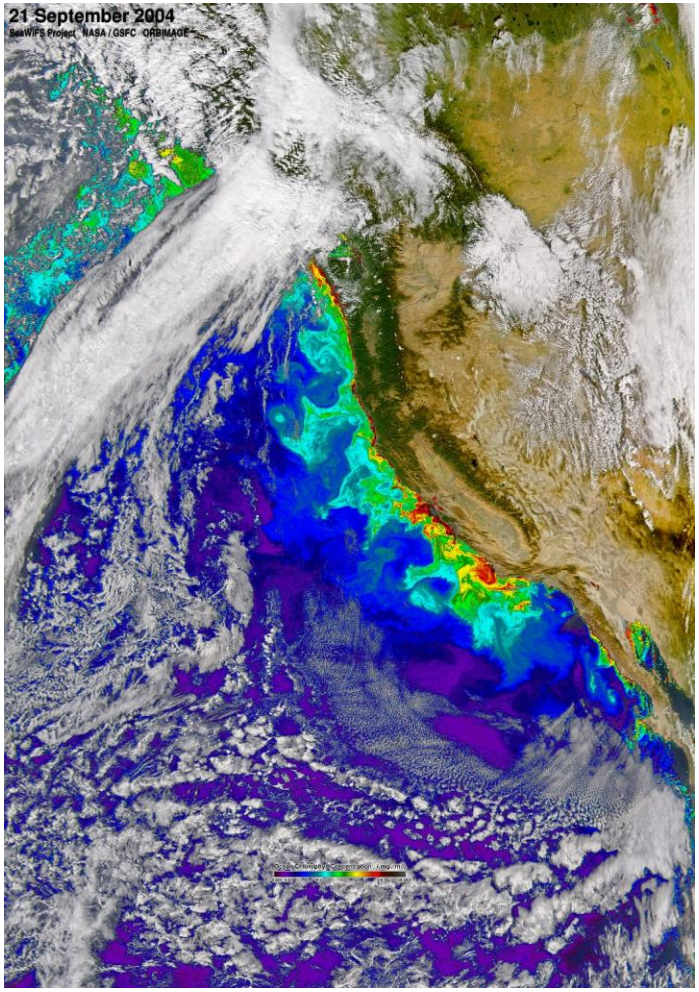
Estimating growth rates and inter-colony structure of harbor seals at Point Reyes National Seashore

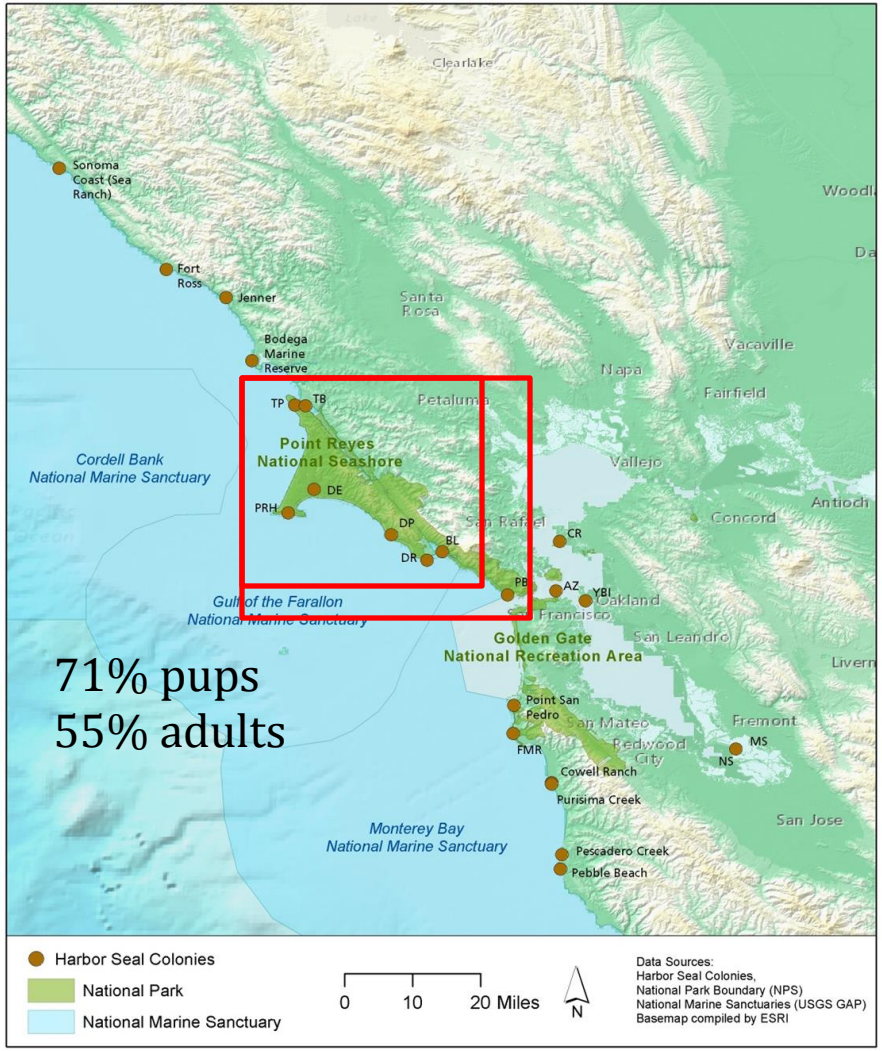
Ben Becker, Sarah Codde, Gabriela Reyes, and Sarah Allen
Point Reyes National Seashore, National Park Service

Marine mammals are sentinels of the sea (Moore 2008)

