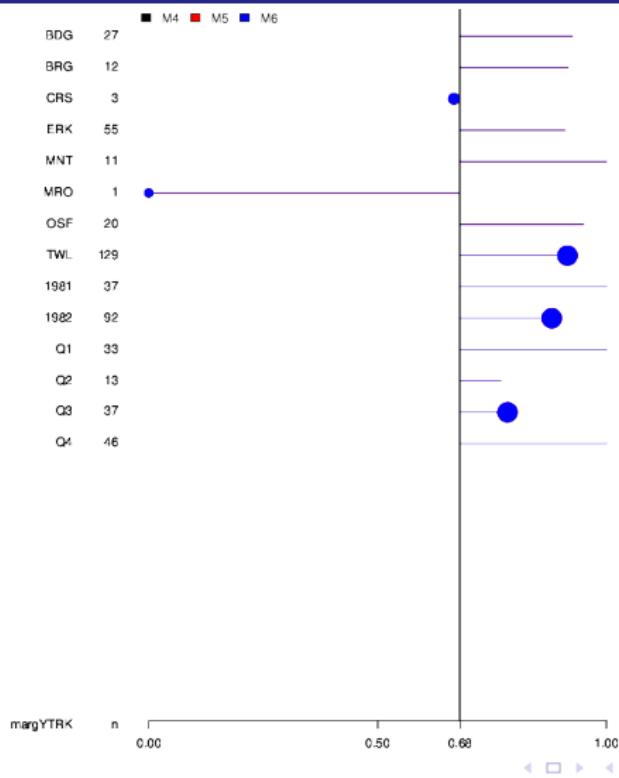
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MCAT 269





MCAT 269

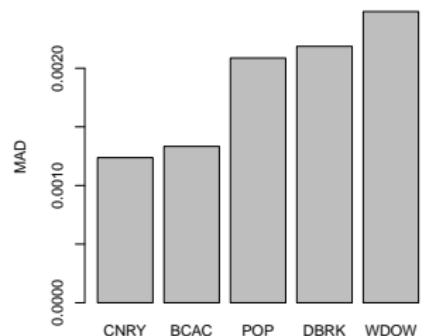


M4

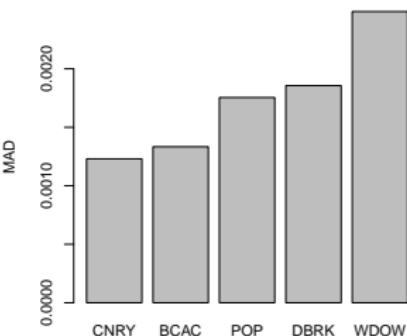
M5

M6

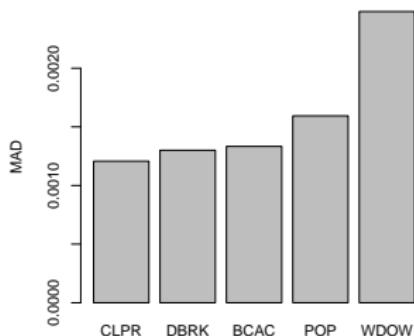
### MAD Ordered by Species



### MAD Ordered by Species



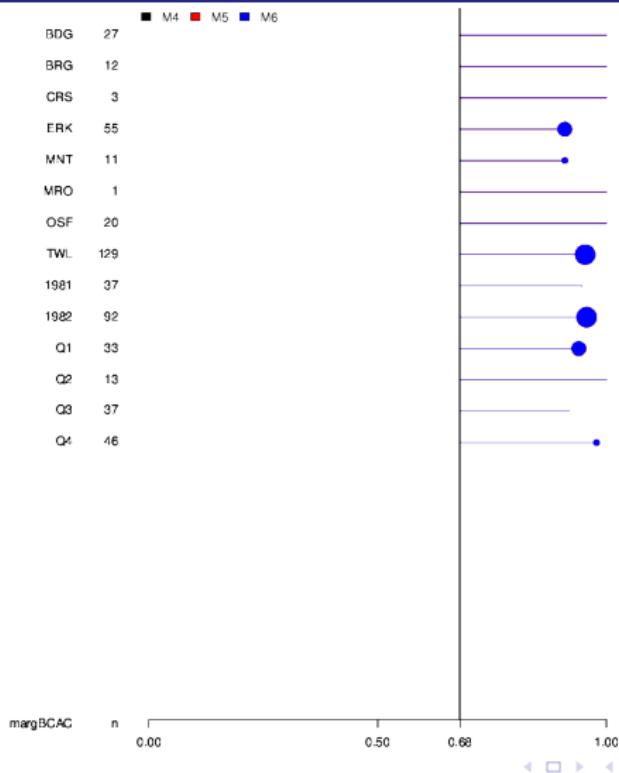
### MAD Ordered by Species



## Combined



MCAT 269



Introduction

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Time Model

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Prior Model

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Interaction Model

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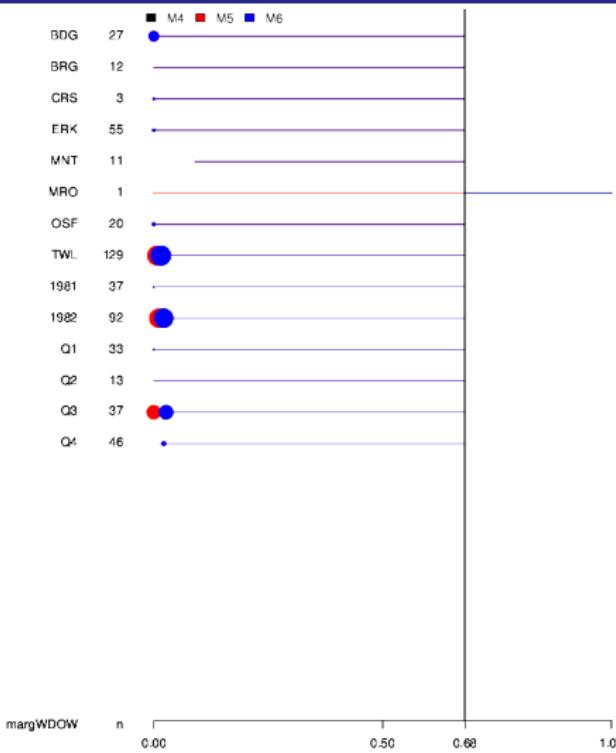
Time Block

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Correlation

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MCAT 269



Landings Sensitivity

**Request:** Compare alternative ComX outputs and the current time series of estimated catches.

**Rationale:** It would be informative to see the landings estimates corresponding to the additional models developed in response to the above requests. The landings estimates can be generated for a small set of illustrative species and do not need to be comprehensive.

**Response:** The following slides show expanded landings (by year and by year:gear) from the early time period, summing across market categories 250, 253, and 269 associated with time model, prior, interaction model, and time block sensitivity runs.

## Introduction

## Time Model

## Prior Model

## Interaction Model

## Time Block

## Correlation

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A 4x6 grid of 24 small circles, arranged in four rows and six columns.

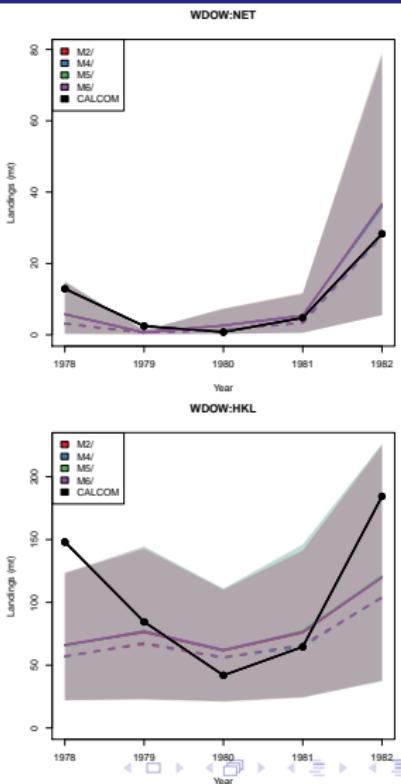
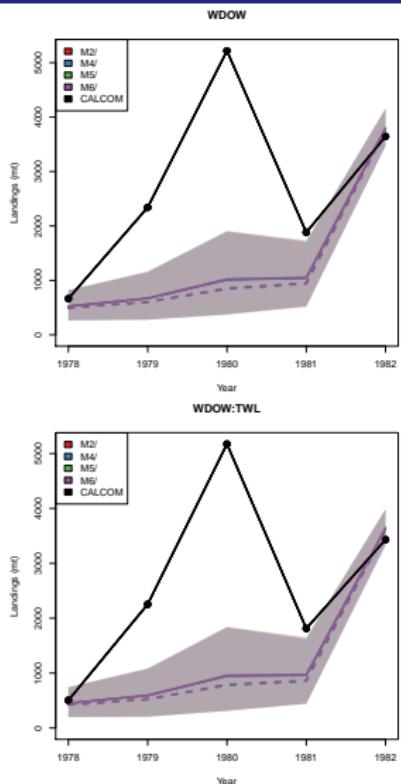
A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x6 grid of 24 small circles, arranged in four rows and six columns.

A 4x6 grid of 24 small circles, arranged in four rows and six columns.

10

Landings Sensitivity



**Nicholas Grunloh In Cooperation With: E.J. Dick, Don Pearson, John Field, Marc Mangel**

## **Improving Catch Estimation Methods in Sparsely Sampled, Mixed Stock Fisheries.**

Introduction

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Time Model

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Prior Model

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Interaction Model

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Time Block

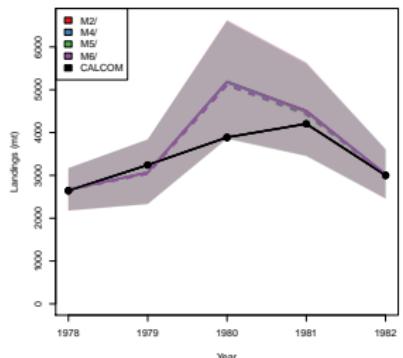
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Correlation

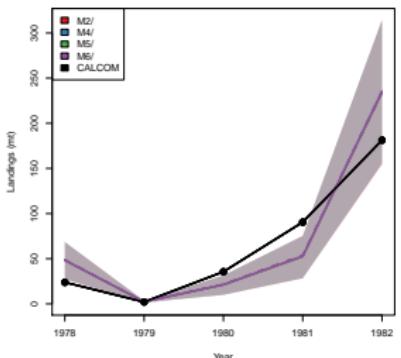
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## Landings Sensitivity

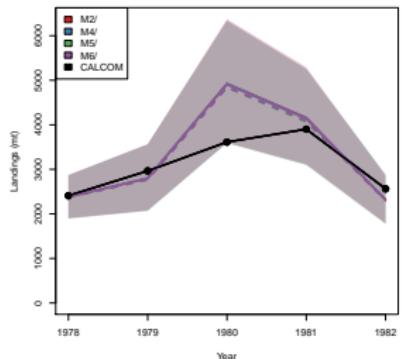
BCAC



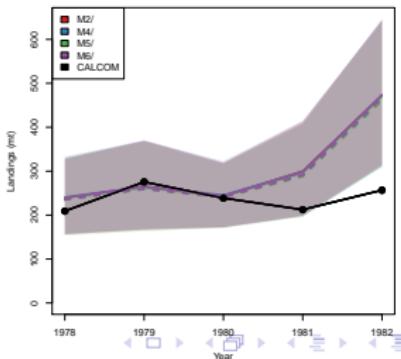
BCAC:NET



BCAC:TWL



BCAC:HKL



Nicholas Grunloh In Cooperation With: E.J. Dick, Don Pearson, John Field, Marc Mangel

Improving Catch Estimation Methods in Sparsely Sampled, Mixed Stock Fisheries.



Introduction

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Time Model

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Prior Model

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Interaction Model

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Time Block

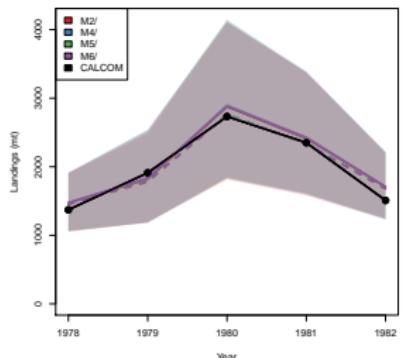
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Correlation

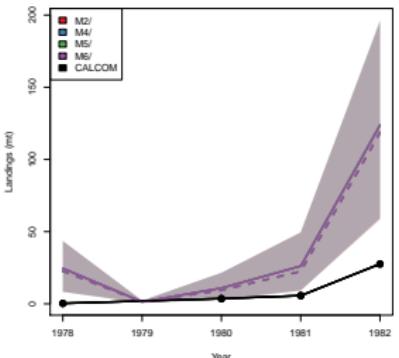
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## Landings Sensitivity

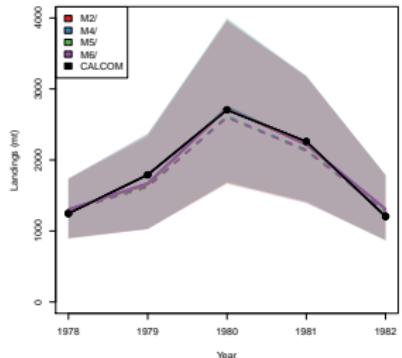
CLPR



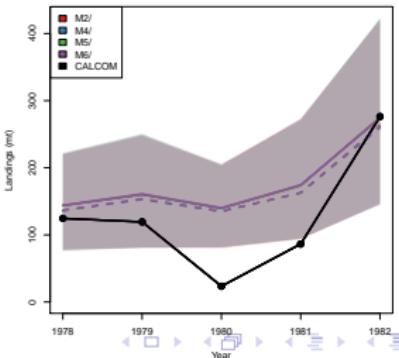
CLPR:NET



CLPR:TWL



CLPR:HKL



Nicholas Grunloh In Cooperation With: E.J. Dick, Don Pearson, John Field, Marc Mangel

Improving Catch Estimation Methods in Sparsely Sampled, Mixed Stock Fisheries.



Introduction

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Time Model

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Interaction Model

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Time Block

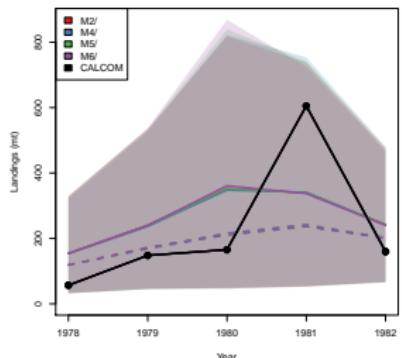
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Correlation

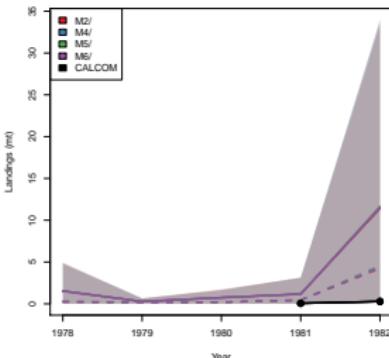
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## Landings Sensitivity

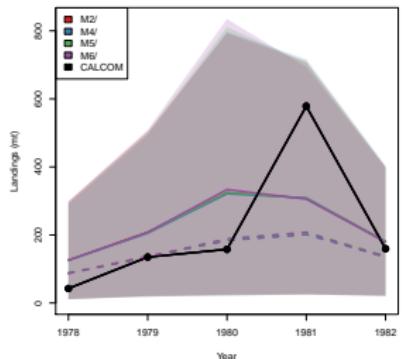
DBRK



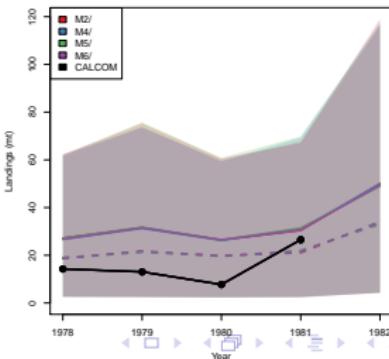
DBRK:NET



DBRK:TWL



DBRK:HKL



Nicholas Grunloh In Cooperation With: E.J. Dick, Don Pearson, John Field, Marc Mangel

Improving Catch Estimation Methods in Sparsely Sampled, Mixed Stock Fisheries.



Introduction

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Time Model

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Prior Model

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Interaction Model

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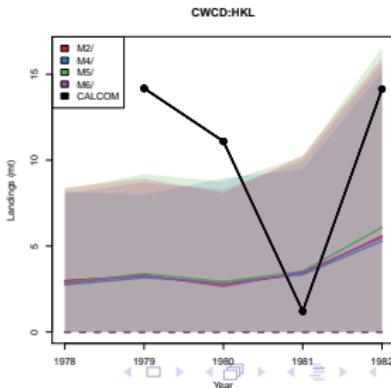
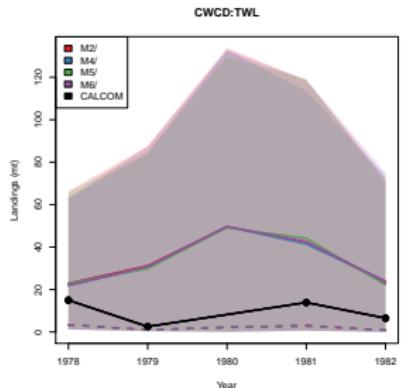
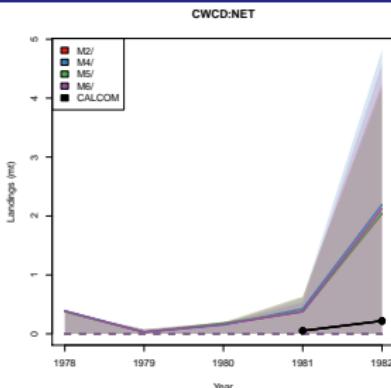
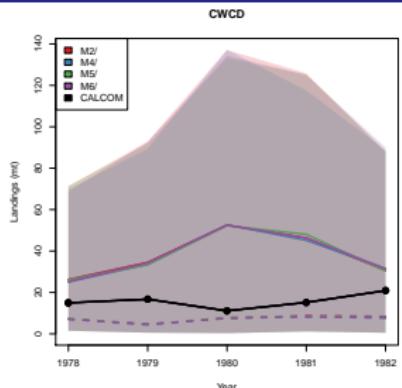
Time Block

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Correlation

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## Landings Sensitivity



Nicholas Grunloh In Cooperation With: E.J. Dick, Don Pearson, John Field, Marc Mangel

Improving Catch Estimation Methods in Sparsely Sampled, Mixed Stock Fisheries.



Introduction

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Time Model

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Prior Model

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Interaction Model

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Time Block

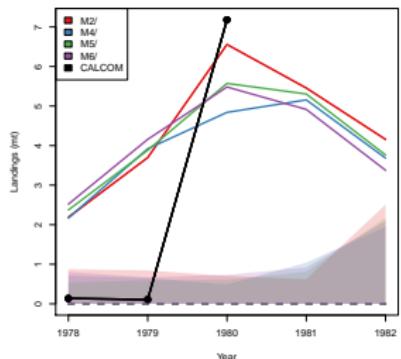
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Correlation

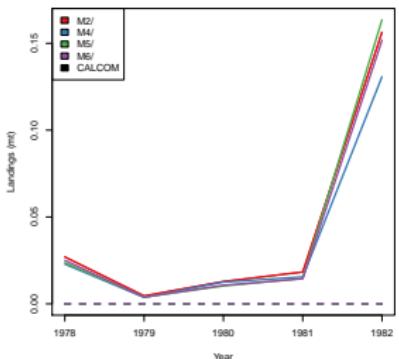
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## Landings Sensitivity

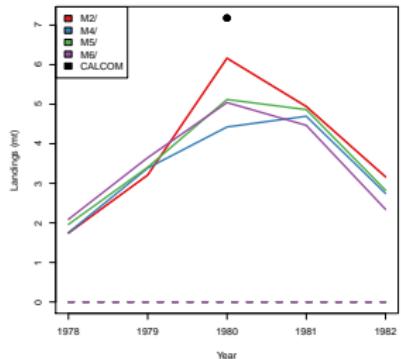
MXRF



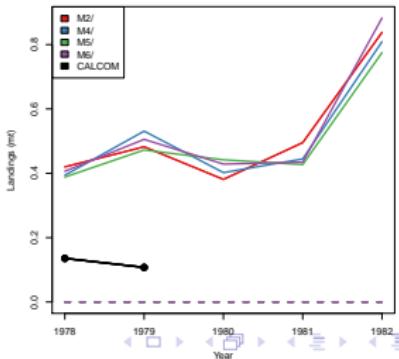
MXRF.NET



MXRF:TWL



MXRF:HKL



Nicholas Grunloh In Cooperation With: E.J. Dick, Don Pearson, John Field, Marc Mangel

Improving Catch Estimation Methods in Sparsely Sampled, Mixed Stock Fisheries.



Landings Sensitivity

## Time Model Summary

- The time model appears to be slightly dependent on market category, although several models perform similarly.
  - M4 generally performs well in a data-poor environment.
  - Differences are small in a data-rich environment.

MCAT 250 Combined Plots

## MCAT 253 Combined Plots

## MCAT 269 Combined Plots

## All Species Landings

## Priors

$$\beta_0 \propto 1$$

$$\beta_i^{(s)} \sim N(0, 32^2)$$

$$\beta_k^{(p)} \sim N(0, 32^2)$$

$$\beta_I^{(g)} \sim N(0, 32^2)$$

$$\text{logit}(\rho) \sim N(0, 2^2)$$

IG :  $v \sim \text{Inv-Gamma}(1, 2 \times 10^3)$   $\forall v$

$$\text{HC1 : } \sqrt{v} \sim \text{Half-Cauchy}(10^1) \quad \forall v$$

$$\text{HC3 : } \sqrt{v} \sim \text{Half-Cauchy}(10^3) \quad \forall v$$

$$U4 : \sqrt{v} \sim \text{Uniform}(0, 10^4) \quad \forall v$$

Introduction

## Time Model

## Prior Model

## Interaction Model

## Time Block

## Correlation

A 4x6 grid of 24 small circles, arranged in four rows and six columns.

