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

Nick Grunloh

UCSC :: CSTAR :: SWFSC :: NMFS

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

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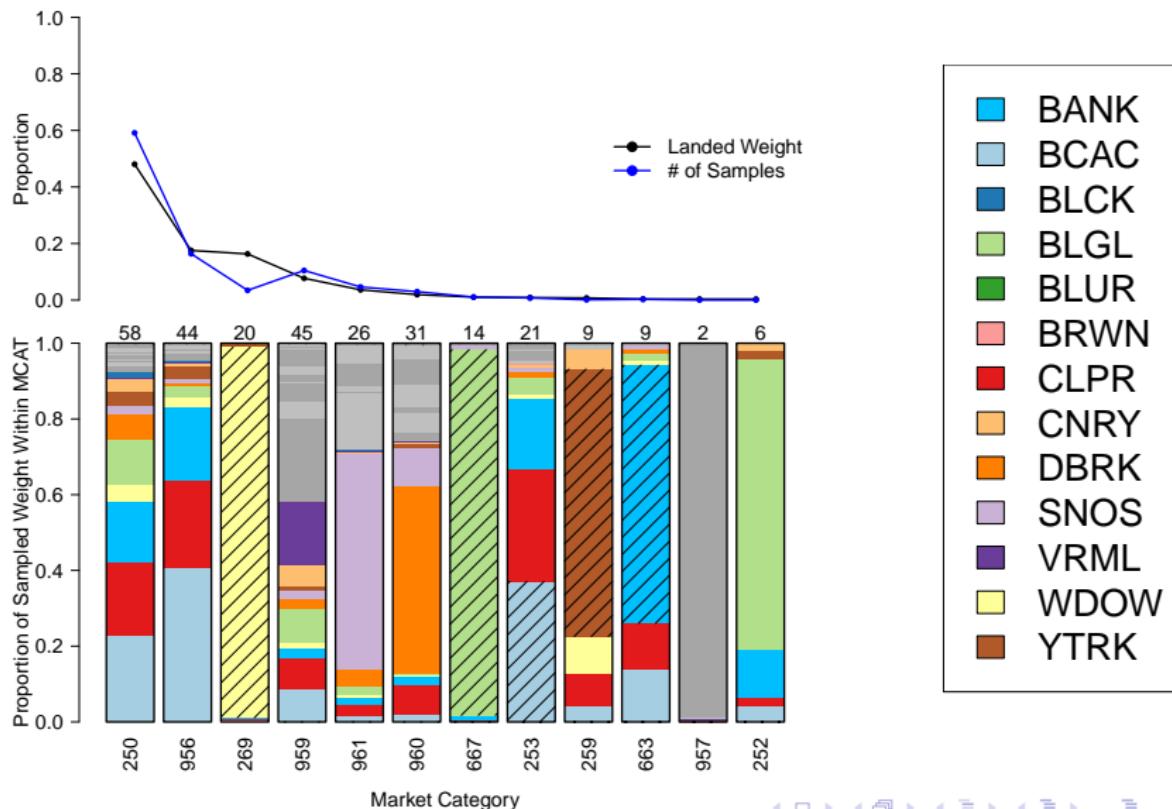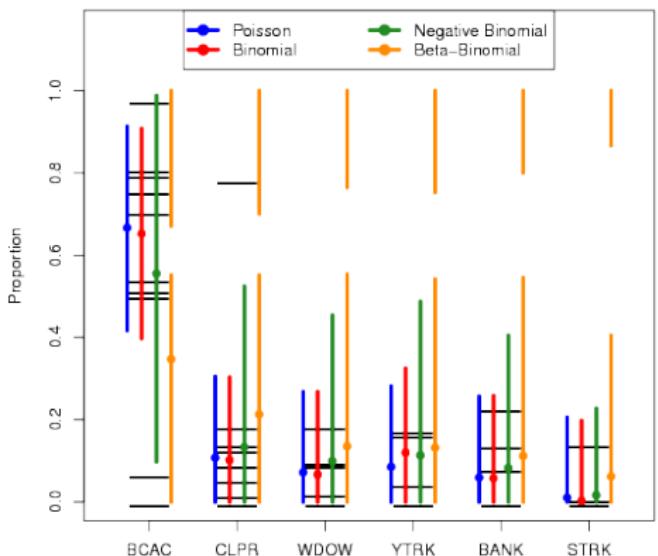
Likelihood
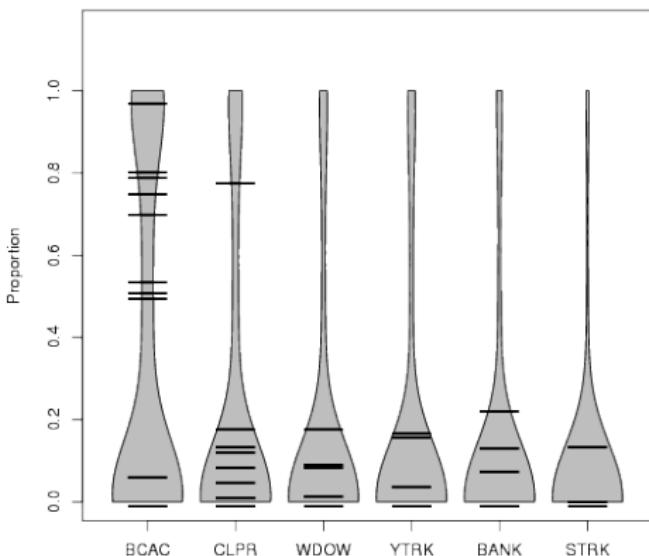
y_{ij}: i^{th} sample of the jth species' integer weight from market category 250, in the Monterey port complex trawl fishery for the second quarter of 1982.

