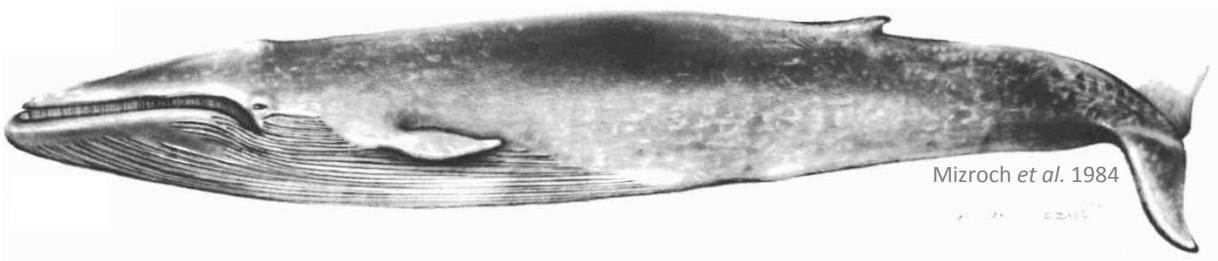


Splitting Historical Blue Whale Catches using Spatial GAMs

Cole Monnahan

1/16/2012

Background/Motivation

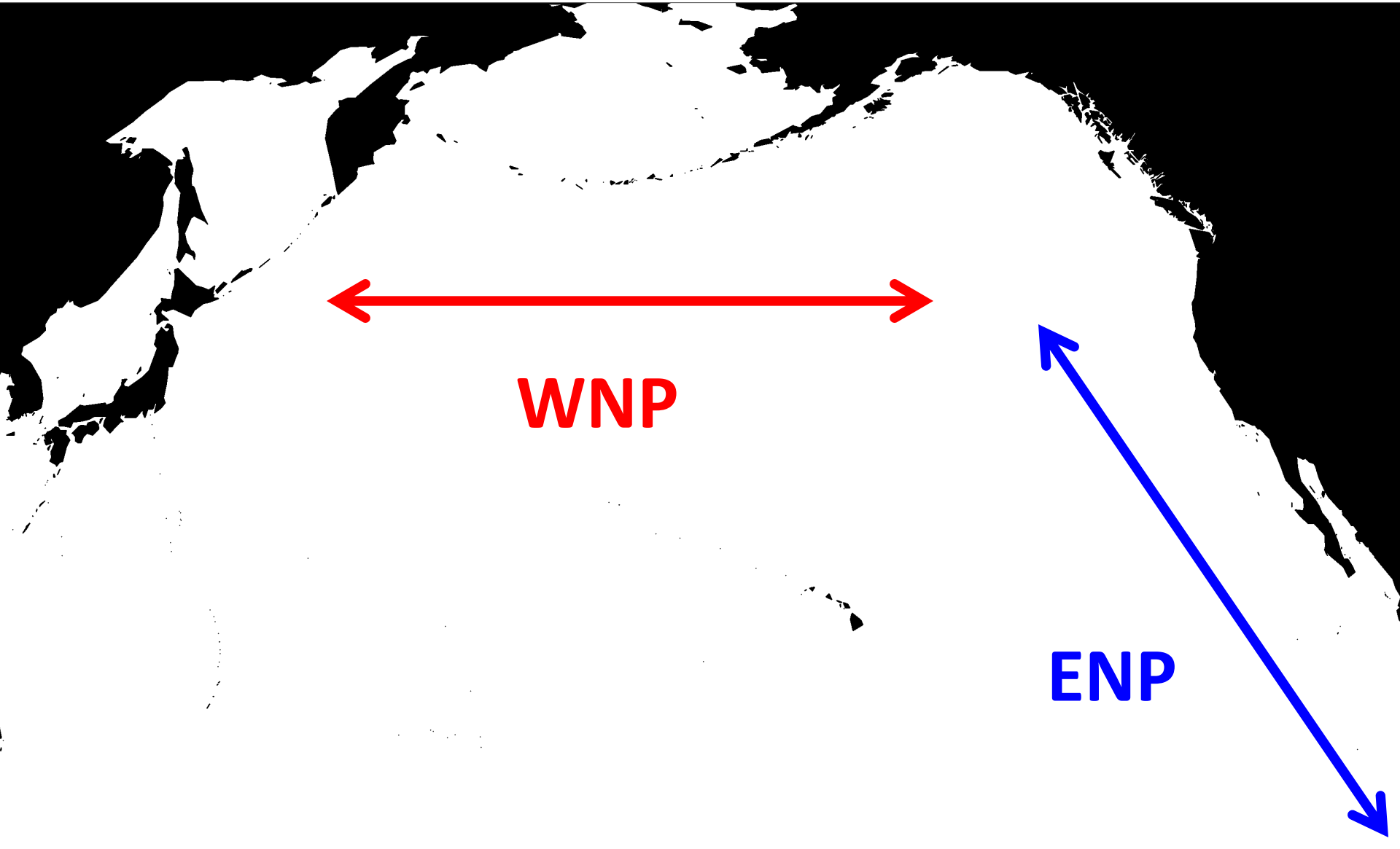
- North Pacific Blue whales (*B. musculus*) were exploited commercially from 1905-1971
- Endangered, but no assessment due in part to **conflated catches**

Themes:

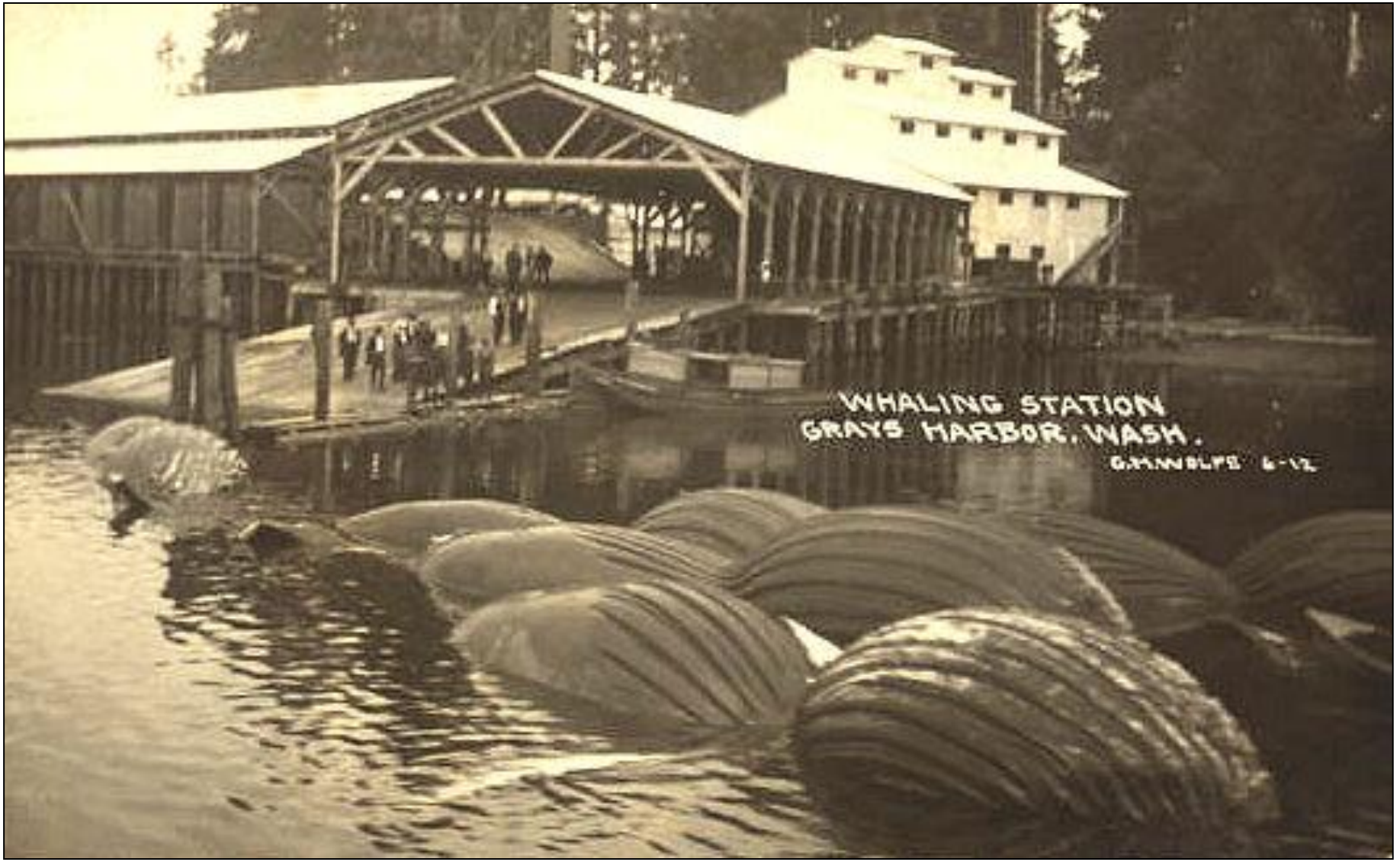
- **2 Stocks:** the eastern (ENP) and western (WNP) based on morphological[1] and acoustic[2] analyses
- **Uncertainty:** date, location, statistical, ecological