A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x6 grid of 24 small circles, arranged in four rows and six columns.

A 4x3 grid of 12 small circles, arranged in four rows and three columns.

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MCAT 250

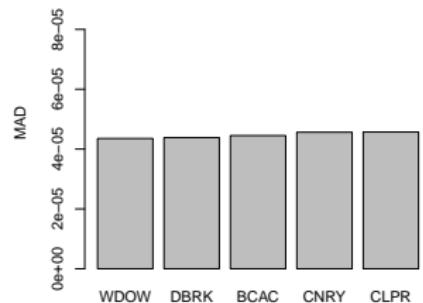
	M4IG	M4HC1	M4HC3	M4U4
$\Delta$ DIC	3.87	0.02	0.1	0
$\Delta$ WAIC	3.78	0.03	0.11	0

M4HC1

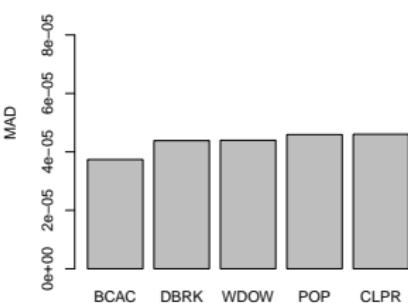
M4HC3

M4U4

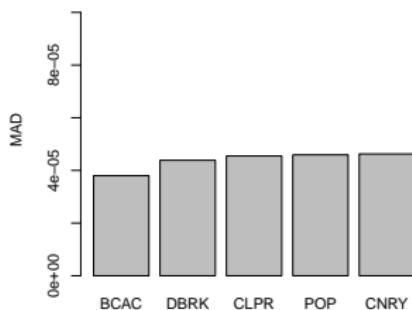
### MAD Ordered by Species



### MAD Ordered by Species



#### MAD Ordered by Species



## Combined

Introduction

## Time Model

## Prior Model

## Interaction Model

## Time Block

## Correlation

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A 4x6 grid of 24 small circles, arranged in four rows and six columns.

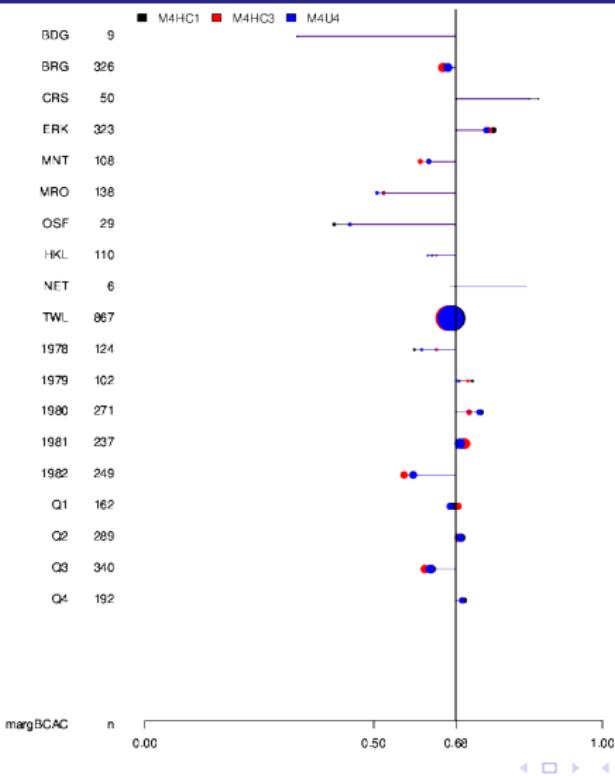
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A 4x6 grid of 24 small circles, arranged in four rows and six columns.

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MCAT 250



Introduction

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Time Model

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Prior Model

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Interaction Model

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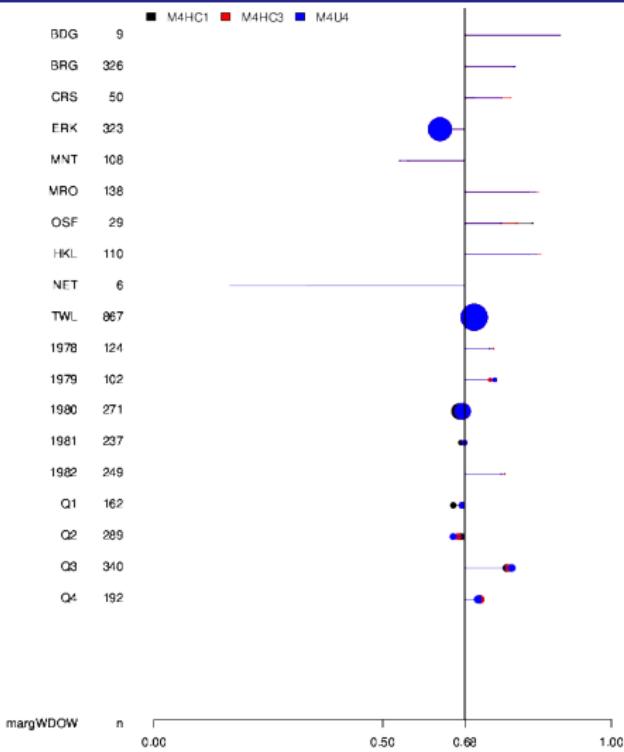
Time Block

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Correlation

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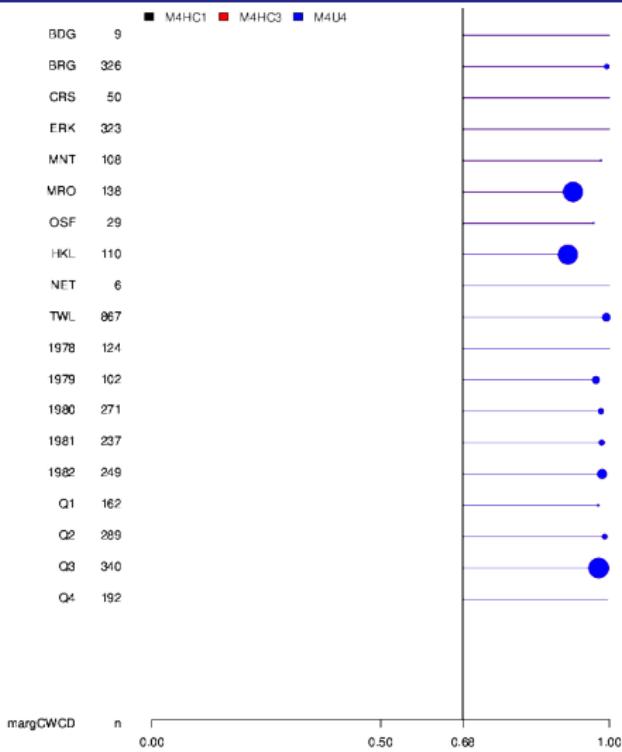
## MCAT 250







## MCAT 250



Introduction

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Time Model

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Prior Model

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Interaction Model

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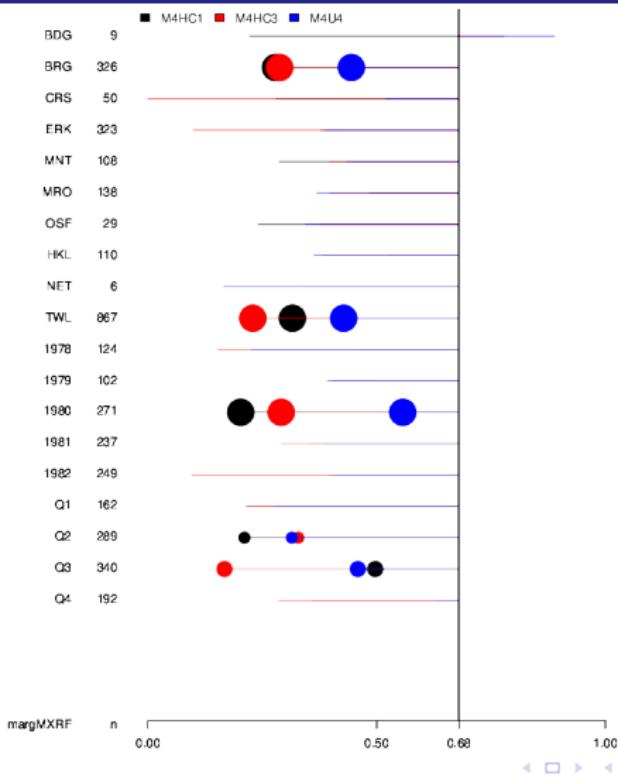
Time Block

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Correlation

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## MCAT 250



## Introduction

## Time Model

## Prior Model

## Interaction Model

## Time Block

## Correlation

A 4x6 grid of 24 small circles, arranged in four rows and six columns.

A 4x6 grid of 24 small circles, arranged in four rows and six columns.

A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x6 grid of 24 small circles, arranged in four rows and six columns.

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MCAT 253

	M4IG	M4HC1	M4HC3	M4U4
$\Delta$ DIC	0.88	0.8	0.8	0
$\Delta$ WAIC	0.76	0.83	0.83	0

Introduction

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Time Model

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Prior Model

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Interaction Model

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Time Block

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Correlation

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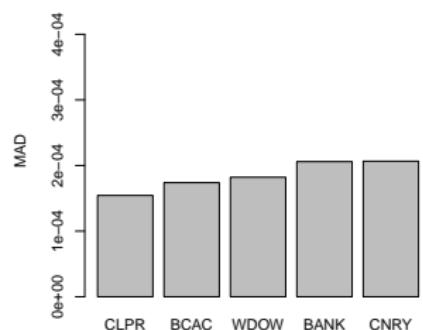
MCAT 253

M4HC1

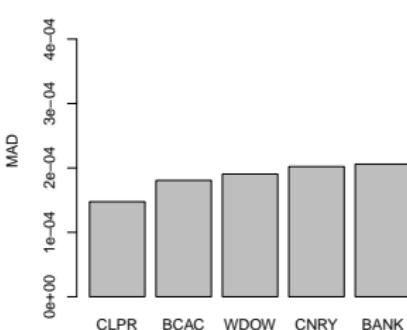
M4HC3

M4U4

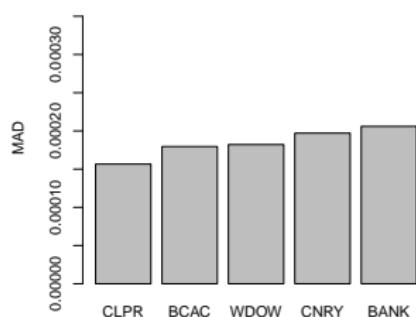
MAD Ordered by Species



MAD Ordered by Species



MAD Ordered by Species



Combined

Introduction

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Time Model

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Prior Model

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Interaction Model

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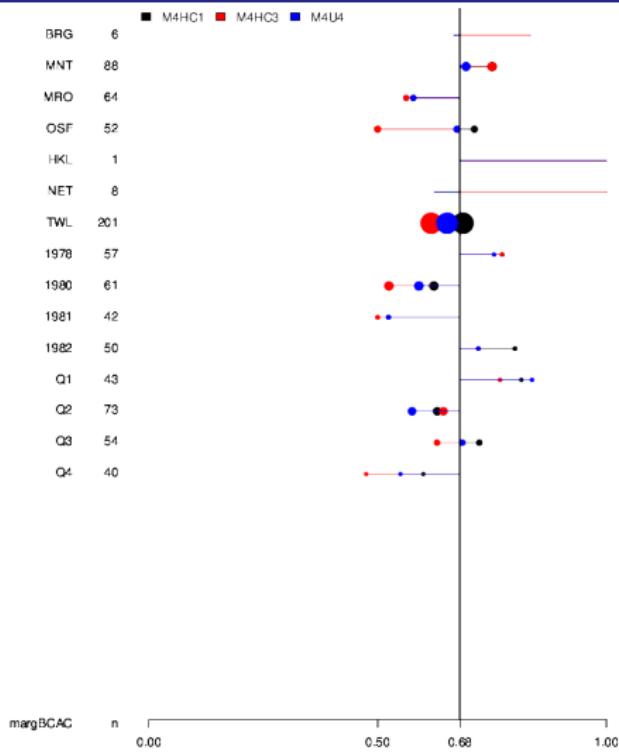
Time Block

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Correlation

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## MCAT 253



Introduction

## Time Model

## Prior Model

## Interaction Model

### Time Block

## Correlation

A 4x5 grid of 20 small circles, arranged in four rows and five columns.

A 4x3 grid of 12 small circles, arranged in four rows and three columns.

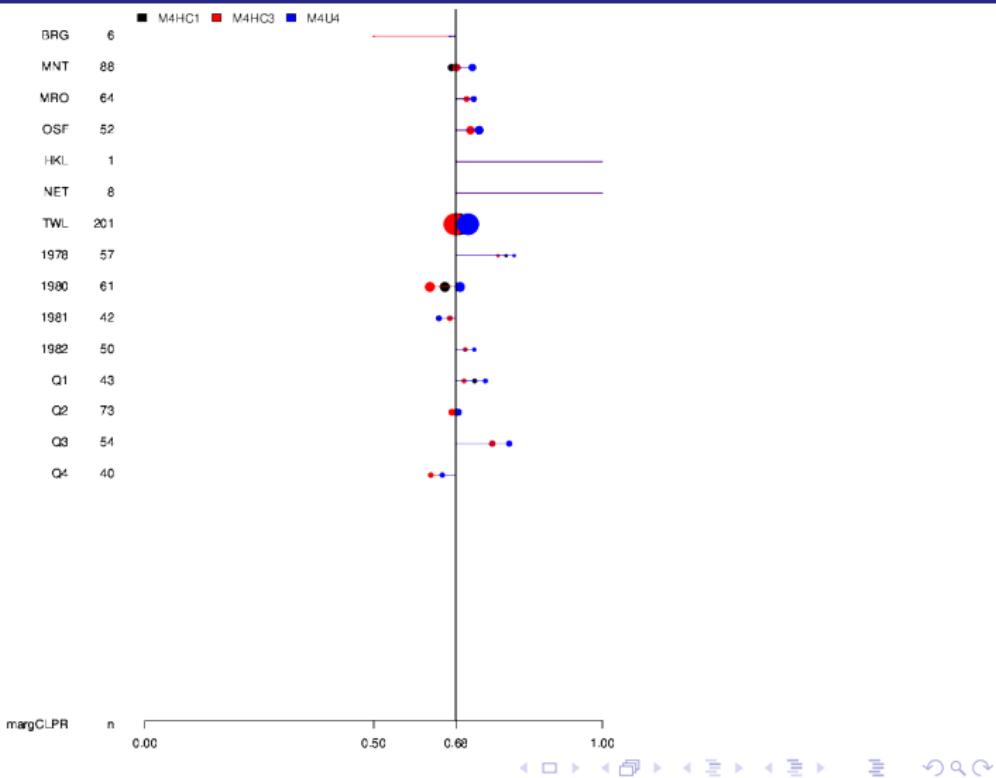
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A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x3 grid of 12 small circles, arranged in four rows and three columns.

6

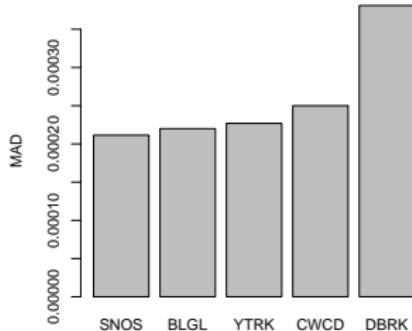
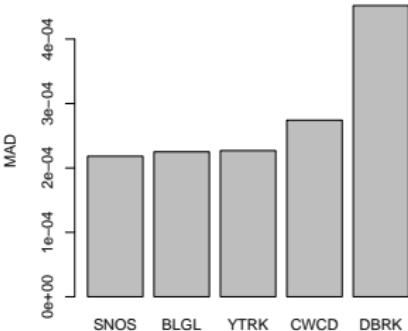
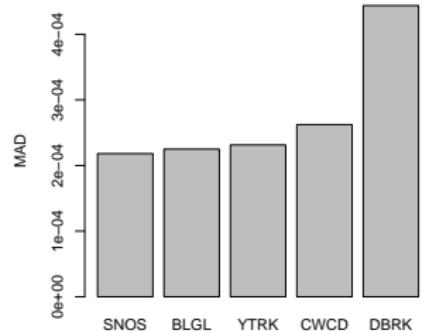
MCAT 253



M4HC1

M4HC3

M4U4



## Combined

Introduction

## Time Model

## Prior Model

## Interaction Model

## Time Block

## Correlation

A 4x5 grid of 20 small circles, arranged in four rows and five columns.

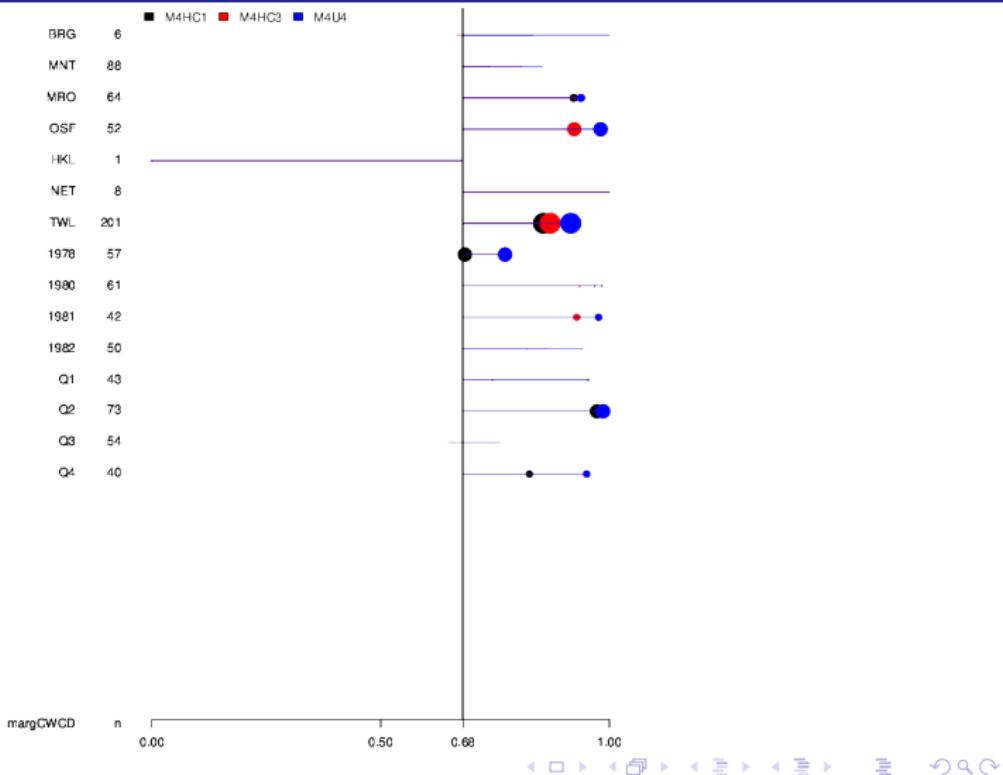
A 4x3 grid of 12 small circles, arranged in four rows and three columns.

A 4x6 grid of 24 small circles, arranged in four rows and six columns.

A 4x3 grid of 12 small circles, arranged in four rows and three columns.

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MCAT 253



Introduction

## Time Model

## Prior Model

## Interaction Model

## Time Block

## Correlation

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A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

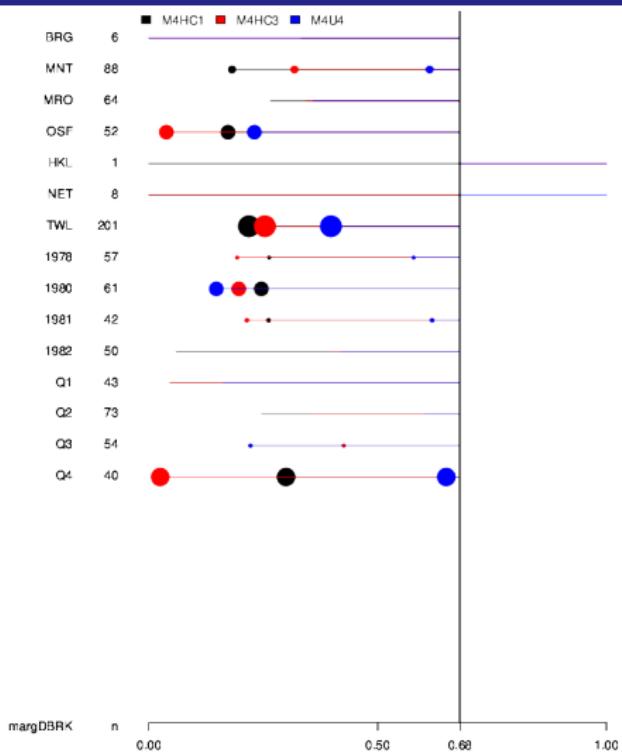
1

A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x6 grid of 24 small circles, arranged in four rows and six columns.

10

MCAT 253



## Introduction

## Time Model

## Prior Model

## Interaction Model

## Time Block

### Correlation

A 4x5 grid of 20 small circles, arranged in four rows and five columns.

