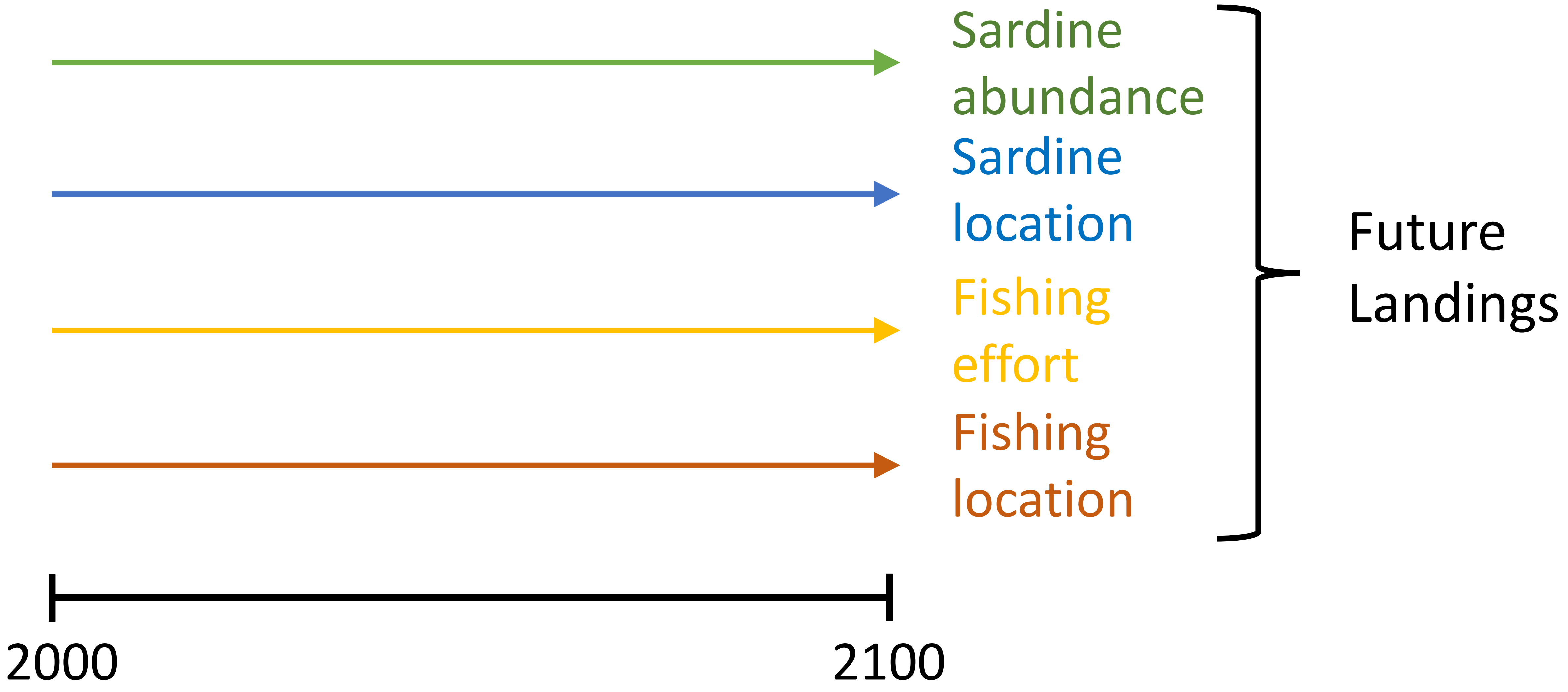
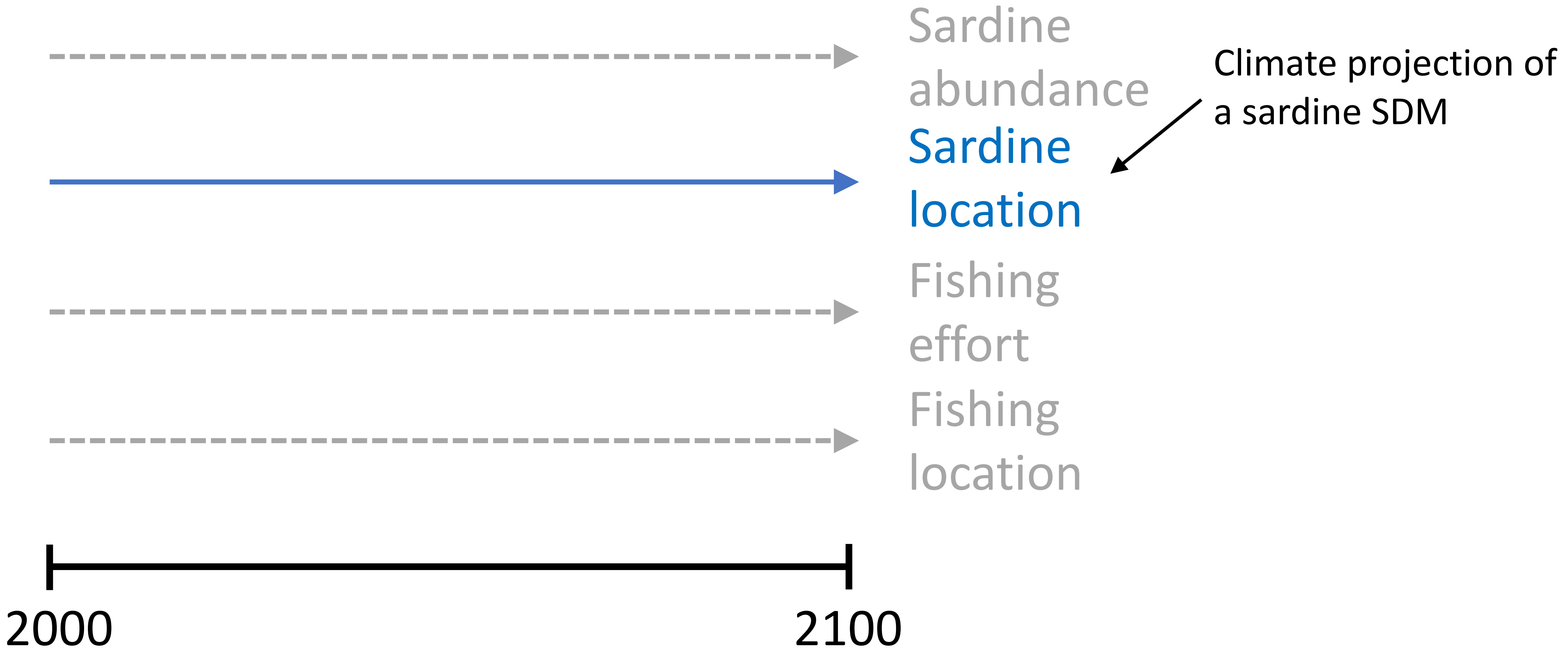
The potential impact of a shifting Pacific sardine distribution on U.S. West Coast landings

