The Effect of Climate Change and Closures on Fisher Portfolios:

Substitution between Coastal Pelagic Species

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November 3rd, 2021

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CAFA
Climate and Fisheries Adaptation

California Current System (CCS)

- Unique ecosystem
- Provides many ecosystem services
- Home to many protected species
- Sustains commercial and recreational fisheries:
  - Forage species
  - Coastal Pelagic Species

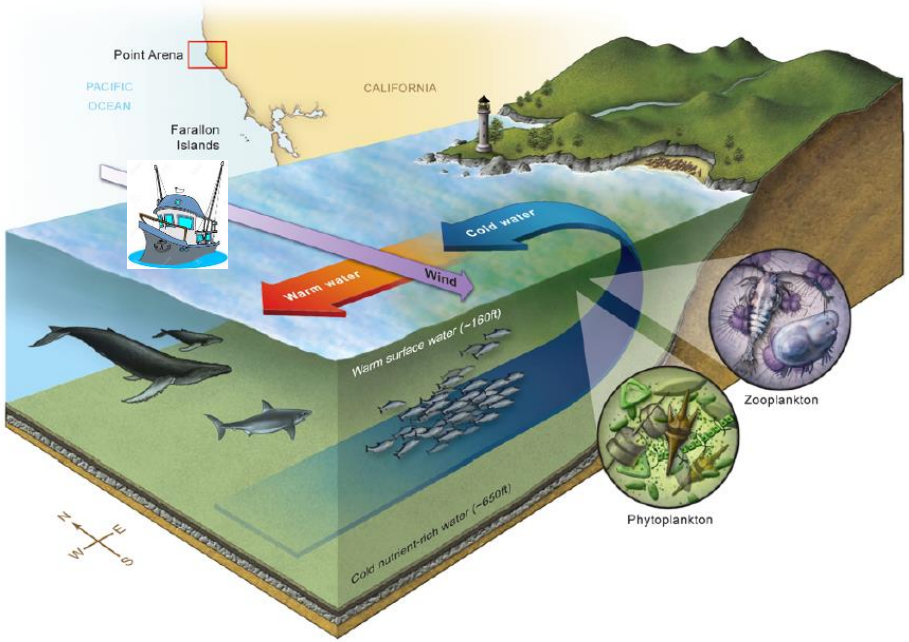


Illustration by Fiona Morris

Coastal Pelagic Species in CCS

Pacific sardine:

- Affected by oceanographic variability
- CPS SAFE: “In 2012, PSDN fishers shifted to squid during the summer due to low abundance”
- Closure in 2015.

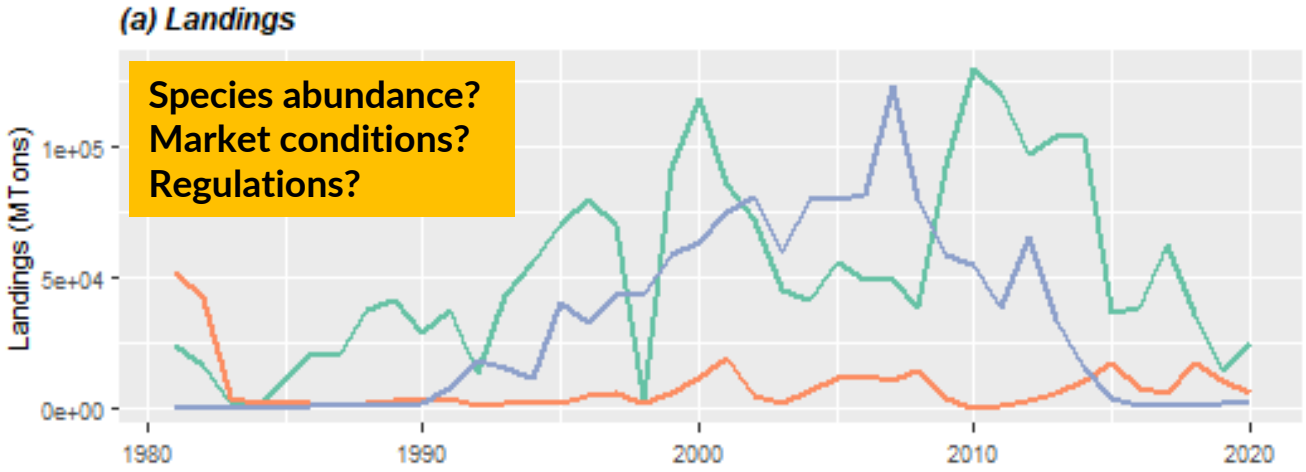
Market squid:

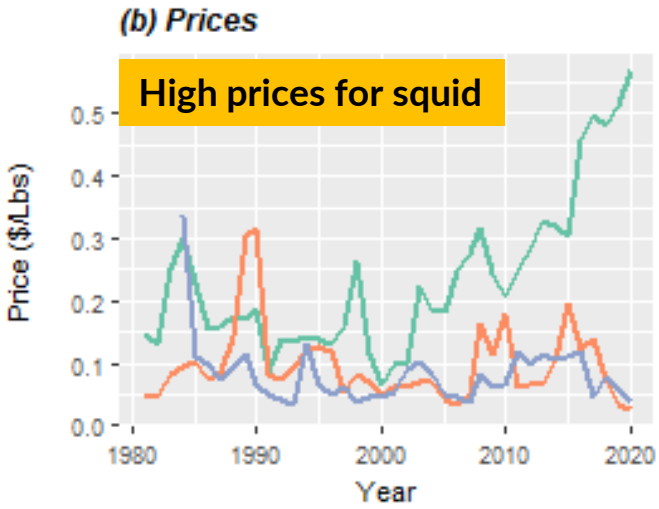
- Limited Entry since 2002
- High prices
- High landings, but decreasing trend in recent years.

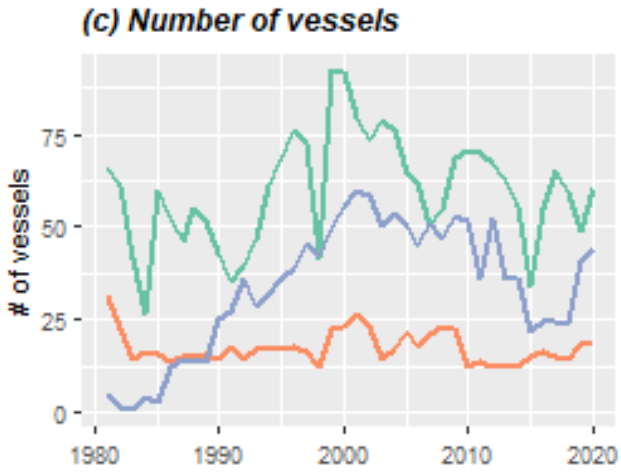
Northern anchovy:

- Low prices and landings
- Highly variable biomass driven by oceanographic
- Reduction quota in place
- Record high abundance since 2017
- “Partial substitute for sardine when its collapsed”

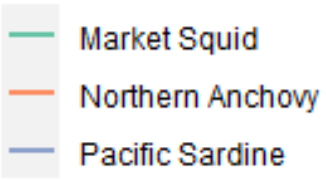
Trends in CPS fishery







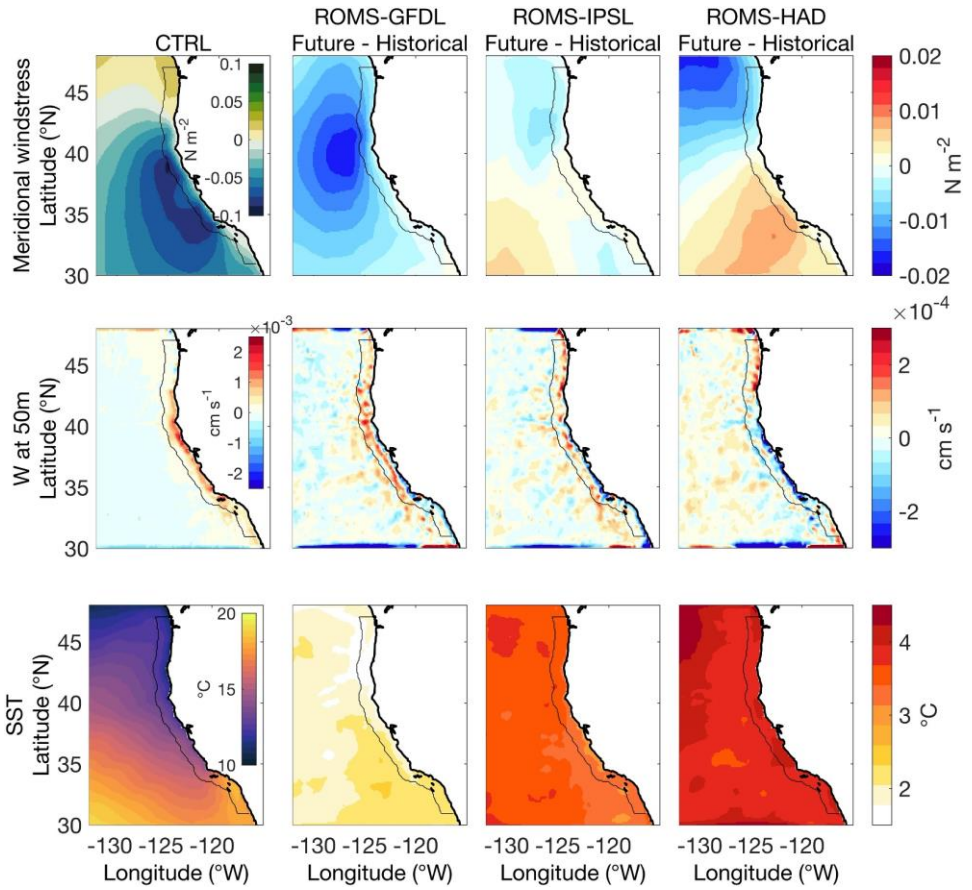
But, decrease of number of vessels for market squid