[1] Gilpatrick & Perryman 2008, [2] Stafford *et al.* 2001

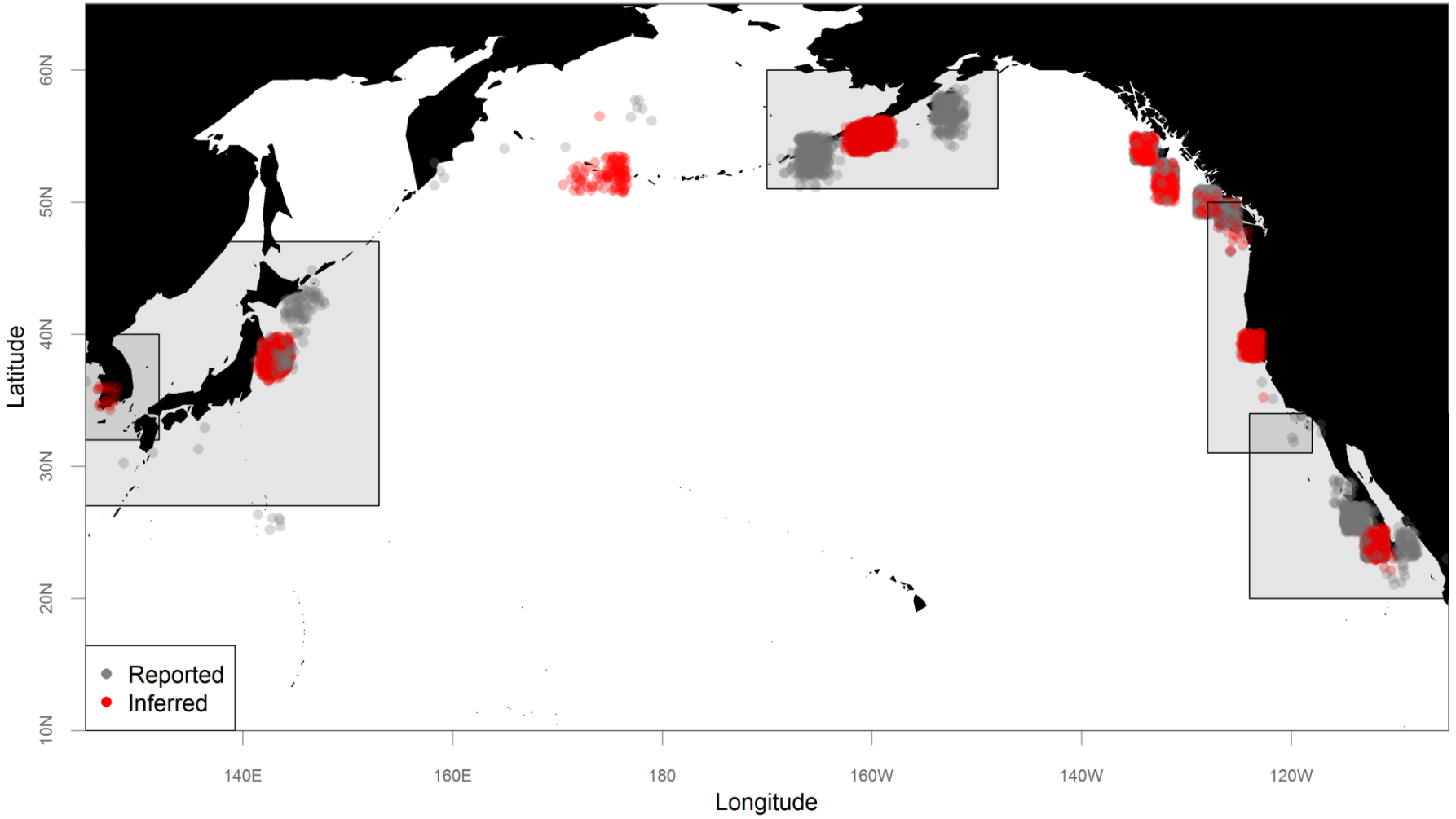
Ecology



Land Stations

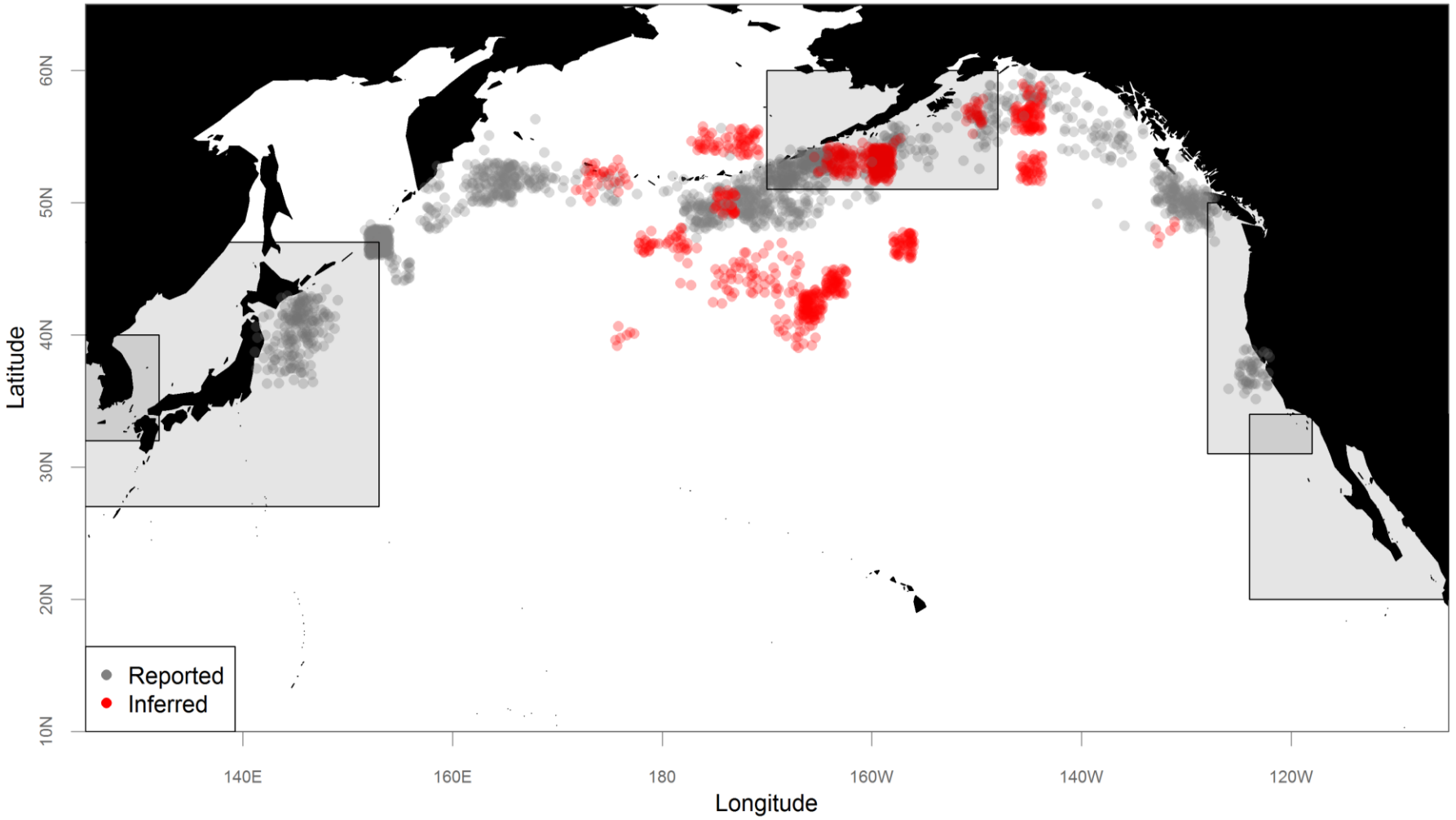


Catches Before 1950

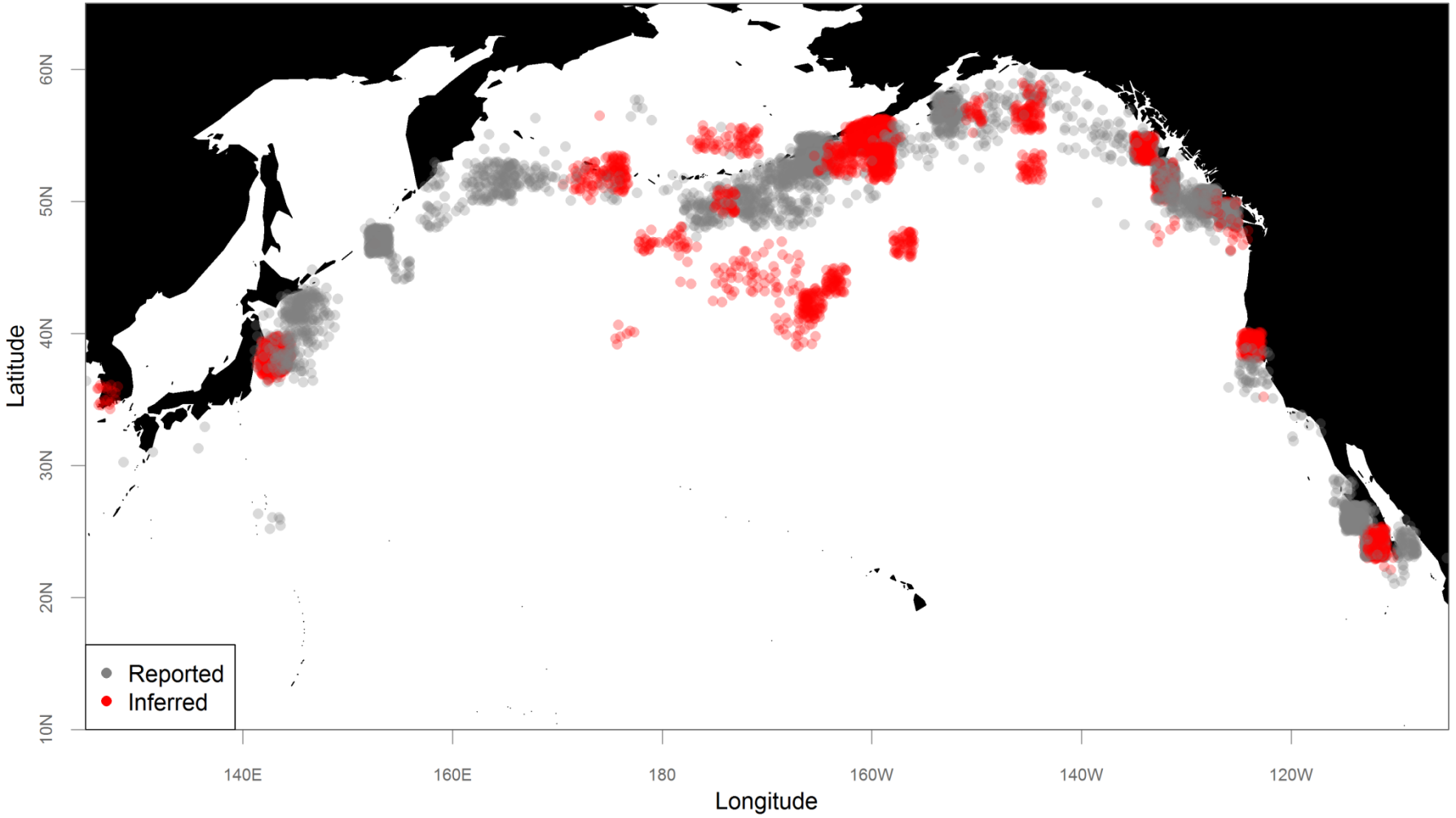