James Smith, SWFSC La Jolla
james.smith@noaa.gov

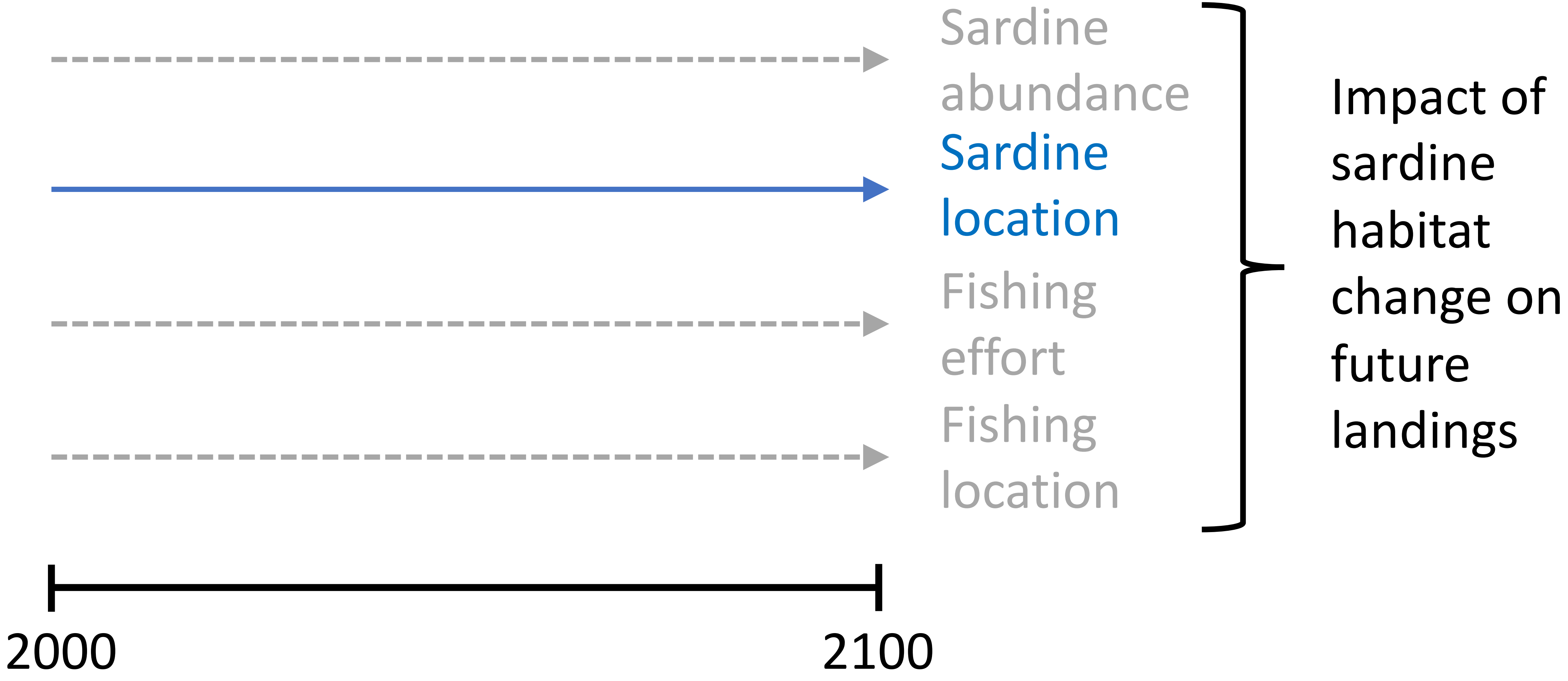
Projecting Landings



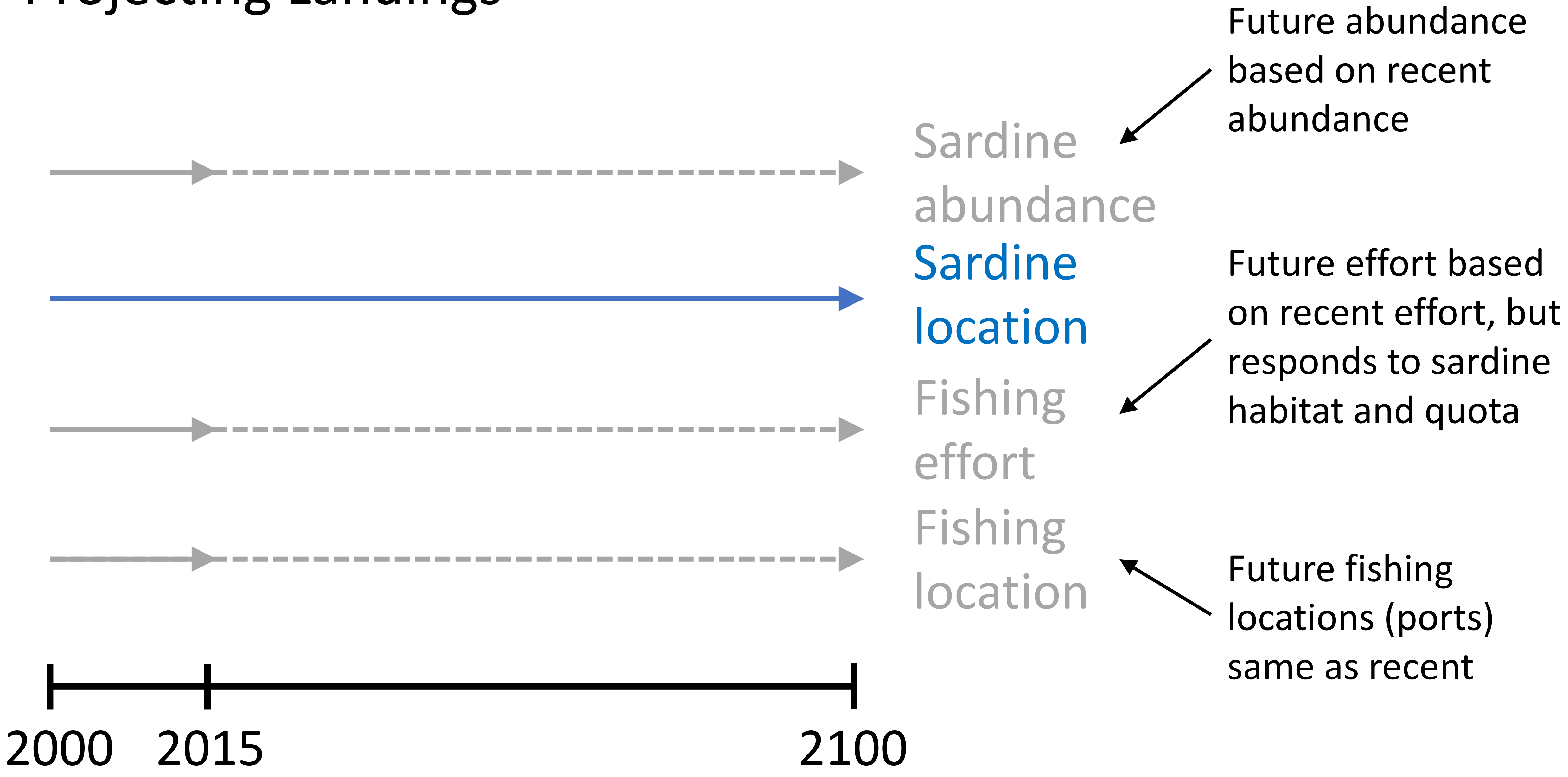
Projecting Landings



Projecting Landings



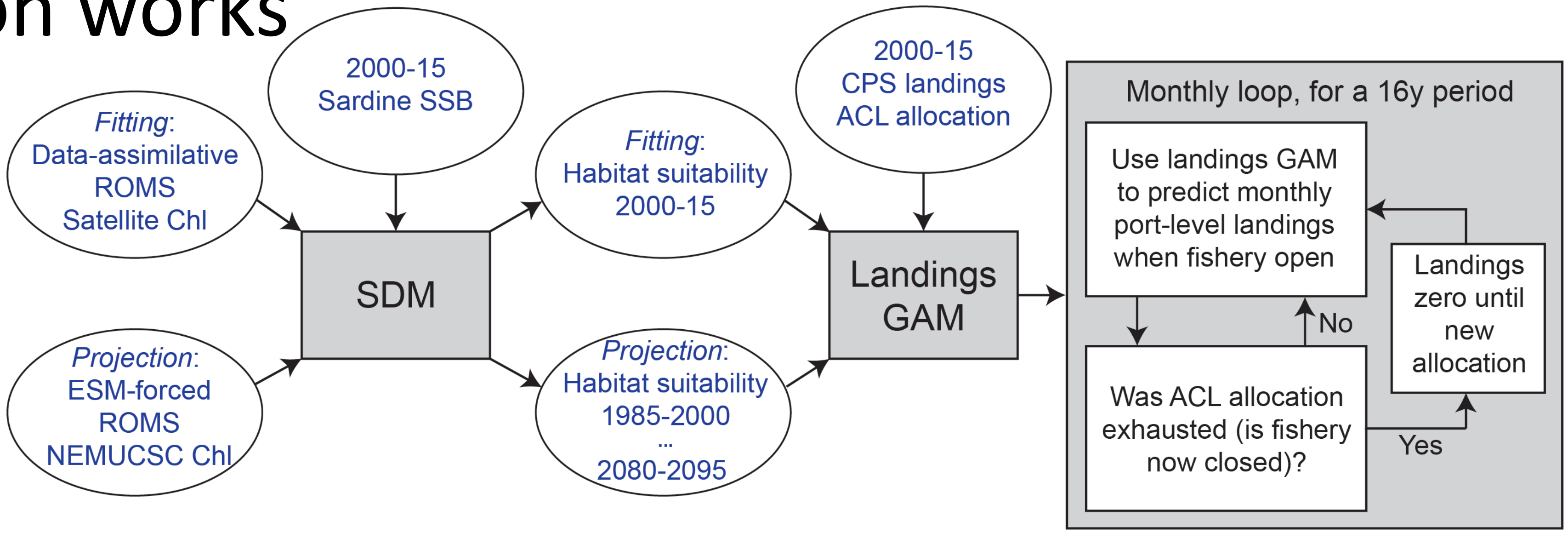
Projecting Landings



The best way to interpret our analysis:

Whatever the future landings will be, *this* is the impact that ocean change and the subsequent redistribution of sardine will have on those landings

How the simulation works



1. Model sardine habitat suitability (SDM)
2. Relate the habitat suitability near port to observed monthly sardine landings (landings GAM), while accounting for landings of other CPS, sardine price etc
3. Project the sardine habitat out to 2100, using ESM climate projections
4. Input this future habitat into landings GAM to calculate landings to 2100, while using a ‘reference period’ to input the other information
5. Use a simulation to allow the fishery to close dynamically based on projected landings (i.e. the ACL is fixed, but how quickly that ACL is reached depends on future habitat)