A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x3 grid of 12 small circles, arranged in four rows and three columns.

6

MCAT 269

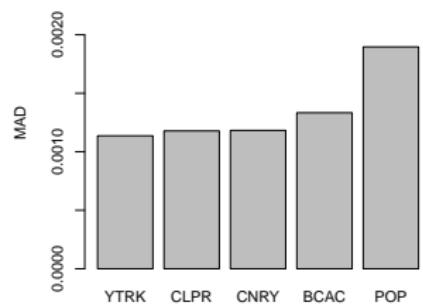
	M4IG	M4HC1	M4HC3	M4U4
$\Delta$ DIC	0.18	176.33	0.2	0
$\Delta$ WAIC	0.08	69.19	0.08	0

M4HC1

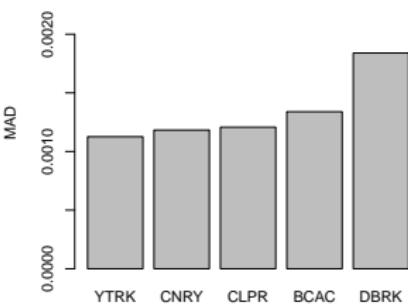
M4HC3

M4U4

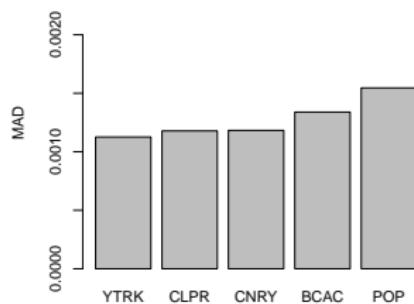
#### MAD Ordered by Species



### MAD Ordered by Species



### MAD Ordered by Species



## Combined

Introduction

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Time Model

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Prior Model

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Interaction Model

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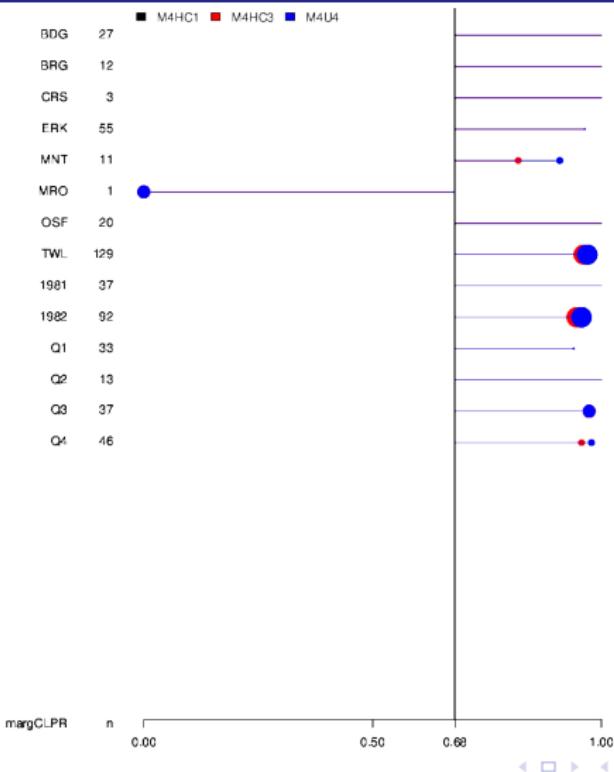
Time Block

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Correlation

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MCAT 269



Introduction

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Time Model

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Prior Model

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Interaction Model

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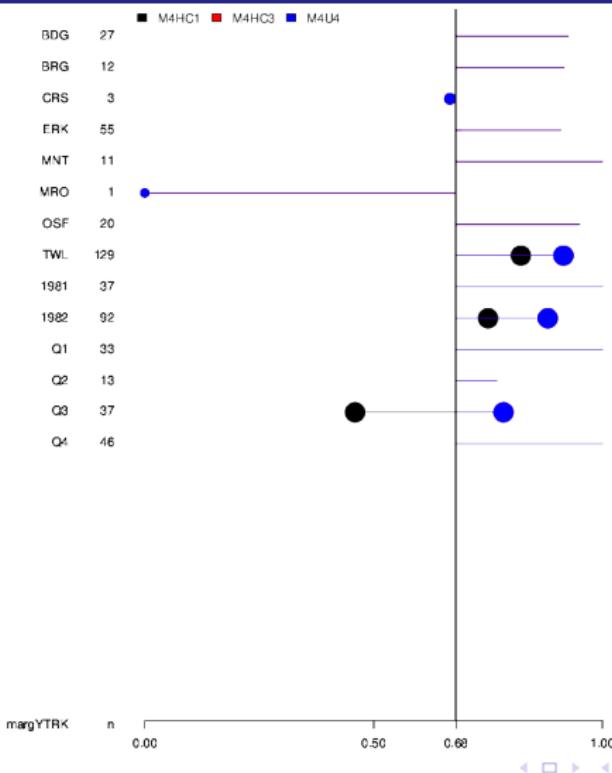
Time Block

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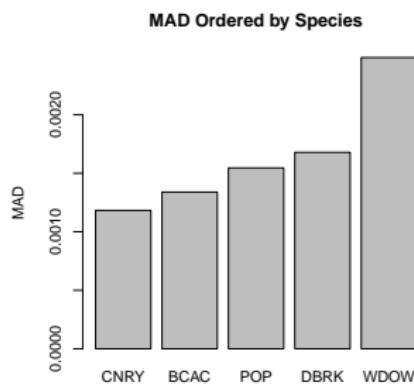
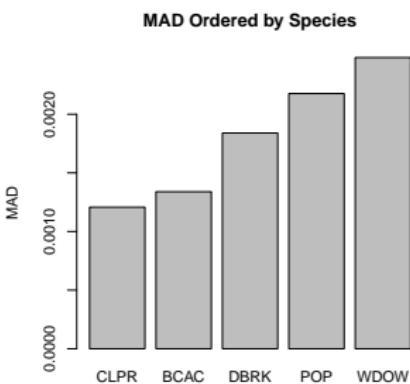
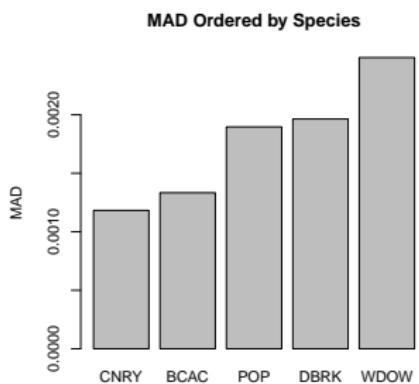
## MCAT 269



M4HC1

M4HC3

M4U4



## Combined

Introduction

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Time Model

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Prior Model

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Interaction Model

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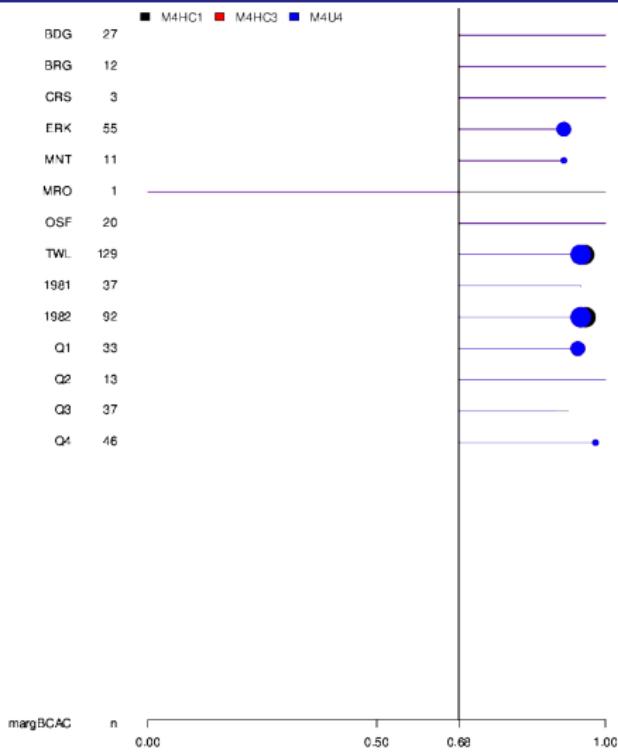
Time Block

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## MCAT 269



Introduction

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Prior Model

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Interaction Model

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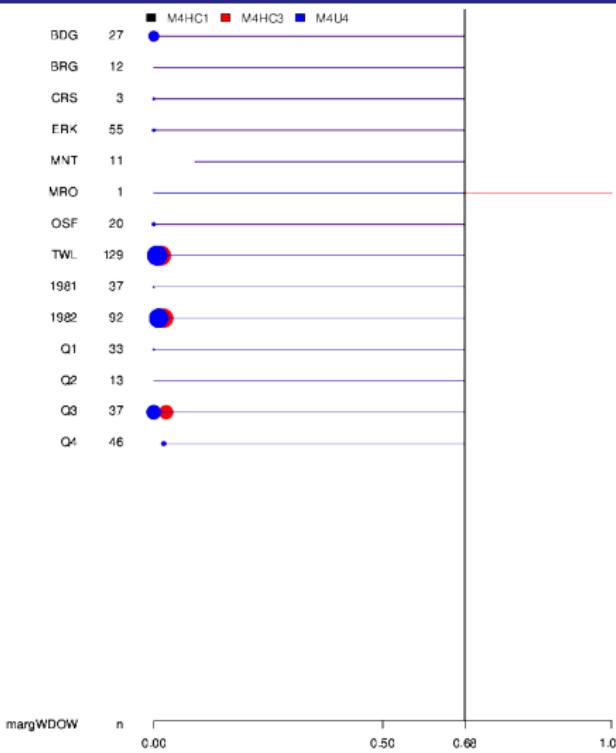
Time Block

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Correlation

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MCAT 269



## Introduction

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## Time Model

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## Prior Model

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## Interaction Model

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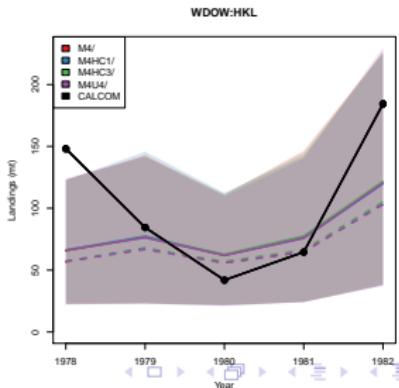
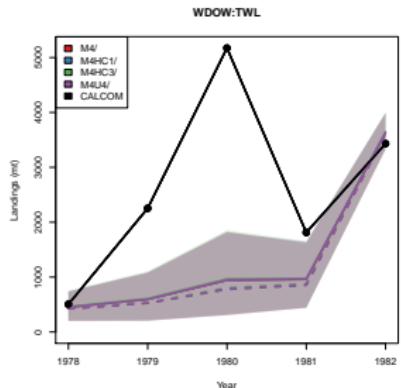
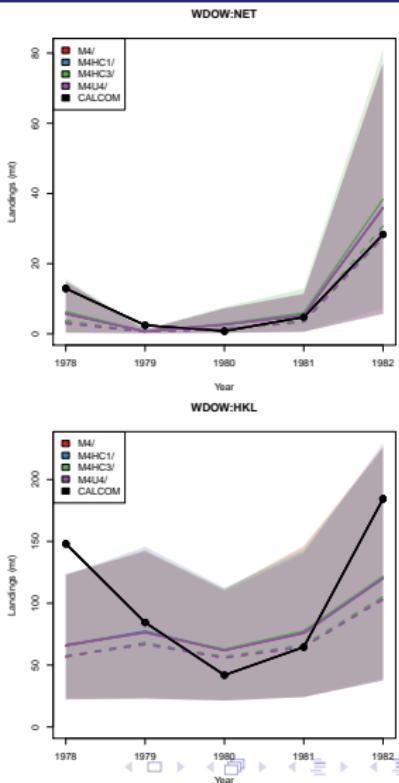
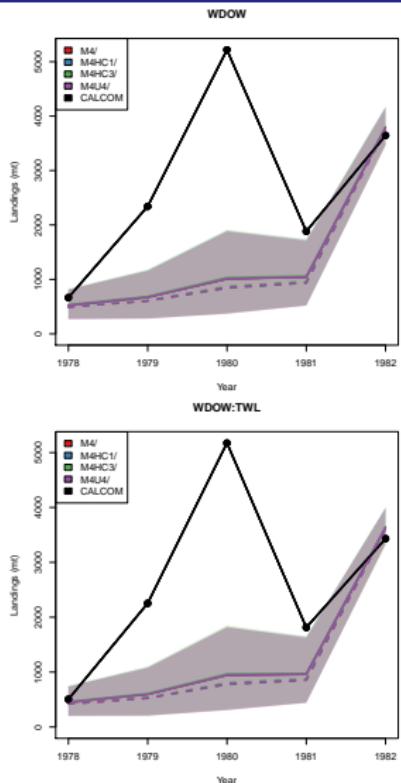
## Time Block

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## Correlation

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## Landings Sensitivity



Nicholas Grunloh In Cooperation With: E.J. Dick, Don Pearson, John Field, Marc Mangel

Improving Catch Estimation Methods in Sparsely Sampled, Mixed Stock Fisheries.



Introduction

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Time Model

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Prior Model

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Interaction Model

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Time Block

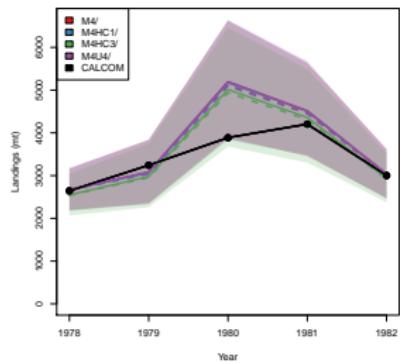
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Correlation

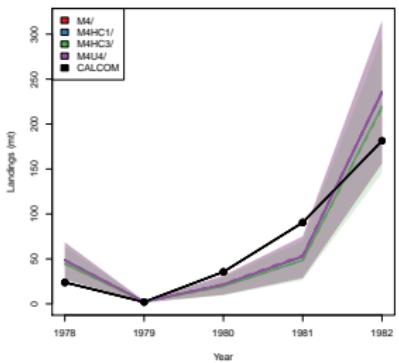
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## Landings Sensitivity

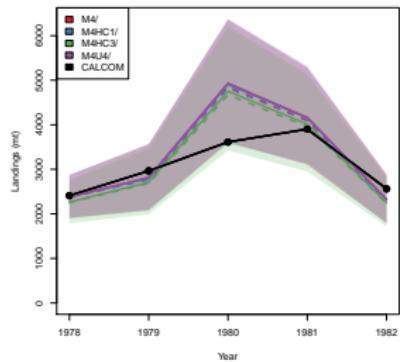
BCAC



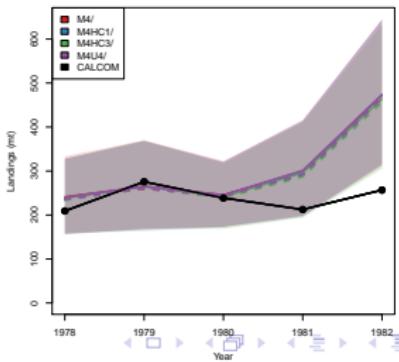
BCAC:NET



BCAC:TWL



BCAC:HKL



Nicholas Grunloh In Cooperation With: E.J. Dick, Don Pearson, John Field, Marc Mangel

Improving Catch Estimation Methods in Sparsely Sampled, Mixed Stock Fisheries.



Introduction

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Time Model

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Prior Model

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Interaction Model

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Time Block

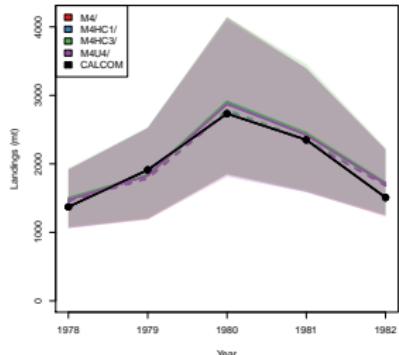
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Correlation

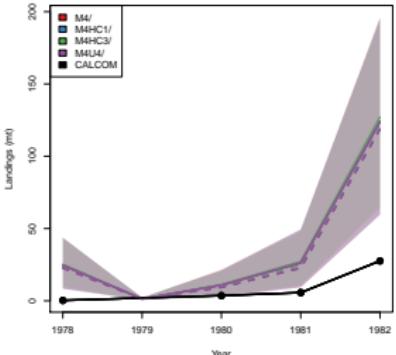
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## Landings Sensitivity

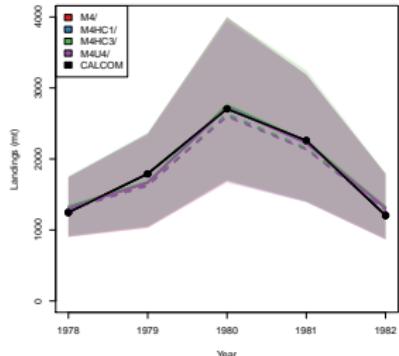
CLPR



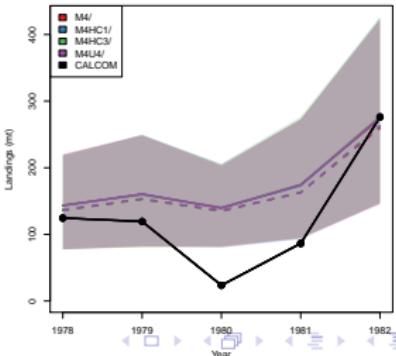
CLPR:NET



CLPR:TWL



CLPR:HKL



Nicholas Grunloh In Cooperation With: E.J. Dick, Don Pearson, John Field, Marc Mangel

Improving Catch Estimation Methods in Sparsely Sampled, Mixed Stock Fisheries.



## Introduction

## Time Model

## Prior Model

## Interaction Model

### Time Block

## Correlation

A 4x5 grid of 20 small circles, arranged in four rows and five columns.

A 4x6 grid of 24 small circles, arranged in four rows and six columns.

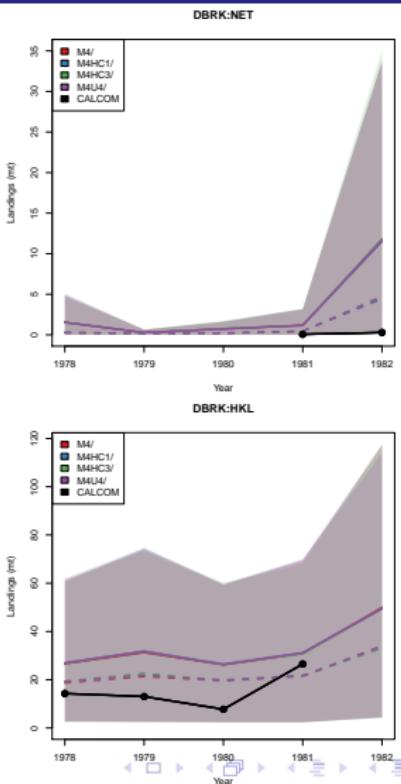
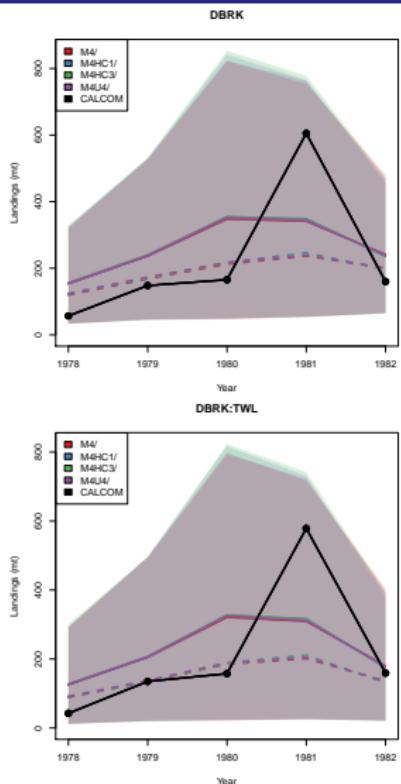
A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x5 grid of 20 open circles, arranged in four rows and five columns.

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Landings Sensitivity



**Nicholas Grunloh In Cooperation With: E.J. Dick, Don Pearson, John Field, Marc Mangel**

## **Improving Catch Estimation Methods in Sparsely Sampled, Mixed Stock Fisheries.**

Introduction

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Time Model

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Prior Model

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Interaction Model

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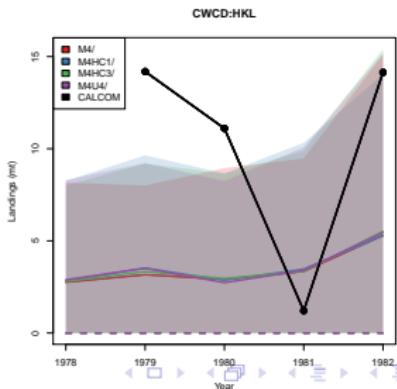
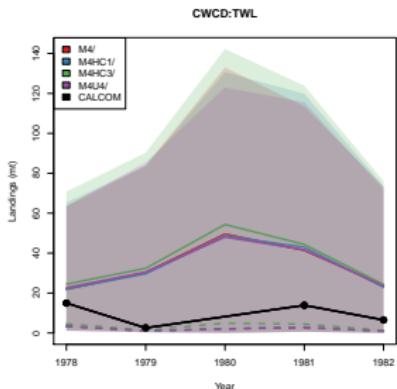
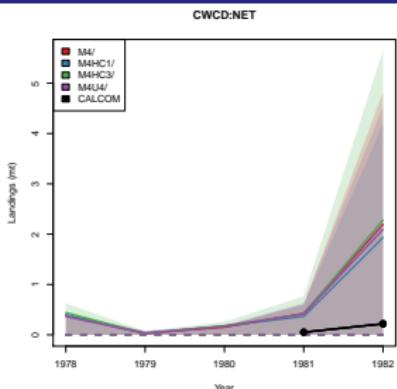
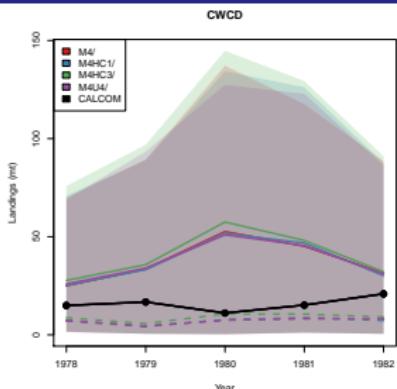
Time Block

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Correlation

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## Landings Sensitivity



Nicholas Grunloh In Cooperation With: E.J. Dick, Don Pearson, John Field, Marc Mangel

Improving Catch Estimation Methods in Sparsely Sampled, Mixed Stock Fisheries.