Hypothesis:

1. Species abundance have decreased
2. Participation decrease when a species is under closure
   - Income diversification (Kasperski & Holland, 2013)

Climate is changing!



Source: Pozo Buil et al. (2021)

- For instance, projected changes in Pacific sardine distribution

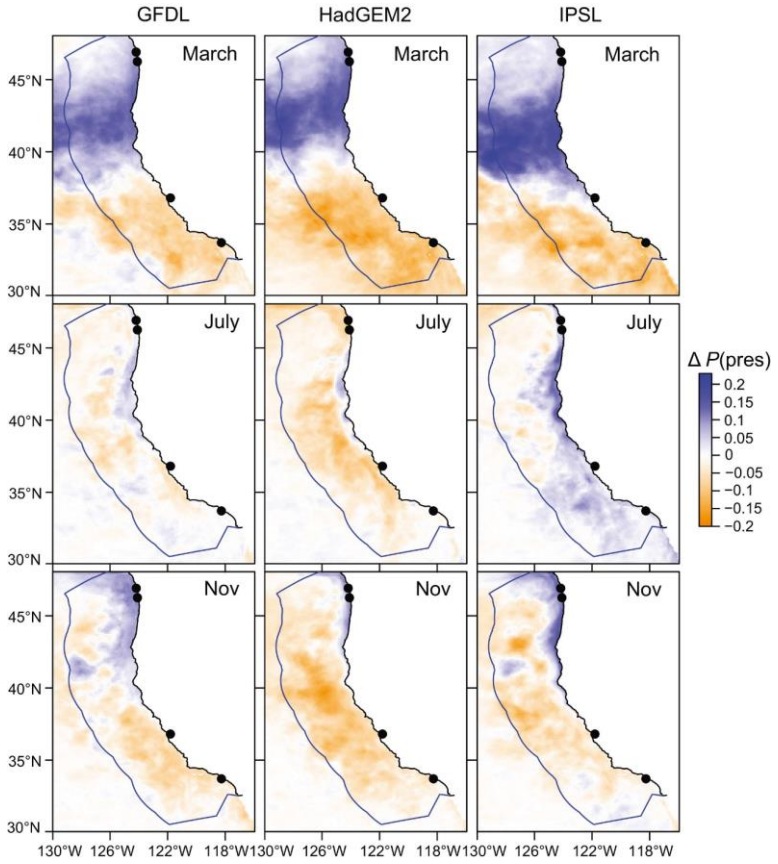
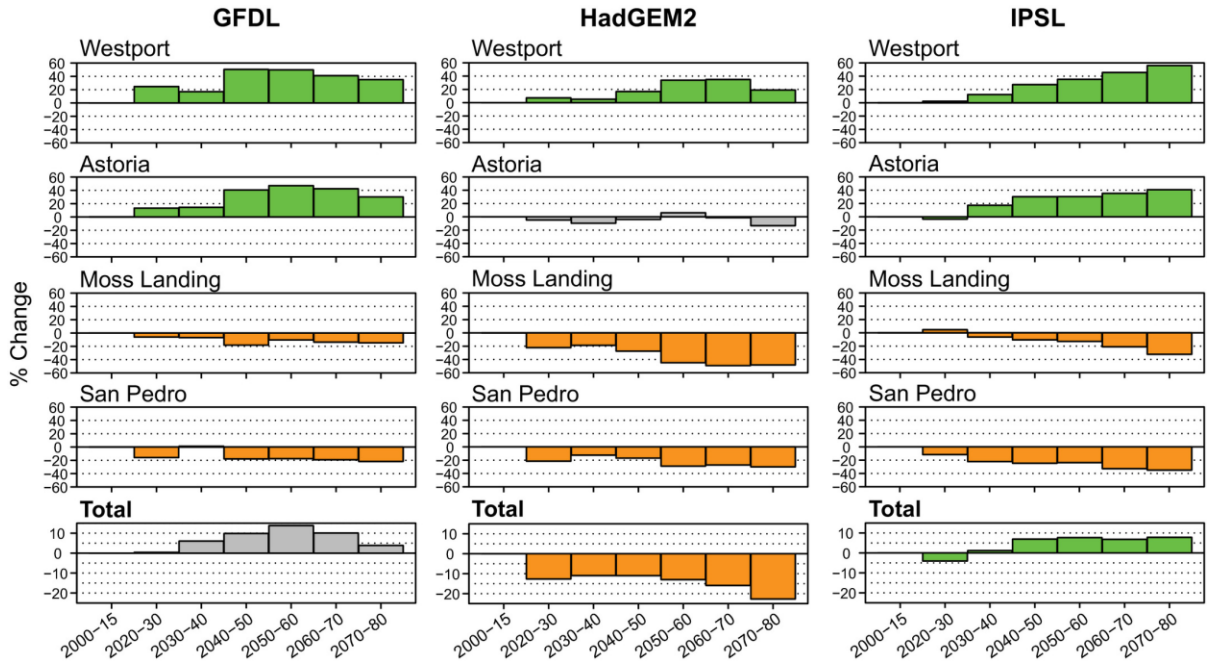