Step 1. Model sardine habitat

DYNAMIC HABITAT USE OF ALBACORE AND THEIR PRIMARY PREY SPECIES IN THE CALIFORNIA CURRENT SYSTEM

BARBARA MUHLING, STEPHANIE BRODIE,
OWYN SNODGRASS, DESIREE TOMMASI
University of California, Santa Cruz
Institute for Marine Science
Santa Cruz, CA
ph: (858) 546-7197
Barbara.Muhling@noaa.gov

BARBARA MUHLING, OWYN SNODGRASS,
HEIDI DEWAR, DESIREE TOMMASI, JOHN CHILDERS
NOAA Southwest Fisheries Science Center
San Diego, CA

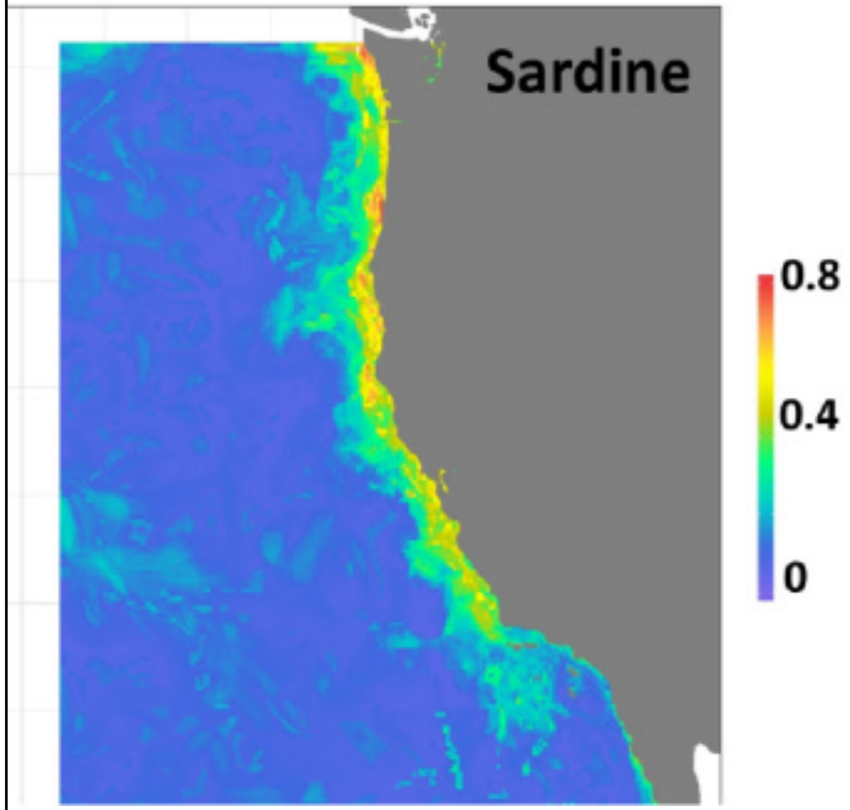
STEPHANIE BRODIE, MICHAEL JACOX
NOAA Southwest Fisheries Science Center
Monterey, CA

MICHAEL JACOX
NOAA Earth System Research Laboratory
Boulder, CO

CHRISTOPHER A. EDWARDS
Ocean Sciences Department
University of California, Santa Cruz, CA