Introduction

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Time Model

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Prior Model

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Interaction Model

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Time Block

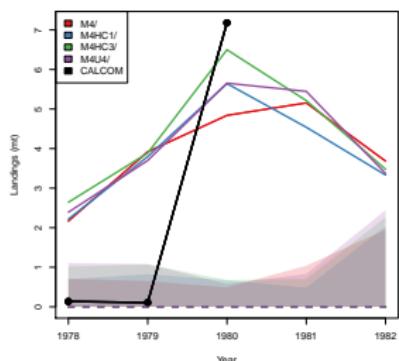
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Correlation

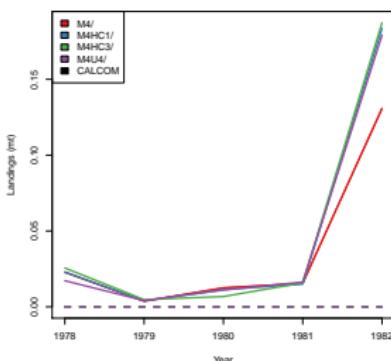
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## Landings Sensitivity

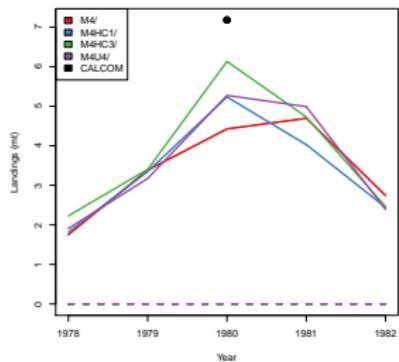
MXRF



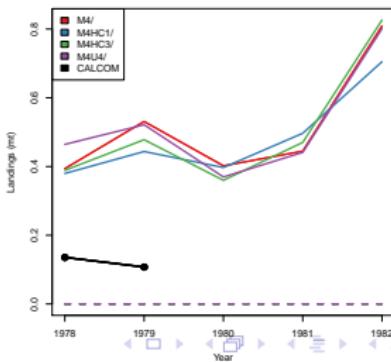
MXRF.NET



MXRF:TWL



MXRF:HKL



Nicholas Grunloh In Cooperation With: E.J. Dick, Don Pearson, John Field, Marc Mangel

Improving Catch Estimation Methods in Sparsely Sampled, Mixed Stock Fisheries.



Landings Sensitivity

## Prior Summary

- In a data-rich setting, the prior has little influence on performance.
  - In a data-poor setting, the U4 prior often performs well.
  - Despite better performance, the U4 prior is less stable in a data-poor setting.

MCAT 250 Combined Plots

## MCAT 253 Combined Plots

## MCAT 269 Combined Plots

## All Species Landings

**Request:** Explore various two-way interactions (beyond the current explorations; e.g., Species : Port and Species : Gear).

**Rationale:** The Team did not have time to search across the multitude of possible interaction terms that they could have included in the model. From various anecdotal comments made during the review it seemed likely that the model would benefit from the inclusion of other interaction terms. Explorations with the diagnostic template may suggest potentially beneficial terms.

**Response:** The following slides show the diagnostic plots as applied to models exploring the inclusion of species:port and species:gear interaction terms.

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Time Model

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Prior Model

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Interaction Model

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Time Block

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Correlation

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MCAT 250

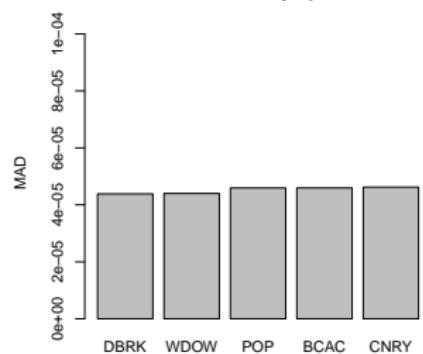
	M4	M4SG	M4SP
$\Delta$ DIC	58229.78	21403.07	0
$\Delta$ WAIC	24203.2	10186.57	0

M4

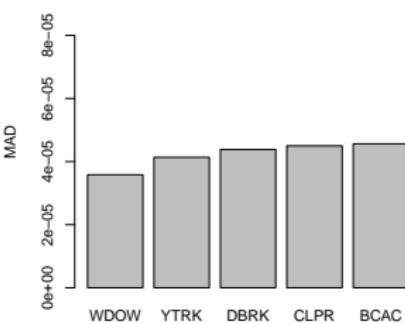
M4SG

M4SP

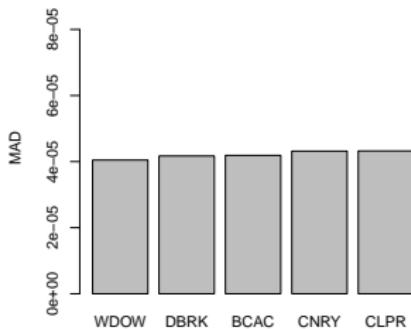
### MAD Ordered by Species



### MAD Ordered by Species



### MAD Ordered by Species



## Combined

Introduction

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Time Model

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Prior Model

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Interaction Model

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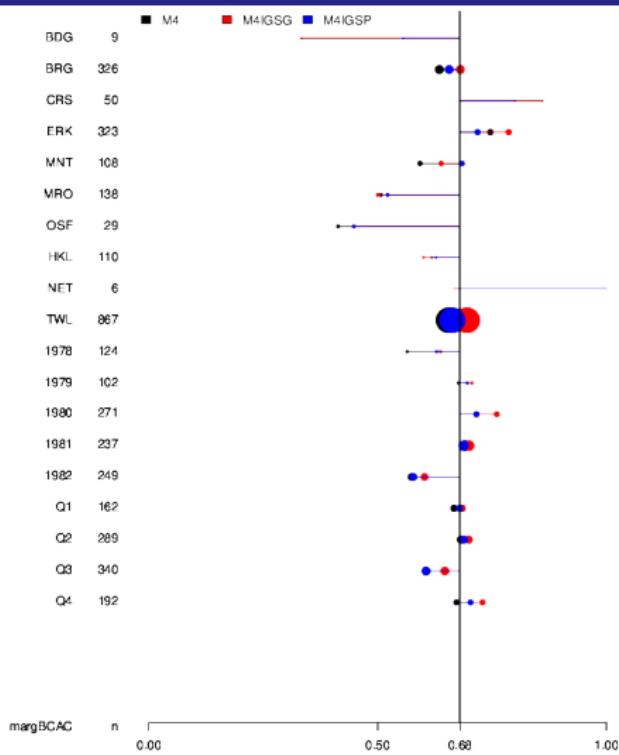
Time Block

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Correlation

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## MCAT 250



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Time Model

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Prior Model

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Interaction Model

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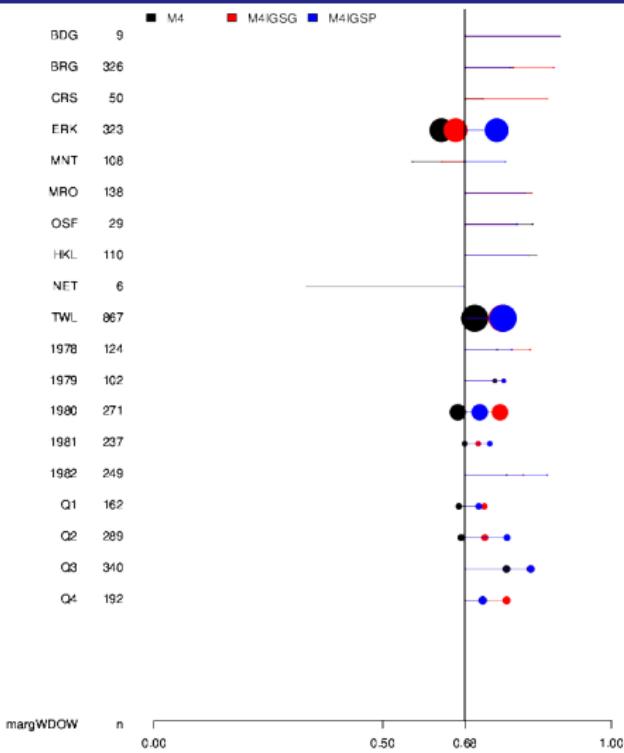
Time Block

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Correlation

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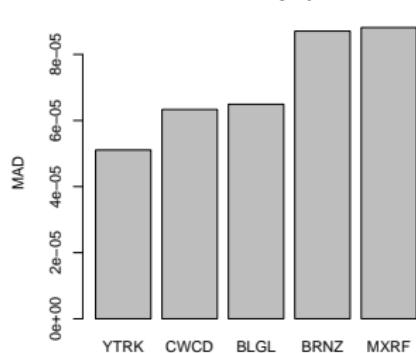
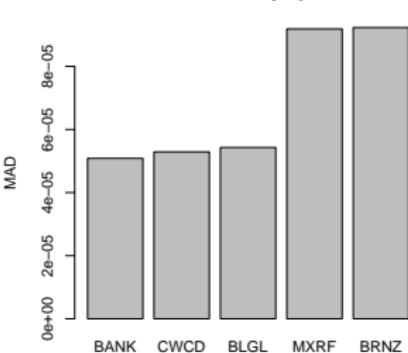
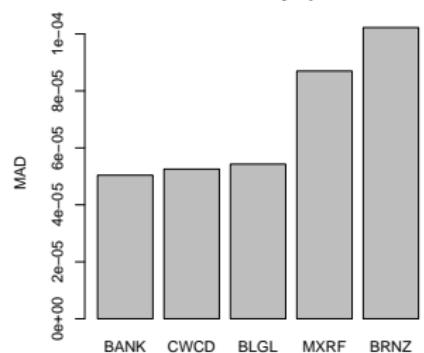
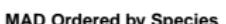
## MCAT 250



M4

M4SG

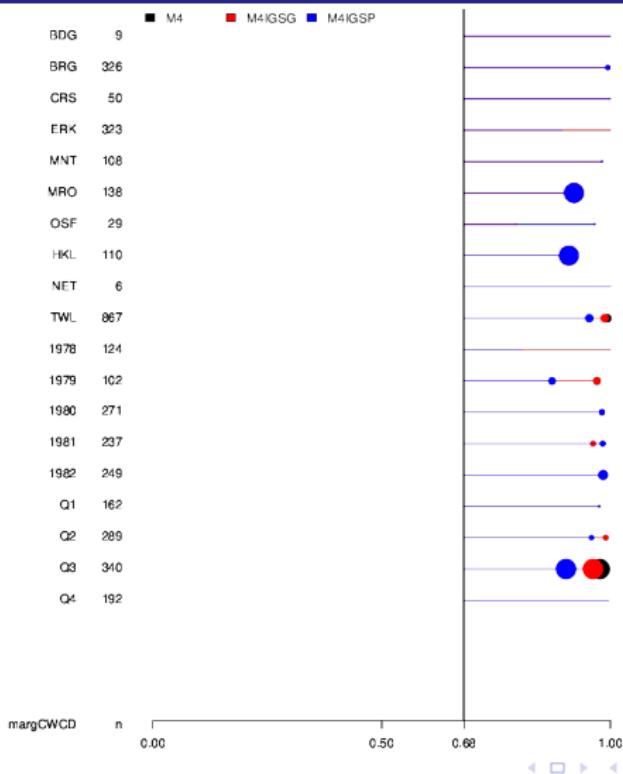
M4SP



# Combined



MCAT 250



Introduction

## Time Model

## Prior Model

## Interaction Model

### Time Block

## Correlation

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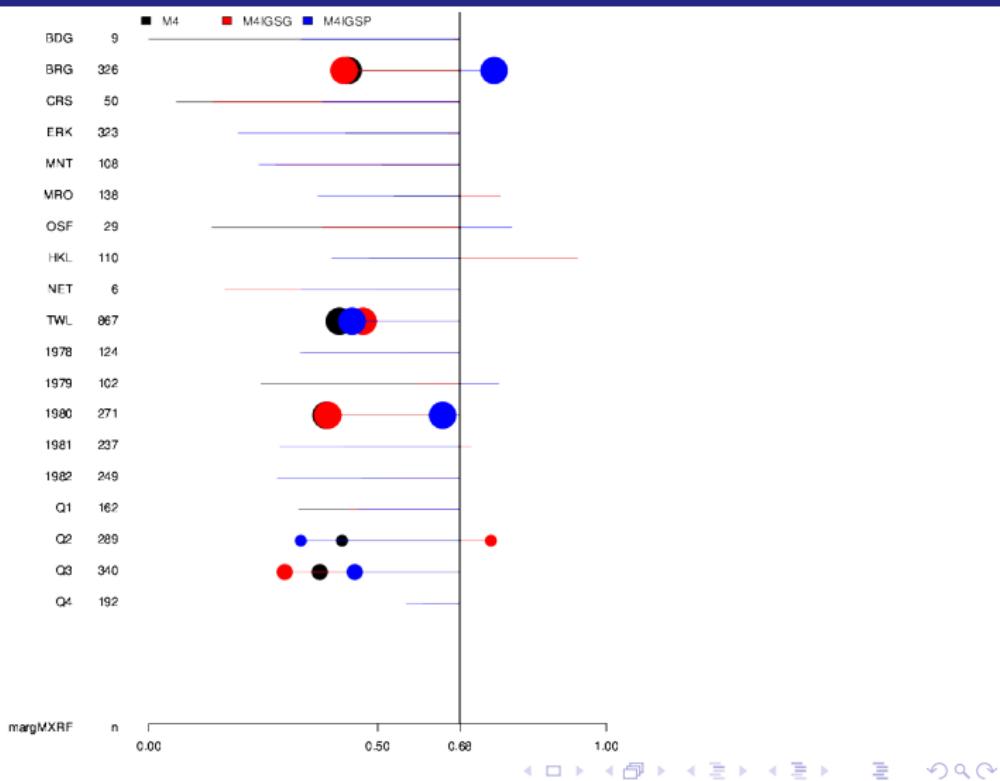
A 4x6 grid of 24 small circles, arranged in four rows and six columns.

A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x6 grid of 24 small circles, arranged in four rows and six columns.

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MCAT 250



Introduction

## Time Model

## Prior Model

## Interaction Model

### Time Block

## Correlation

A 4x6 grid of 24 small circles, arranged in four rows and six columns.

A 4x6 grid of 24 small circles, arranged in four rows and six columns.

A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

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MCAT 253

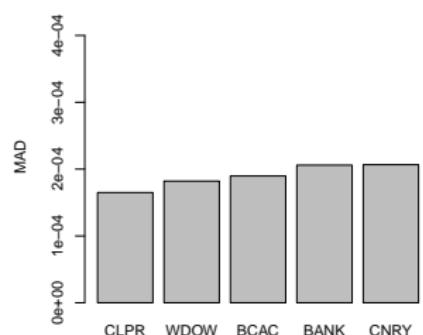
	M4	M4SG	M4SP
$\Delta$ DIC	403.42	308.65	0
$\Delta$ WAIC	872.35	778.17	0

M4

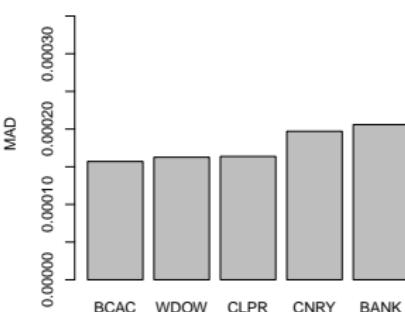
M4SG

M4SP

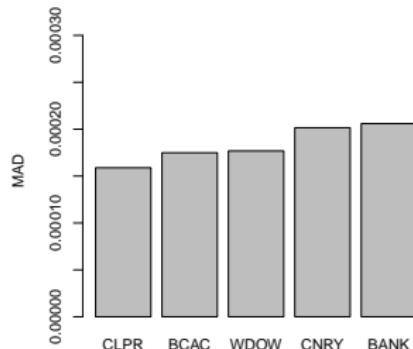
### MAD Ordered by Species



### MAD Ordered by Species



#### MAD Ordered by Species



## Combined

Introduction

## Time Model

## Prior Model

## Interaction Model

## Time Block

## Correlation

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A 4x6 grid of 24 small circles, arranged in four rows and six columns.

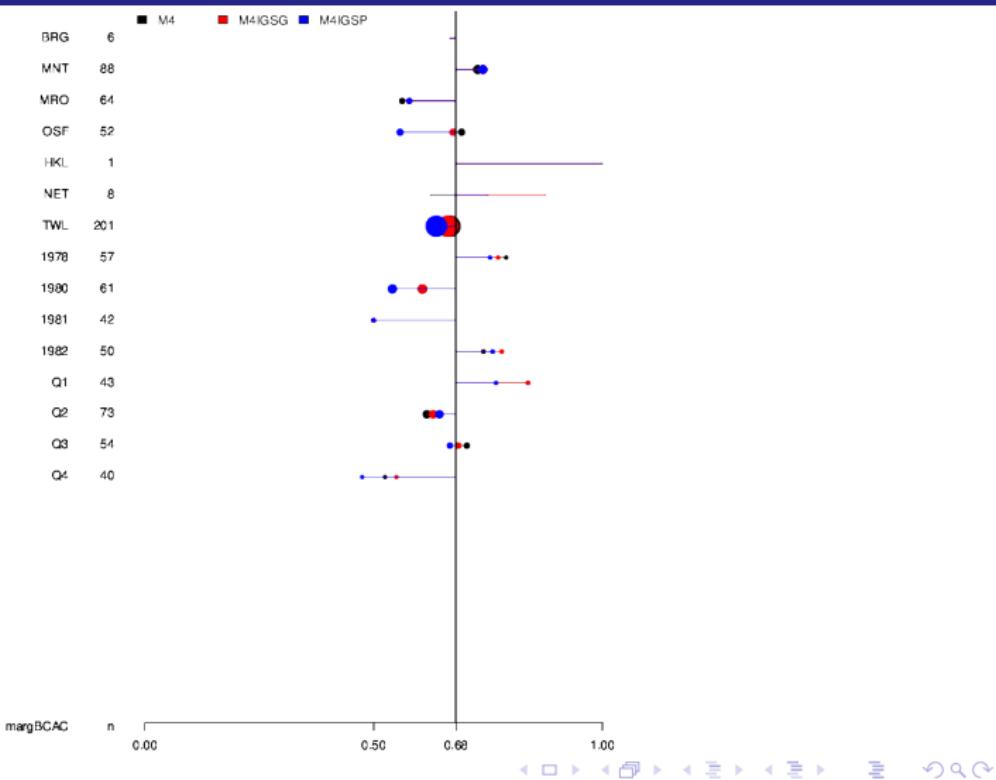
A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

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A 4x6 grid of 24 small circles, arranged in four rows and six columns.