Indicators of the condition of marine ecosystems

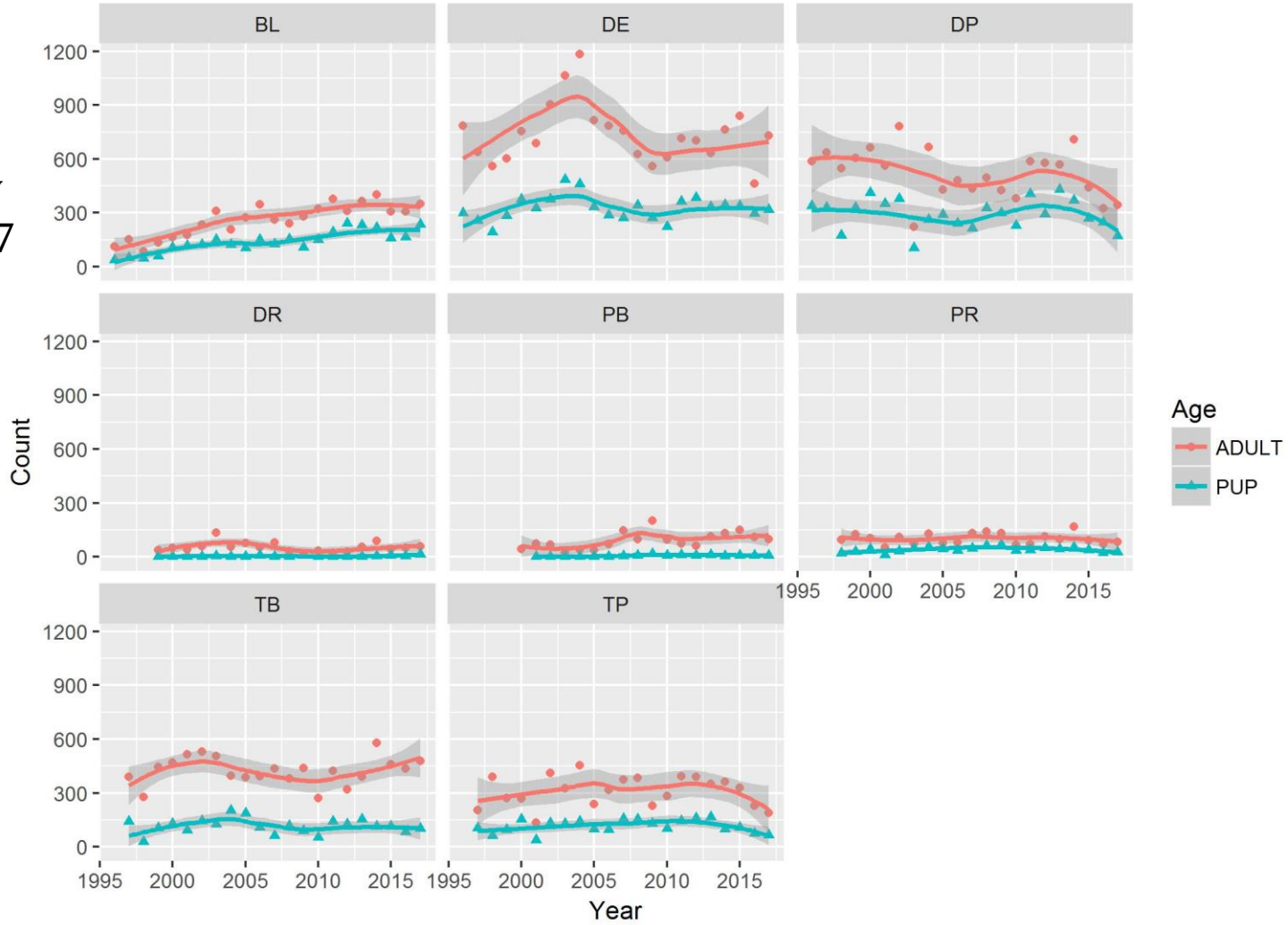


Regional Harbor Seal Colony Sites

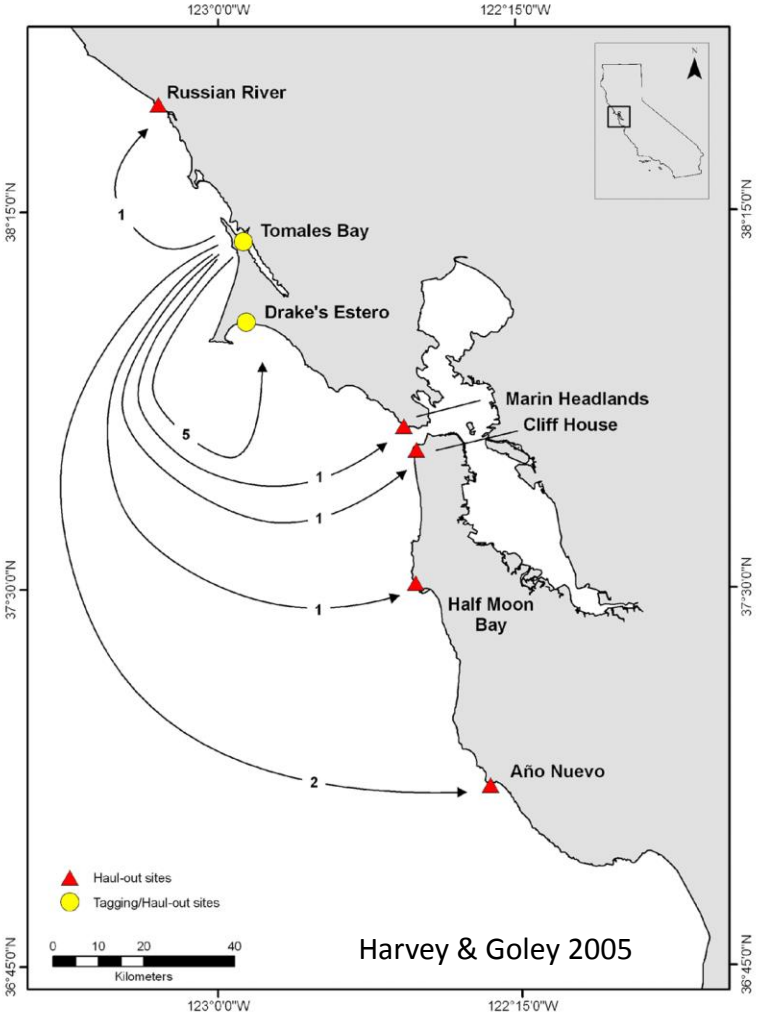


Peak Pupping Season Counts of Adults and Pups at Marin County Colonies: 1996 – 2017

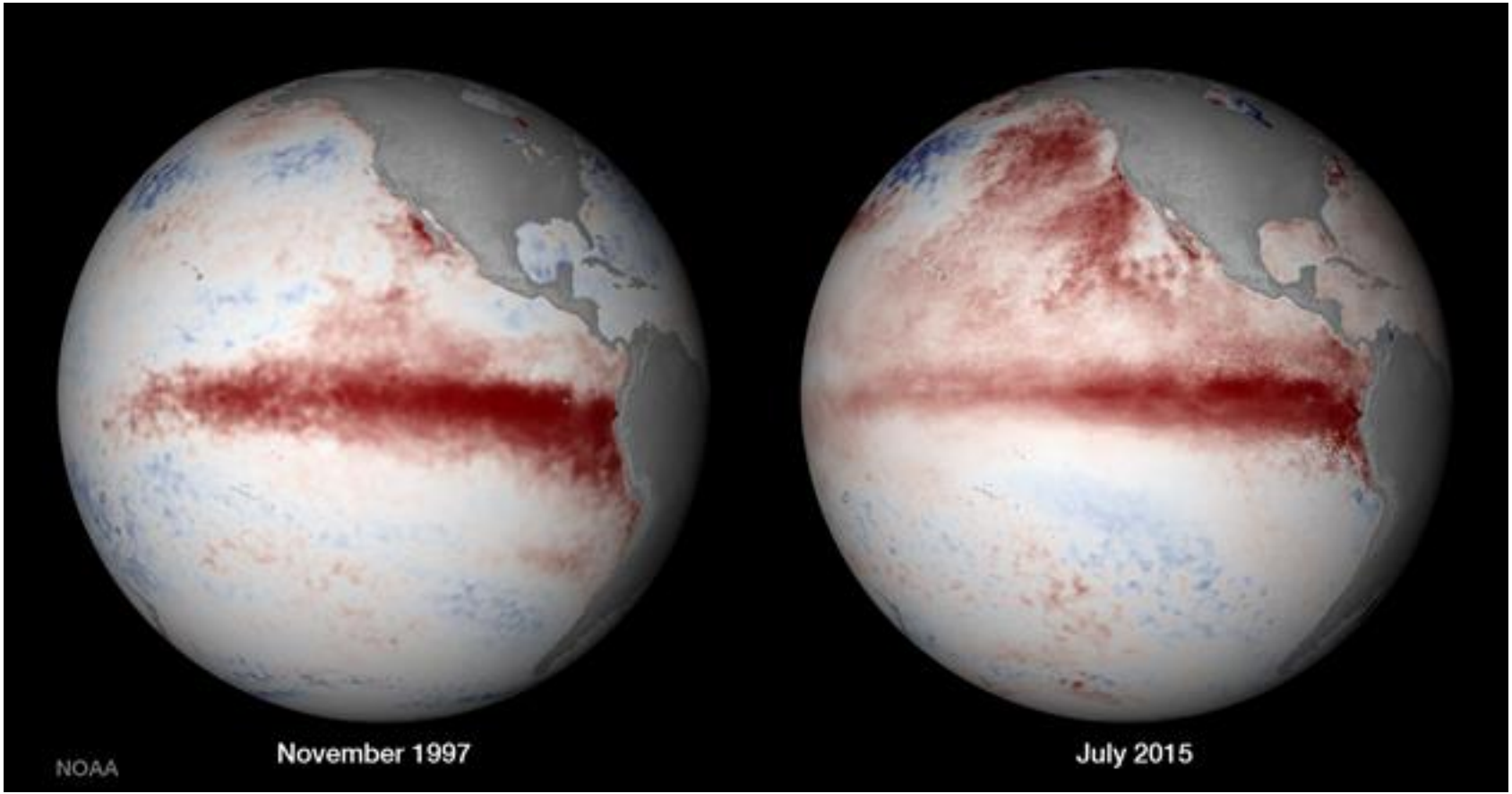
f(process + unobserved error)



Limited telemetry data shows regional movement



El Niño Events and the “Blob”



Human Disturbances

Coyote returns

Photos Jason Thompson

Bald Eagle returns

Drakes Estero – Sandbar Morphology

2002

2009

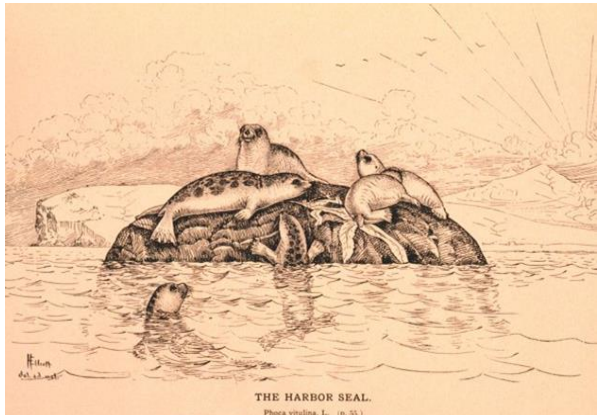
Seal Haul-out vs In-water Patterns

When	Where	n	p(Hauled-out)	Citation
Breeding season	WA and OR	124	**0.54 - 0.74**	Huber et al. 2001
Ideal Conditions Molt Period	Alaska	68	**0.81 - 0.86**	Simpkins et al. 2003
Molt Period	CA	180	**0.60**	Harvey and Goley 2011