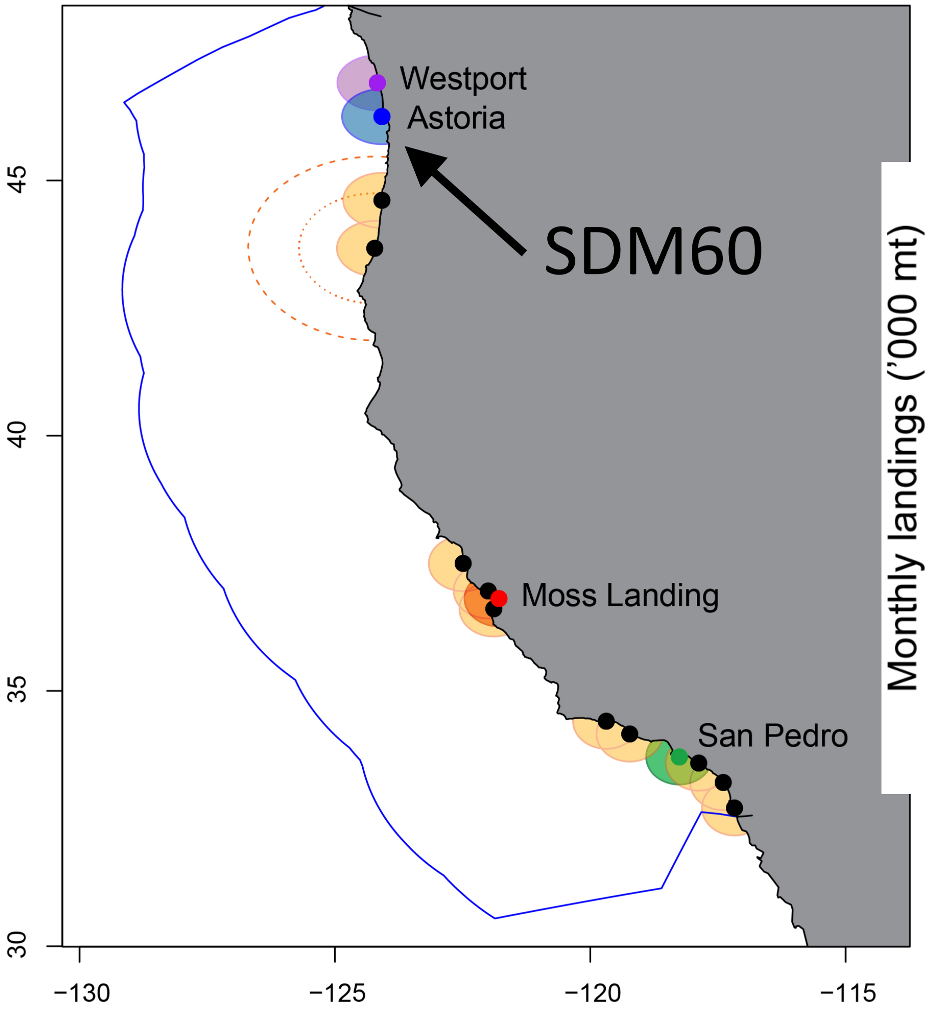
YI XU
Department of Fisheries and Oceans
Delta, British Columbia, Canada

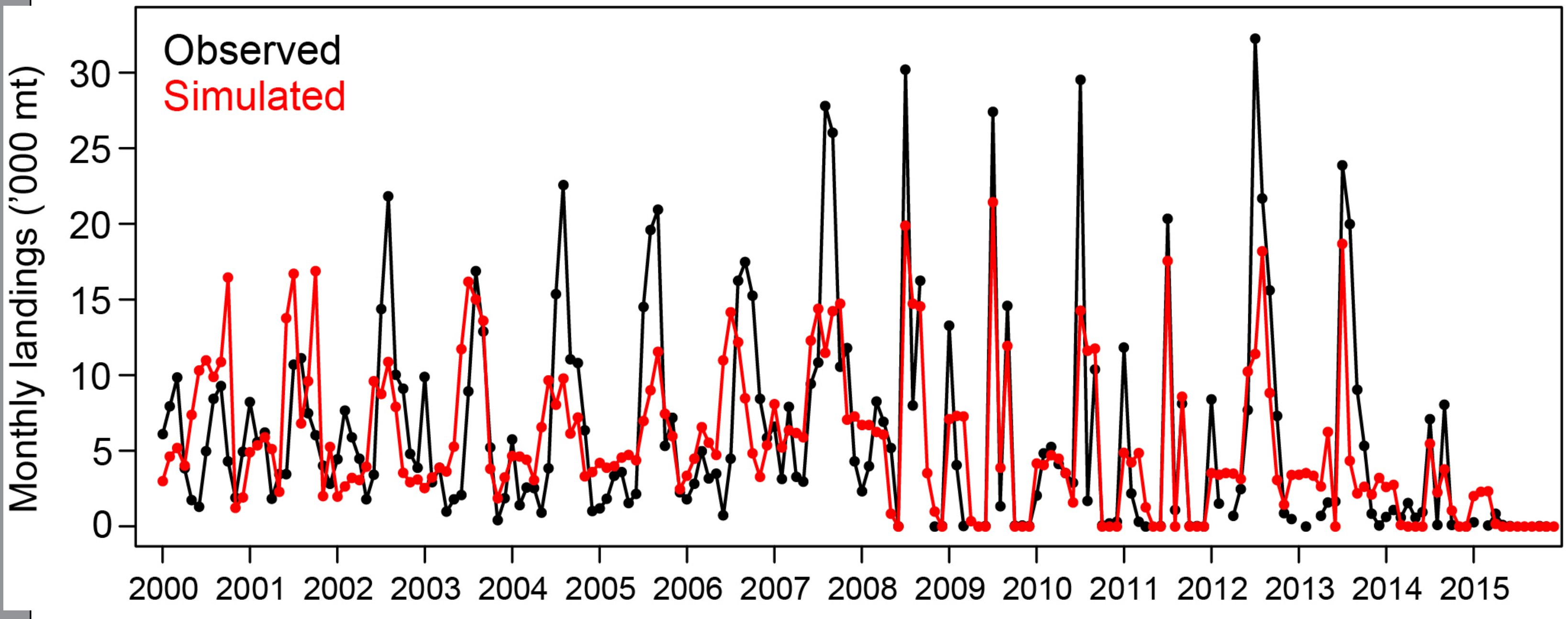
STEPHANIE SNYDER
Thomas More University,
Crestview Hills, KY