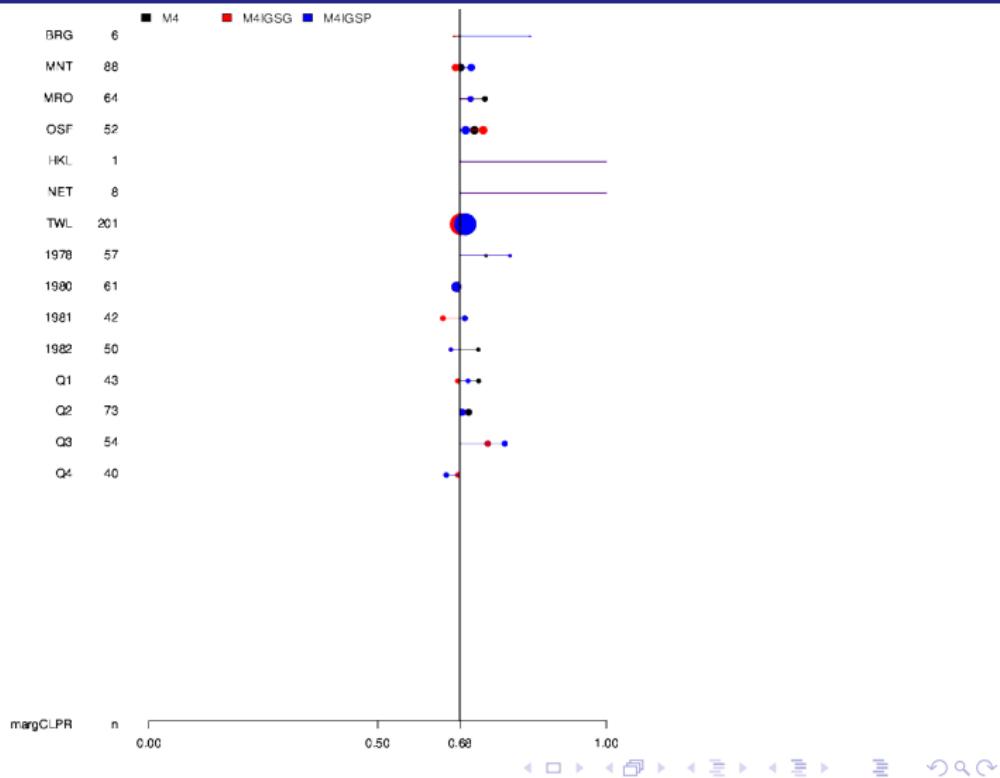
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MCAT 253





MCAT 253

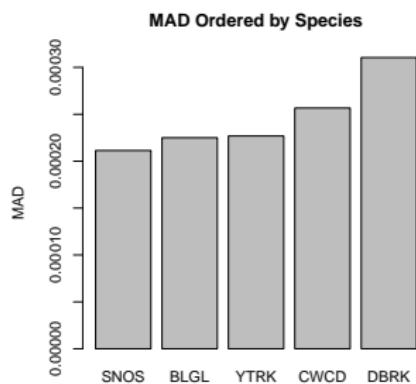
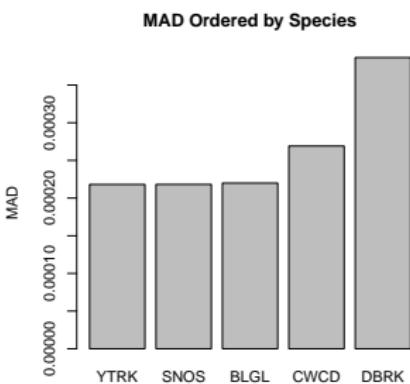
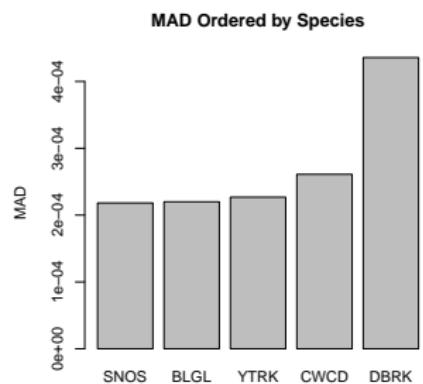


MCAT 253

M4

M4SG

M4SP



## Combined

## Introduction

## Time Model

## Prior Model

## Interaction Model

## Time Block

## Correlation

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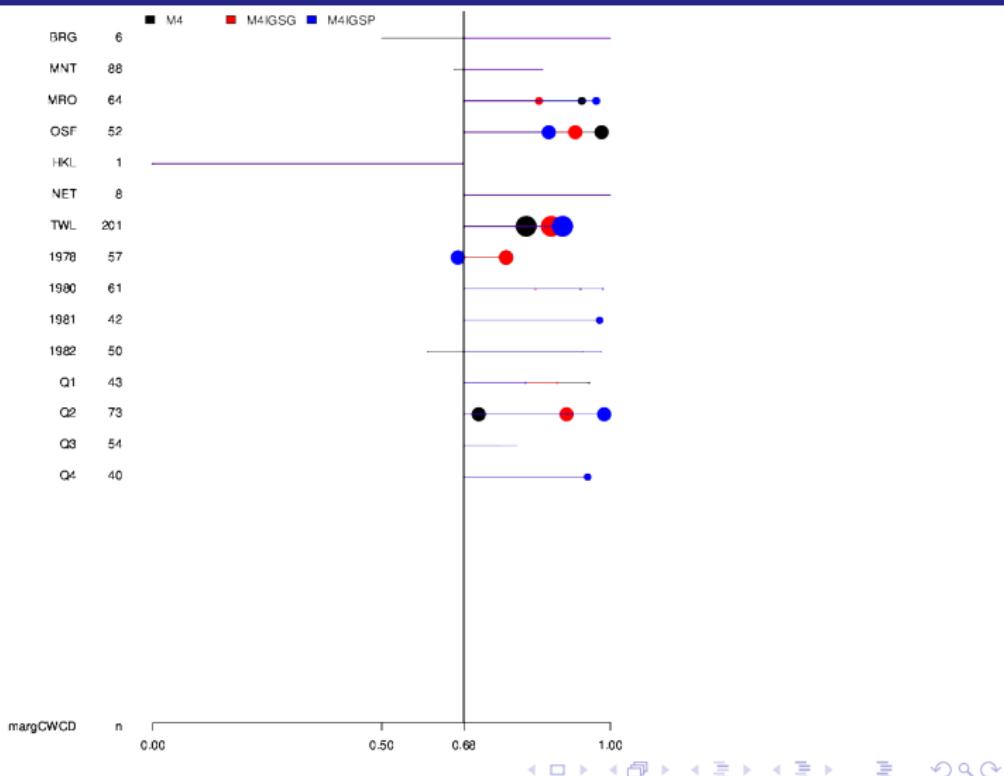
A 4x6 grid of 24 small circles, arranged in four rows and six columns.

A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x6 grid of 24 small circles, arranged in four rows and six columns.

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MCAT 253



Introduction

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Time Model

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Prior Model

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Interaction Model

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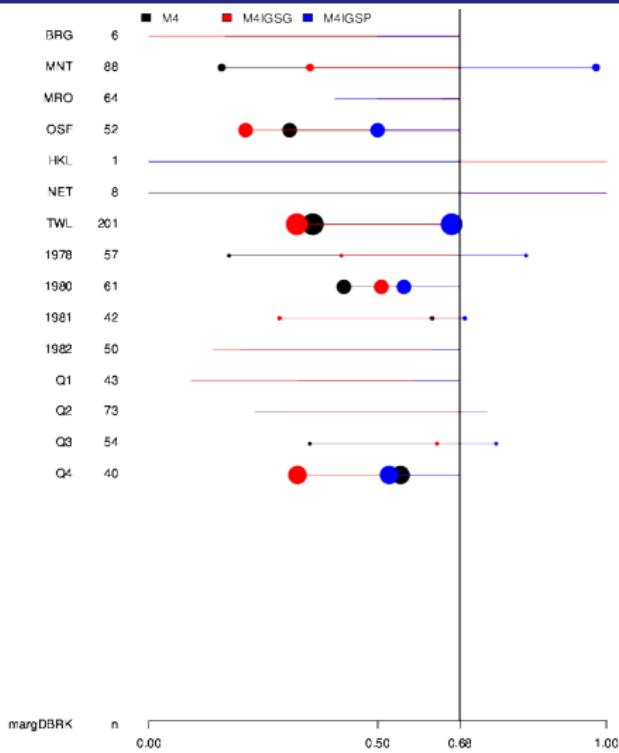
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Correlation

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## MCAT 253



Introduction

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Time Model

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Prior Model

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Interaction Model

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Time Block

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Correlation

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MCAT 269

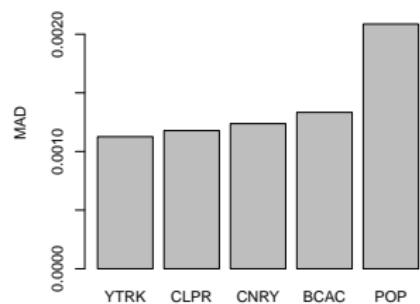
	M4	M4SG	M4SP
$\Delta$ DIC	0	0.31	182.15
$\Delta$ WAIC	0	0.13	68.48

M4

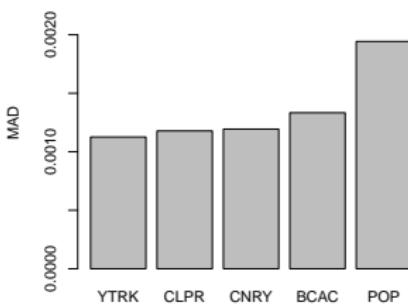
M4SG

M4SP

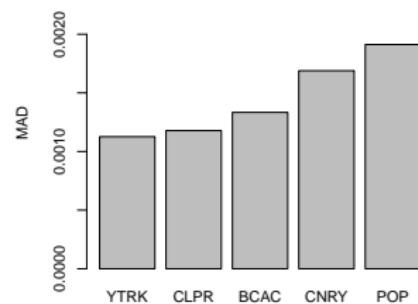
### MAD Ordered by Species



### MAD Ordered by Species



### MAD Ordered by Species



## Combined

Introduction

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Time Model

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Prior Model

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Interaction Model

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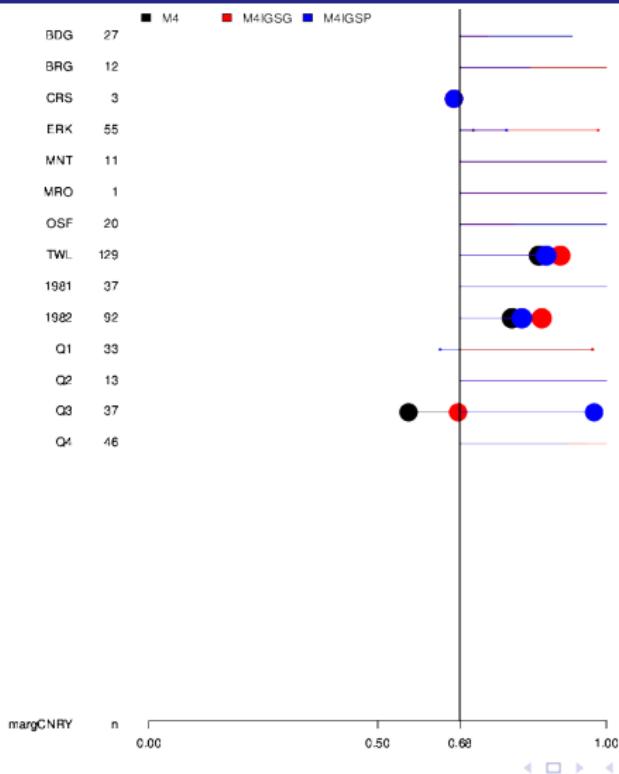
Time Block

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Correlation

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MCAT 269



Introduction

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Time Model

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Prior Model

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Interaction Model

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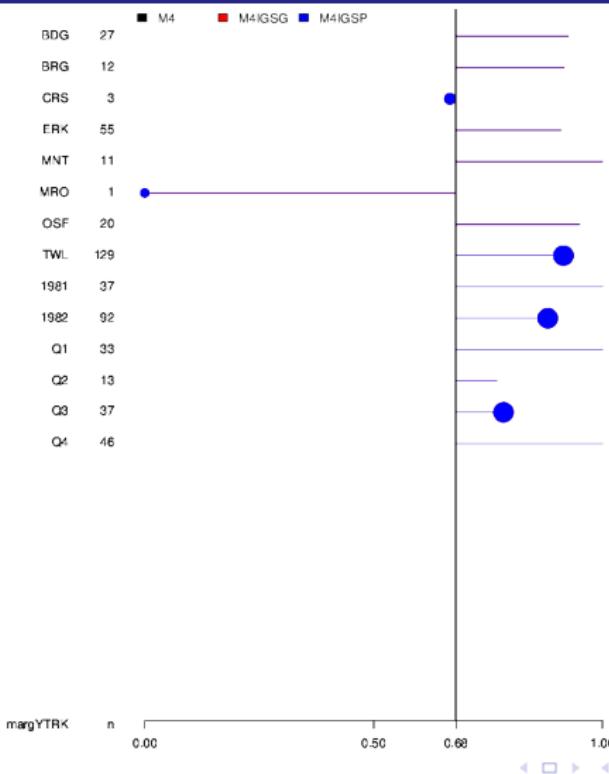
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Correlation

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## MCAT 269

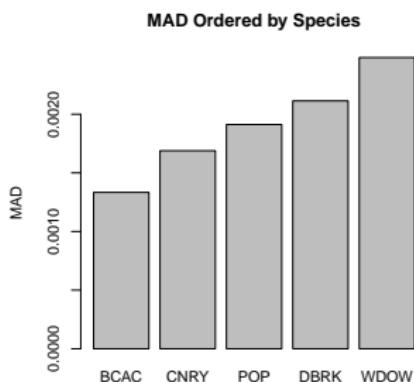
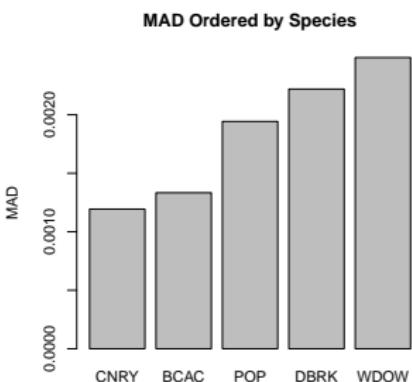
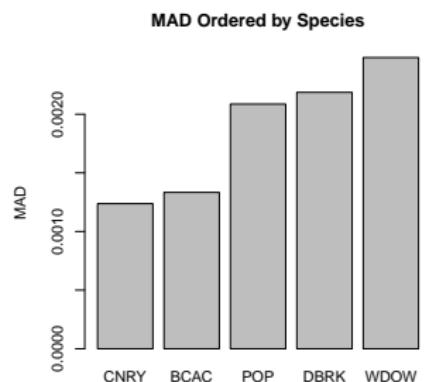


MCAT 269

M4

M4SG

M4SP



## Combined

Introduction

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Time Model

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Prior Model

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Interaction Model

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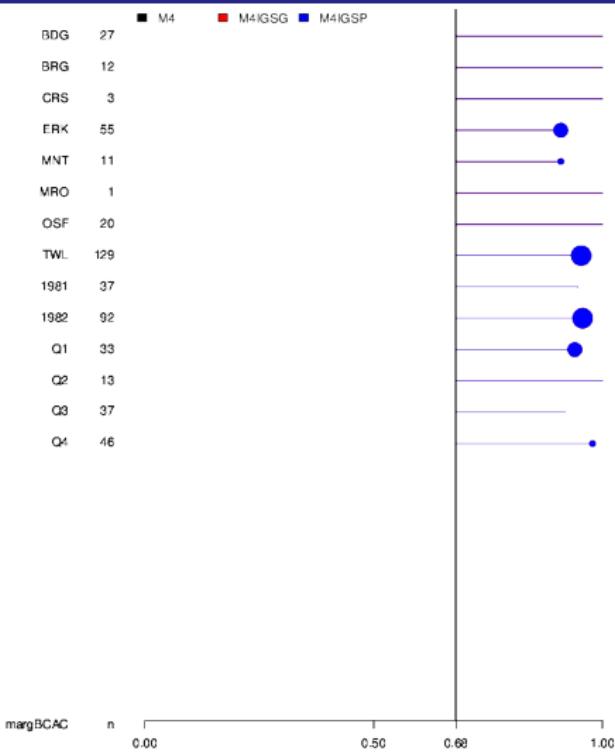
Time Block

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Correlation

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## MCAT 269



Introduction

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Time Model

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Prior Model

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Interaction Model

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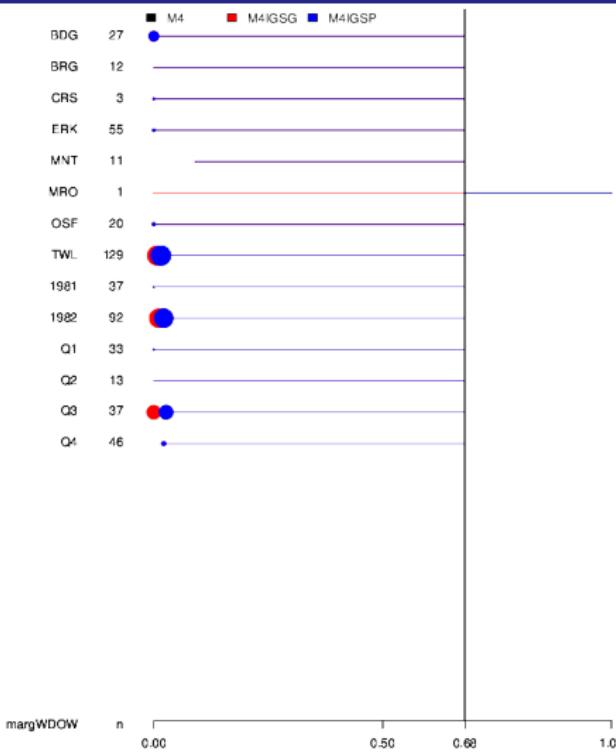
Time Block

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Correlation

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MCAT 269



## Introduction

## Time Model

## Prior Model

## Interaction Model

### Time Block

## Correlation

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○

A 4x3 grid of 12 small circles, arranged in four rows and three columns.

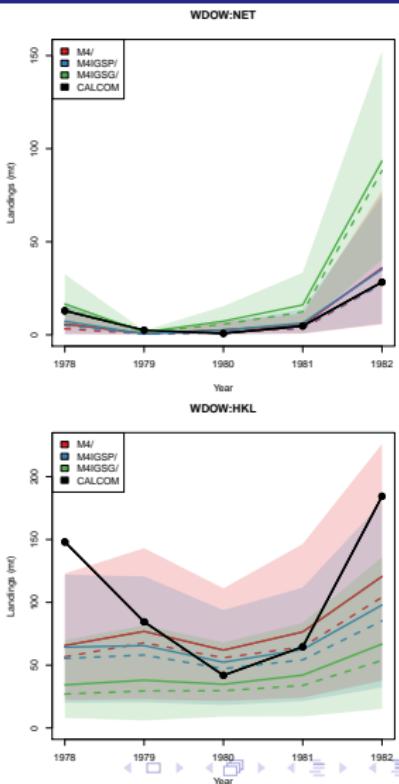
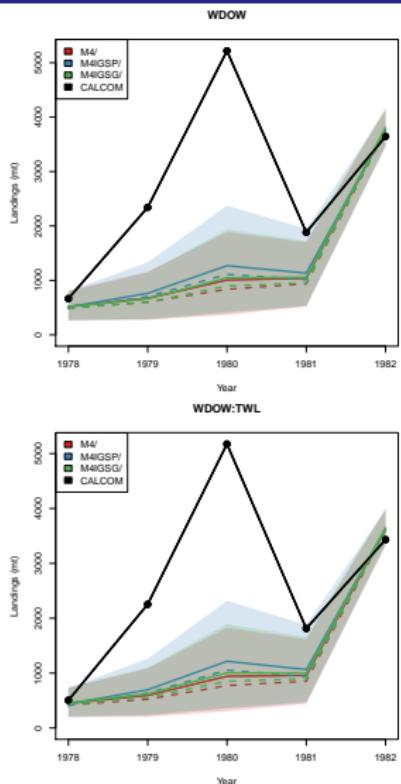
A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

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1

Landings Sensitivity



Introduction

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Time Model

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Prior Model

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Interaction Model

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Time Block

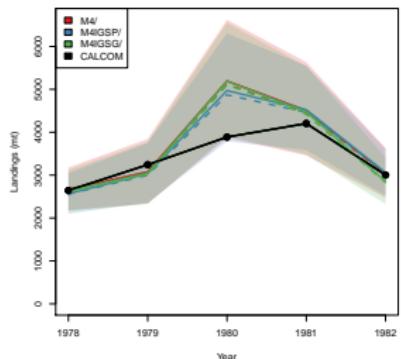
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Correlation

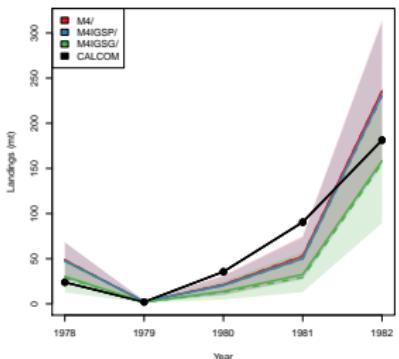
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## Landings Sensitivity

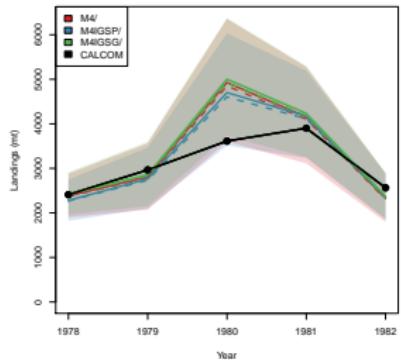
BCAC



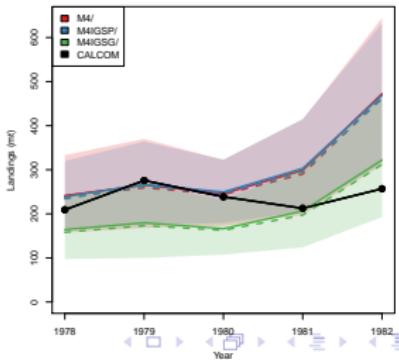
BCAC:NET



BCAC:TWL



BCAC:HKL



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Improving Catch Estimation Methods in Sparsely Sampled, Mixed Stock Fisheries.