Figure. Mean change in projected sardine habitat suitability (2040–55 period minus 2000–2015 period), in the three ESMs. Source: Smith et al. (2020)

Effect on landings



Source: Smith et al. (2020)

- Smith et al. (2020) found a positive effect of species distribution on Pacific sardine landings.
- Changings on distribution could also trigger changes in regulation (e.g. closures)

Research Question

How will climate change impact fishing communities?

- Specific questions:
  - How do changes in species distribution and regulations (i.e. closures) affect landings and vessel participation in the multispecies *Coastal Pelagic Species (CPS)* fishery?

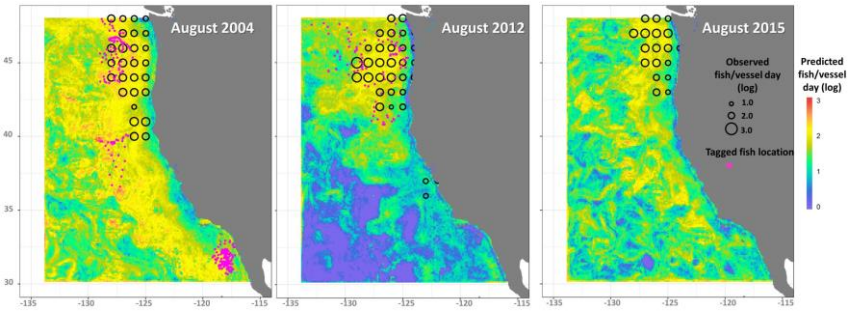
- Contribution:
  - *Previous work has focused on one species*
  - *Important to study other species and their interactions in fishers' portfolio to assess climate impacts on CPS fleet.*
  - *Presence of other species might impact targeting decisions.*

Methodology

- Two approaches
  - Landings model (results using public aggregate data).
  - Participation model (no results yet).

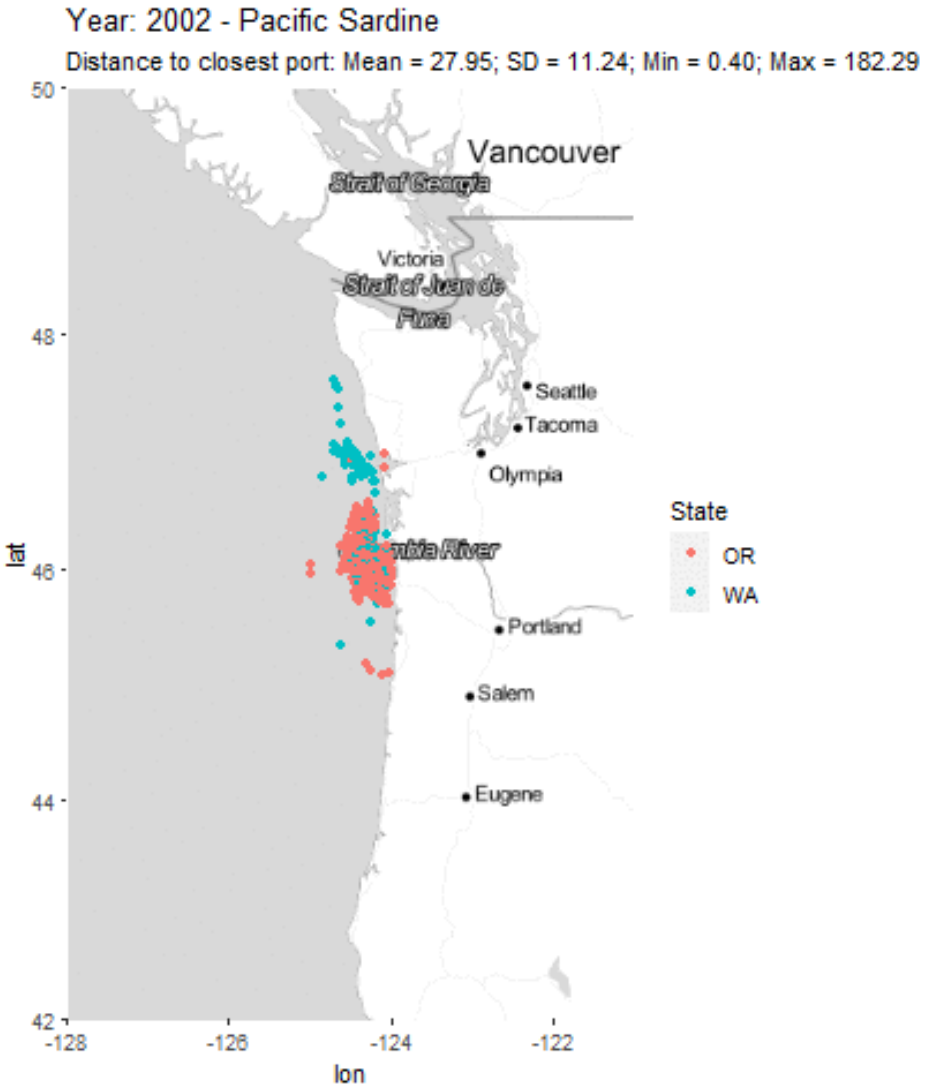
- Data
  - Fish tickets from The Pacific Fisheries Information Network (PacFIN) from 1980-2020
  - Current and projected species distribution from Species Distribution Models (SDMs) from **1997-2018**