Floating Factories

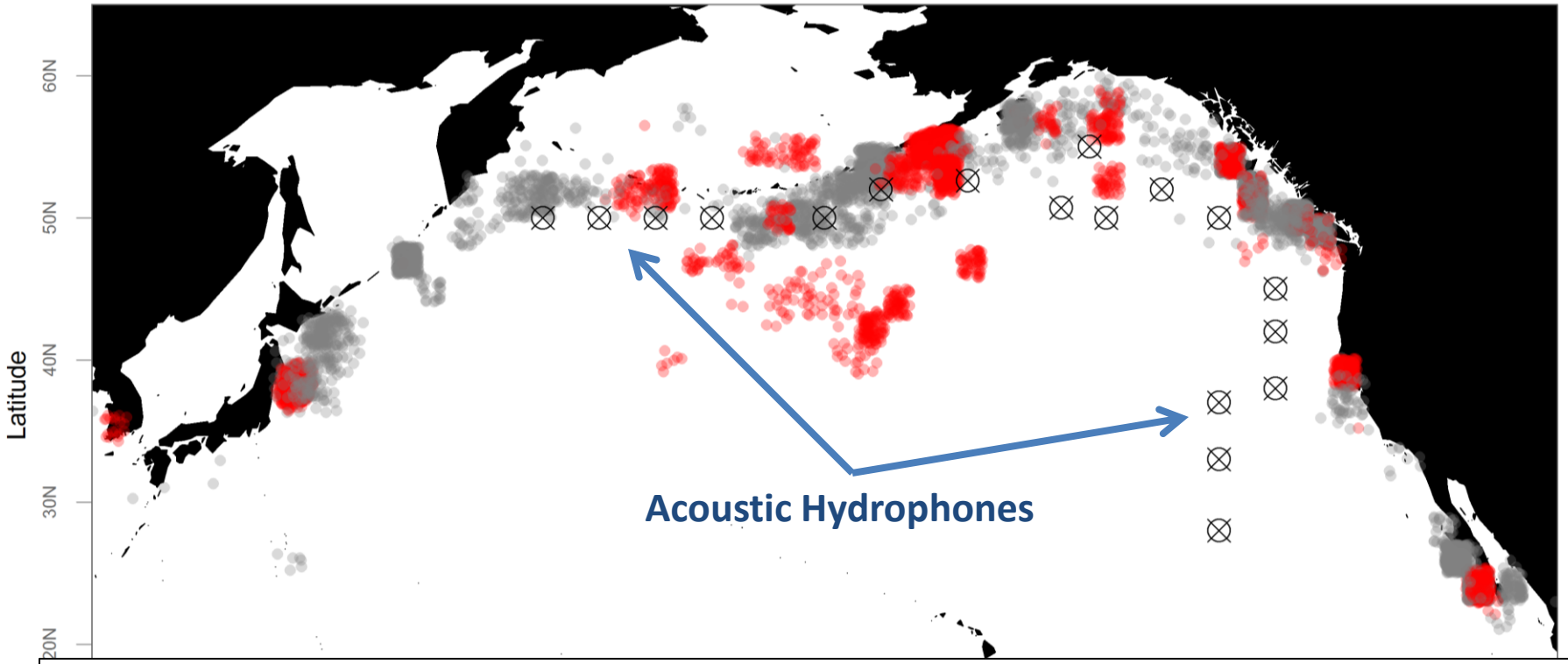
Catches After 1950



Catches from 1905-1971

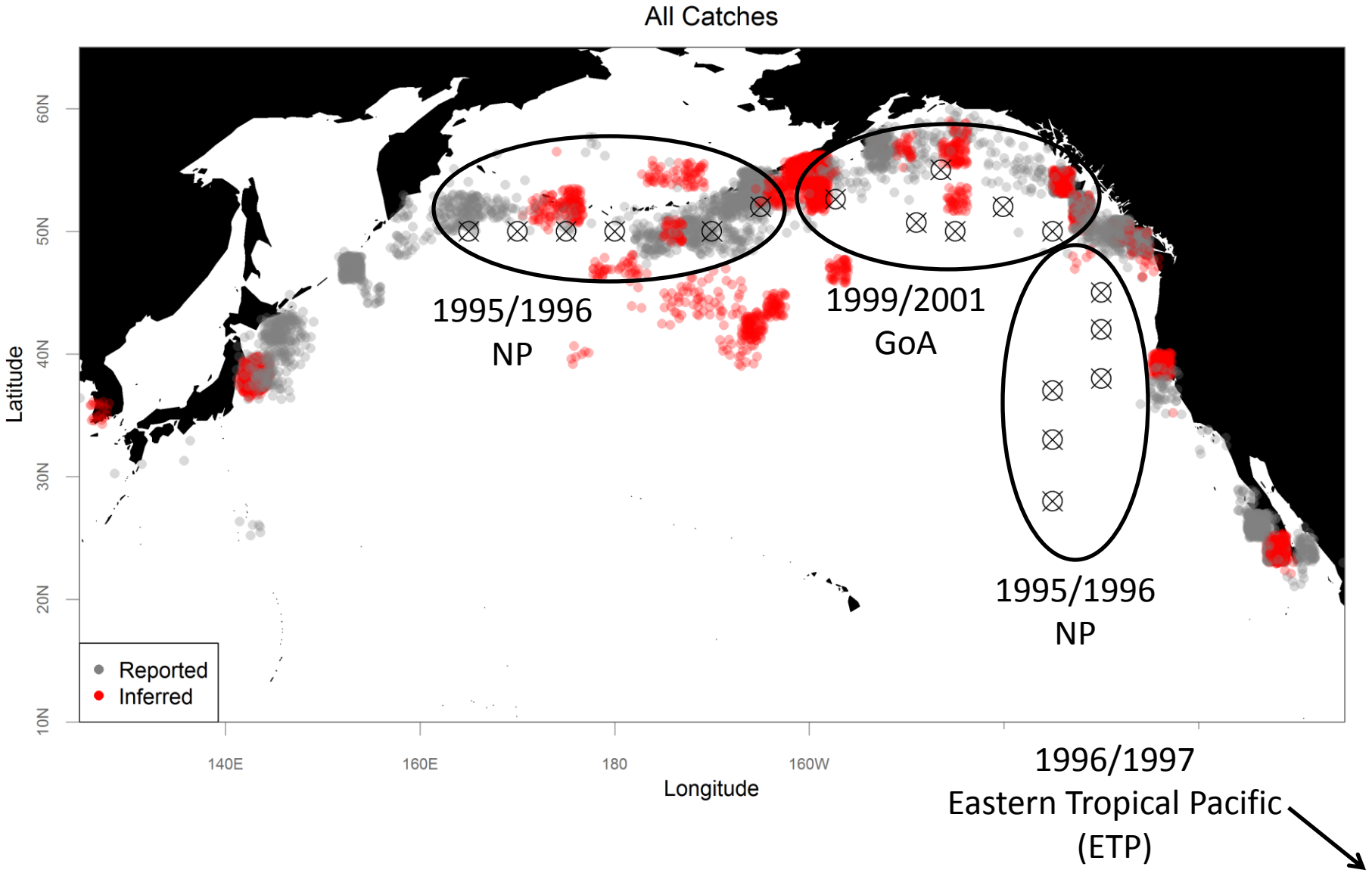


Acoustic Data Locations



Goal: Infer stock identity of catches
(using the acoustic data)