$$y_{ij} \sim \text{Pois}(\theta_j) \quad y_{ij} \sim \text{Bin}(\theta_j) \quad y_{ij} \sim \text{NB}(\theta_j, \phi) \quad y_{ij} \sim \text{BB}(\theta_j, \phi)$$

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95% Predictive HDI Model Comparison

Beta–Binomial Posterior Predictive Species Compositions

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	Poisson	Binomial	NB	BB
MSE	0.06412	0.06264	0.05171	0.04479
Δ DIC	1001.41	1230.60	5.03	0
Δ WAIC	1079.95	1323.75	3.43	0
$pr(M|y)$	≈ 0	≈ 0	$\approx 10^{-7}$	$\approx 1 - 10^{-7}$

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Beta-Binomial Model

$$y_{ijklm\eta} \sim \text{Beta-Binomial}\Big(\mu_{jklm\eta}, \ \sigma^2_{jklm\eta}\Big)$$

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

$$\sigma^2_{jklm\eta} = \mu_{jklm\eta}\Big(1 - \frac{\mu_{jklm\eta}}{n}\Big)\Big(1 + (n-1) \ \rho\Big)$$

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

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

$$
\begin{aligned}
j &\in \{1, ..., J\} \ \text{Species} \\
k &\in \{1, ..., K\} \ \text{Ports} \\
l &\in \{1, ..., L\} \ \text{Gears} \\
m &\in \{1, ..., M\} \ \text{Years} \\
\eta &\in \{1, ..., H\} \ \text{Quarters}
\end{aligned}
$$

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Time Model

(M1)

$$\beta_{m\eta}^{(t)} = \beta_m^{(y)} + \beta_\eta^{(q)}$$
$$\beta_m^{(y)} \sim N(0, 32^2)$$
$$\beta_\eta^{(q)} \sim N(0, 32^2)$$

(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)

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

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Priors

$$\beta_0 \propto 1$$
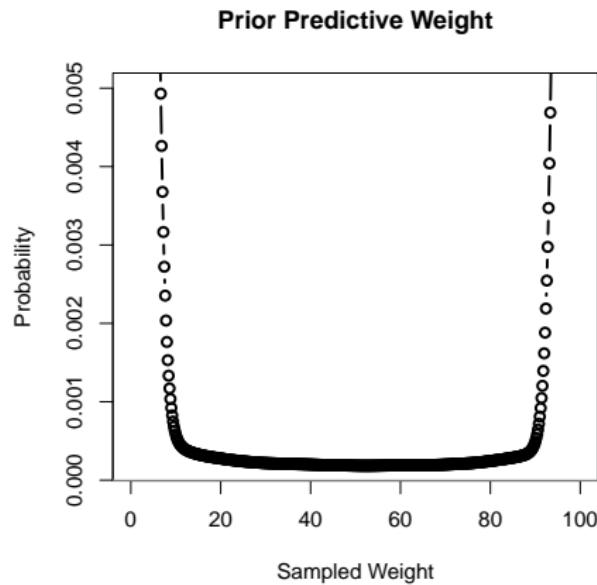
$$\beta_j^{(s)} \sim N(0, 32^2)$$