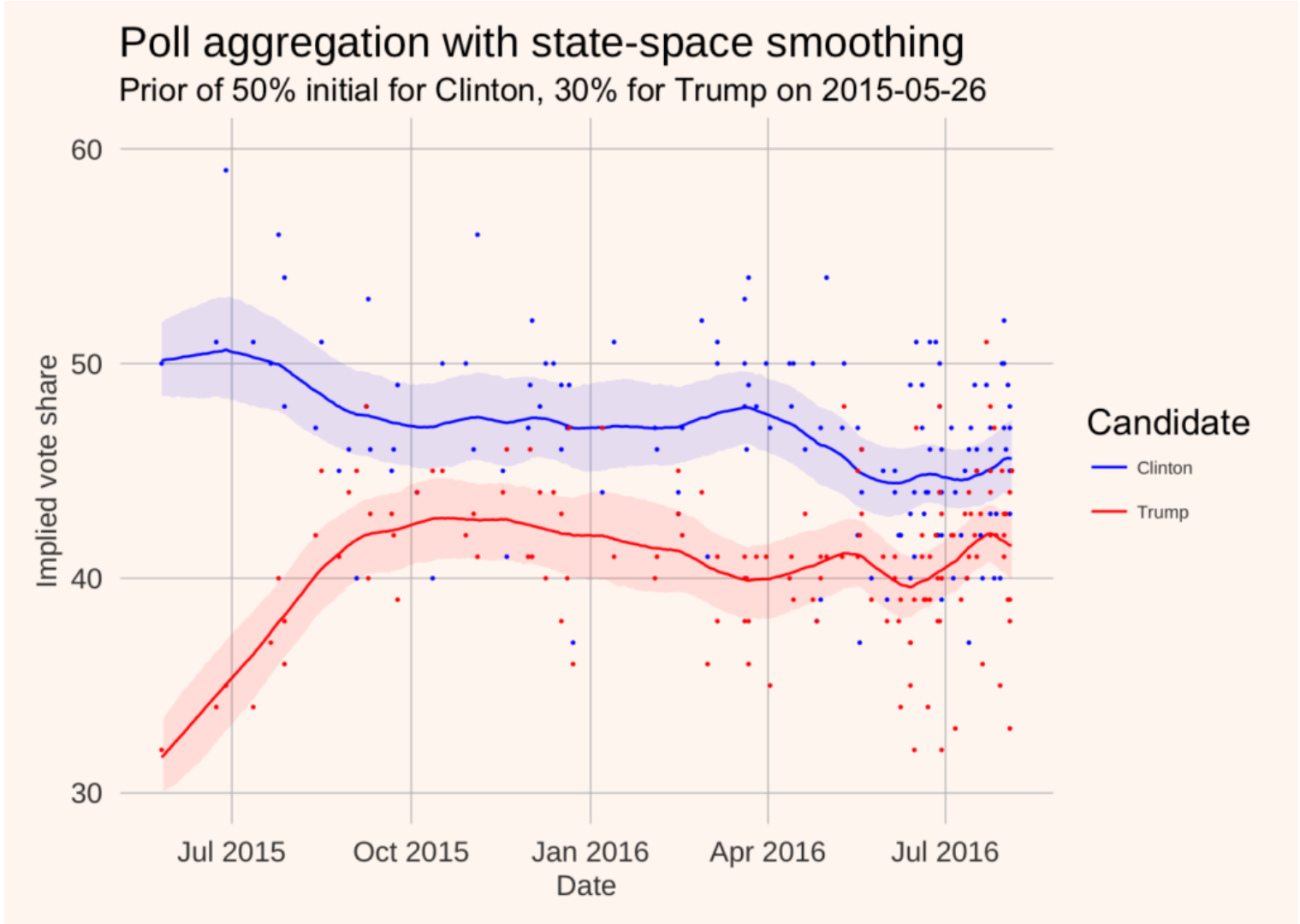
Sources of Variation		Analysis Mitigations
Varying site conditions	→	Model habitat?
Overall ENSO or food supply effects	→	Covariates ?
Disturbances	→	Covariates ?
Movement between sites/colonies	→	Tracking ?
Tide	→	Survey at low tide & peak pupping season

Sources of Error

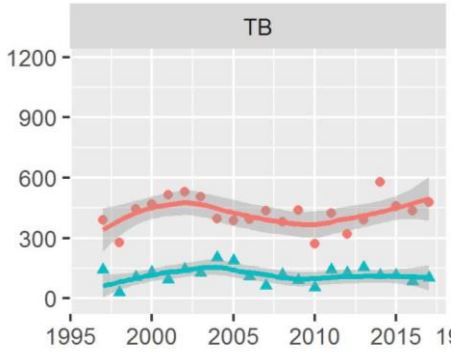
Poor visibility	→	Don't survey
Observer error	→	Screening/training/covariate?
Seals in water	→	Telemetry Correction?



Take peak count from year, but still can suffer from sources of error


Poll aggregation with state-space smoothing
Prior of 50% initial for Clinton, 30% for Trump on 2015-05-26
Implied vote share
60
50
40
30
Jul 2015
Oct 2015
Jan 2016
Apr 2016
Jul 2016
Date
Candidate
Clinton
Trump

State-Space Modeling



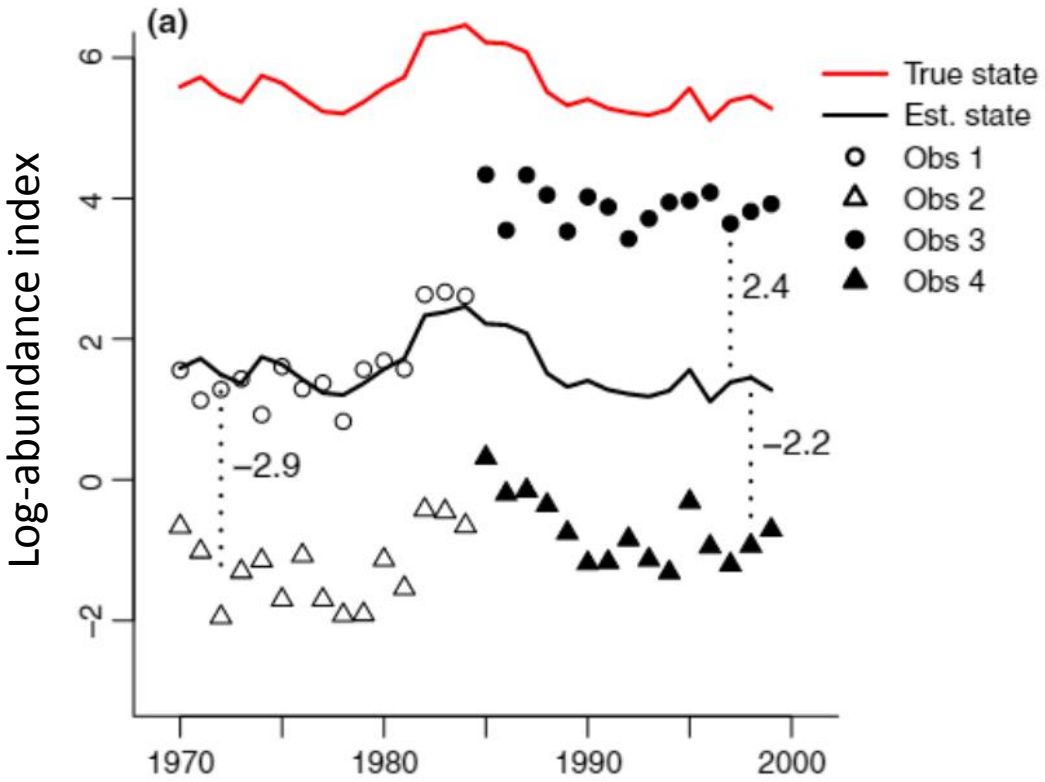
Observations y_{t-1} y_t y_{t+1}

Hidden Process x_{t-1} → Time → x_t → x_{t+1} →

- Tide
- Proportion in water
- Environmental impacts
- Disturbance
- Short-term movements

Trends in Ecology & Evolution

Example: State-Space Modeling



Tolimieri et al. 2017

Wanted:
Hidden, true abundance and population trajectory.

Method:
All data assumed to be observing same population

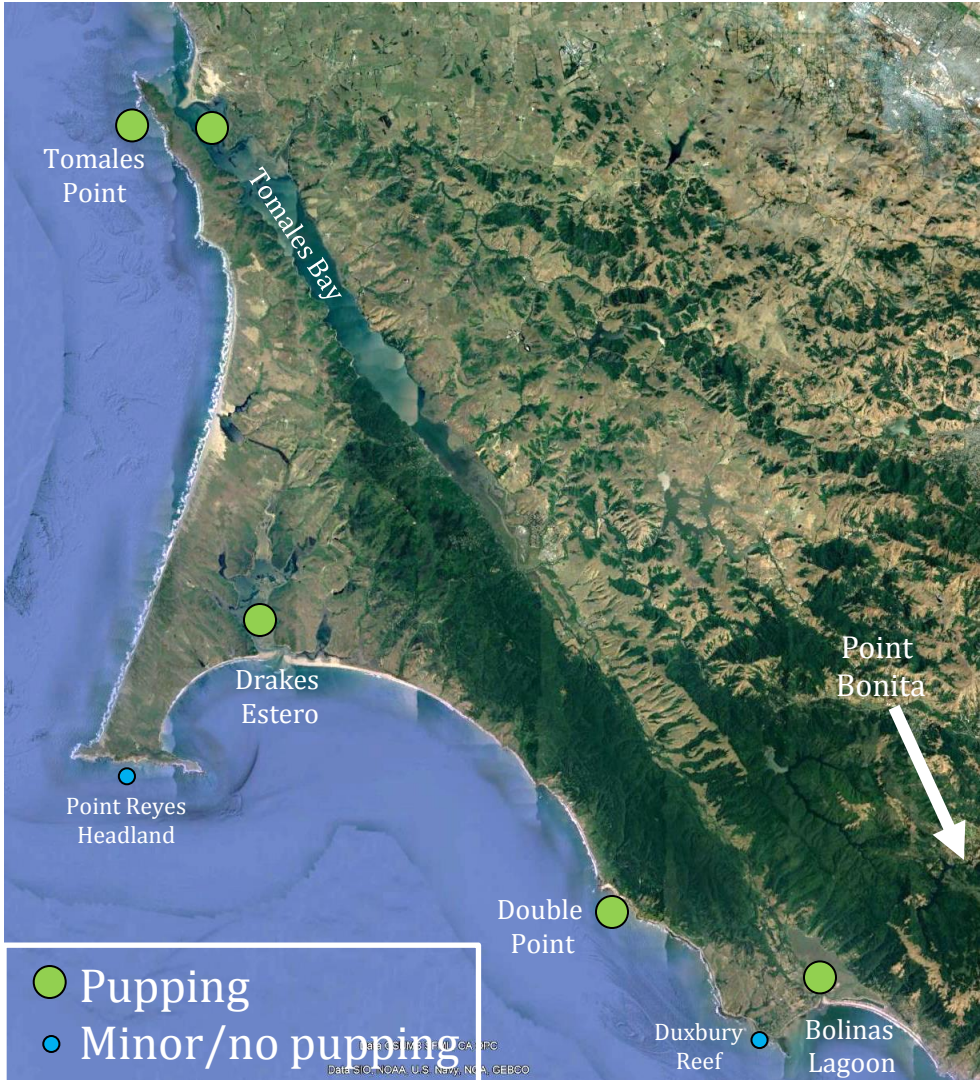
Partition variance in time-series data into process and observation variances