Acoustic Data Dates



Acoustic Spectrograms

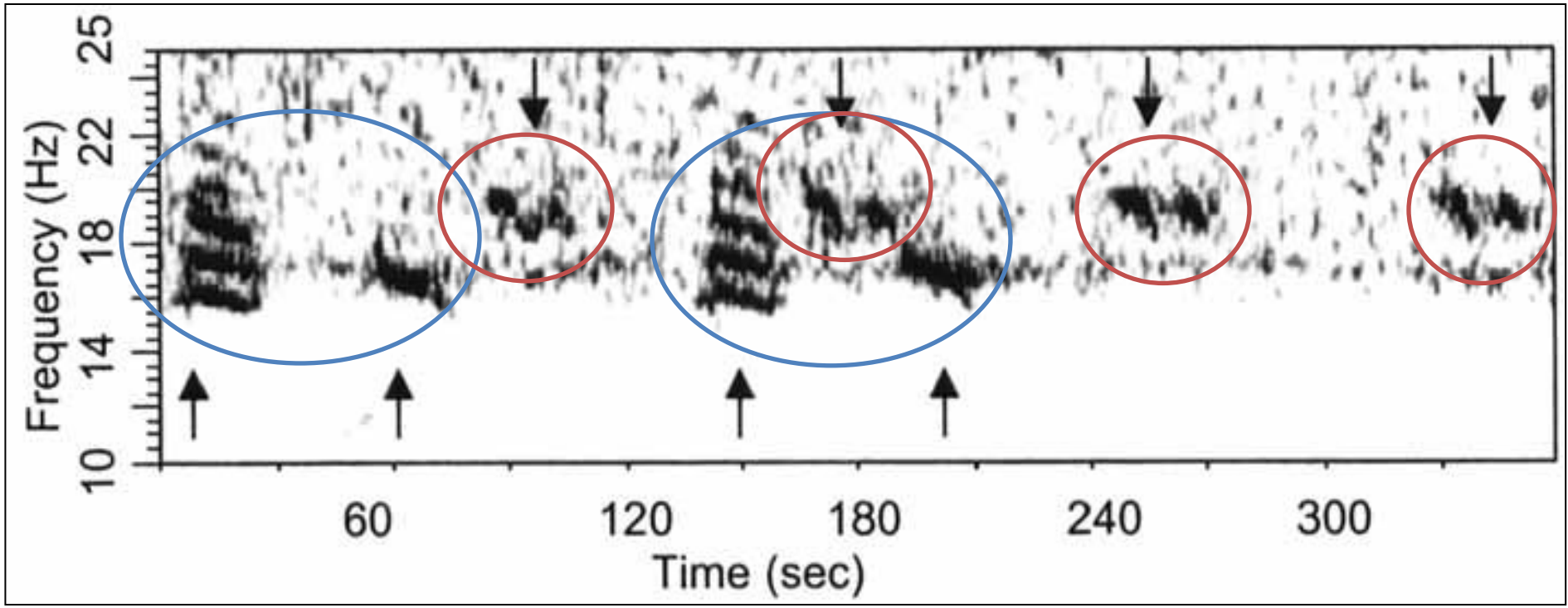
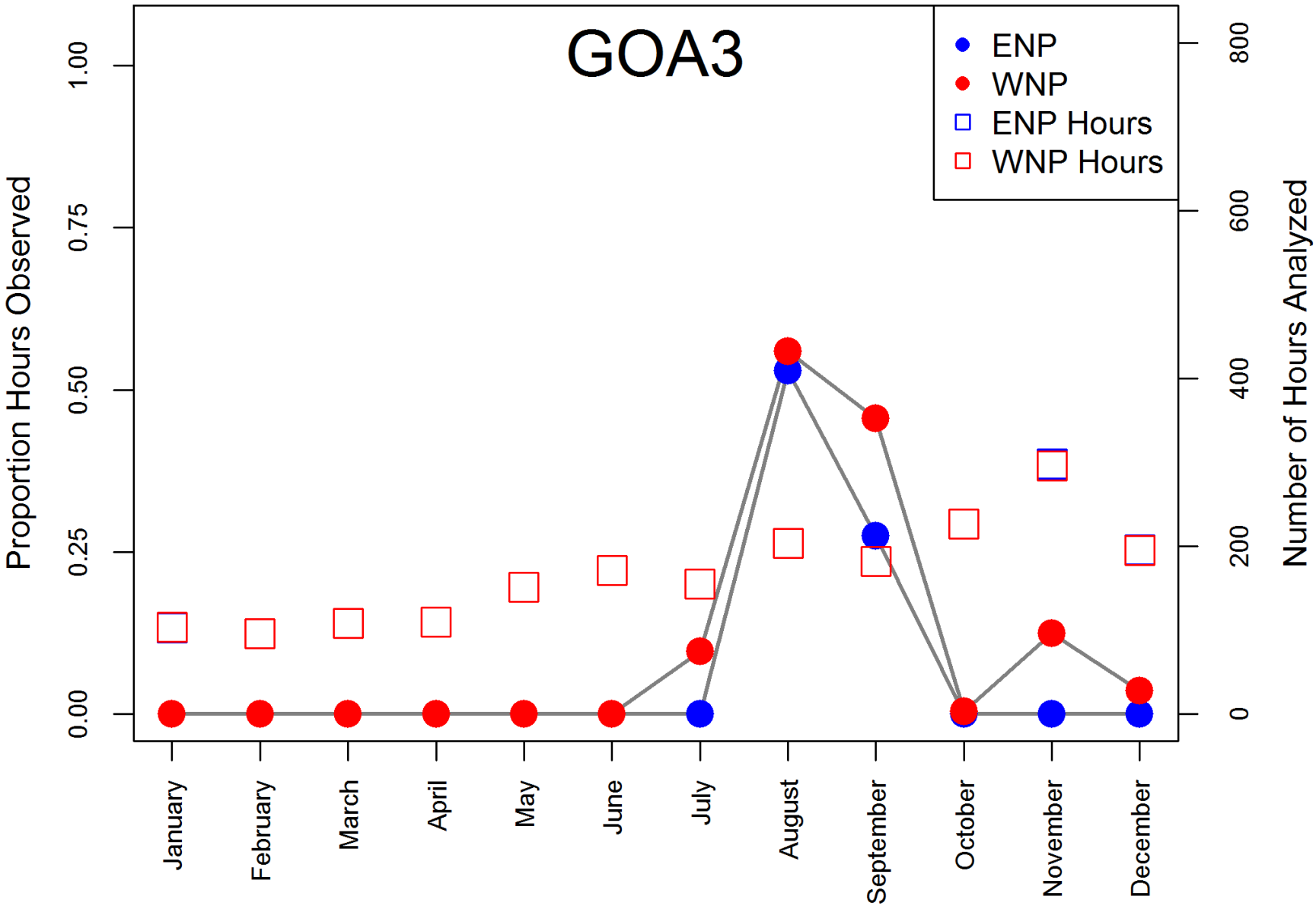
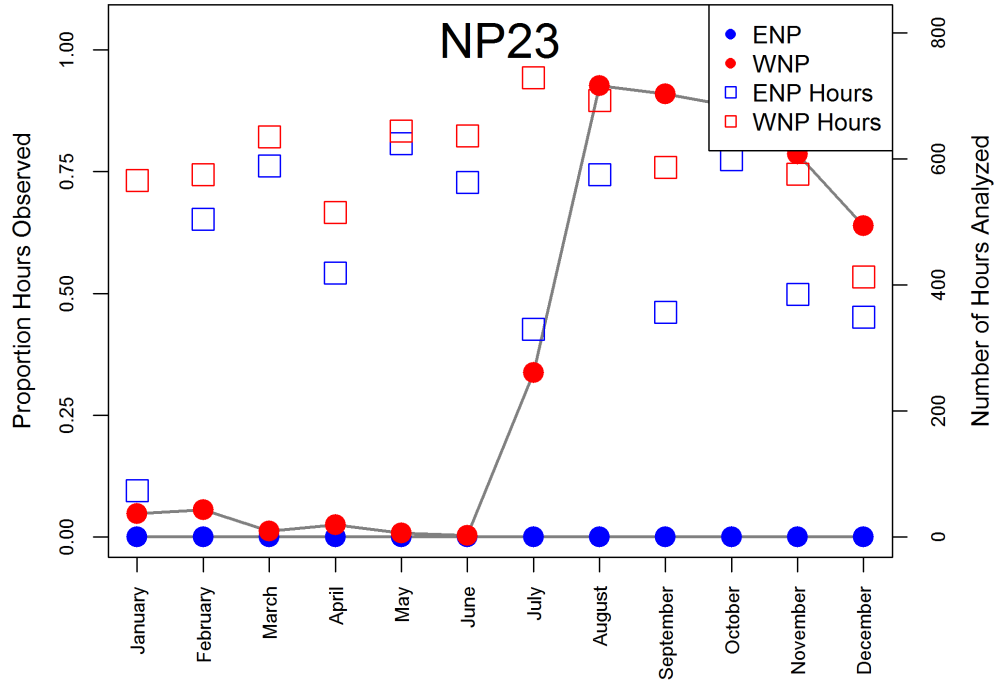
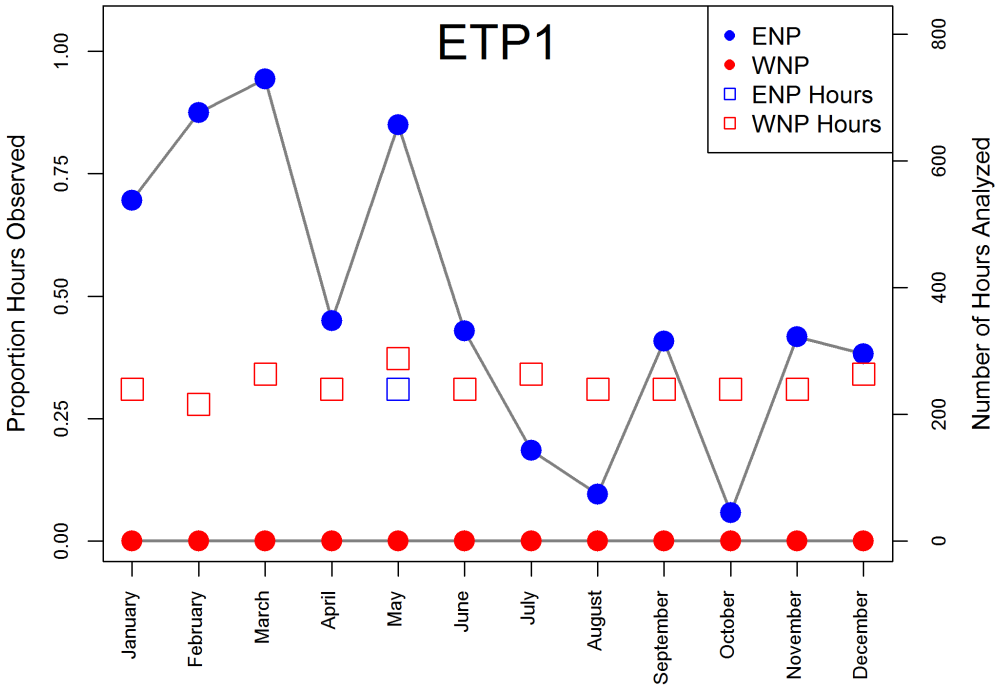


Image from: Stafford 2003, Two types of blue whale calls recorded in the Gulf of Alaska

Acoustic Data







Western population only in western Aleutians

Eastern population only in ETP

Models

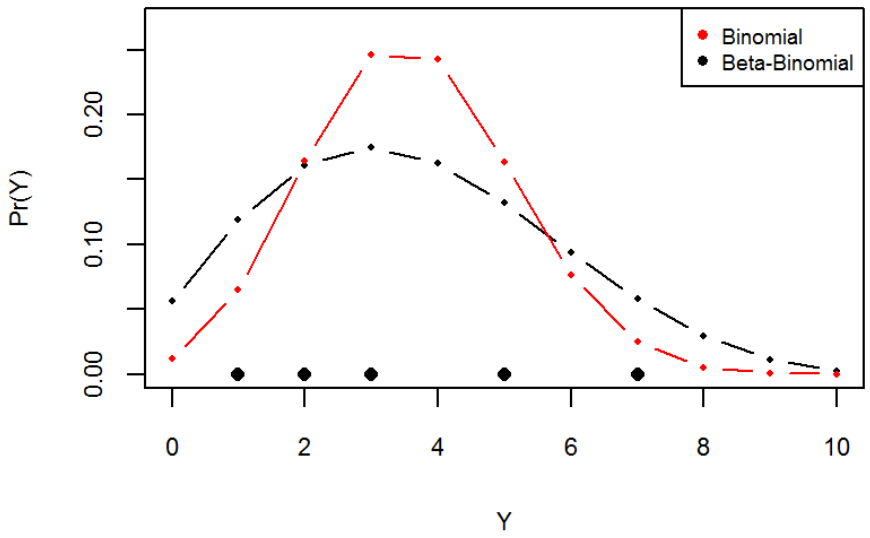
- *A priori* predictors: **Lat/Long and Month** cover the spatial and temporal stock movements
- Generalized Additive Models **(GAM)**
- Over-dispersion is expected, so a **beta-binomial** distribution is used
- ~~Jackknifing~~ bootstrapping to quantify statistical uncertainty of predictions

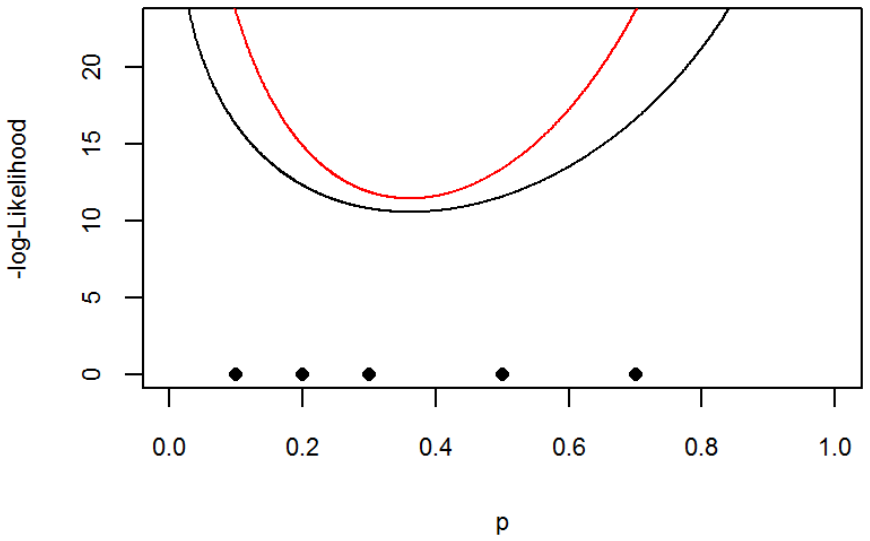
Binomial vs. Beta-Binomial

	Binomial	Beta-Binomial
params	$0 \le p \le 1$	$0 \le p \le 1$ $\sigma > 0$
p.m.f	$\binom{n}{y} p^y (1-p)^{n-y}$	$\binom{n}{y} \cdot \left[\frac{\Gamma\left(\frac{1}{\sigma}\right)\Gamma\left(y+\frac{p}{\sigma}\right)\Gamma\left(n+\frac{1-p}{\sigma}-y\right)}{\Gamma\left(n+\frac{1}{\sigma}\right)\Gamma\left(\frac{p}{\sigma}\right)\Gamma\left(\frac{1-p}{\sigma}\right)} \right]$
mean	np	np
variance	$np(1-p)$	$np(1-p)\left[1+\frac{\sigma}{1+\sigma}(n-1)\right]$