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

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

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

$$v \sim IG(1, \ 2x10^3) \quad \forall \quad v$$

Prior Predictive Weight

Probability (y-axis, values 0.000 to 0.005)

Sampled Weight (x-axis, values 0 to 100)

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1978-1982

	M1	M2	M3	M4	M5	M6
MSE	0.12725	0.12704	0.12680	0.12237	0.12724	0.12657
Δ DIC	2558.56	2259.94	2013.21	0	2175.32	2174.71
Δ WAIC	2562.65	2263.58	2009.32	0	2171.18	2170.56
$pr(M|y)$	≈ 0	≈ 0	≈ 0	≈ 1	≈ 0	≈ 0
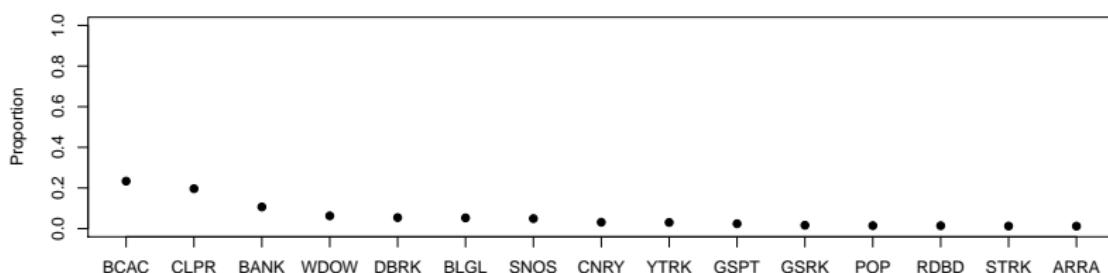
1983-1990*

	M1	M2	M3	M4	M5	M6
MSE	?	?	?	?	?	?
Δ DIC	-312058.47	-312104.63	-210648.29	-210614.84		
Δ WAIC	455961.15	450718.16	-6325.51	-8641.92		
$pr(M|y)$	-75989.25	-75966.82	-76003.24	-75970.74	≈ 0	≈ 0

Posterior Predictive Weight
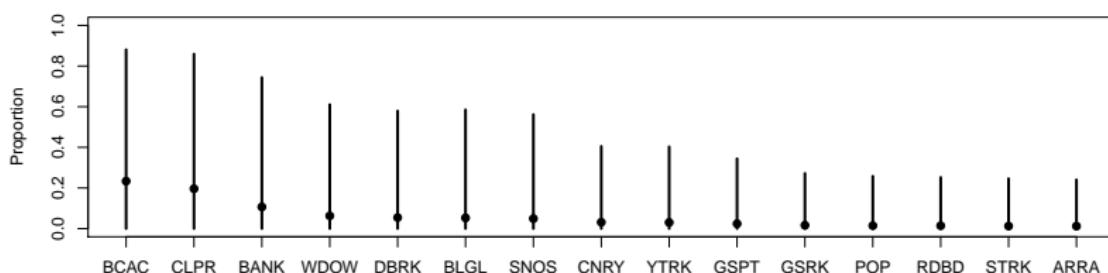
$$p(y^*_{jklm\eta}|\mathbf{y}) = \iint \text{BB}\Big(y^*_{jklm\eta}|\mu_{jklm\eta}, \sigma^2_{jklm\eta}\Big) P\Big(\mu_{jklm\eta}, \sigma^2_{jklm\eta}|\mathbf{y}\Big) d\mu_{jklm\eta} d\sigma^2_{jklm\eta}$$

$$\pi^*_{jklm\eta} = \frac{y^*_{jklm\eta}}{\sum_j y^*_{jklm\eta}} \quad \mathbf{y}^*_{klm\eta} \neq \mathbf{0}$$