Species Distribution Model (SDM)

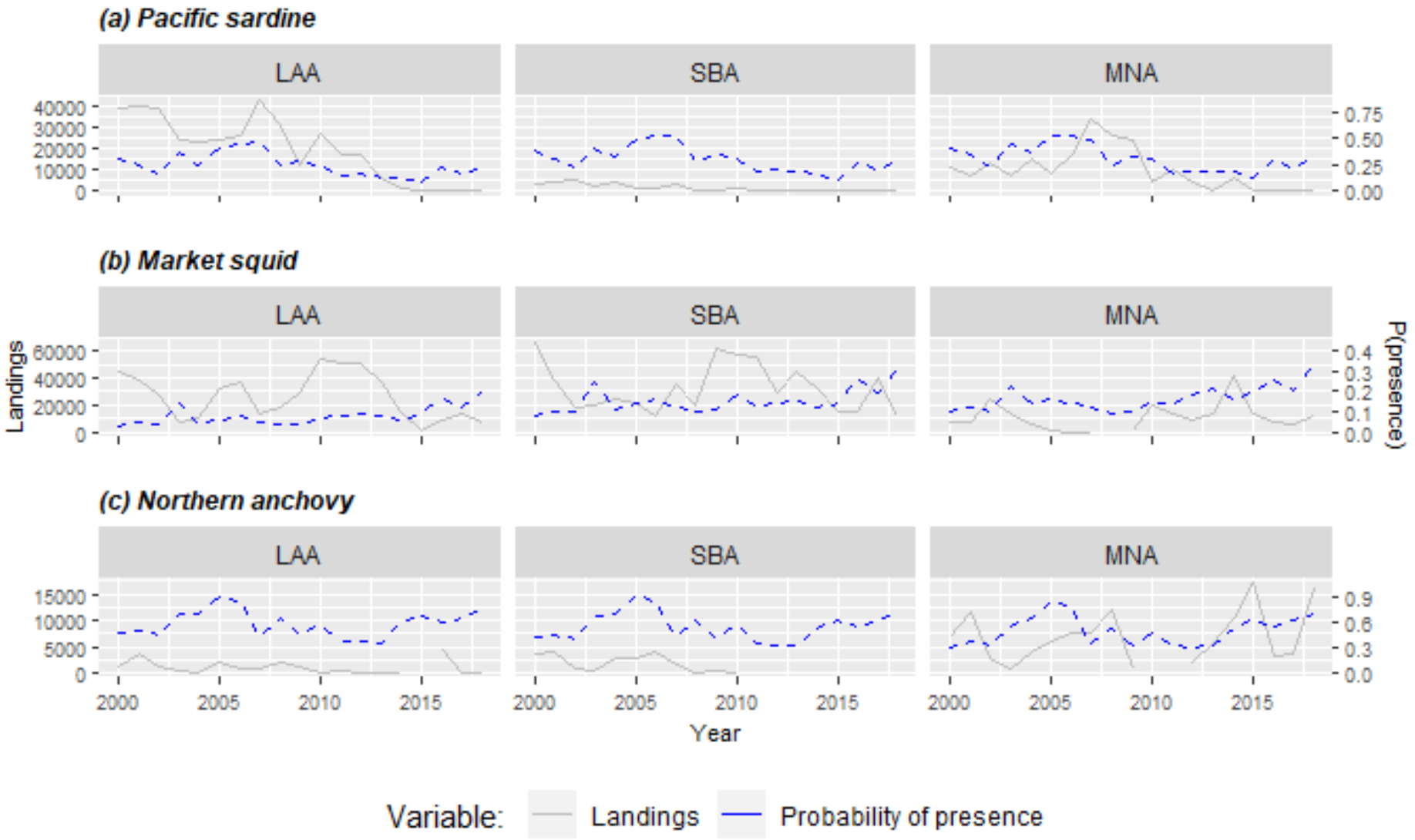


- SDMs to model distribution of sardine, anchovy, market squid, herring (Muhling et al. 2019, 2020, Brodie et al. 2021)

- SDM are at the 0.1 degree of resolution.
- We use port radius to construct our variable of abundance
  - Fishery operates close to shore
  - Mostly undergoing daily trips
  - Data: Logbooks
- Problem with selection



SDMs and Landings



Landing model

- Hierarchical Bayesian Hurdle model (separate model by species)
  - All parameters are random variables (uncertainty)
  - Incorporate previous knowledge, as priors
  - Multilevel effects (i.e. hierarchical effects by ports/vessel)
    - More flexible than Maximum Likelihood Methods
    - Group-specific effects vary randomly according to a prior distribution.