Introduction

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Time Model

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Prior Model

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Interaction Model

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Time Block

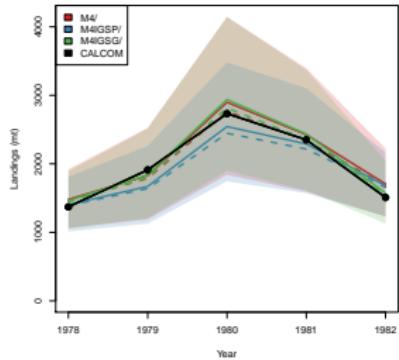
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Correlation

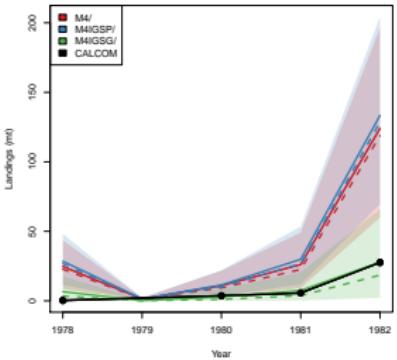
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## Landings Sensitivity

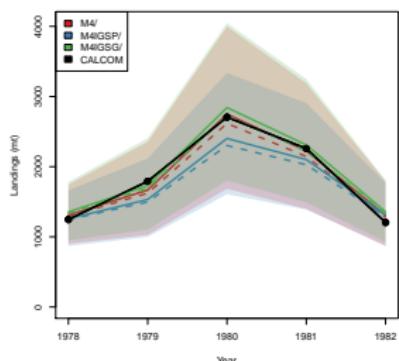
CLPR



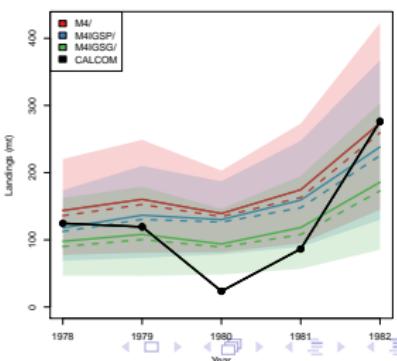
CLPR:NET



CLPR:TWL



CLPR:HKL



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Improving Catch Estimation Methods in Sparsely Sampled, Mixed Stock Fisheries.



## Introduction

## Time Model

## Prior Model

## Interaction Model

## Time Block

## Correlation

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○

A 4x6 grid of 24 small circles, arranged in four rows and six columns.

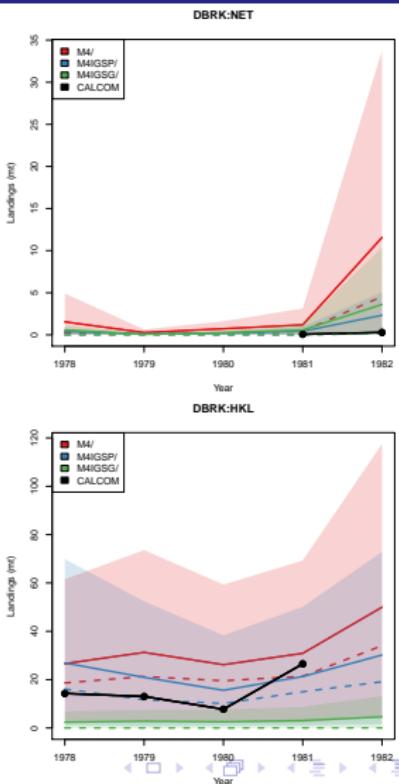
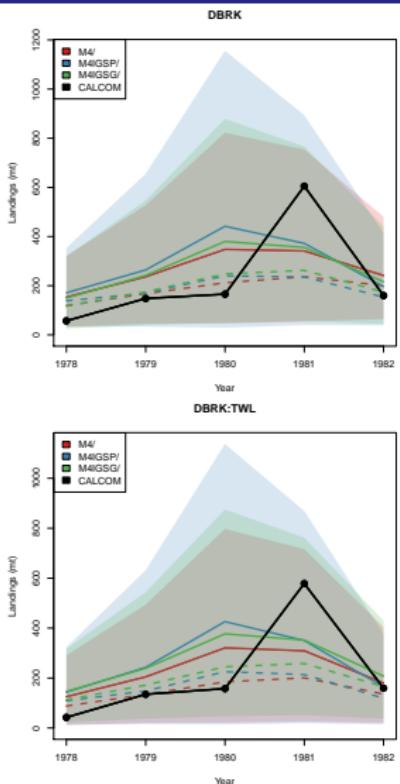
A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x6 grid of 24 small circles, arranged in four rows and six columns.

1

Landings Sensitivity



**Nicholas Grunloh In Cooperation With: E.J. Dick, Don Pearson, John Field, Marc Mangel**

## **Improving Catch Estimation Methods in Sparsely Sampled, Mixed Stock Fisheries.**

Introduction

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Time Model

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Prior Model

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Interaction Model

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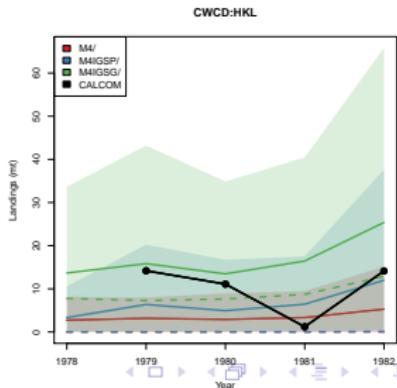
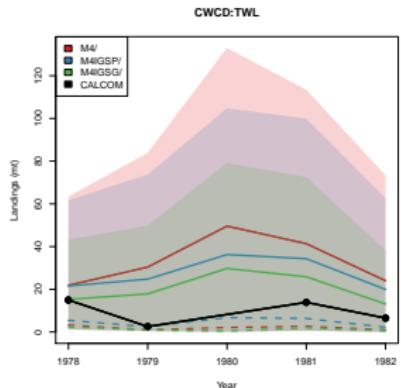
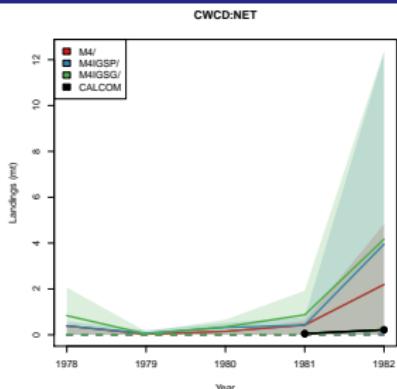
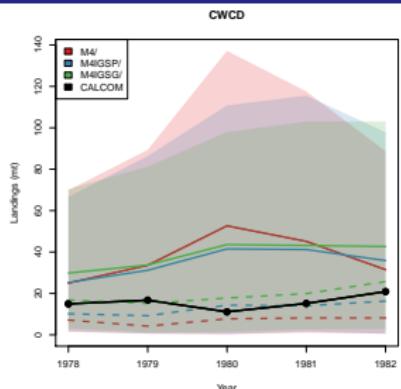
Time Block

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Correlation

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## Landings Sensitivity



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Improving Catch Estimation Methods in Sparsely Sampled, Mixed Stock Fisheries.



Introduction

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Time Model

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Prior Model

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Interaction Model

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Time Block

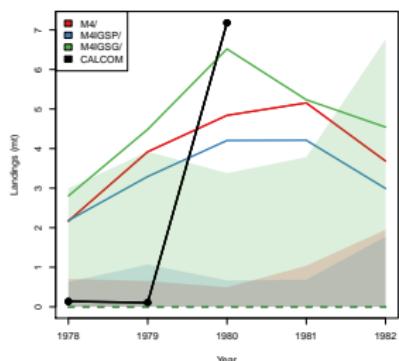
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Correlation

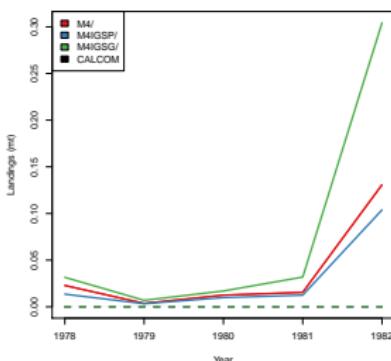
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## Landings Sensitivity

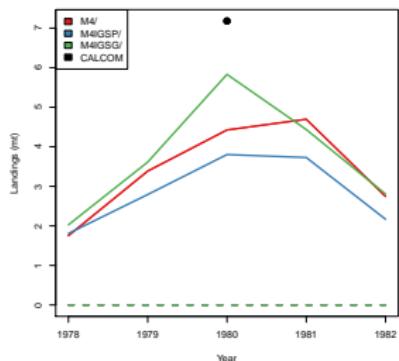
MXRF



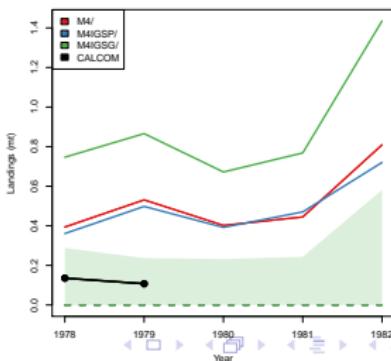
MXRF.NET



MXRF:TWL



MXRF:HKL



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Improving Catch Estimation Methods in Sparsely Sampled, Mixed Stock Fisheries.



## Landings Sensitivity

## Interaction Summary

- Both Species:Gear and Species:Port interactions may be appropriate.
  - Interactions appear to be market category dependent.
  - Possibly include both with shrinkage priors to allow each to fit on a MCAT-to-MCAT basis.
    - 250 253 269
    - Landings

## MCAT 250 Combined Plots

MCAT 253 Combined Plots

MCAT 269 Combined Plots

## All Species Landings

**Request:** Explore an alternative time block: an extension of 1983 and 1984 to the first time block.

**Rationale:** The panel expressed concerns about how the model would perform when applied to shorter time periods, as will occur when the model is used with data more recent than 1990. Results from the above recommendation could be compared to the results from the current two time blocks (1978-1982; 1983-1990) to explore how fits to data from the late period degrade when the model for the late period is based on fewer years of data. Also, comparisons of the two forms of blocking serve as a sensitivity evaluation of the selection of the block boundary, which was chosen on a fairly arbitrary basis.

**Response:** The following slides show the diagnostic plots as applied to model M4 when fit to data from 78-82 as well as data from 78-83, 78-84, and 78-85.

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A 4x6 grid of 24 small circles, arranged in four rows and six columns.

A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

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3

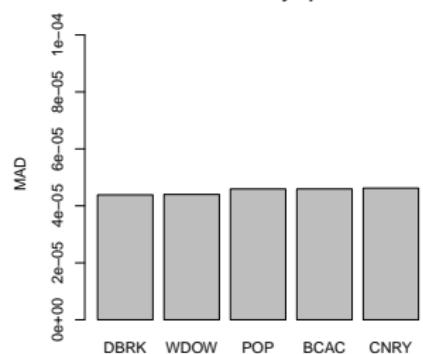
MCAT 250

78-82

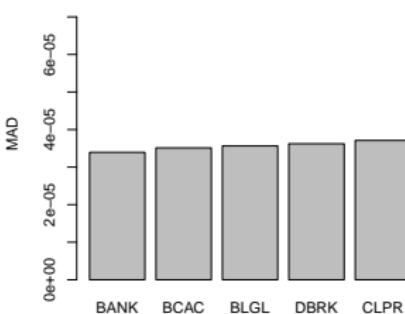
78-83

78-84

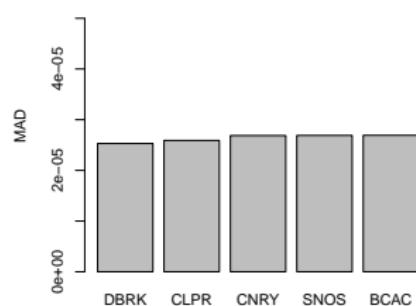
### MAD Ordered by Species



### MAD Ordered by Species



### MAD Ordered by Species



## Combined

## Introduction

## Time Model

## Prior Model

## Interaction Model

## Time Block

## Correlation

A 4x4 grid of 16 small circles, arranged in four rows and four columns.

10

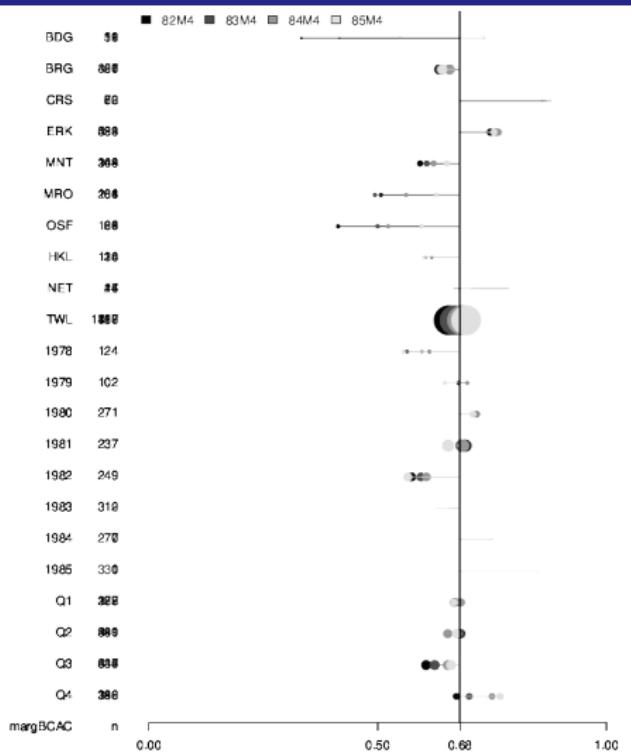
A 5x5 grid of 25 small circles, arranged in five rows and five columns.

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MCAT 250



Introduction

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Time Model

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Prior Model

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Interaction Model

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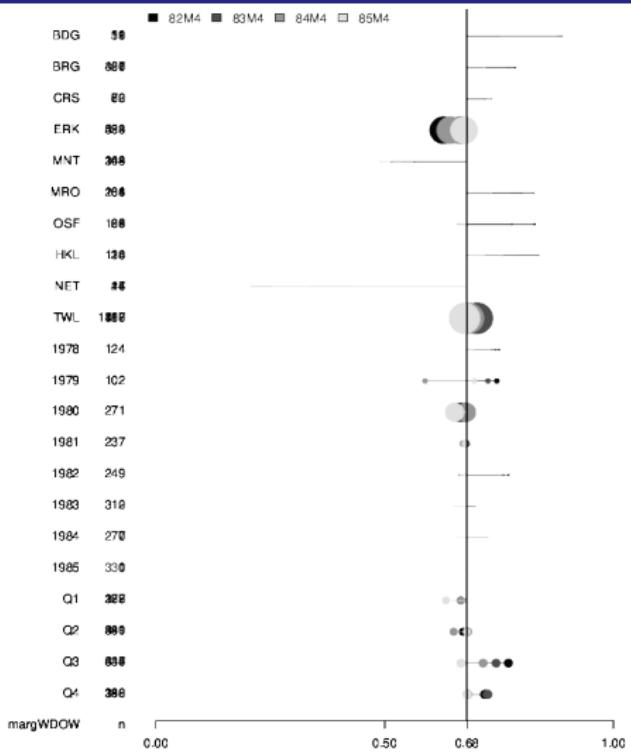
Time Block

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Correlation

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## MCAT 250

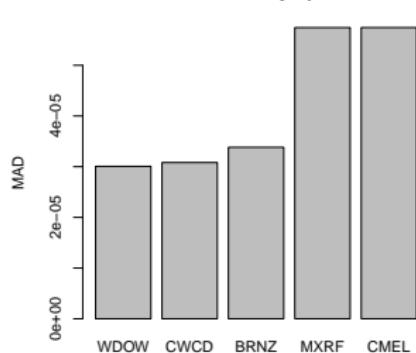
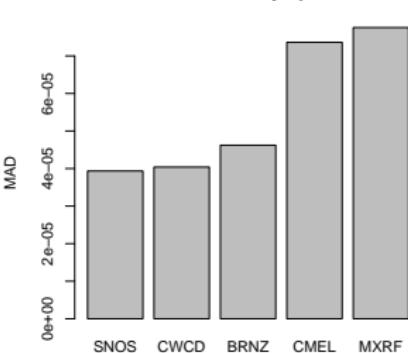
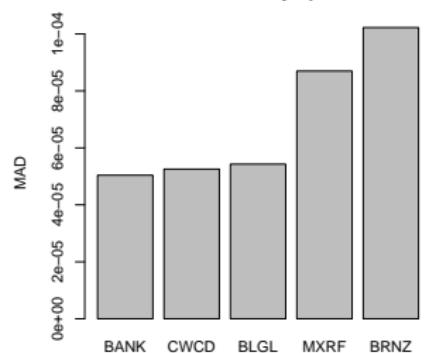


MCAT 250

78-82

78-83

78-84



## Combined

## Introduction

## Time Model

## Prior Model

## Interaction Model

### Time Block

## Correlation

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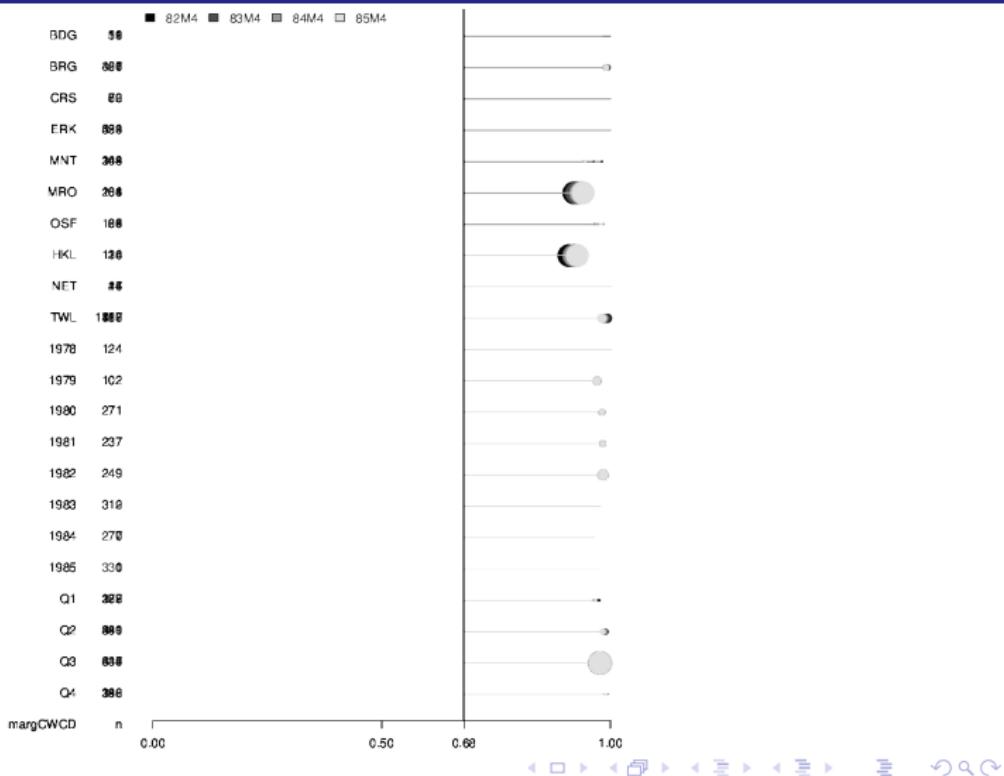
A 4x6 grid of 24 small circles, arranged in four rows and six columns.

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○

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MCAT 250



## Introduction

## Time Model

## Prior Model

## Interaction Model

## Time Block

## Correlation

A 5x5 grid of 25 small circles, arranged in five rows and five columns.

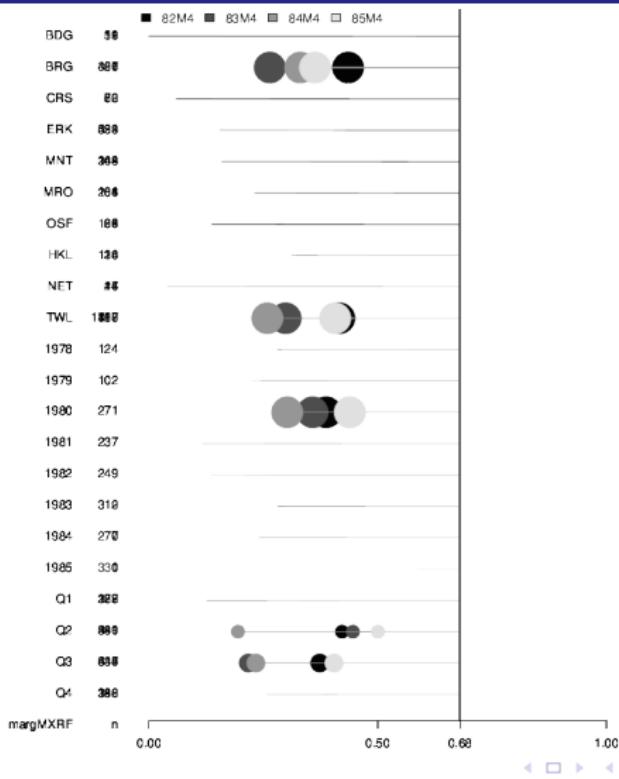
A 5x5 grid of 25 small circles, arranged in five rows and five columns.