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Posterior Predictive Weight

$$p(y^*_{jklm\eta}|\mathbf{y}) = \iint BB\Big(y^*_{jklm\eta}|\mu_{jklm\eta}, \sigma^2_{jklm\eta}\Big) P\Big(\mu_{jklm\eta}, \sigma^2_{jklm\eta}|\mathbf{y}\Big) d\mu_{jklm\eta} d\sigma^2_{jklm\eta}$$

$$\pi^*_{jklm\eta} = \frac{y^*_{jklm\eta}}{\sum_j y^*_{jklm\eta}} \quad \mathbf{y}^*_{klm\eta} \neq \mathbf{0}$$


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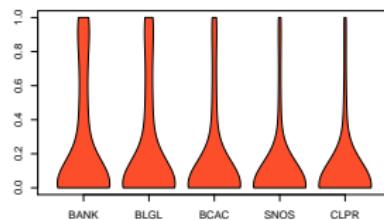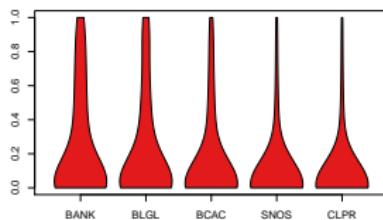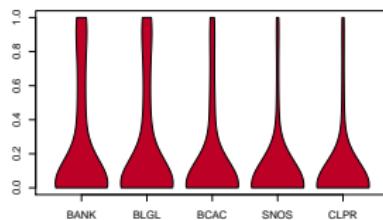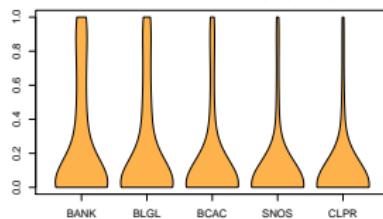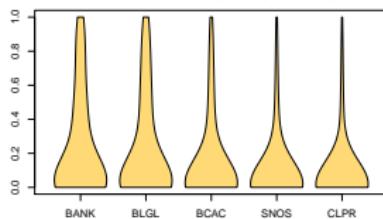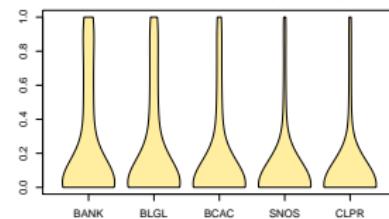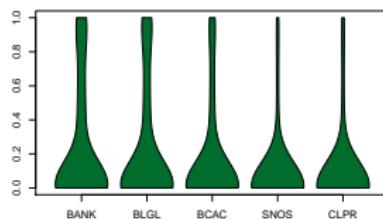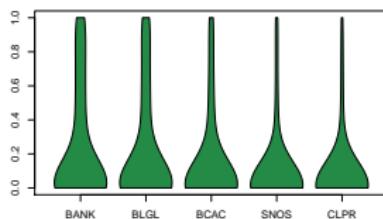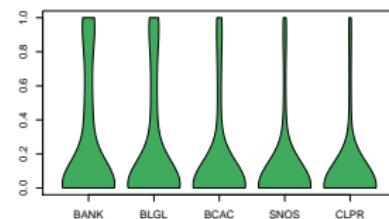
Single Quarter Hindcast (MCAT 250) update

Predictive Accuracy

	68%	95%	99%
250	67.1%	96.1%	98.7%
253	67.3%	96.3%	98.9%
262	67.4%	93.8%	95.3%
265	69.6%	96.0%	97.8%
269	68.2%	88.8%	90.2%
270	68.6%	93.6%	96.7%
956	68.3%	96.7%	99.2%
959	68.5%	96.3%	98.1%
961	69.3%	93.2%	95.3%
AVG	68.3%	94.5%	96.7%

1978-1982

	68%	95%	99%
245	60.8%	94.9%	97.7%
250	68.1%	96.0%	99.0%
253	69.3%	97.1%	98.9%
259	83.8%	91.9%	92.9%
262	68.5%	95.1%	95.9%
269	68.6%	94.2%	94.7%
270	67.9%	94.2%	96.7%
663	68.1%	94.1%	96.3%
667	69.4%	92.5%	93.5%
956	67.5%	96.2%	99.0%
959	67.4%	96.4%	99.0%
960	68.0%	96.1%	98.6%
961	68.6%	94.6%	97.8%
AVG	68.9%	94.9%	96.9%