Step 2. Relate sardine habitat to landings

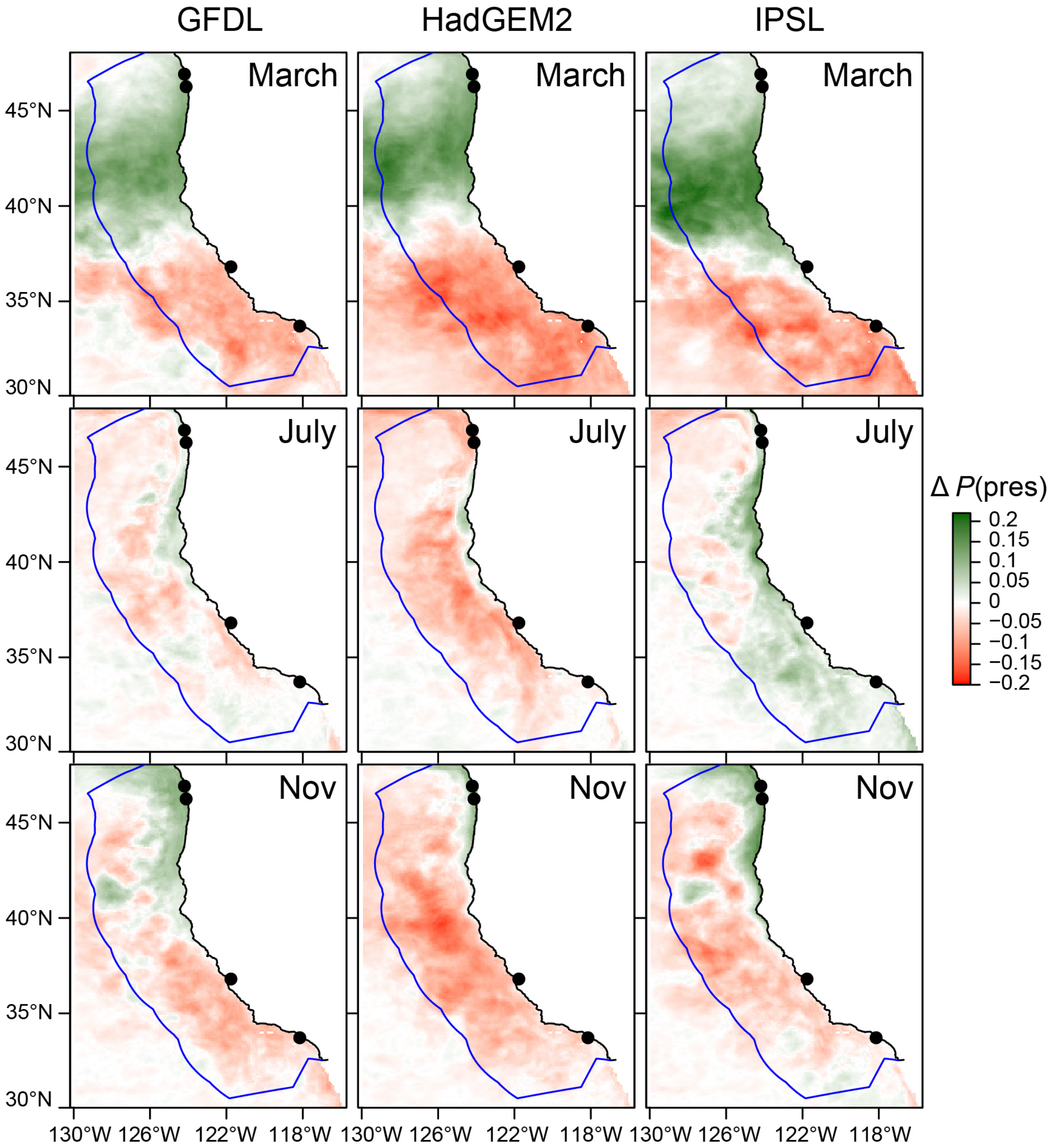
$$Landings \sim s(SDM60\!:\!port) + s(ACL) + s(Squid\!:\!port) + s(Anch\!:\!port) + port$$