  - Hurdle allows to model the zeros, observed with probability $p_{i,t}$
- Ports were chosen if we observe at least one year landings
  - Selection bias problem?
- SDMs outputs: Projection and interactions.
  - Important to include dynamic SDMs of all species
  - Smith et al. (2020) did not project future changes in squid/anchovy abundance.

Methodology

- If $q_{i,t} > 0$, then the probability density function is

$$[1 - p_{i,t}]\,\text{gamma}\left(q_{it} | \frac{\mu_{it}^2}{\sigma^2}, \frac{\mu_{it}}{\sigma^2}\right)$$

- Specifically μ_{it} is defined as the following:

$$\mu_{it} = \beta_i^0 + \beta_i^1 \Pr(Pres.PSDN)_{it} + \beta_i^2 \Pr(Pres.MSQD)_{it} + \beta_i^3 \Pr(Pres.NANC)_{it} + \beta_i \boldsymbol{X}$$

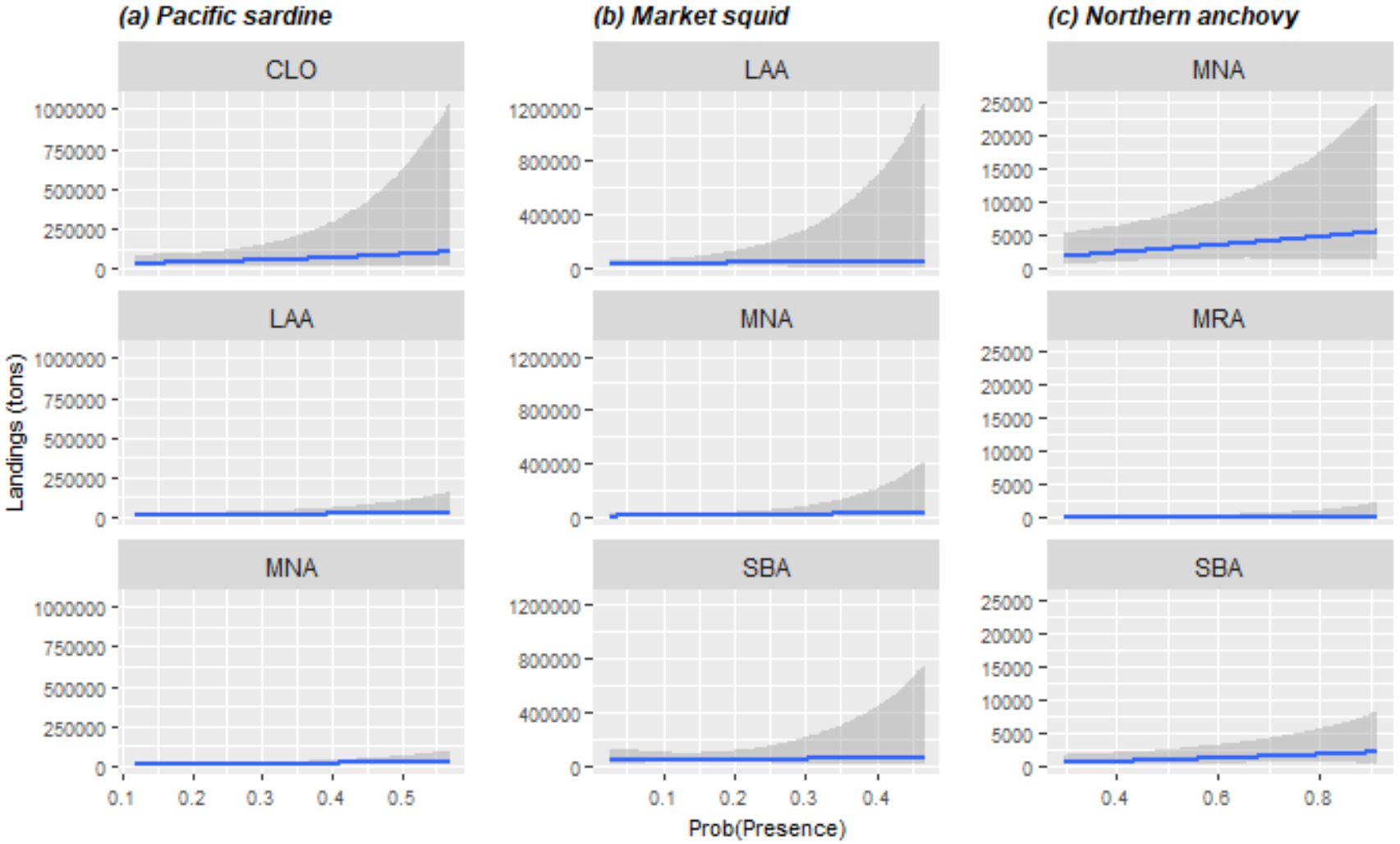
where $\Pr(Pres)$ is the probability of presence.