1983-1990

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Speciated Landings

If $\lambda_{\cdot klm\eta}$ is the observed landings of **all species** in the kth port, caught with the lth gear, in the ηth quarter, of year m, in particular market category. Then,

$$\lambda^*_{jklm\eta} = \lambda_{\cdot klm\eta} \pi^*_{jklm\eta}$$

$$\lambda^*_{jklm\cdot} = \sum_\eta \lambda^*_{jklm\eta}$$

$$\lambda^*_{j\cdot lm\cdot} = \sum_k \sum_\eta \lambda^*_{jklm\eta}$$

$$\lambda^*_{j\cdot\cdot m\cdot} = \sum_l \sum_k \sum_\eta \lambda^*_{jklm\eta}$$

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$$\text{MSE}(\hat{\theta}) = \mathbb{E}\left[\ (\hat{\theta} - \theta)^2\ \right] = \overbrace{\mathbb{E}\left[\ \left(\hat{\theta} - \mathbb{E}(\hat{\theta})\right)^2\ \right]}^{\text{Var}(\hat{\theta})} + \overbrace{\left(\ \mathbb{E}(\hat{\theta}) - \theta\ \right)^2}^{\text{Bias}(\hat{\theta}, \theta)^2}$$

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$$B_K = \sum_{\kappa=0}^{K} \frac{1}{\kappa!} \left(\sum_{j=0}^{\kappa} (-1)^{\kappa-j} \binom{\kappa}{j} j^K \right)$$

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$$B_{10} = 115975$$

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$$\bar{B}_{10} = 61136$$

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$$\hat{B}_{10} = 512$$

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$$\hat{\hat{B}}_{10} = 274$$

Bayesian Model Averaging (BMA)

Consider a set of Models (M) indexed by ι:

$$\omega_\iota = Pr(M_\iota|y) = \frac{p(y|M_\iota)p(M_\iota)}{\sum_\iota p(y|M_\iota)p(M_\iota)}$$

$$\bar{p}(\boldsymbol{\theta}|\mathbf{y}) = \sum_\iota \omega_\iota p(\boldsymbol{\theta}|\mathbf{y}, M_\iota)$$
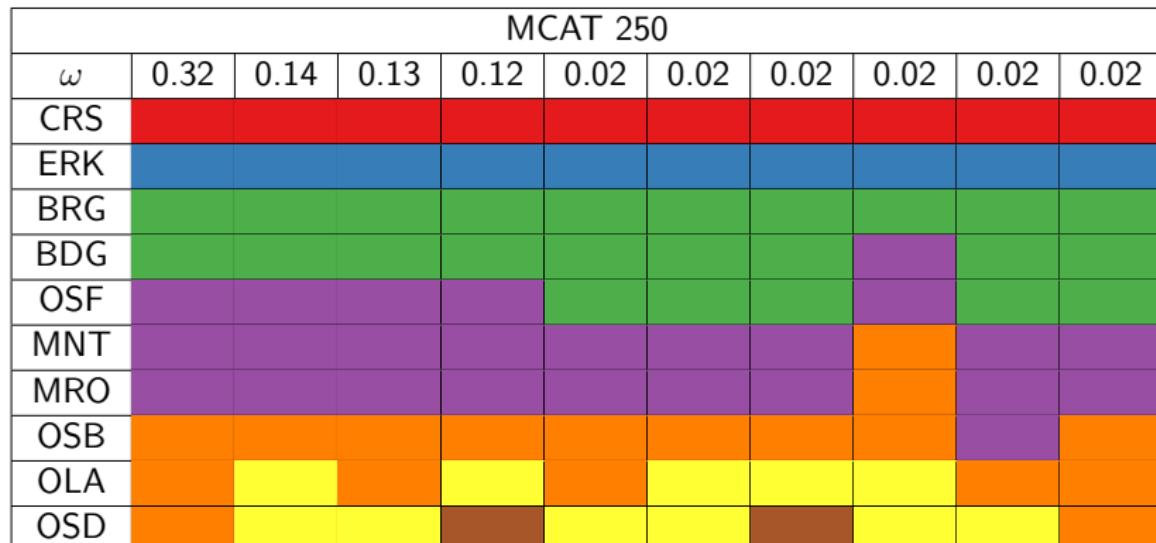
if f only depends on M through $\boldsymbol{\theta}$, then

$$\bar{p}(y^*|\mathbf{y}) = \int f(y^*|\boldsymbol{\theta})\bar{p}(\boldsymbol{\theta}|\mathbf{y})\mathbf{d}\boldsymbol{\theta}$$

* Hoeting, J. A., Madigan, D., Raftery, A. E., and Volinsky, C. T. (1999). Bayesian model averaging: a tutorial.