Point Reyes National Seashore
Marin County, California

8 Harbor seal colonies
5 “Pupping” colonies

<u>“Pupping Population” Hypotheses</u>

Independent
Panmictic
North-South
Estuary-Ocean
Bolinas Independent



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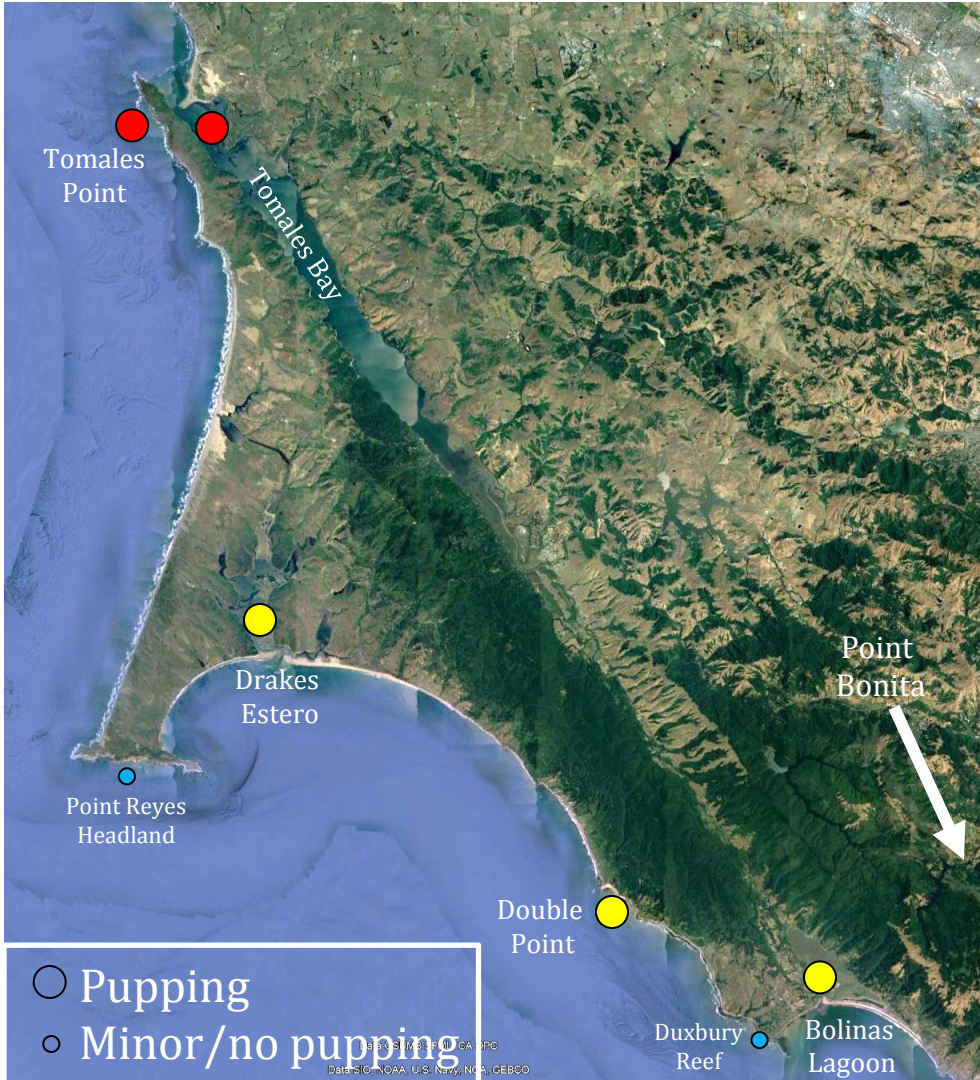

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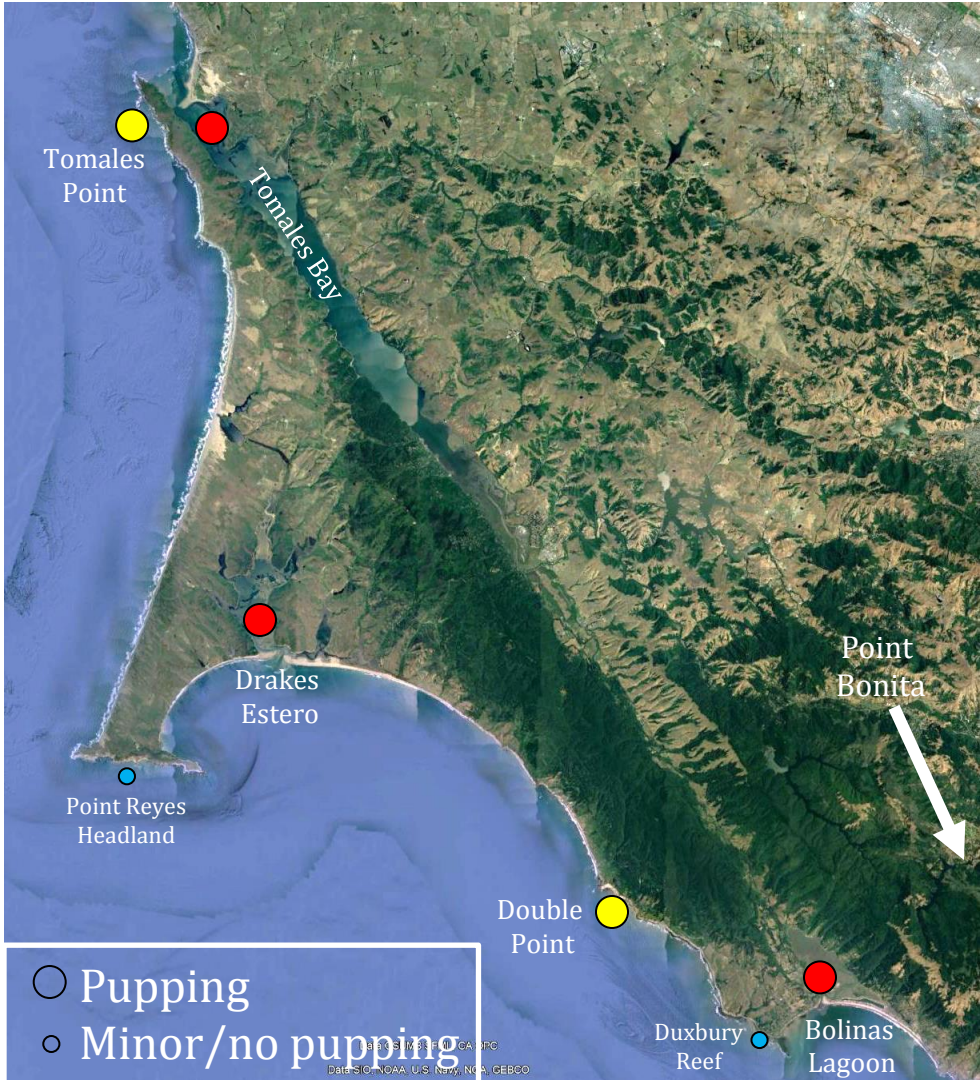