- β_i^0 correspond to port random-effects.
- logit(p_{it}) follows the same structure.
- How to deal with (under a Bayesian framework):
  - Serial correlation? Maybe assuming correlation within a level.
  - Non-stationarity? Include variables as differences?
  - Selection bias from choosing ports?

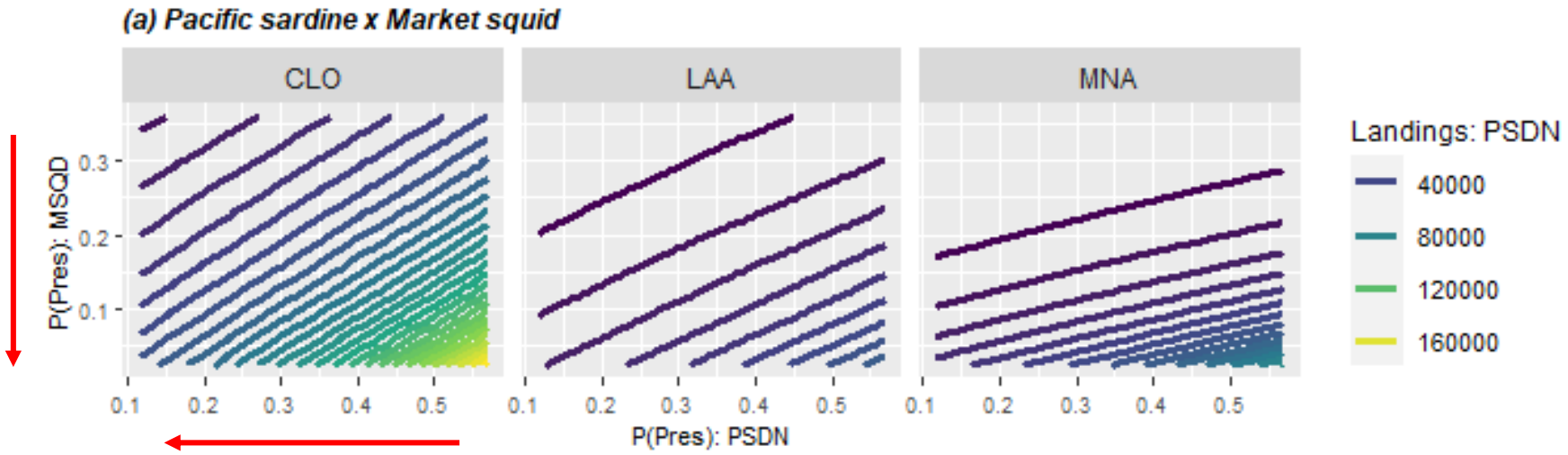
Methodology

- Additional explanatory variables:
  - Annual Catch Limits (ACL)
  - Dummy variable for closure (Sardine models estimate before closure)
  - Annual landing prices by port
    - Likely to be exogenous as the US small exporter
  - Average distances traveled (To be included)
    - May be **endogenous** as further fishing areas might be more suitable for fishing
      - Congestion externality (Huang & Smith, 2014)
  - Fuel prices (To be included)
  - Weather events that affect fishers (To be included)
    - Storm warning by port
    - Winds and current at 0.1 degree of resolution
- Endogeneity?
  - Bayesian IV literature