Statistical science, 382-401.

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1978-1982

MCAT 250									
ω	0.32	0.14	0.13	0.12	0.02	0.02	0.02	0.02	0.02	0.02
CRS										
ERK										
BRG										
BDG										
OSF										
MNT										
MRO										
OSB										
OLA										
OSD										

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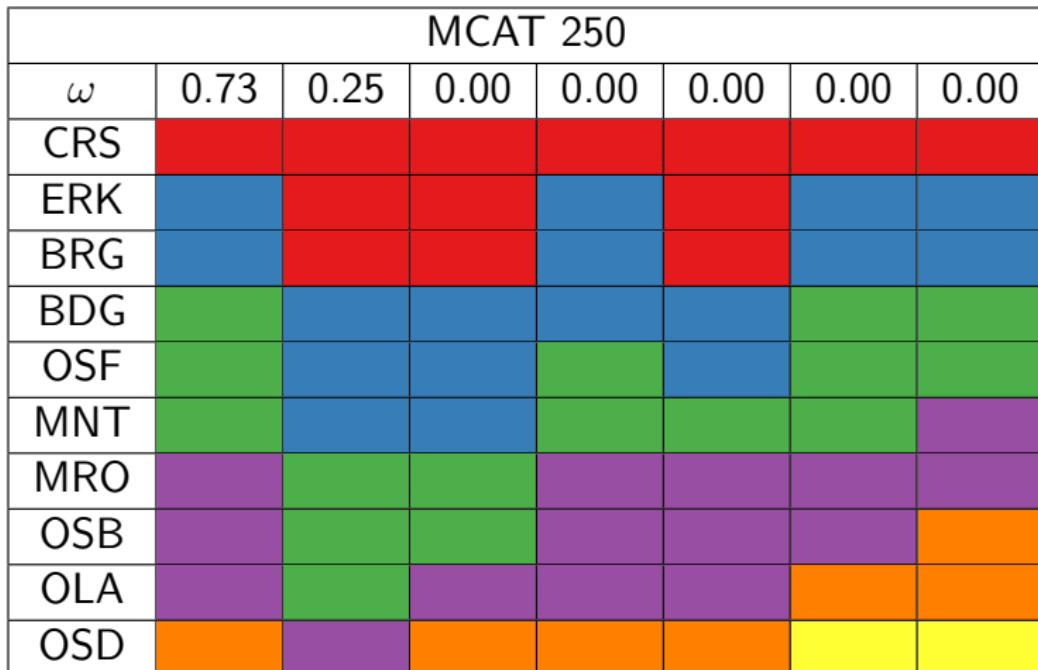
1978-1982

MCAT 253					
ω	0.14	0.14	0.14	0.10	0.06
CRS					
ERK					
BRG					
BDG					
OSF					
MNT					
MRO					
OSB					
OLA					
OSD					

MCAT 269					
ω	0.19	0.14	0.14	0.13	0.07
CRS					
ERK					
BRG					
BDG					
OSF					
MNT					
MRO					
OSB					
OLA					
OSD					