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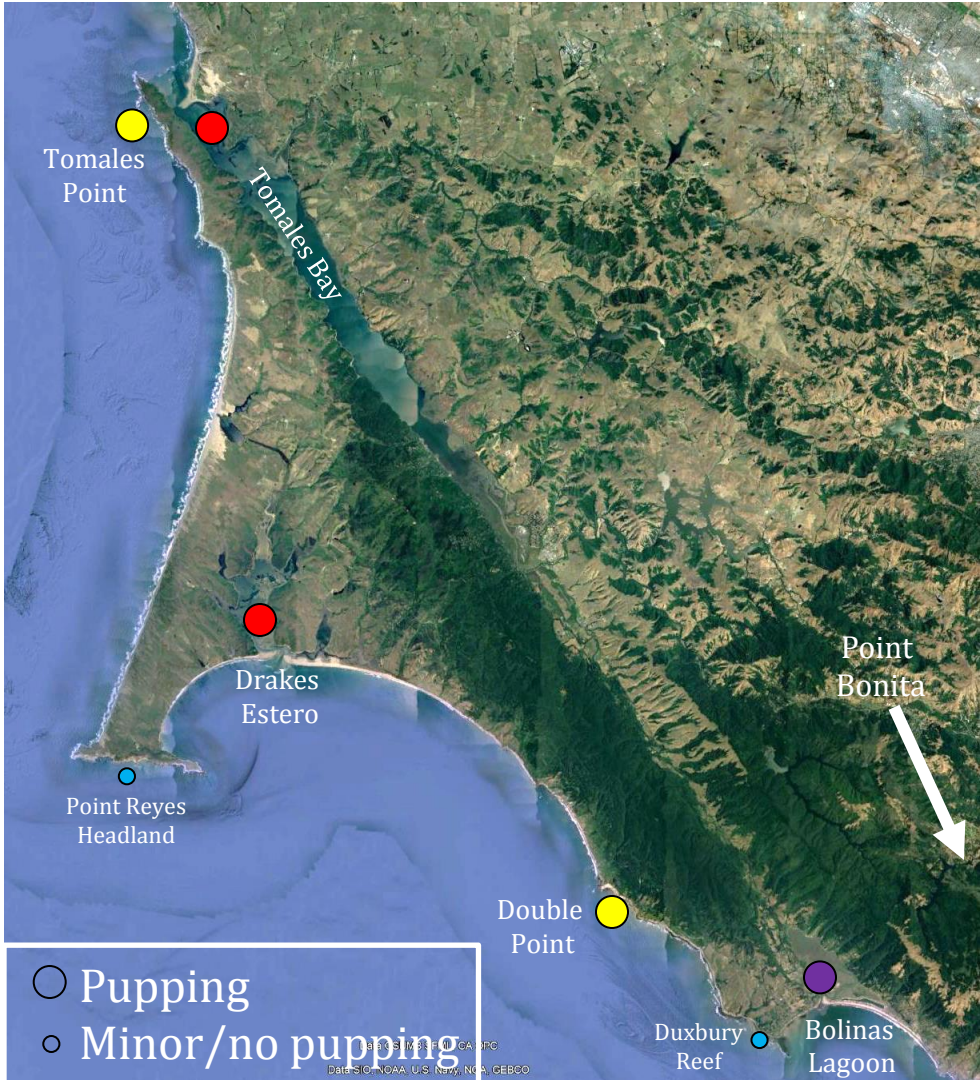
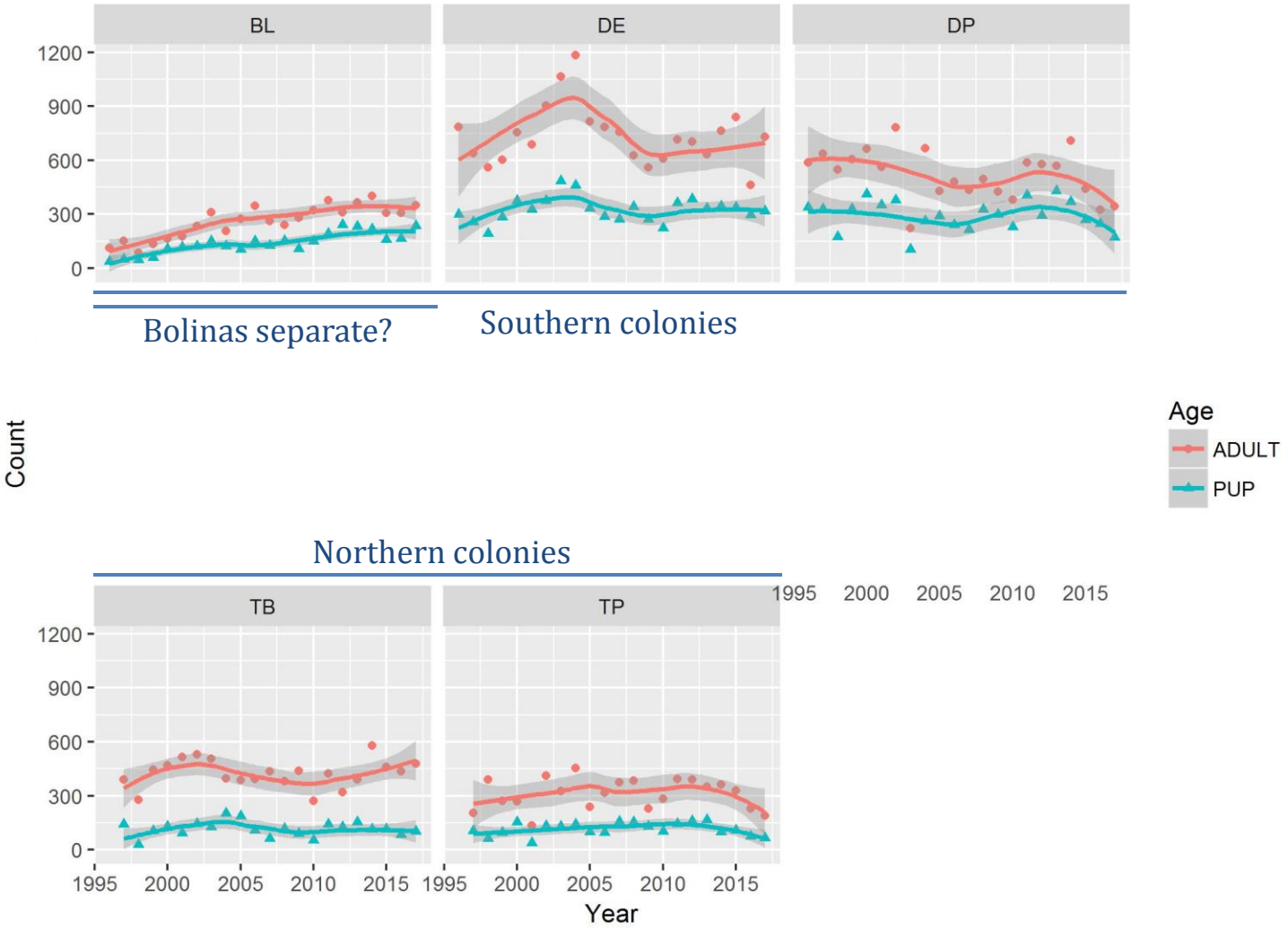


Seal Counts
1996 – 2017

8 Colonies
5 “Pupping”



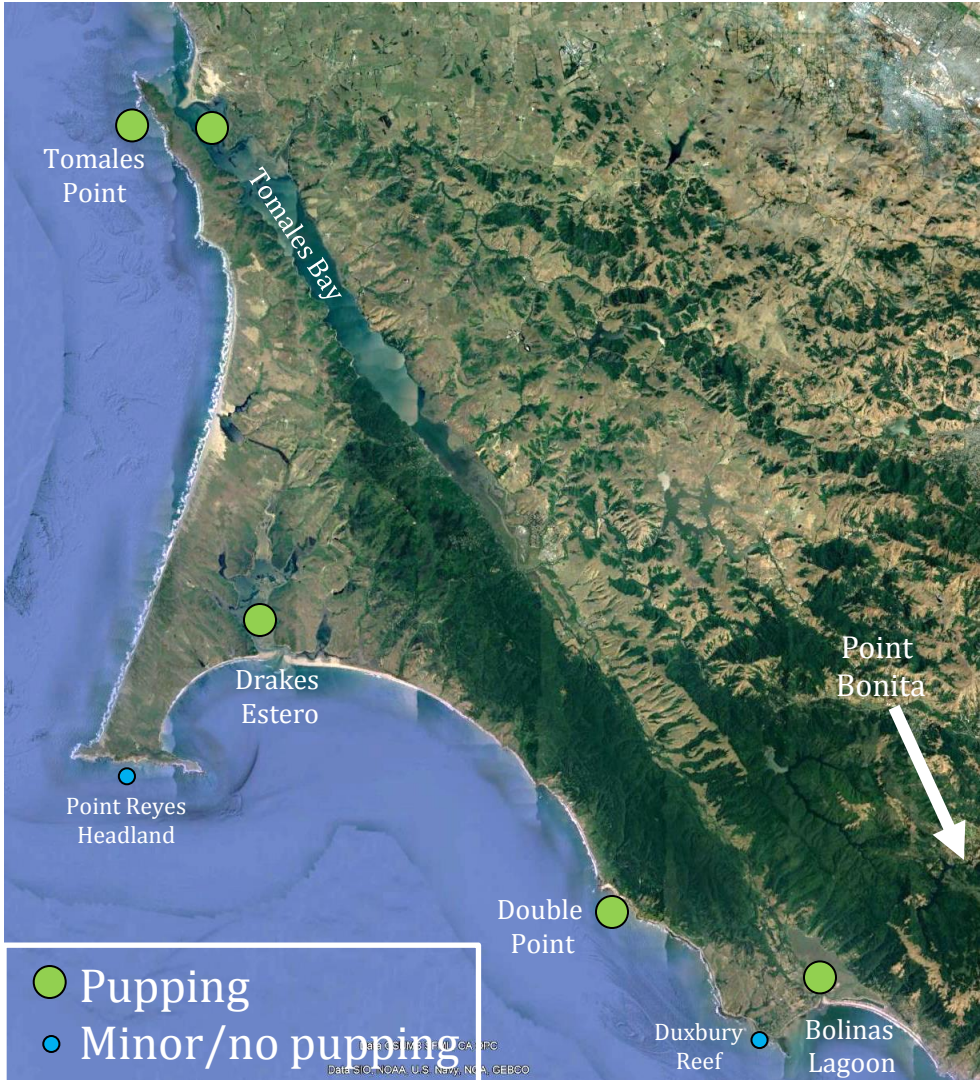
“Pupping Population” Hypotheses

Independent
Panmictic
North-South
    + Bolinas Independent
Estuary-Ocean
    + Bolinas Independent

Secondary Hypotheses

Independent growth rates?
Error rates independent?
Hidden processes?
Effect of site A on site B?

Use **MARSS** Modeling Package



RESULTS

Hypothesis	Hidden State Process Correlation	ΔAICc	AIC weight
North/South/BL	equal	0.00	0.53
Coast/Est/BL	equal	2.39	0.16
North/South/BL	equal varcov	2.57	0.15
Panmictic	equal	4.23	0.06
North/South/BL	unequal	5.09	0.04
Coast/Est/BL	equal varcov	5.67	0.03
Panmictic	equal varcov	6.93	0.02
Coast/Est/BL	unequal	7.60	0.01
North/South/BL	unconstrained	11.97	0.00
Panmictic	unequal	15.06	0.00

RESULTS

Hypothesis	Hidden State Process Correlation	ΔAICc	AIC weight
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North/South/BL	unconstrained	11.97	0.00
Panmictic	unequal	15.06	0.00

North/South/BL = 0.73

“Pupping Population” Hypotheses

	AICw
Independent	0.00
Panmictic	0.08
North-South-BL	**0.73**
Estuary-Ocean	0.26

“Hidden Processes”