Point: σ accounts for over-dispersion

Over-dispersed Binomial





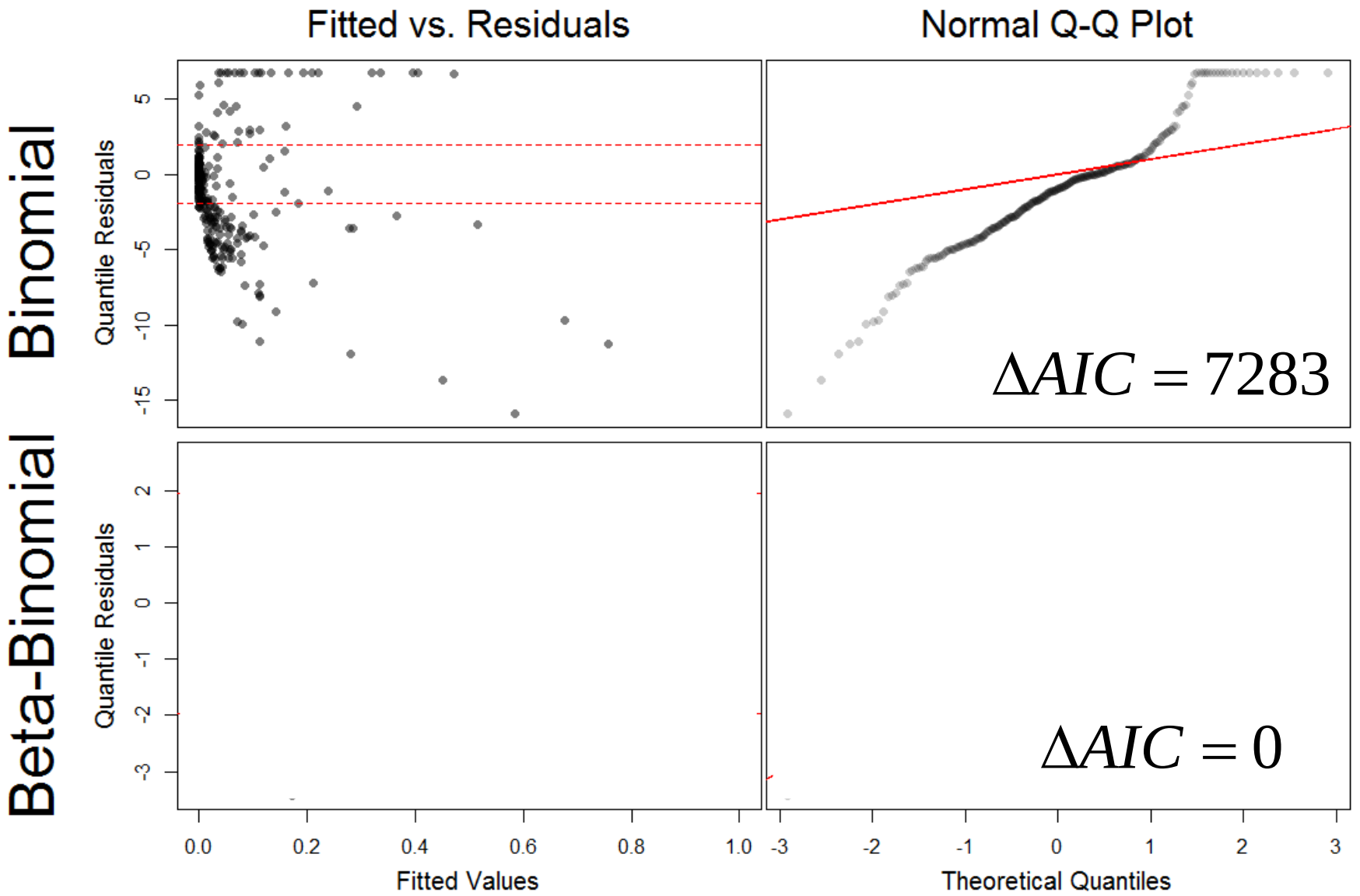
GAM Models

- AIC supports beta-binomial and GAM
- GAMLSS [Rigby & Stasinopoulos 2002] in R
- Separate models for ENP and WNP of form:

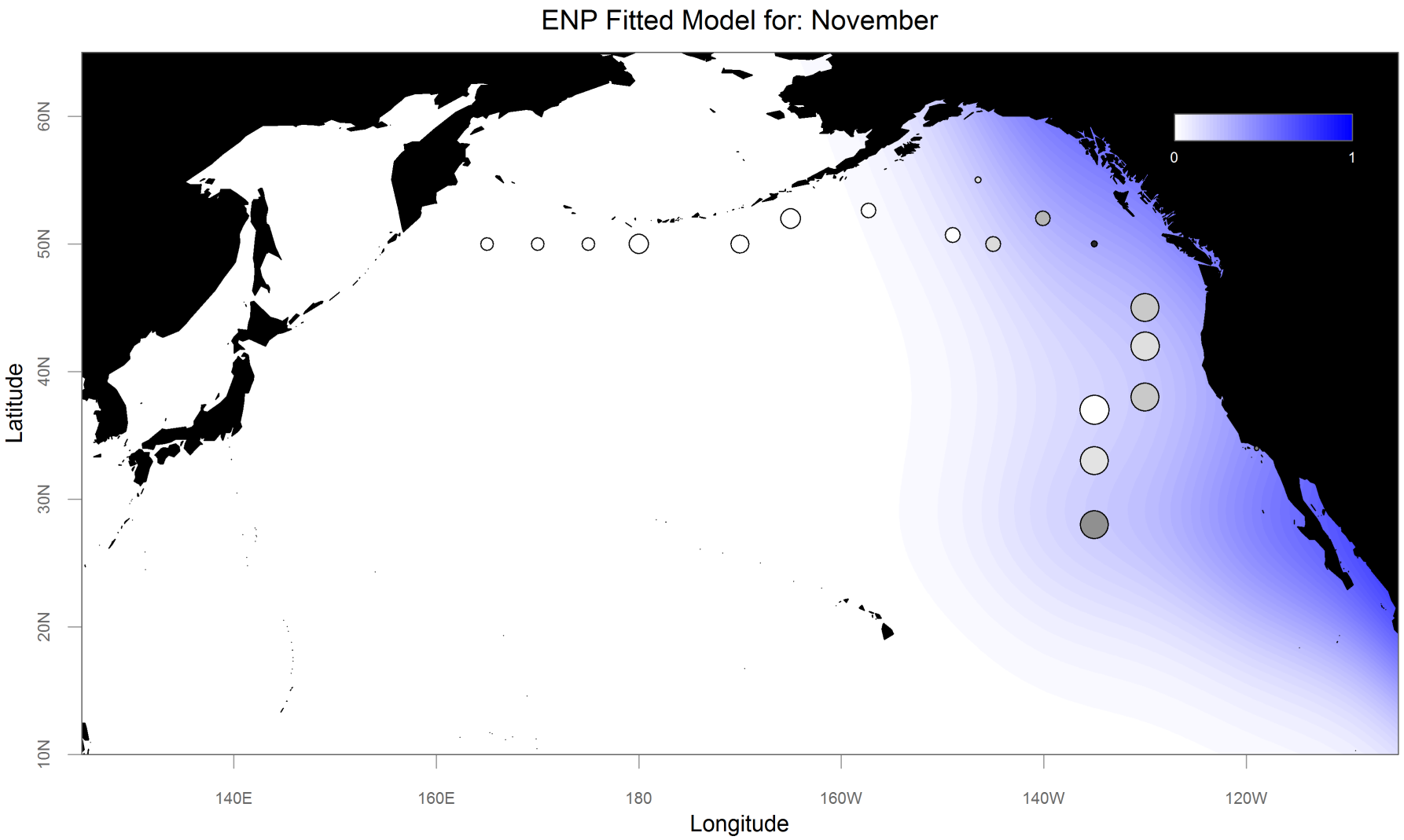
$$\text{logit } p = \text{cs(Long)} + \text{cs(Lat)} + \text{Month}$$
$$\log \sigma = \text{cs(Long)} + \text{cs(Lat)} + \text{Month}$$

The model predicts: the **probability of observing a call** at a given location/month in an hour. $= p_{ENP}$ or p_{WNP}

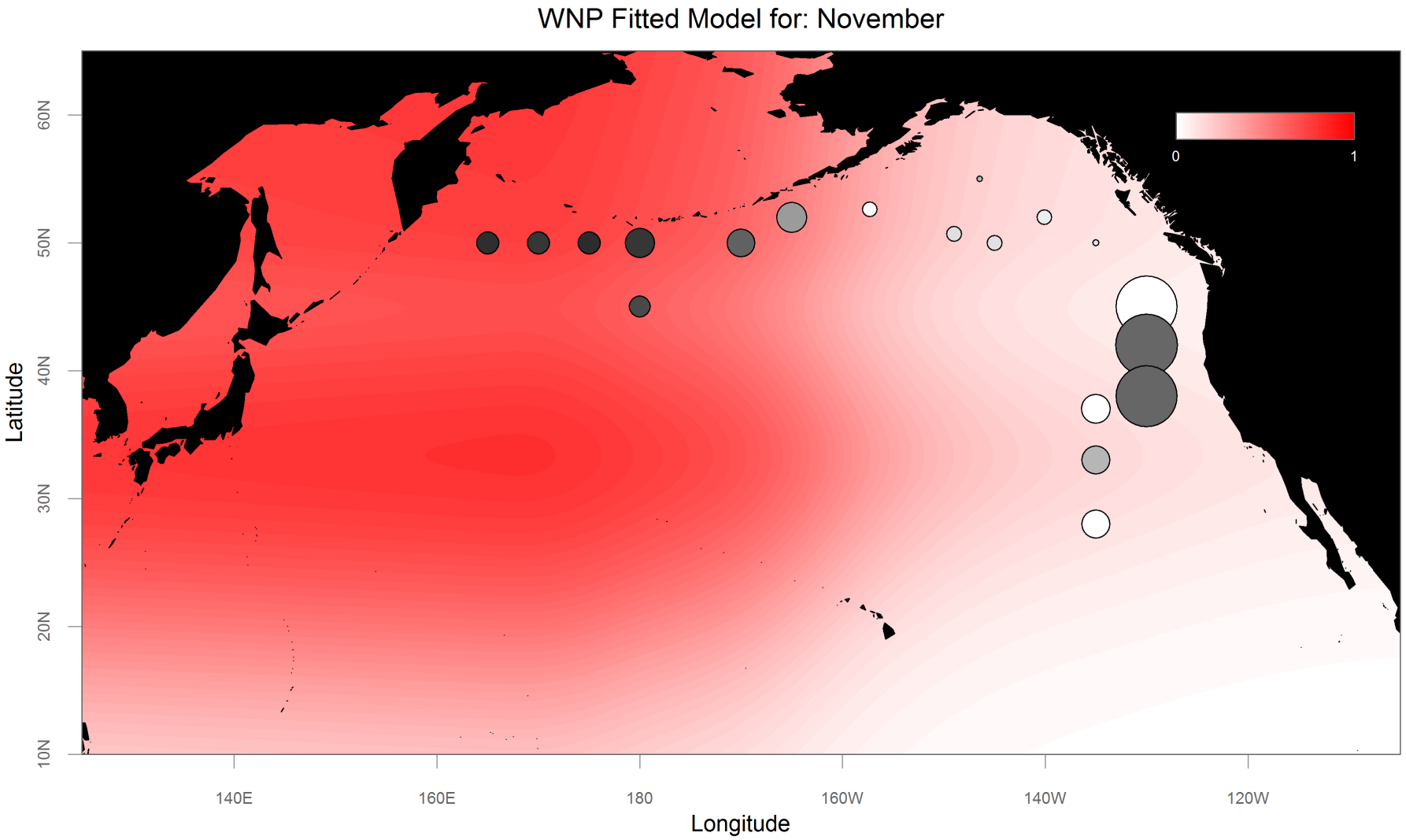
Residuals for ENP Models



Eastern Model Surface



Western Model Surface



Final Model

The final probability of catch being ENP is then:

$$\frac{p_{ENP}}{p_{ENP} + p_{WNP}} = \Pr\left(ENP \mid \text{observed}\right) \approx \Pr(\text{Catch} = ENP)$$