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1983-1990

MCAT 250							
ω	0.73	0.25	0.00	0.00	0.00	0.00	0.00
CRS							
ERK							
BRG							
BDG							
OSF							
MNT							
MRO							
OSB							
OLA							
OSD							
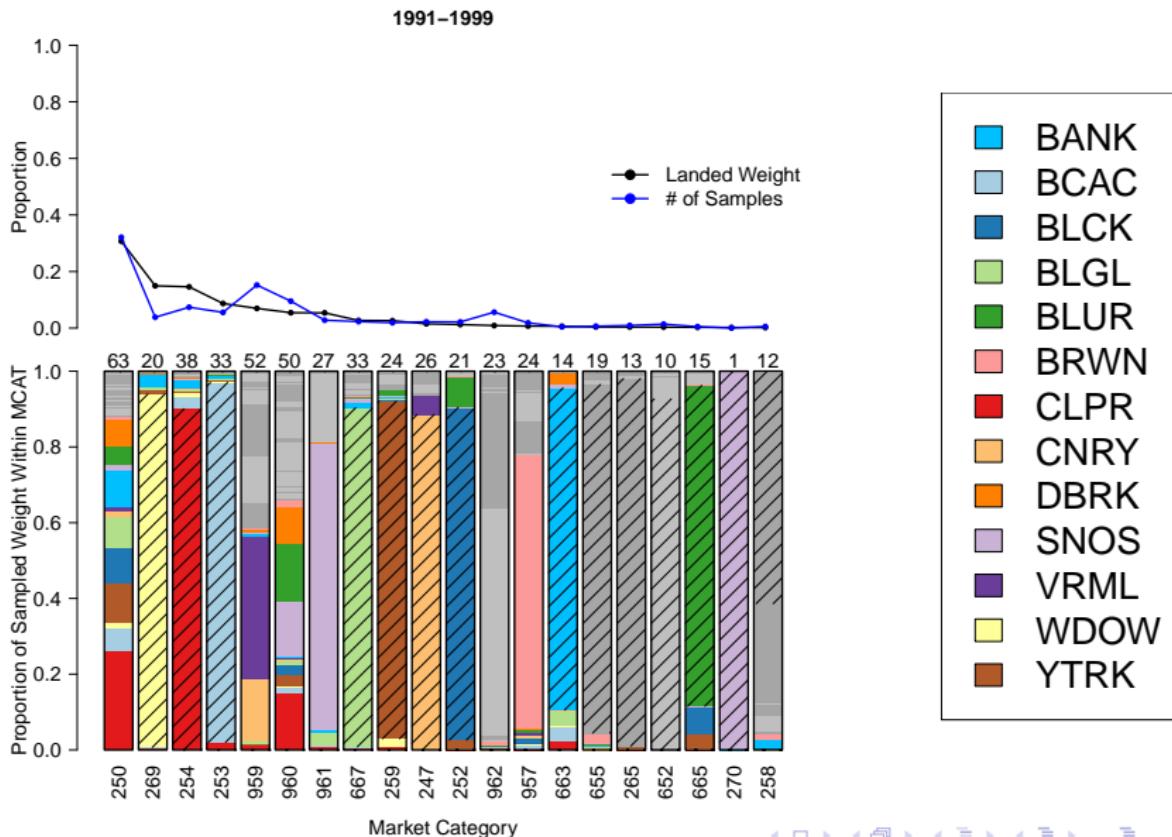
1983-1990
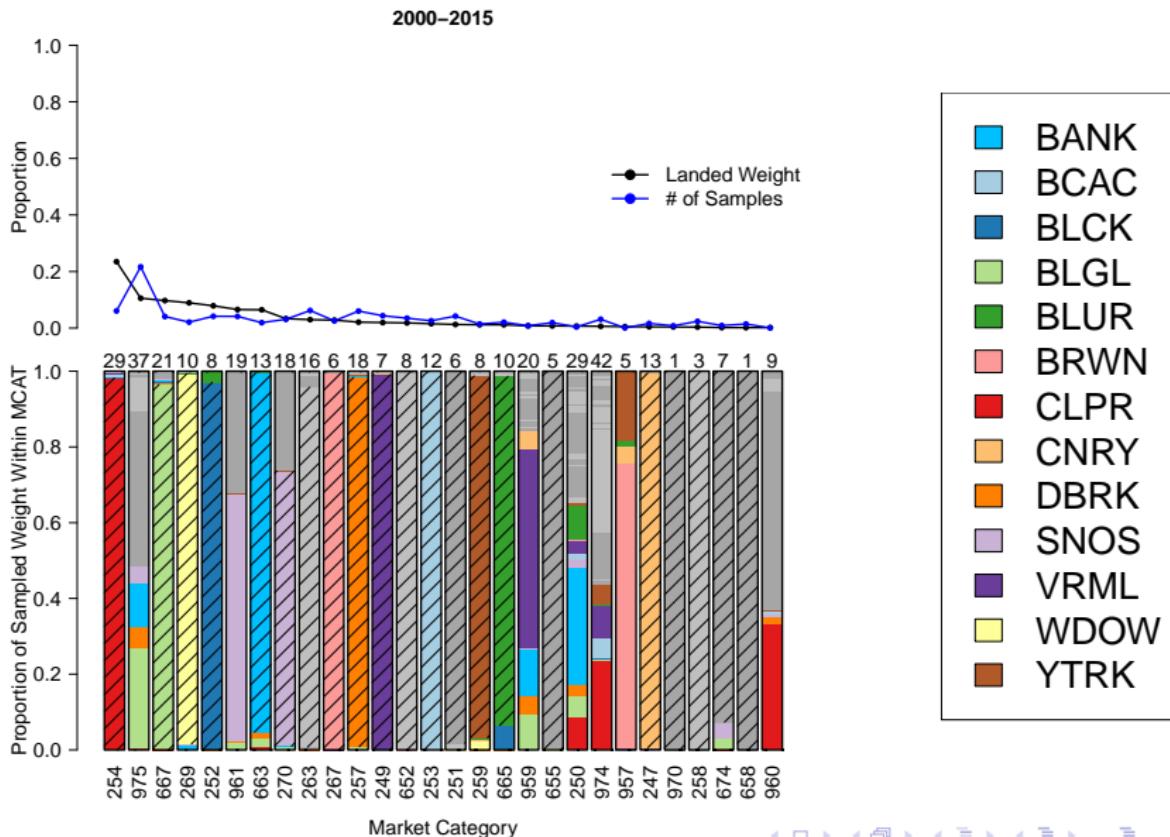
MCAT 956					
ω	0.26	0.21	0.19	0.11	0.10
CRS					
ERK					
BRG					
BDG					
OSF					
MNT					
MRO					
OSB					
OLA					
OSD					