Equal among sites	**0.75**
Equal varcov	0.20
Unequal	0.05

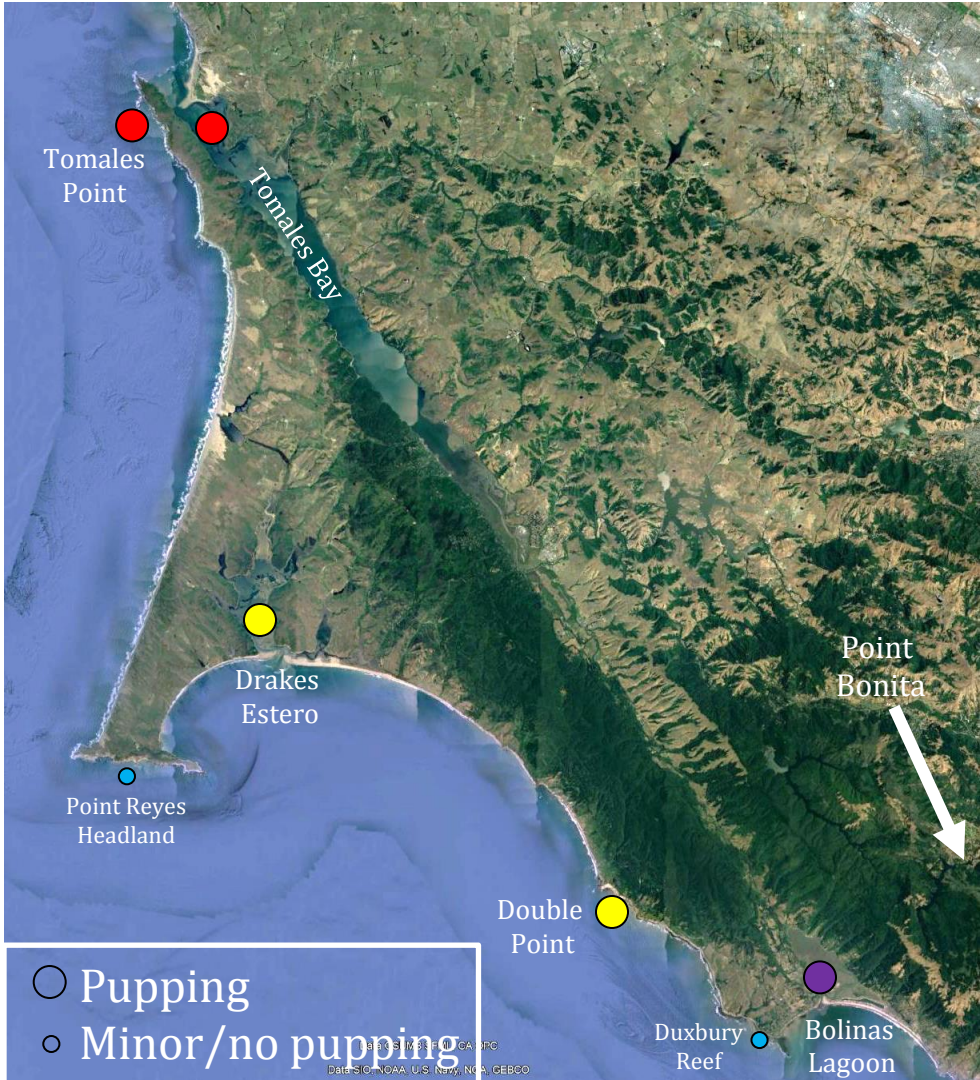
Tide

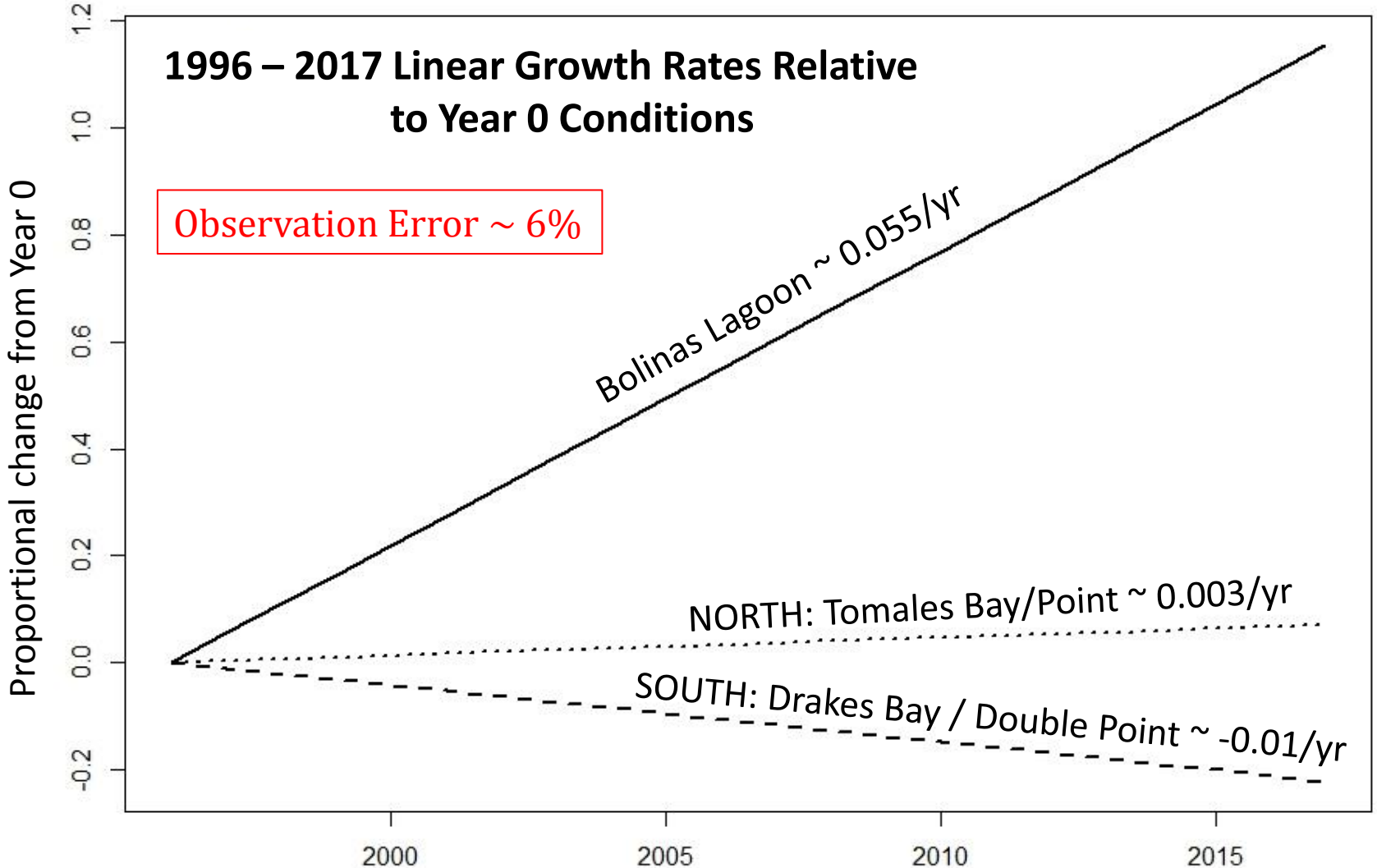
Proportion time in water

Environmental covariates

Disturbance (human and natural)

Short-term movements



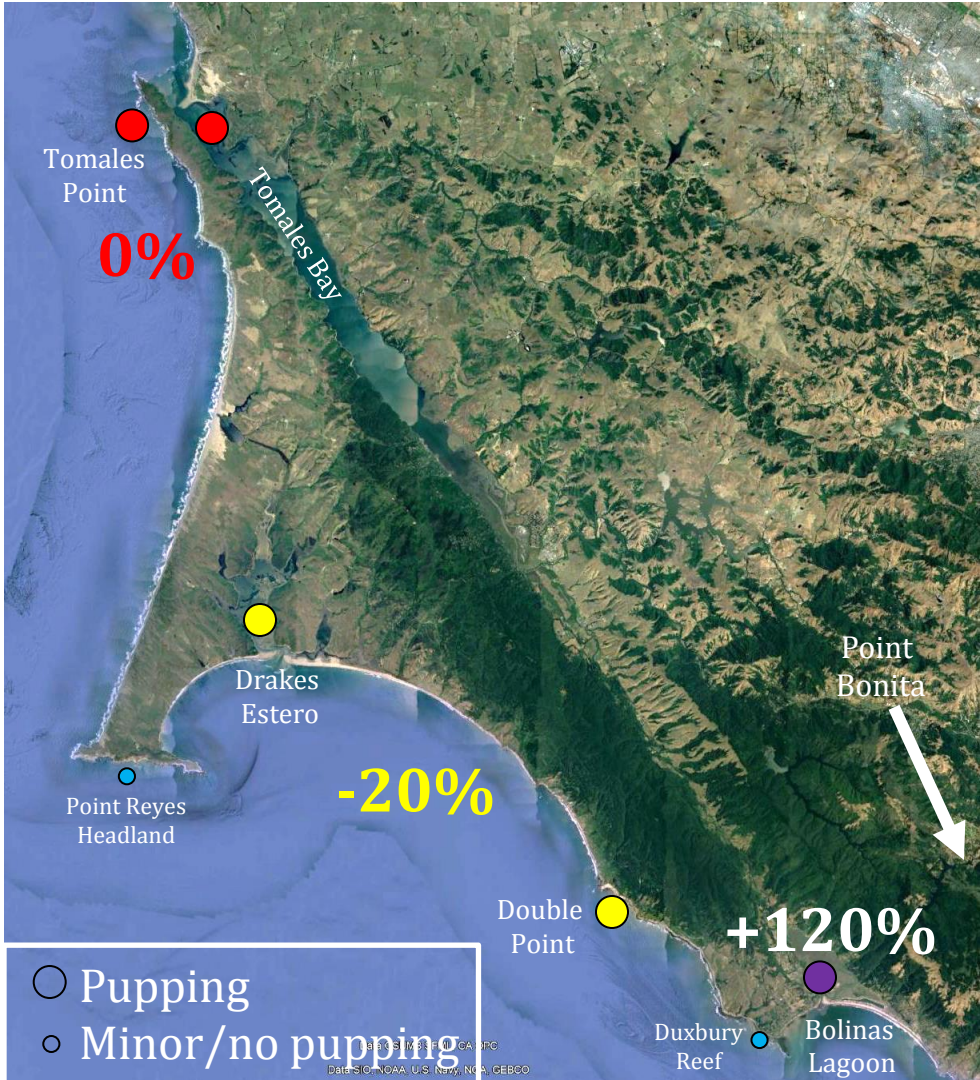

1996 – 2017 Linear Growth Rates Relative to Year 0 Conditions
Observation Error ~ 6%
Bolinas Lagoon ~ 0.055/yr
NORTH: Tomales Bay/Point ~ 0.003/yr
SOUTH: Drakes Bay / Double Point ~ -0.01/yr
Proportional change from Year 0
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
2000
2005
2010
2015