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MCAT 250

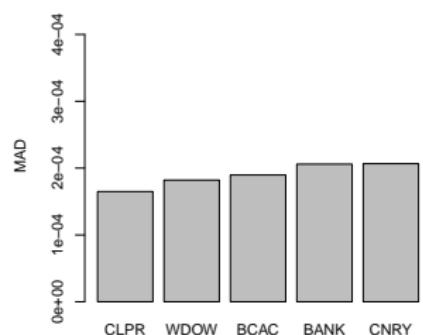


78-82

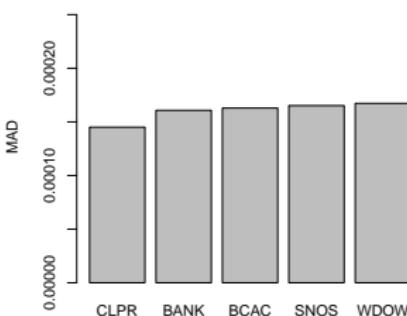
78-83

78-84

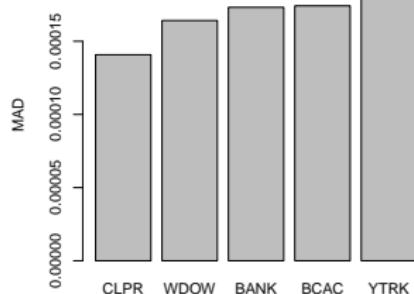
### MAD Ordered by Species



### MAD Ordered by Species



### MAD Ordered by Species



## Combined

Introduction

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Time Model

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Prior Model

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Interaction Model

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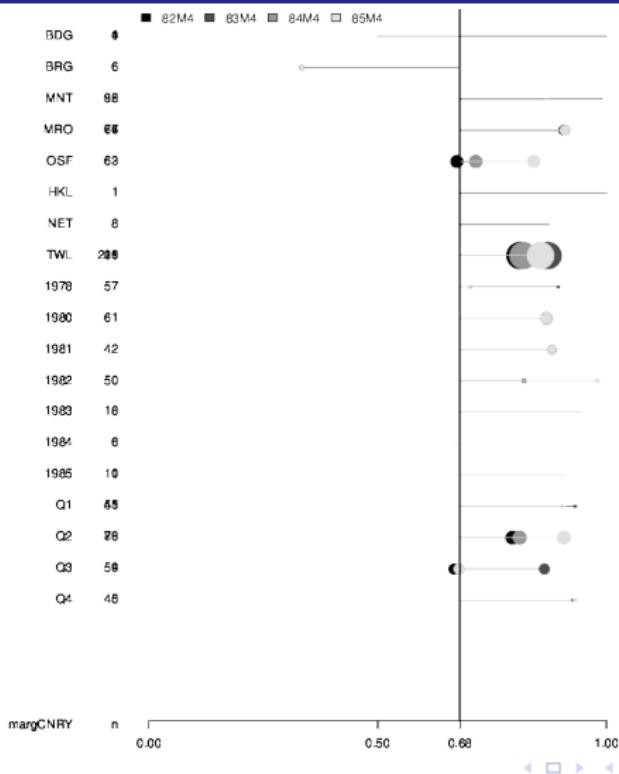
Time Block

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Correlation

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MCAT 253



Introduction

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○

Time Model

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Prior Model

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Interaction Model

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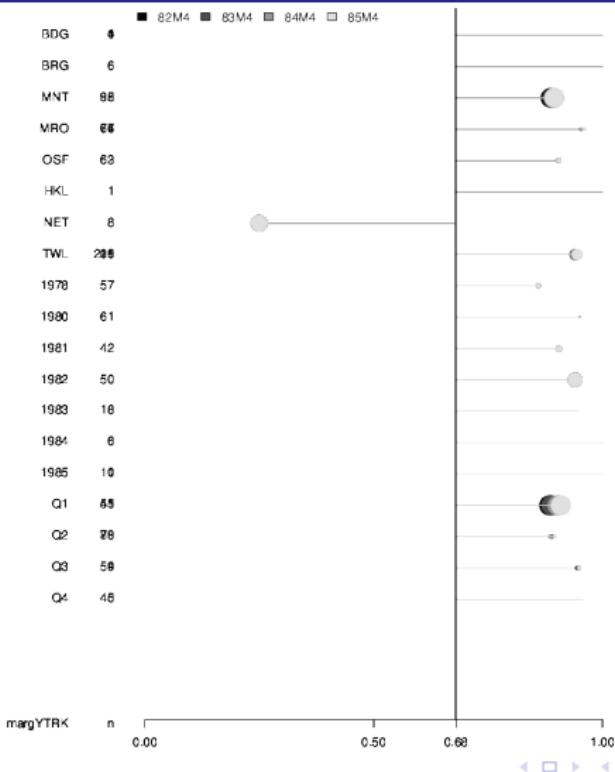
Time Block

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Correlation

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MCAT 253

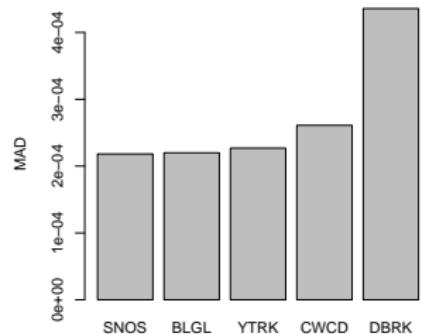


78-82

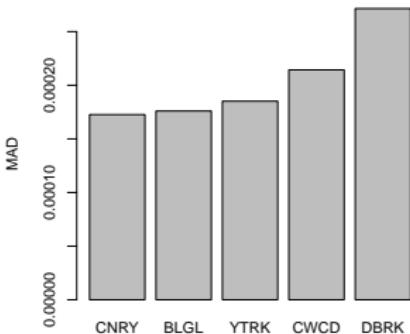
78-83

78-84

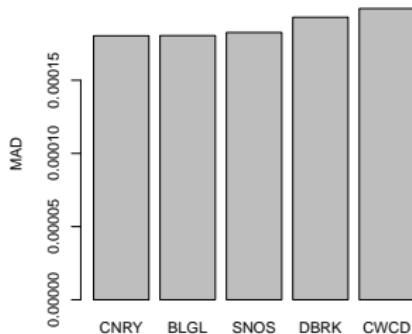
#### MAD Ordered by Species



### MAD Ordered by Species



### MAD Ordered by Species



## Combined

Introduction

## Time Model

## Prior Model

## Interaction Model

## Time Block

## Correlation

A 4x4 grid of 16 small circles, arranged in four rows and four columns.

A 5x5 grid of 25 small circles, arranged in five rows and five columns.

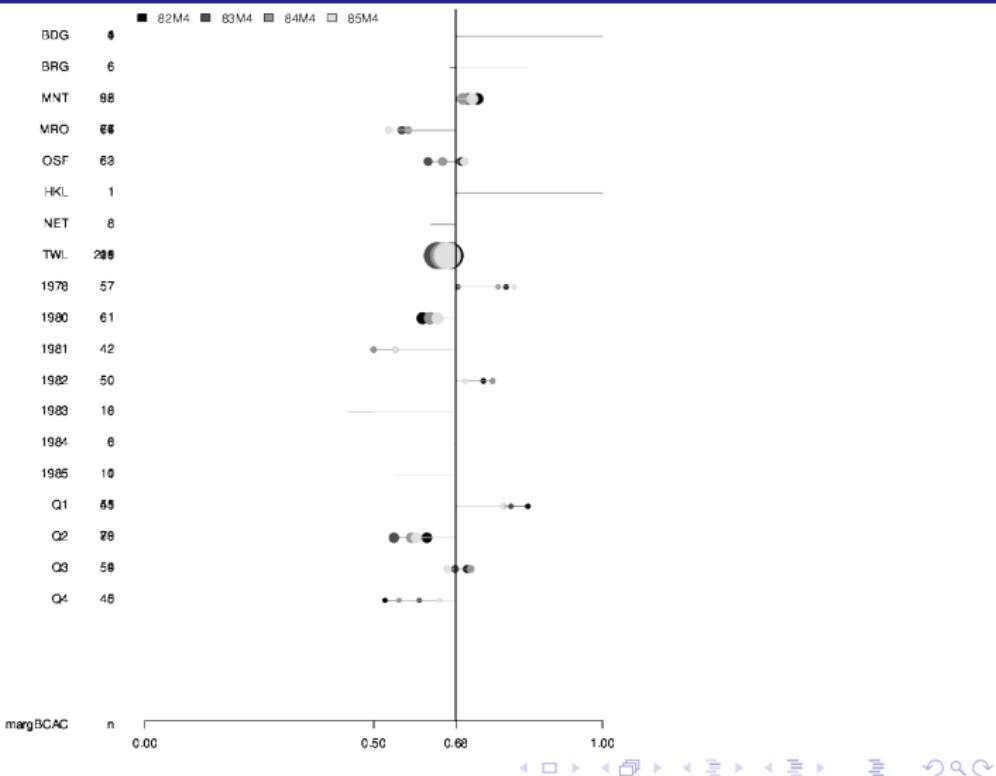
A 5x5 grid of 25 small circles, arranged in five rows and five columns.

A 5x5 grid of 25 small circles, arranged in five rows and five columns.

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MCAT 253



Introduction

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Interaction Model

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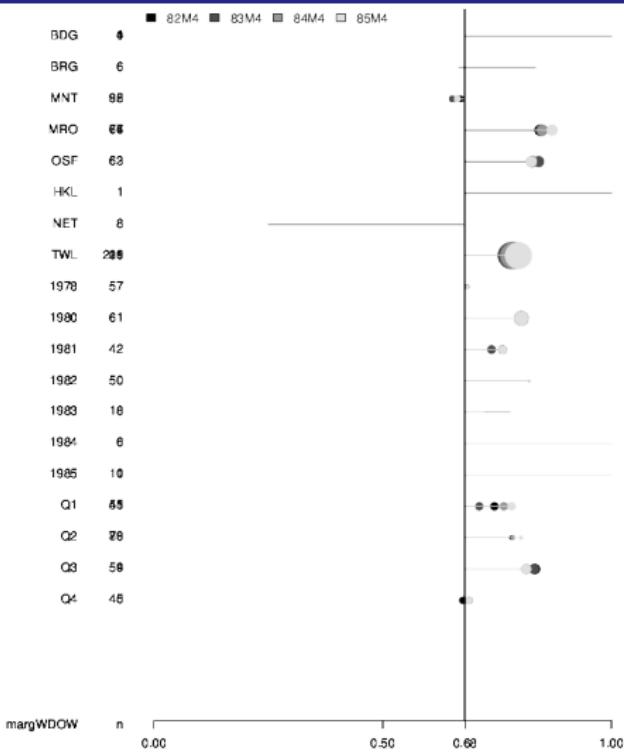
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Correlation

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MCAT 253

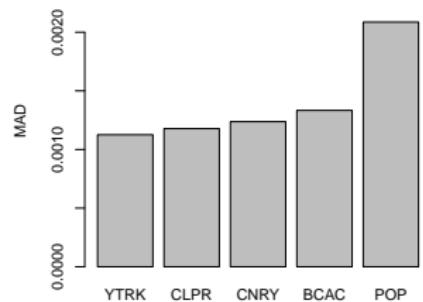


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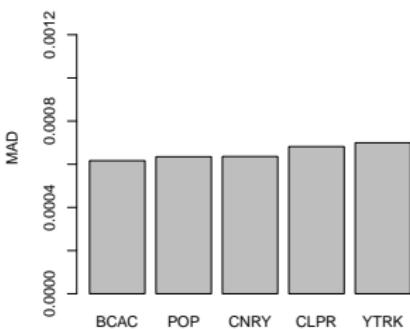
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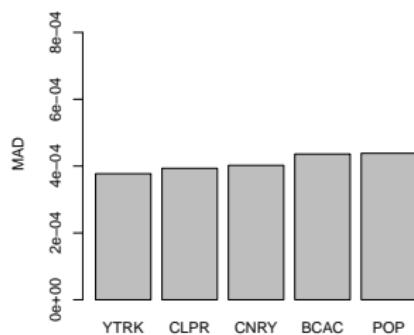
#### MAD Ordered by Species



### MAD Ordered by Species



#### MAD Ordered by Species



## Combined

## Introduction

## Time Model

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## Interaction Model

## Time Block

## Correlation

A 4x5 grid of 20 small circles, arranged in four rows and five columns.

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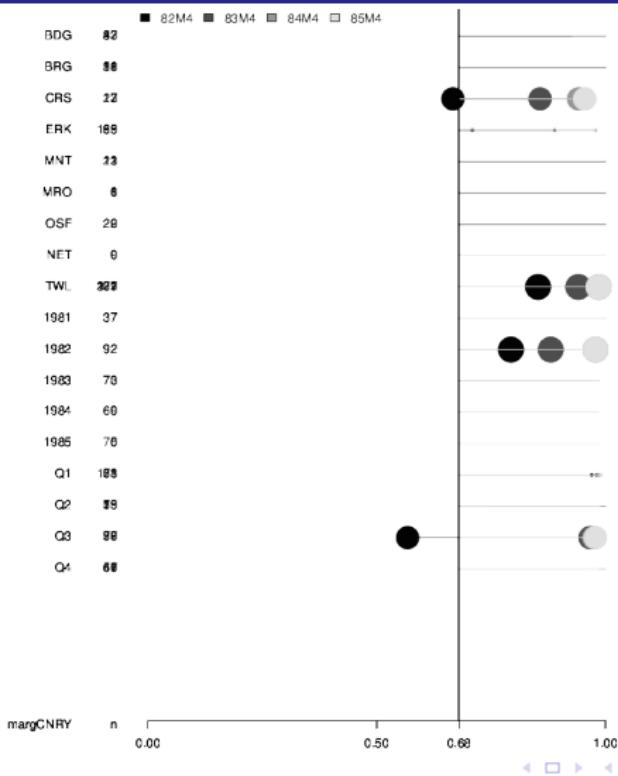
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MCAT 269



## Introduction

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## Prior Model

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## Time Block

## Correlation

A 4x5 grid of 20 small circles, arranged in four rows and five columns.

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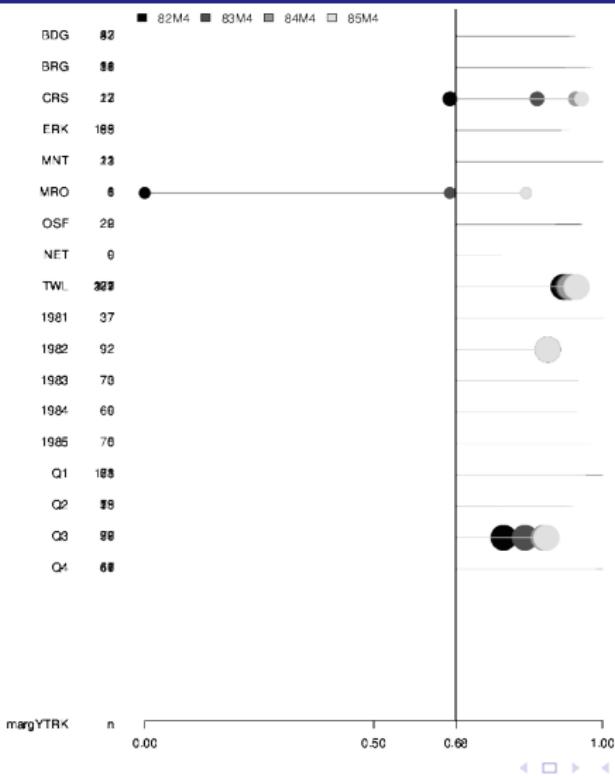
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MCAT 269

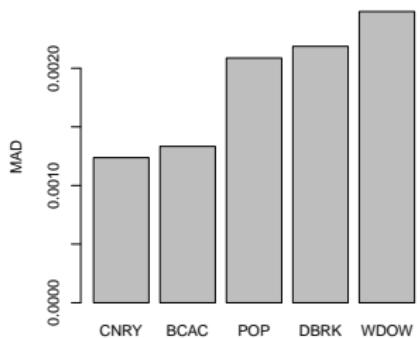


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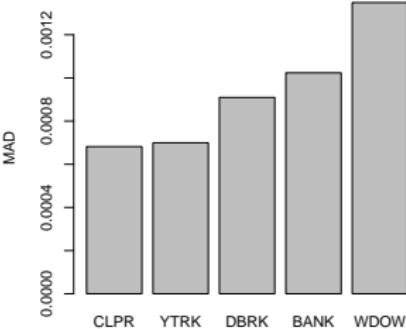
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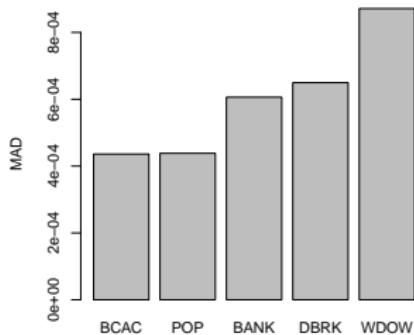
#### MAD Ordered by Species



### MAD Ordered by Species



#### MAD Ordered by Species



# Combined

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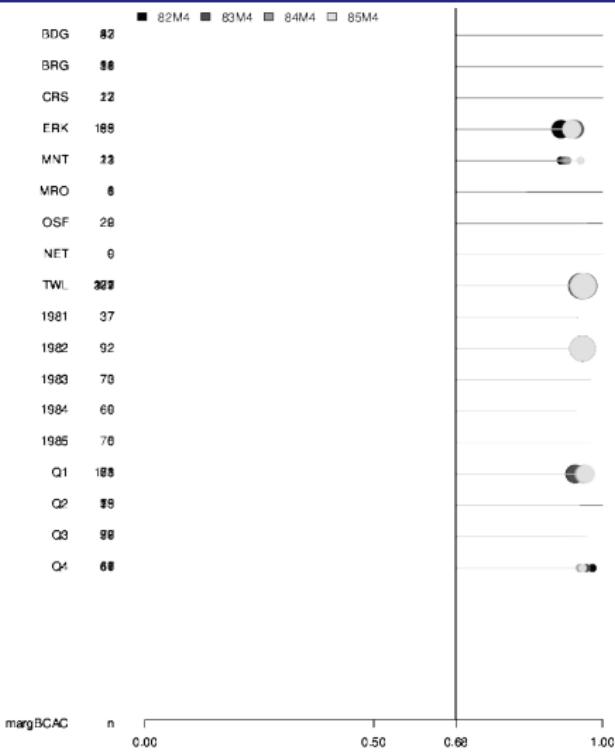
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MCAT 269



## Introduction

## Time Model

## Prior Model

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### Time Block

## Correlation

A 4x5 grid of 20 small circles, arranged in four rows and five columns.

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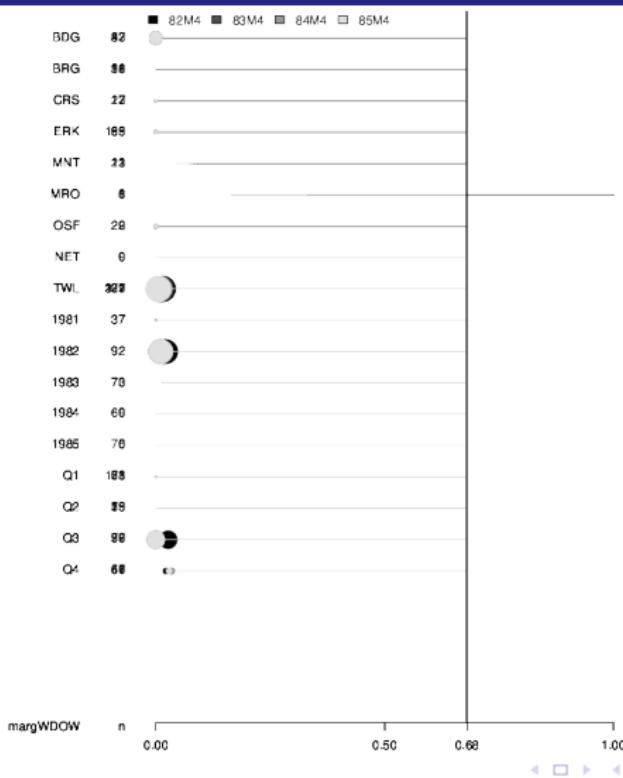
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MCAT 269



## Introduction

## Time Model

## Prior Model

## Interaction Model

### Time Block

## Correlation

A 4x3 grid of 12 small circles, arranged in four rows and three columns.

A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

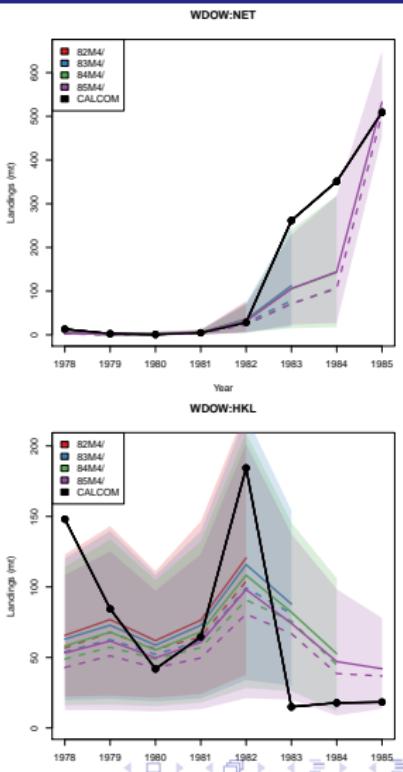
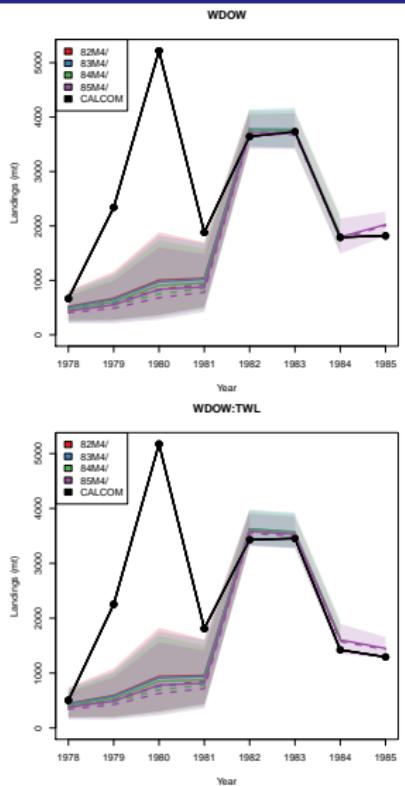
A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x6 grid of 24 small circles, arranged in four rows and six columns.