MCAT 269					
ω	0.64	0.12	0.07	0.06	0.04
CRS					
ERK					
BRG					
BDG					
OSF					
MNT					
MRO					
OSB					
OLA					
OSD					

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Conclusion

- Red stuff
- Species Composition Proof

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1991–1999

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2000–2015

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ρ Posterior

MCAT	Mean	Median	SD
250	0.55	0.55	0.004
253	0.39	0.39	0.001
262	0.35	0.35	0.008
265	0.64	0.64	0.002
269	0.52	0.52	0.019
270	0.53	0.54	0.020
956	0.35	0.35	0.007
959	0.47	0.47	0.070
961	0.55	0.55	0.004

1978-**1982**

MCAT	Mean	Median	SD
245	0.65	0.65	0.014
250	0.51	0.51	0.002
253	0.47	0.47	0.010
259	0.75	0.75	0.009
262	0.41	0.41	0.001
269	0.57	0.57	0.046
270	0.74	0.75	0.027
663	0.51	0.51	0.001
667	0.49	0.49	0.022
956	0.43	0.43	0.003
959	0.55	0.55	0.004
960	0.45	0.45	0.004
961	0.59	0.59	0.001

1983-**1990**

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v Posterior

MCAT	Mean	Median	SD
250	12915.85	18523.12	8699.87
253	22747.87	23063.76	1535.53
262	20254.41	20506.36	2581.87
265	15846.22	16694.98	7601.15
269	20135.05	19975.15	4667.11
270	19931.96	19955.13	6033.35
956	19659.11	19795.60	1227.99
959	19159.69	13375.80	19256.94
961	18631.44	19498.31	7970.44

1978-1982

MCAT	Mean	Median	SD
245	20211.82	20204.95	1276.83
250	236.03	192.53	134.67
253	20455.18	20140.50	1521.72
259	20246.14	20186.61	898.99
262	20445.49	20348.56	343.70
269	34386.49	25951.03	24030.32
270	20253.34	19908.07	9269.02
663	19563.87	19624.09	331.04
667	20089.55	20078.27	2723.34
956	20581.67	20664.71	913.92
959	19242.41	18707.09	5076.03
960	20059.66	20012.80	1703.89
961	20127.69	20141.04	580.80

1983-1990

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