Preliminary Conclusions

- Three distinct spatially correlated units temporally correlated for population trajectory
- Little between-unit annual correlation
- Similar “hidden” processes affecting all sites, but they are small (~0.06)

Next steps

- Validate models / more robust algorithms
- Larger area / additional colonies
- Include molt season
- Overall population growth rate



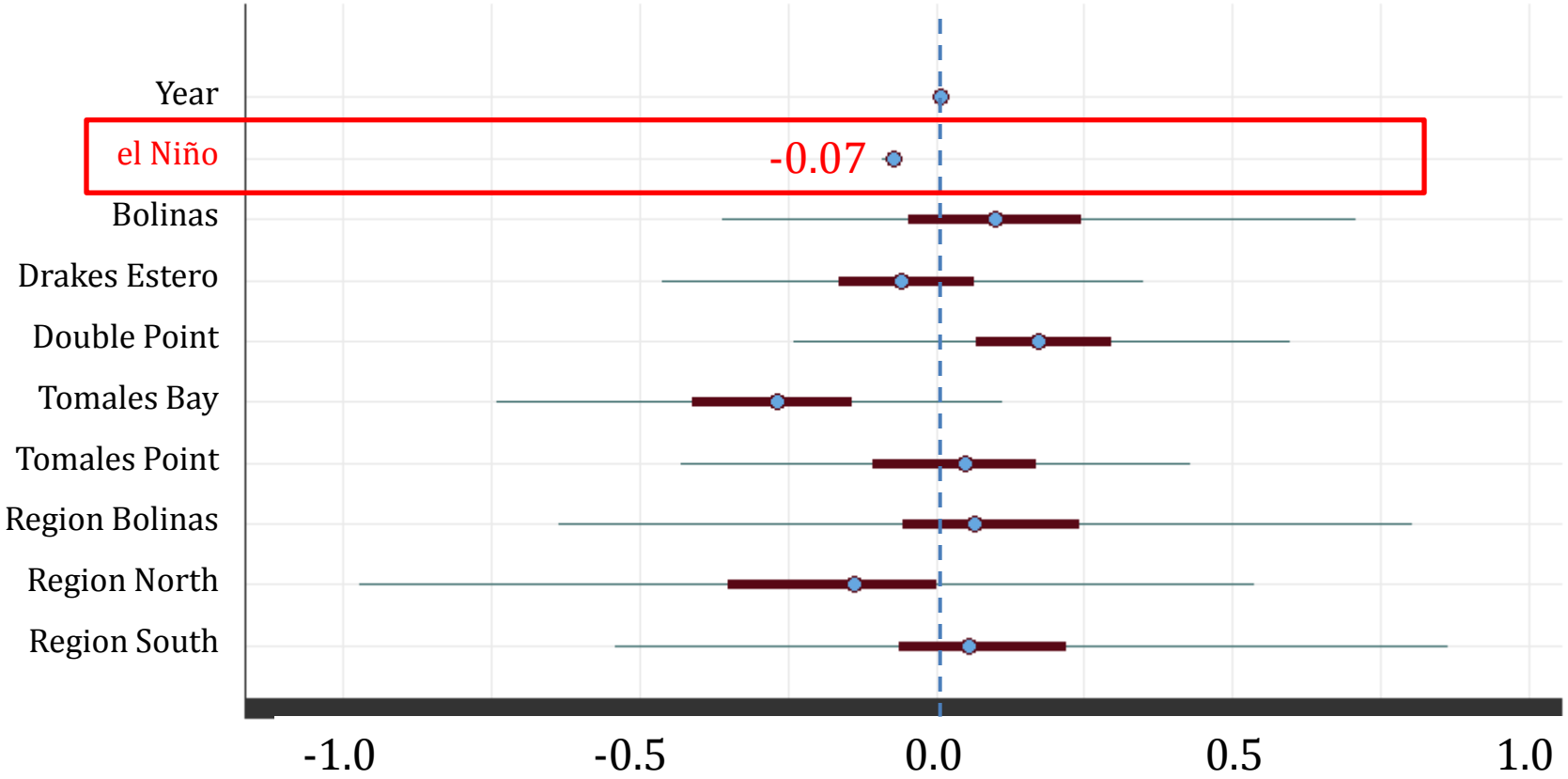
Acknowledgements

Point Reyes National Seashore Harbor Seal Monitoring Volunteers

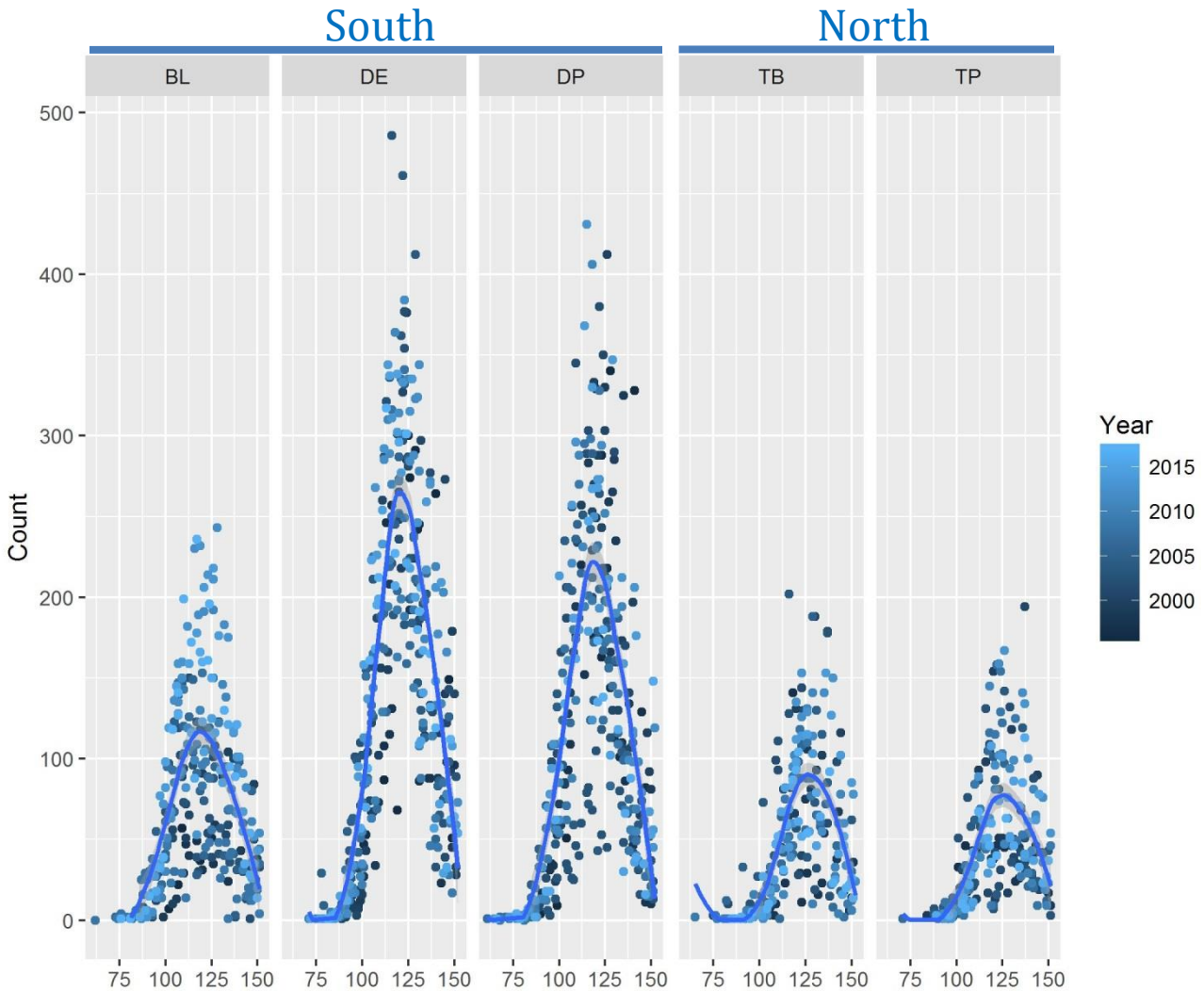
MARSS Package Authors

El Niño Effects 1996-2017

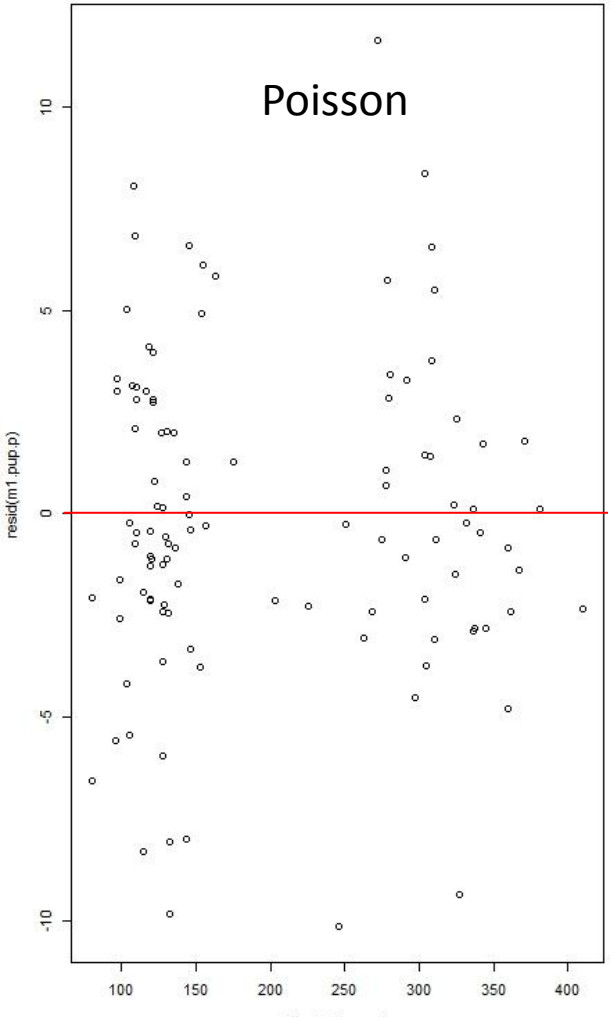
Bayesian GLMM coefficients on proportion of population that are pups