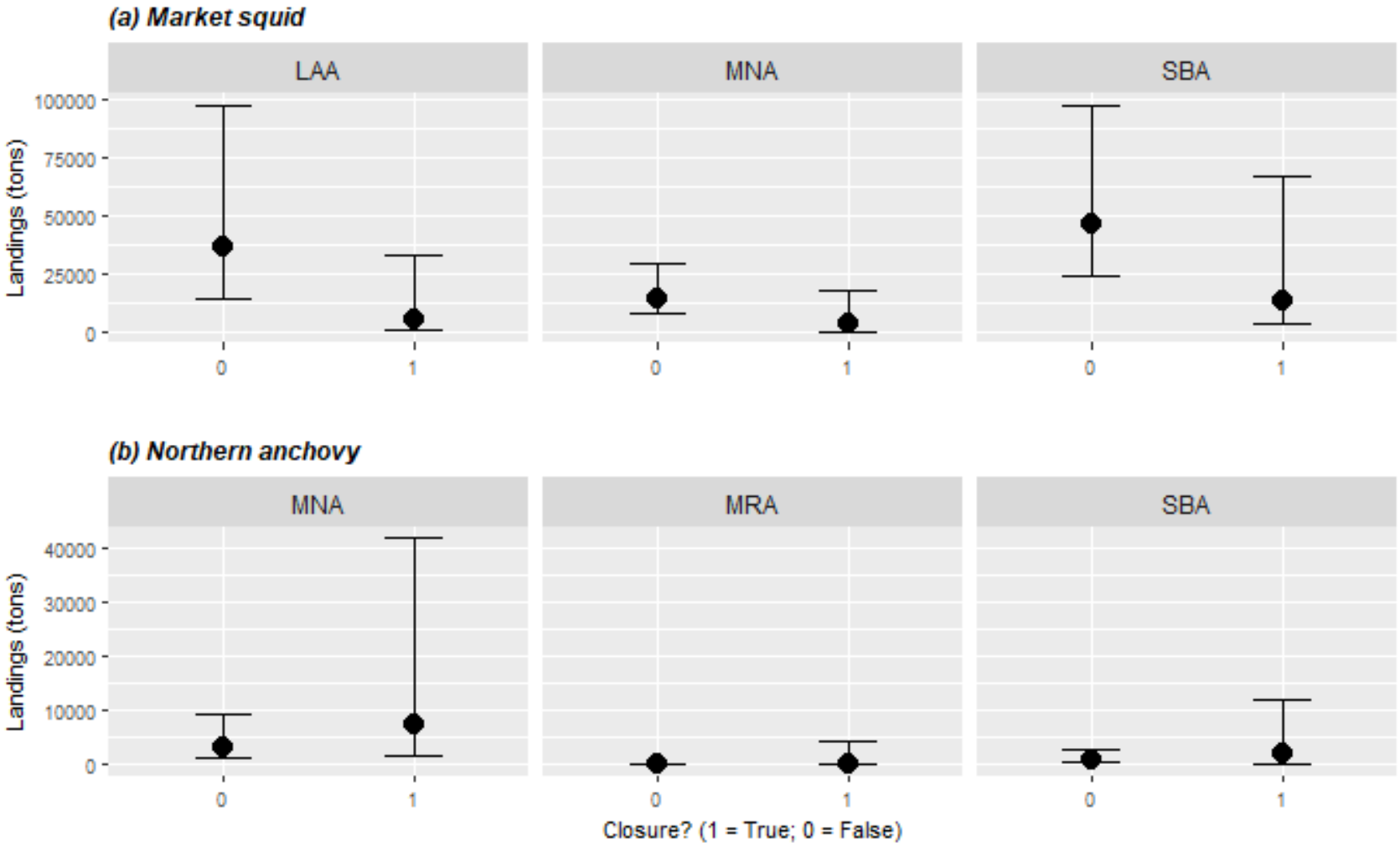
Results: Landings positively related to probability of presence



Results: Squid is a substitute of sardine



Results: Sardine closure reduce squid landings



Conclusions

1. Slightly positive effect of presence on landings.
2. Substitution between market squid and Pacific sardine.
3. Closure reduce market squid landings. Is this because of a lower participation in fishing?

Future work

- Incorporate individual vessel-level data for landings.
  - Check whether a vessel can switch between species or ports.
  - Vessels/port landings.
  - Vessel/port hierarchal effects.
- Econometrics:
  - Serial Correlation
  - Non-stationarity
  - Selection Bias
  - How to test them in a Bayesian framework??
- Estimate a discrete choice model for participation.
- Forecast landings & participation using SDM projections.

Thanks for your attention!

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