1

Landings Sensitivity



**Nicholas Grunloh In Cooperation With: E.J. Dick, Don Pearson, John Field, Marc Mangel**

## **Improving Catch Estimation Methods in Sparsely Sampled, Mixed Stock Fisheries.**

Introduction

## Time Model

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## Correlation

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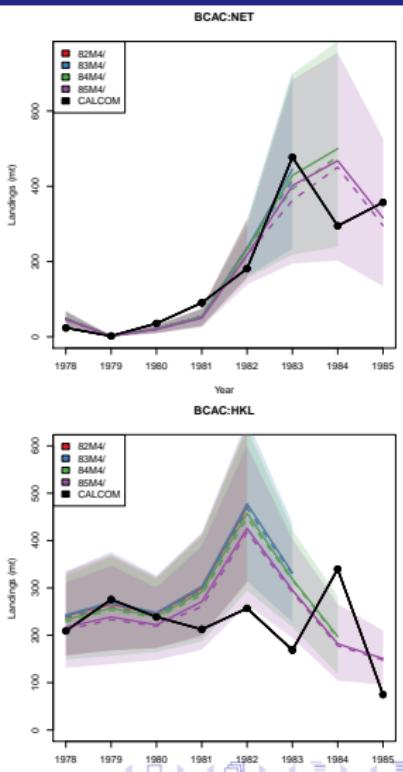
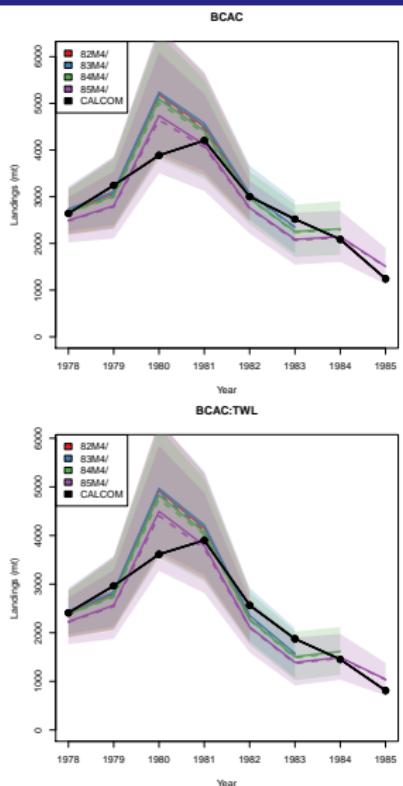
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A 4x5 grid of 20 small circles, arranged in four rows and five columns.

10

Landings Sensitivity



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## **Improving Catch Estimation Methods in Sparsely Sampled, Mixed Stock Fisheries.**



## Introduction

## Time Model

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## Correlation

A 4x3 grid of 12 small circles, arranged in four rows and three columns.

A 4x6 grid of 24 small circles, arranged in four rows and six columns.

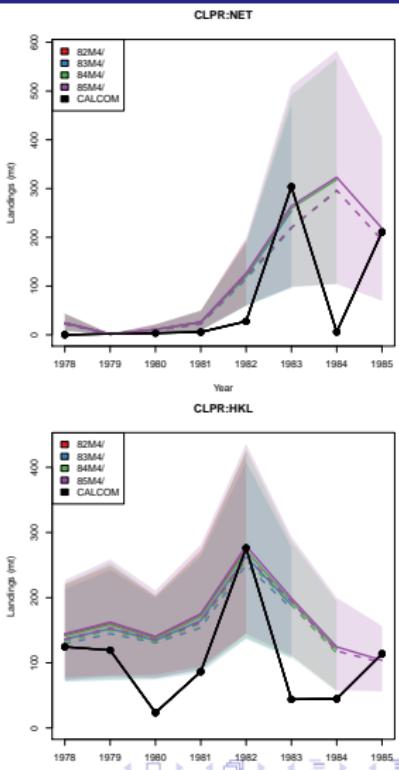
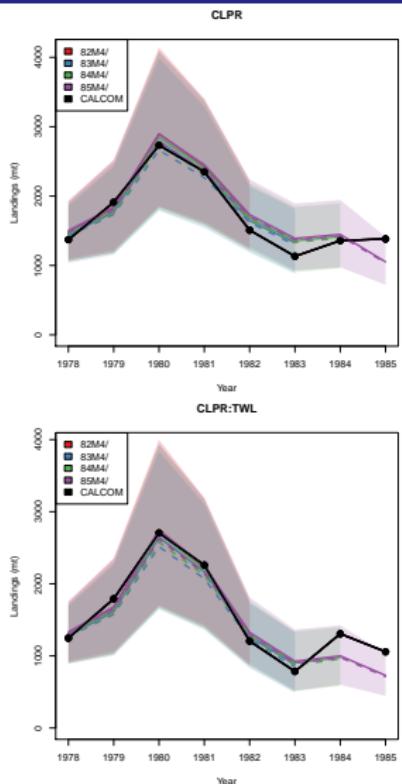
A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x7 grid of 28 small circles, arranged in four rows and seven columns.

A 4x6 grid of 24 small circles, arranged in four rows and six columns.

1

Landings Sensitivity



Introduction

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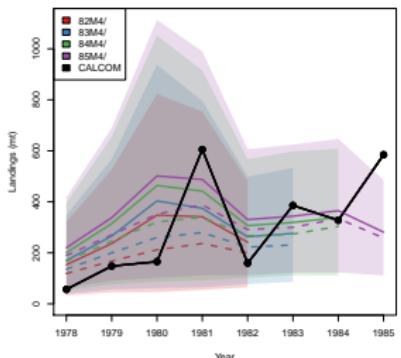
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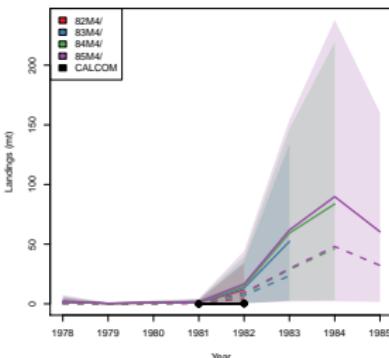
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## Landings Sensitivity

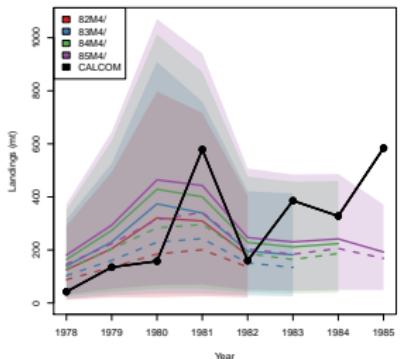
DBRK



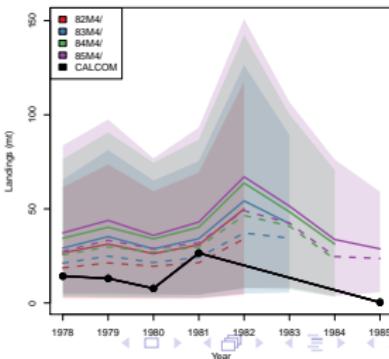
DBRK-NET



DBRK:TWL



DBRK:HKL



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Improving Catch Estimation Methods in Sparsely Sampled, Mixed Stock Fisheries.



## Introduction

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## Time Model

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## Prior Model

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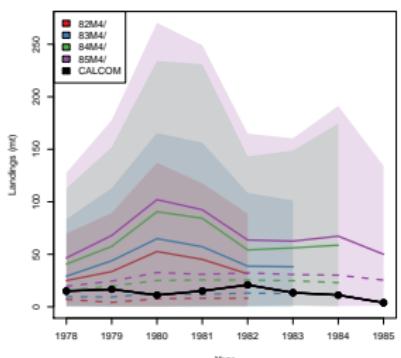
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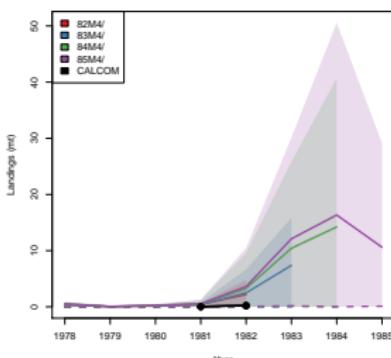
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## Landings Sensitivity

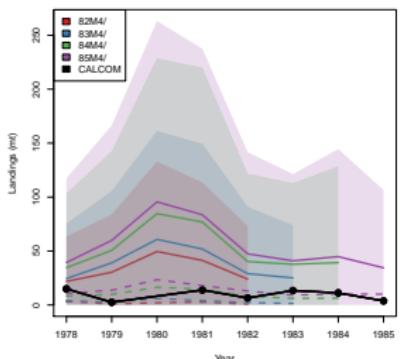
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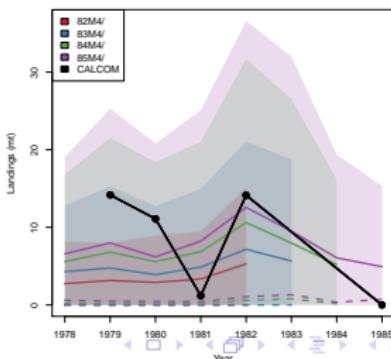
CWCD:NET



CWCD:TWL



CWCD:HKL



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Improving Catch Estimation Methods in Sparsely Sampled, Mixed Stock Fisheries.



Introduction

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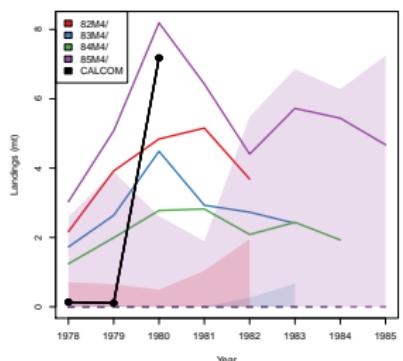
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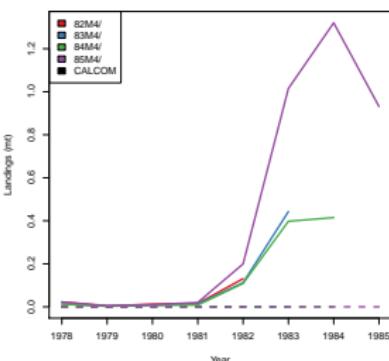
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## Landings Sensitivity

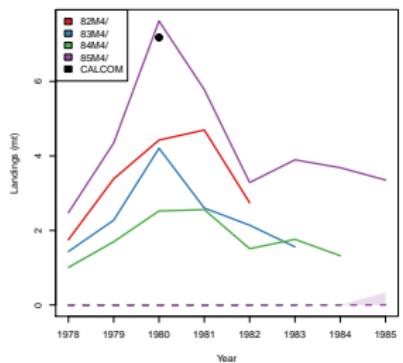
MXRF



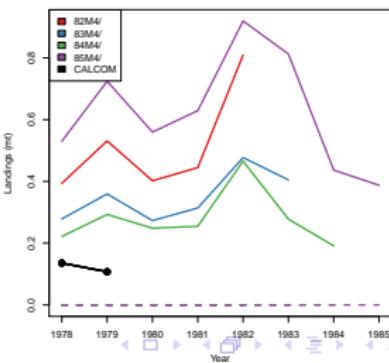
MXRF:NET



MXRF:TWL



MXRF:HKL



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Landings Sensitivity

## Time Blocking Summary

- The presented model is reasonably robust to time blocking decisions.
  - MCATs 250 and 253 show small shifts in performance.
  - MCAT 269 shifts performance to a greater extent.

## MCAT 250 Combined Plots

MCAT 253 Combined Plots

## MCAT 269 Combined Plots

## All Species Landings

For the sake of clarifying the correlation structure implied by the Multinomial-Poisson Transformation, consider the following:

$$X_1 \sim \text{Poisson}(\theta_1) \quad X_2 \sim \text{Poisson}(\theta_2)$$

The random variables  $X_1$  and  $X_2$  are *not* necessarily negatively correlated. They simply allow us to learn  $\theta_1$  and  $\theta_2$ .  $\theta_1$  and  $\theta_2$  are *not* necessarily negatively correlated. However, via the Multinomial-Poisson transformation ( $f(\mathbf{x}) = \frac{x_i}{\sum_j x_j}$ ),  $\theta_1$  and  $\theta_2$  jointly contain the same information as the Multinomial  $\pi$  parameter. The individual components of  $\pi$  are necessarily negatively correlated (I prove this later). The components of a new (multivariate) random variable  $\mathbf{Y} \sim MN(\pi)$  are necessarily negatively correlated.

In our modeling strategy we replace the Poisson distributions with Beta-Binomial distributions.

$$X_1 \sim \text{BB}(\theta_1, \rho) \quad X_2 \sim \text{BB}(\theta_2, \rho).$$

Just as in the previous slide, the random variables  $X_1$  and  $X_2$  are not necessarily negatively correlated.  $\theta_1$  and  $\theta_2$  are not necessarily negatively correlated. However computing species compositions using the  $f(\mathbf{x}) = \frac{\mathbf{x}_i}{\sum_j \mathbf{x}_j}$  transformation, provides negative correlation among our species compositions, just as it does in the previous case. In the next slides I show that it is the structure of the  $f(\mathbf{x}) = \frac{\mathbf{x}_i}{\sum_j \mathbf{x}_j}$  transformation that produces this negative correlation. The Multinomial-Poisson transformation is only special in that it's particular application of this transformation among the parameters of Poisson distributions, analytically results in the Multinomial distribution. The particular form of the Poisson distribution is not required to guarantee negative correlation, the transformation itself provides the negative correlation.

## Species Comps are Negatively Correlated.

Consider a two species system.

$$\pi_1 = \frac{x_1}{x_1 + x_2} \quad \pi_2 = \frac{x_2}{x_1 + x_2} \quad \Rightarrow \quad \pi_1 + \pi_2 = 1$$

We seek to show  $\text{Corr}(\pi_1, \pi_2) < 0$ .

$$Corr(\pi_1, \pi_2) = \frac{Cov(\pi_1, \pi_2)}{\sigma_{\pi_1}\sigma_{\pi_2}} \quad \sigma_{\pi_1} \geq 0, \sigma_{\pi_2} \geq 0$$

$$\text{Corr}(\pi_1, \pi_2) \leq 0 \iff \text{Cov}(\pi_1, \pi_2) \leq 0$$

Introduction

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Time Model

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Prior Model

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Interaction Model

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Time Block

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$$\begin{aligned} \text{Cov}(\pi_1, \pi_2) &= \mathbb{E}[(\pi_1 - \mathbb{E}[\pi_1])(\pi_2 - \mathbb{E}[\pi_2])] \\ &= \mathbb{E}[\pi_1 \pi_2] - \mathbb{E}[\pi_1] \mathbb{E}[\pi_2] \end{aligned}$$

$$\text{Cov}(\pi_1, \pi_2) \leq 0 \iff \mathbb{E}[\pi_1] \mathbb{E}[\pi_2] \geq \mathbb{E}[\pi_1 \pi_2]$$

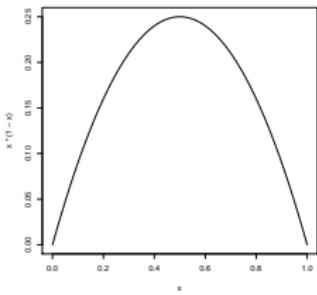
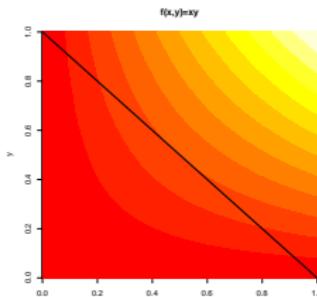
Now consider  $f(x, y) = xy$  such that  $x+y=1$ ,  $x \geq 0$ , and  $y \geq 0$ .

Jensen's Inequality for  $f$  is:

$$f(\mathbb{E}[x], \mathbb{E}[y]) \geq \mathbb{E}[f(x, y)] \quad (1)$$

Applying (1) to  $\pi$  gives  $\mathbb{E}[\pi_1] \mathbb{E}[\pi_2] \geq \mathbb{E}[\pi_1 \pi_2]$ , with equality only when  $\pi$  is a constant.

Thus  $\text{Cov}(\pi_1, \pi_2) < 0$  and  $\text{Corr}(\pi_1, \pi_2) < 0$ .



## Introduction

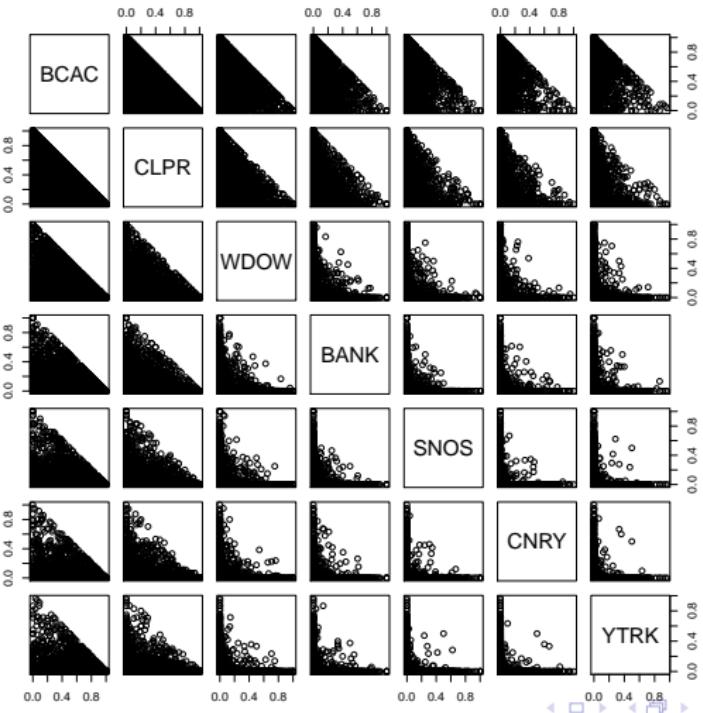
## Time Model

## Prior Model

## Interaction Model

### Time Block

## Correlation



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## **Improving Catch Estimation Methods in Sparsely Sampled, Mixed Stock Fisheries.**

Introduction

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Time Model

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Proofs

## Proof: Species Comps Sum to One... as do Their Means.

If  $y_{jk}$  is the  $k^{\text{th}}$  draw,  $k \in \{1, \dots, K\}$ , of the posterior predictive weight of species  $j$  in a particular stratum. Then,

$$\pi_{jk} = \frac{y_{jk}}{\sum_j y_{jk}} \quad \mathbf{y}_k \neq \mathbf{0}. \quad (2)$$

The predictive mean for species  $j$  is,

$$\hat{\pi}_j = \frac{\sum_k^K \pi_{jk}}{K}. \quad (3)$$

Summing  $\hat{\pi}_j$  across species, it follows from (1) and (2) that,

$$\sum_j \hat{\pi}_j \stackrel{(2)}{=} \sum_j \frac{\sum_k^K \pi_{jk}}{K} = \frac{\sum_k^K \sum_j \pi_{jk}}{K} \stackrel{(1)}{=} \frac{\sum_k^K \sum_j \frac{y_{jk}}{\sum_j y_{jk}}}{K} = \frac{\sum_k^K 1}{K} = \frac{K}{K} = 1. \blacksquare$$

Introduction

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Time Block

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Correlation

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Proofs

## Proof: Species Comps are Negatively Correlated.

Here we seek to show for any two species  $I \neq m$ ,  $\text{Corr}(\pi_I, \pi_m) < 0$ .

Recall:

$$\text{Corr}(\pi_I, \pi_m) = \frac{\text{Cov}(\pi_I, \pi_m)}{\sigma_{\pi_I} \sigma_{\pi_m}} \quad \sigma_{\pi_I} \geq 0, \quad \sigma_{\pi_m} \geq 0$$

$$\text{Corr}(\pi_I, \pi_m) \leq 0 \iff \text{Cov}(\pi_I, \pi_m) \leq 0$$

$$\begin{aligned} \text{Cov}(\pi_I, \pi_m) &= \mathbb{E}[(\pi_I - \mathbb{E}[\pi_I])(\pi_m - \mathbb{E}[\pi_m])] \\ &= \mathbb{E}[\pi_I \pi_m] - \mathbb{E}[\pi_I] \mathbb{E}[\pi_m] \end{aligned}$$

$$\text{Cov}(\pi_I, \pi_m) \leq 0 \iff \mathbb{E}[\pi_I] \mathbb{E}[\pi_m] \geq \mathbb{E}[\pi_I \pi_m]$$

Proofs

Proof: Species Comps are Negatively Correlated Cont.

Consider the strictly concave function:

$$f(\mathbf{x}) = \prod_i x_i : \mathbf{x} \subset \left\{ \mathbf{y} \mid \sum_i y_i = 1, \ y_i \geq 0 \right\}$$

Jensen's Inequality for  $f$  is,

$$f(\mathbb{E}[\mathbf{x}]) \geq \mathbb{E}[f(\mathbf{x})]. \quad (4)$$

From the previous proof:  $\sum_j \pi_j = 1$ ,  $\pi_j \geq 0$  and  $\sum_j \hat{\pi}_j = 1$ ,  $\hat{\pi}_j \geq 0$ . Thus applying (4) to  $\pi$  gives

$$\mathbb{E}[\pi_I]\mathbb{E}[\pi_m] \geq \mathbb{E}[\pi_I\pi_m] \quad (5)$$

with equality only if  $\pi$  is a constant. Since  $\pi$  is never a constant,

$$\mathbb{E}[\pi_I]\mathbb{E}[\pi_m] > \mathbb{E}[\pi_I\pi_m] \implies \text{Cov}(\pi_I, \pi_m) < 0 \implies \text{Corr}(\pi_I, \pi_m) < 0.$$