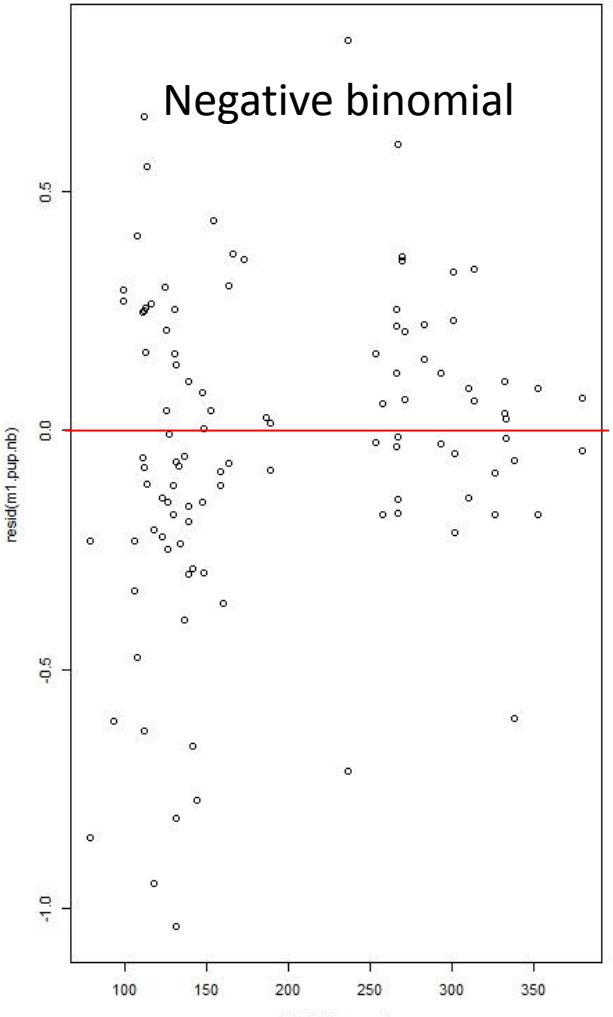


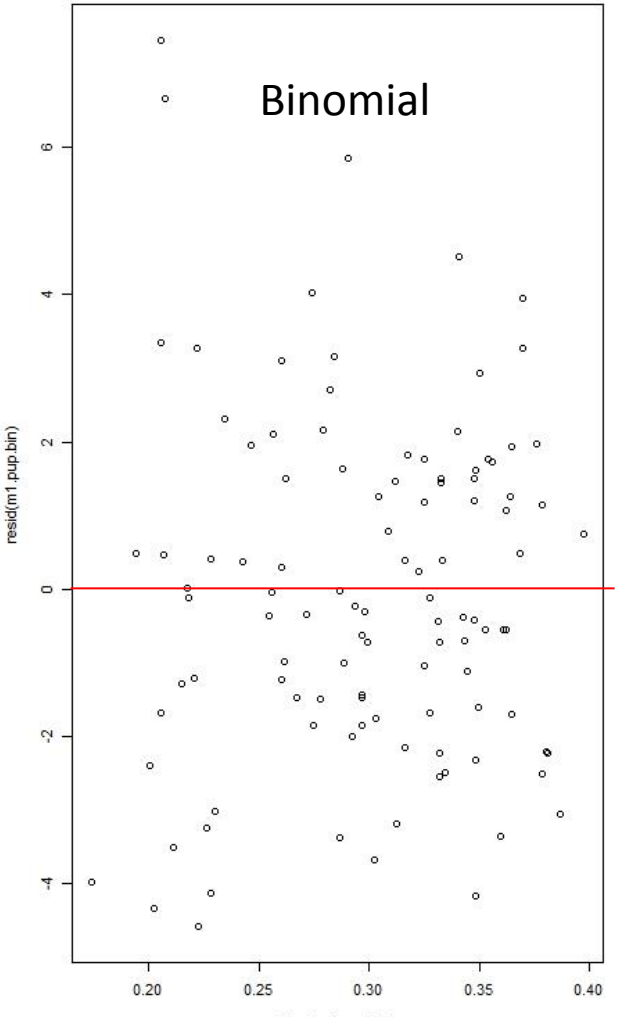
Peak Pup Count by Julian Date at 5 primary colonies

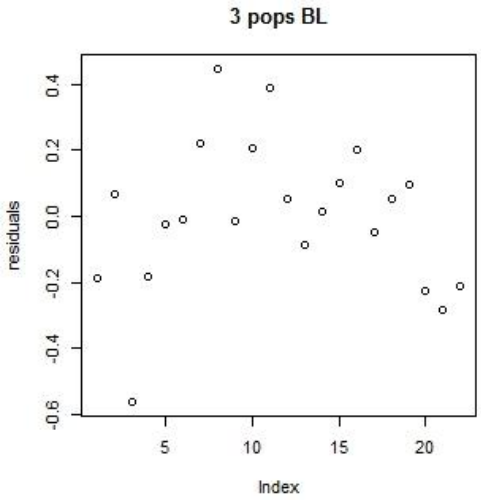


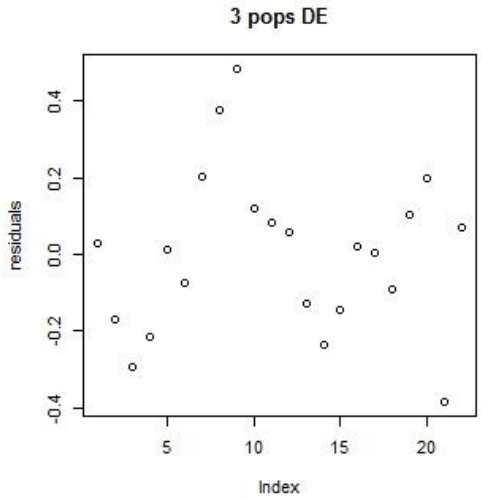
GLMM Residuals

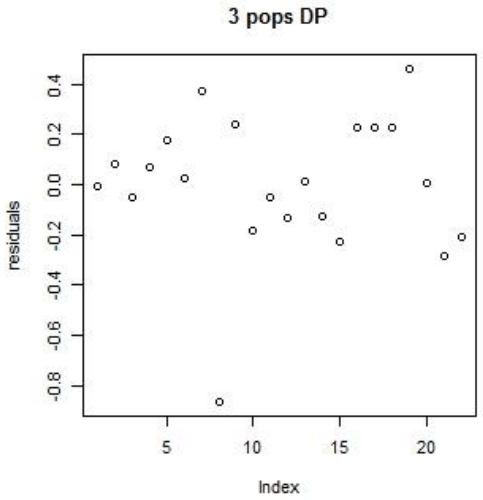


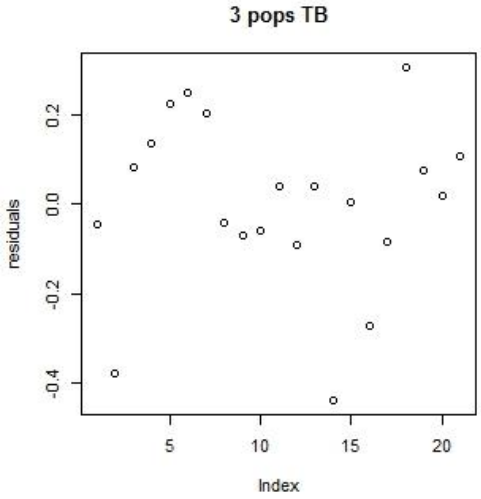


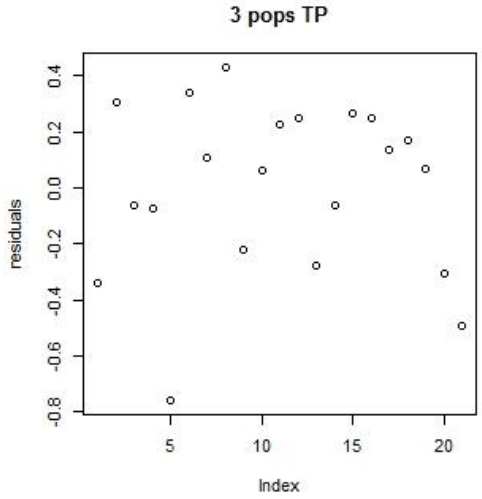












MARSS Residuals