Ecological Assumptions:

1. Populations call at the same rates
2. Relative population sizes stable over decades
3. Movement patterns stable over many decades
4. AB song distribution reflects all demographic groups

Ecological Uncertainty

$$\Pr(ENP) = \Pr(\text{Catch is } ENP \mid \text{month, location})$$

$$= \frac{density_{ENP}}{density_{ENP} + density_{WNP}}$$

$$\approx \frac{\alpha_{ENP} p_{ENP}}{\alpha_{ENP} p_{ENP} + \alpha_{WNP} p_{WNP}}$$

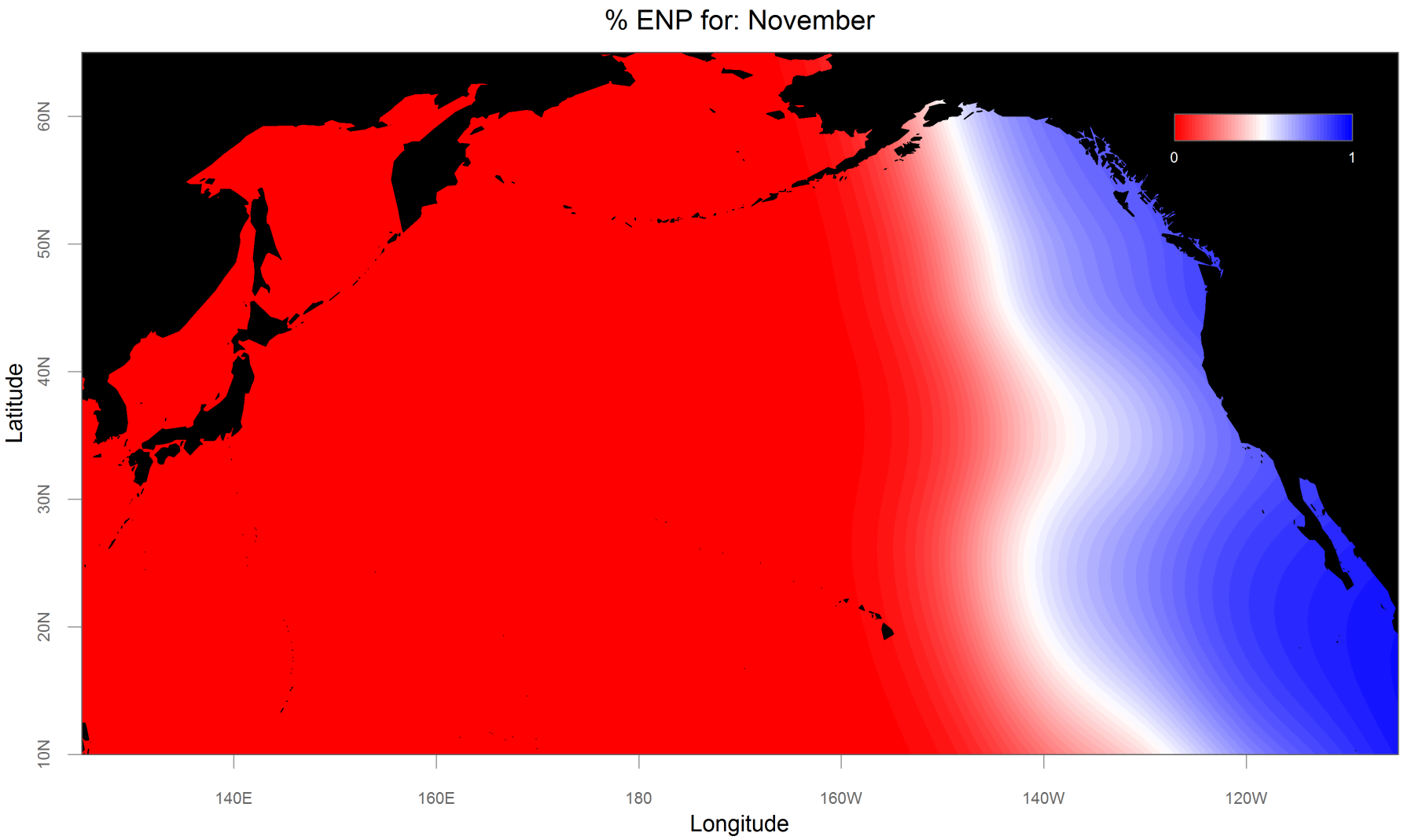
$$= \frac{p_{ENP}}{p_{ENP} + \alpha p_{WNP}}$$

Deviations from α=1 lead to **unexplained uncertainty**

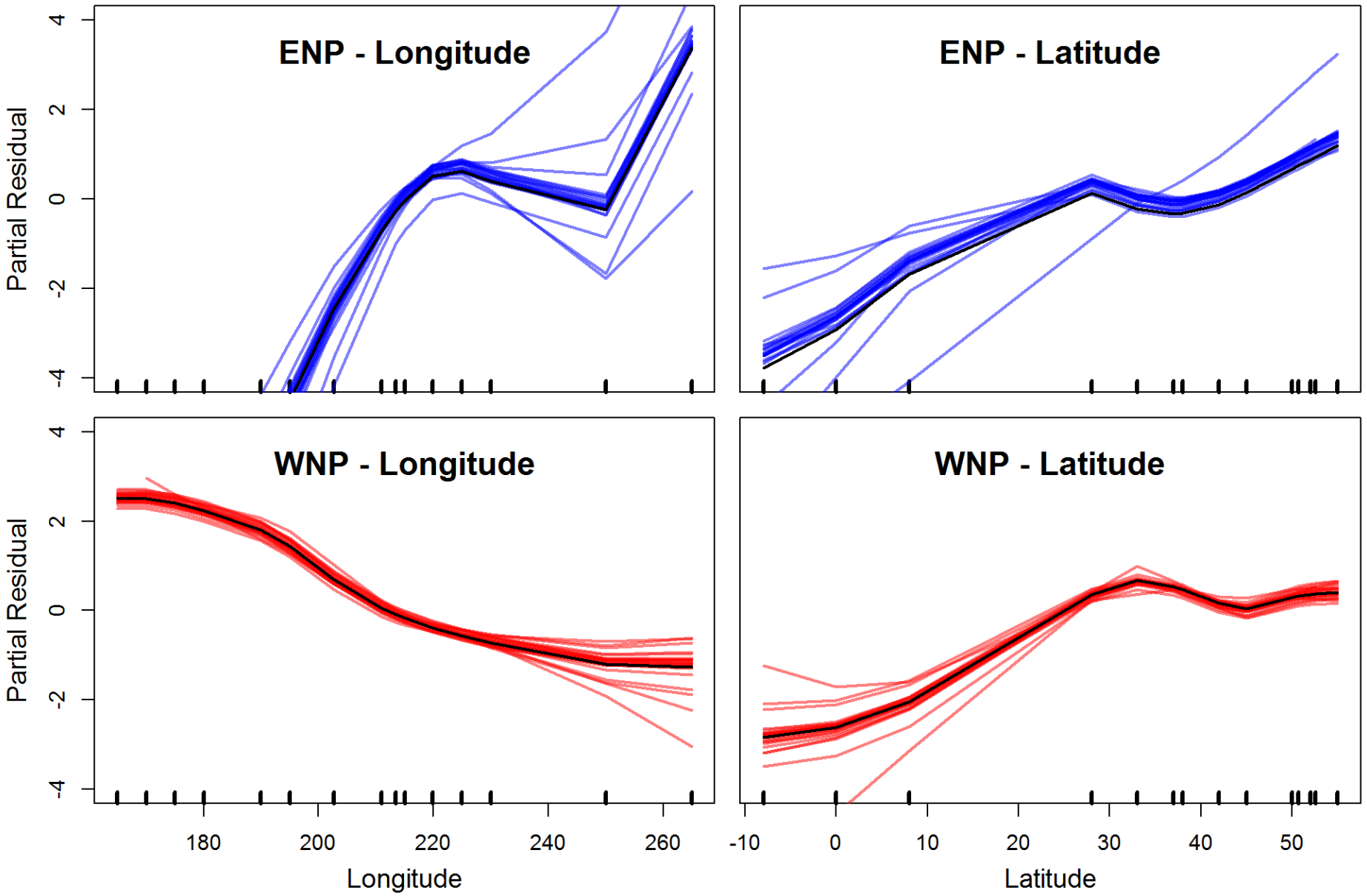
⇩

Vary α to explore sensitivity to assumptions

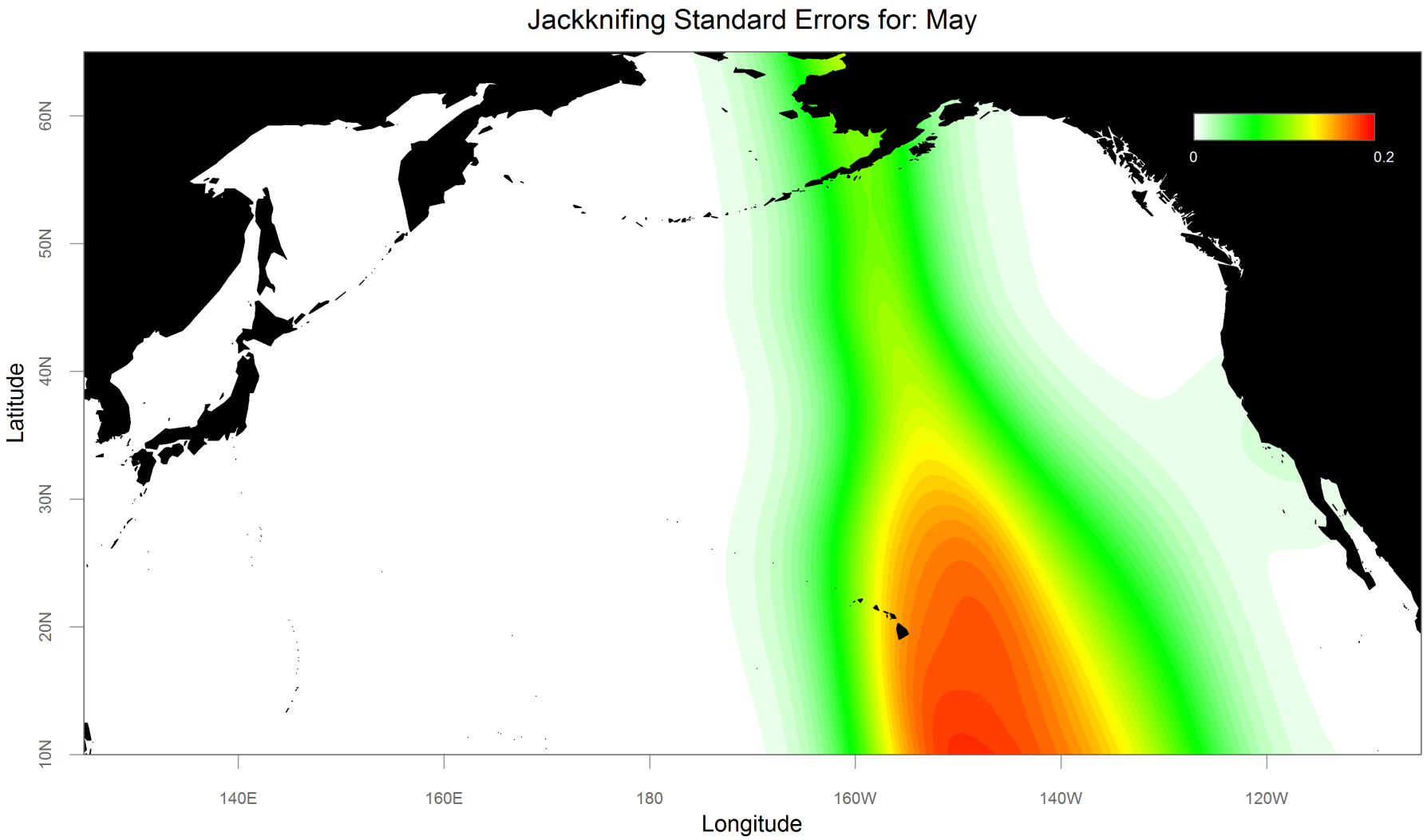
Probability of Eastern (α=1)



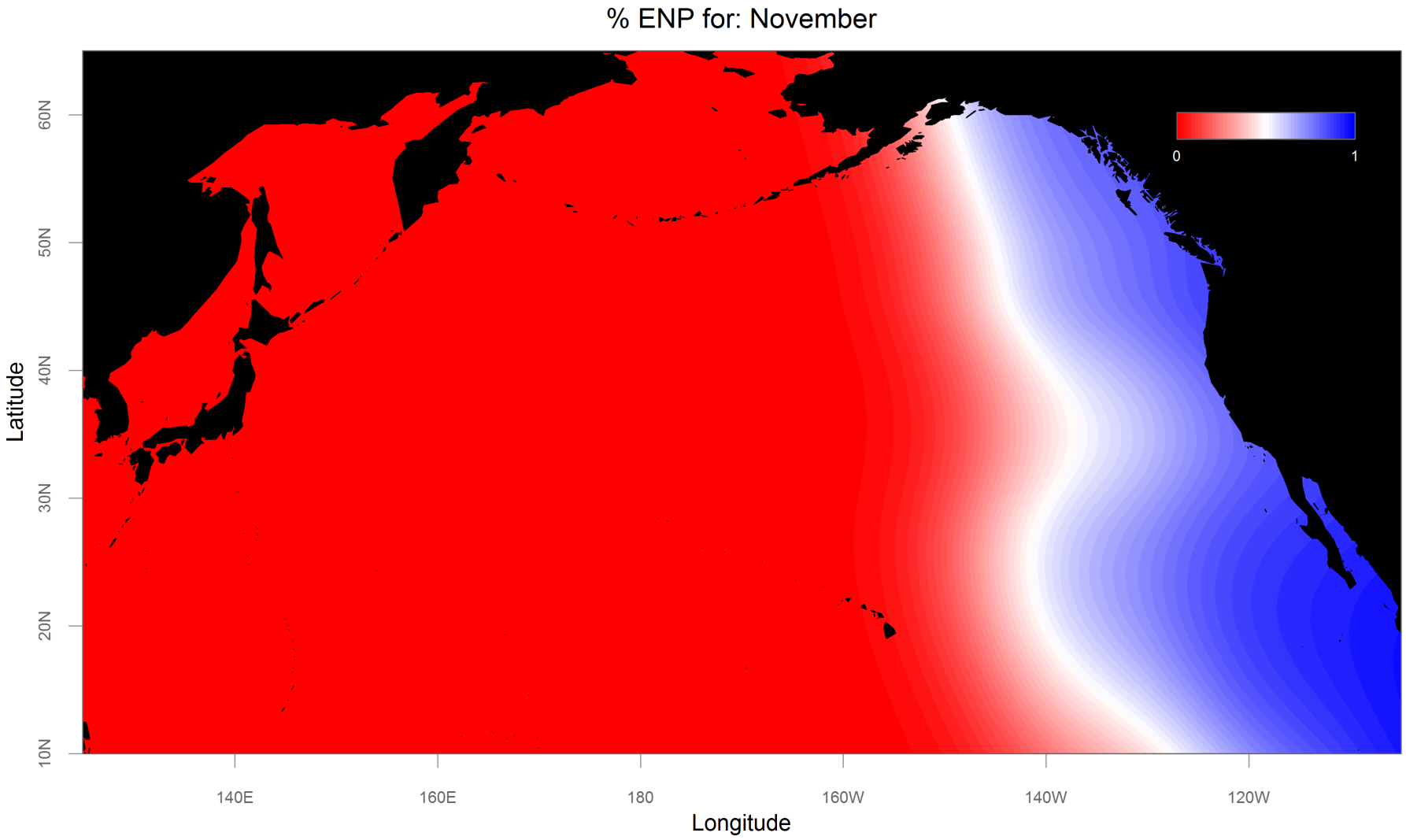
Statistical Uncertainty: Jackknifing



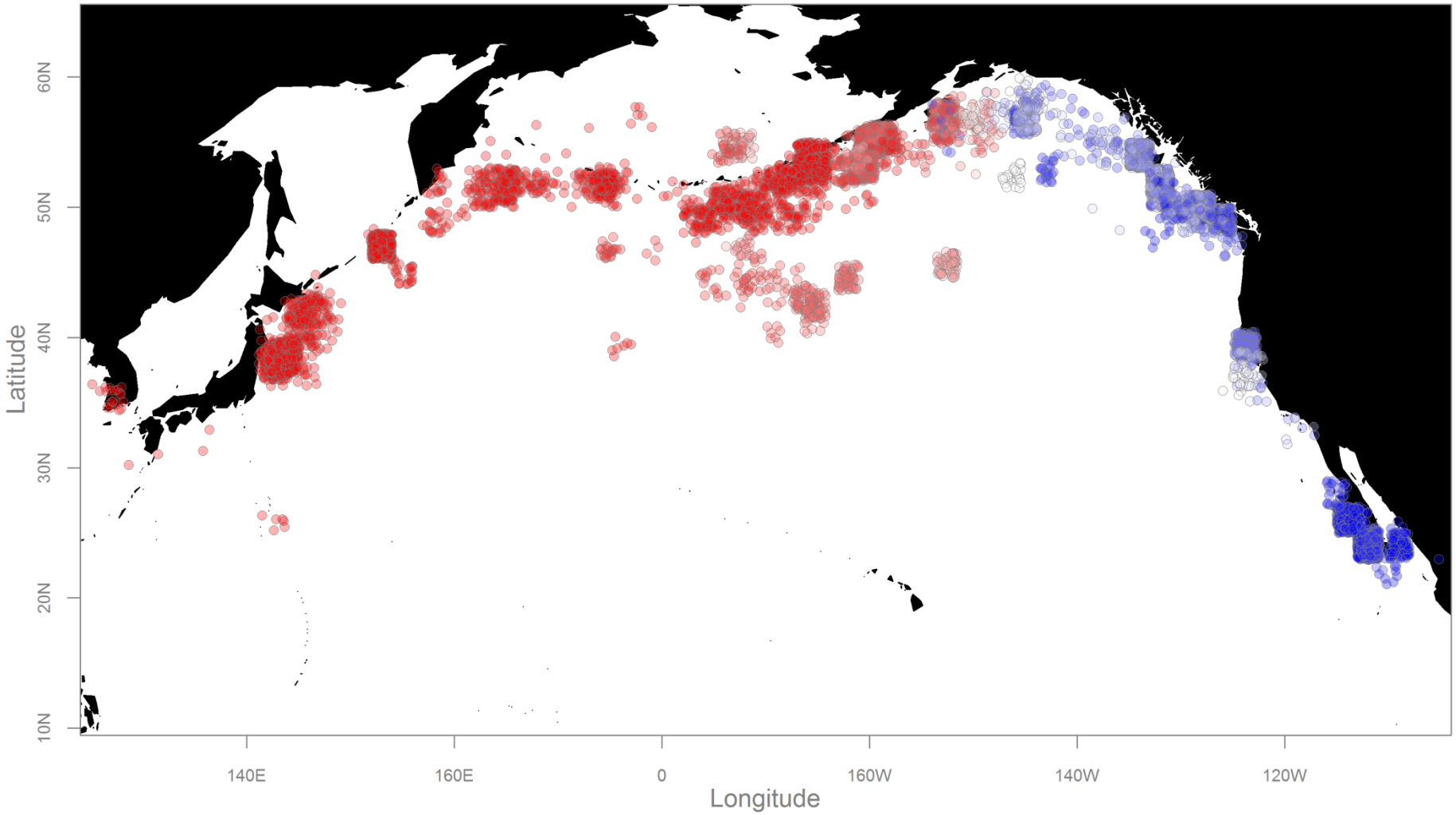
Jackknifed Errors: May



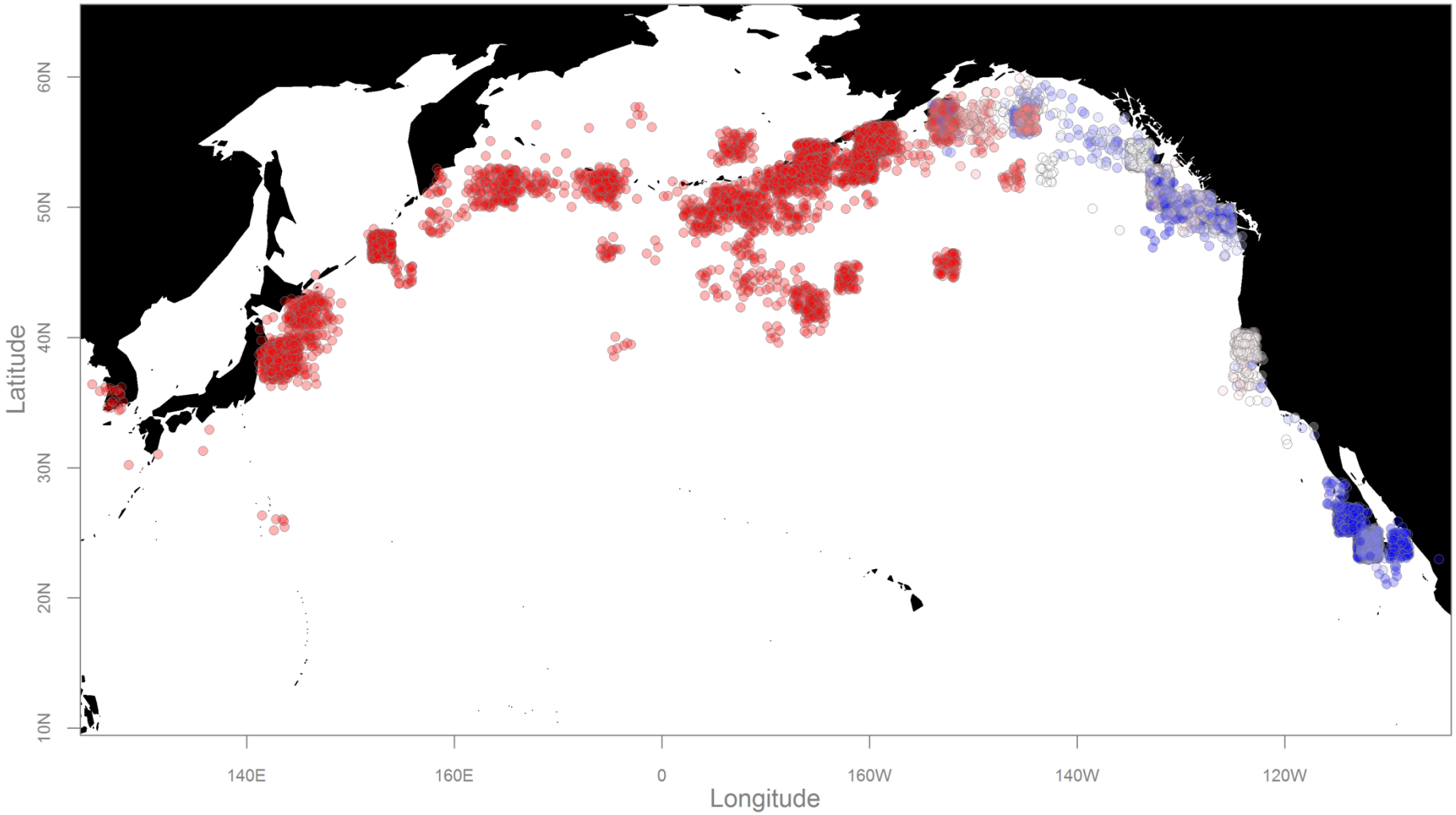
Probability of Eastern (α=1)



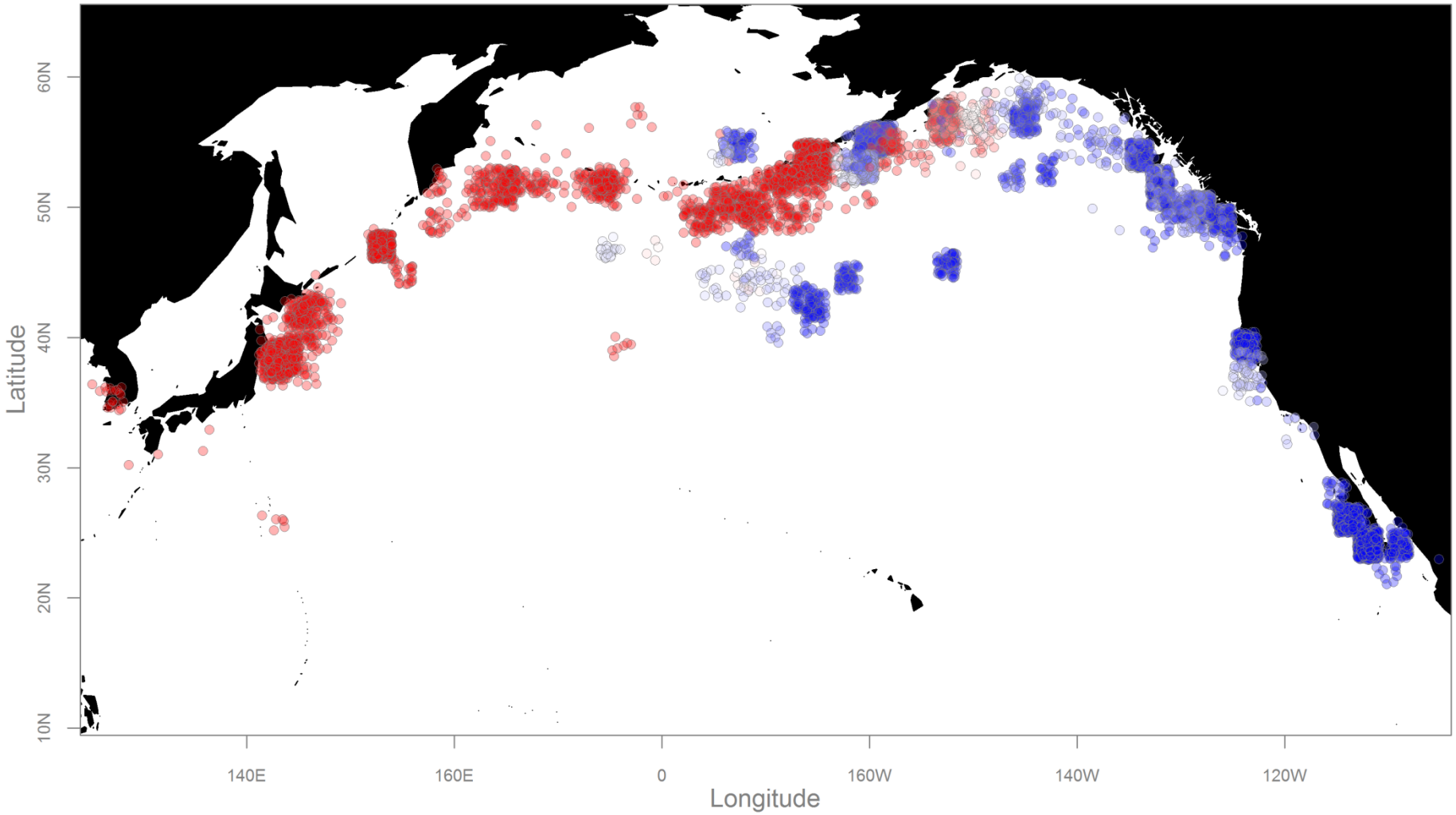
Results: Best Estimate



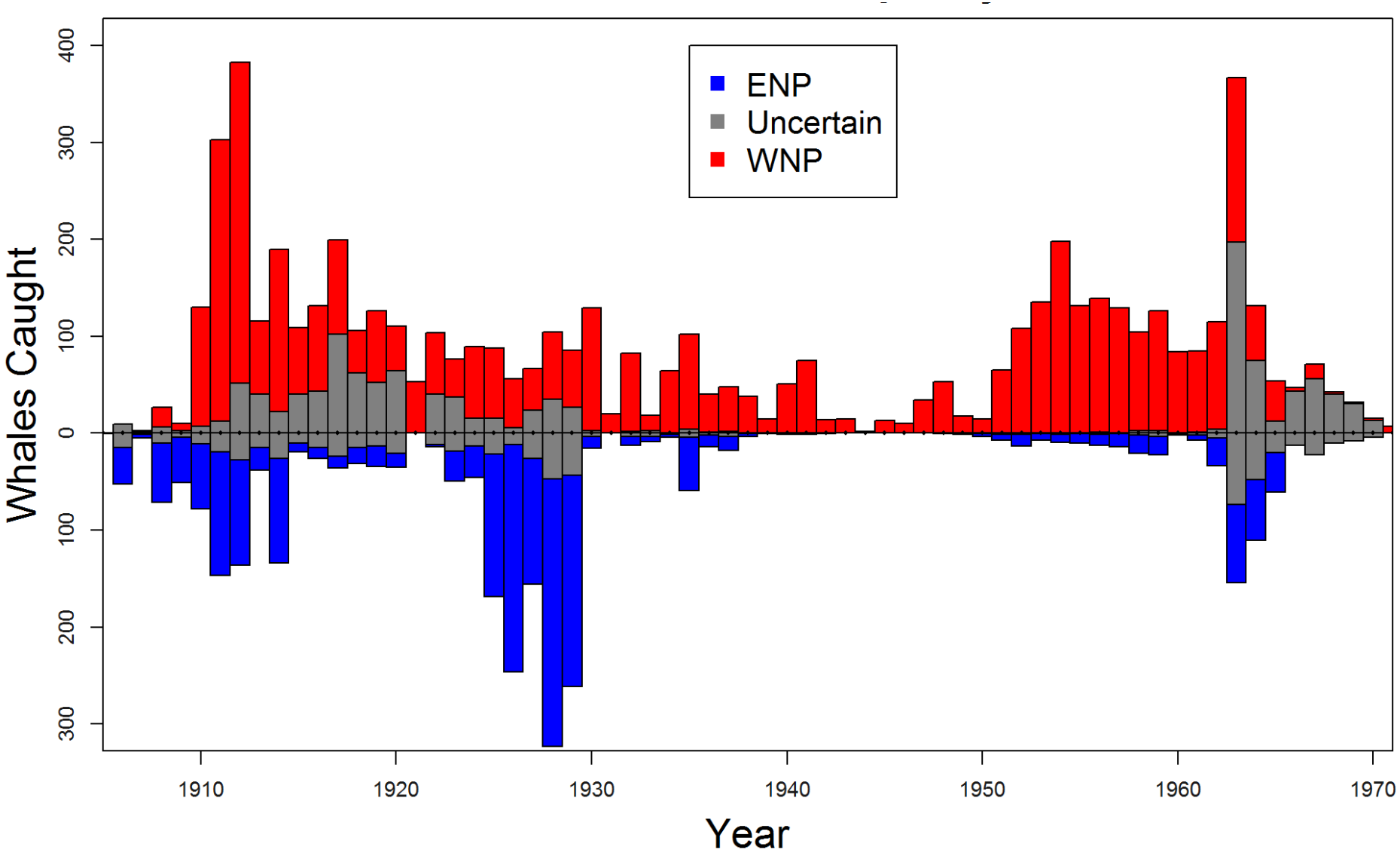
Results: Min ENP



Results: Max ENP



Final Results



Conclusions

1. This approach splits the catches and tries to accurately **quantify the uncertainty**

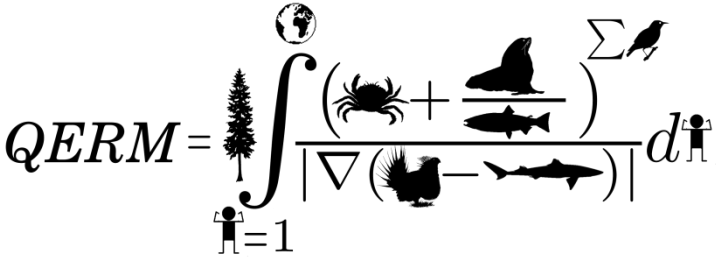
2. With more data, the ecological assumptions could be tested. But sensitivity analyses are best option.

3. It allows assessment of ENP (chapter 2!)…and maybe WNP in the future

Acknowledgements

- **Trevor Branch**: Advice and funding
- International Whaling Commission (**IWC**): Provided annual catch and individual database.
- **Kate Stafford** (UW Applied Physics Lab): Raw acoustic data on call types (+ advice).
- **Yulia Ivashchenko** (NMML): Providing Soviet catch data
- **Andre Punt** (UW SAFS): Suggesting the beta-binomial GAM

And of course….



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