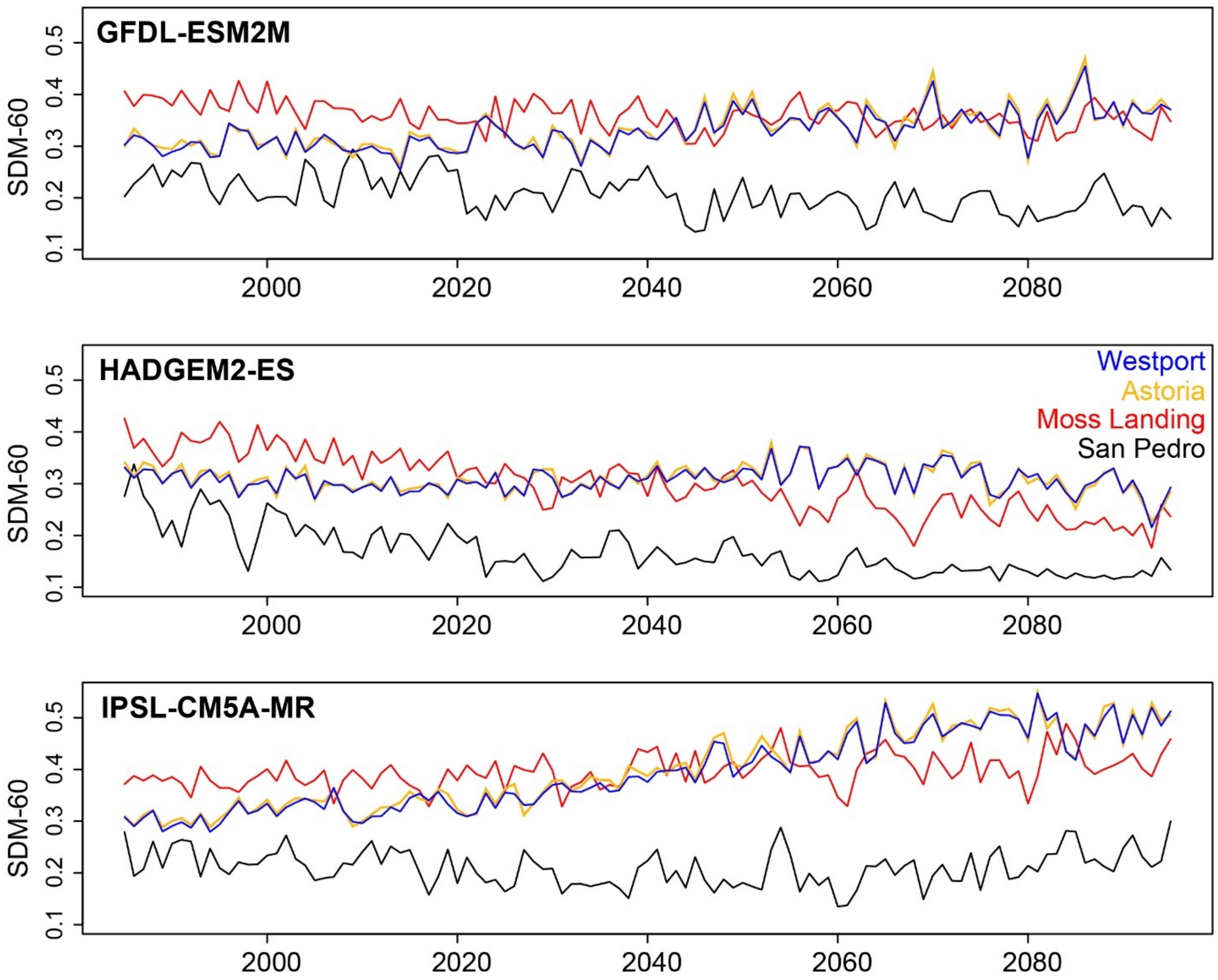
Step 3. Project sardine habitat out to 2100

- This shows the mean change in sardine habitat suitability, as the change from 2000-15 to 2040-55
- Green indicates an increase in habitat suitability, and red a decrease



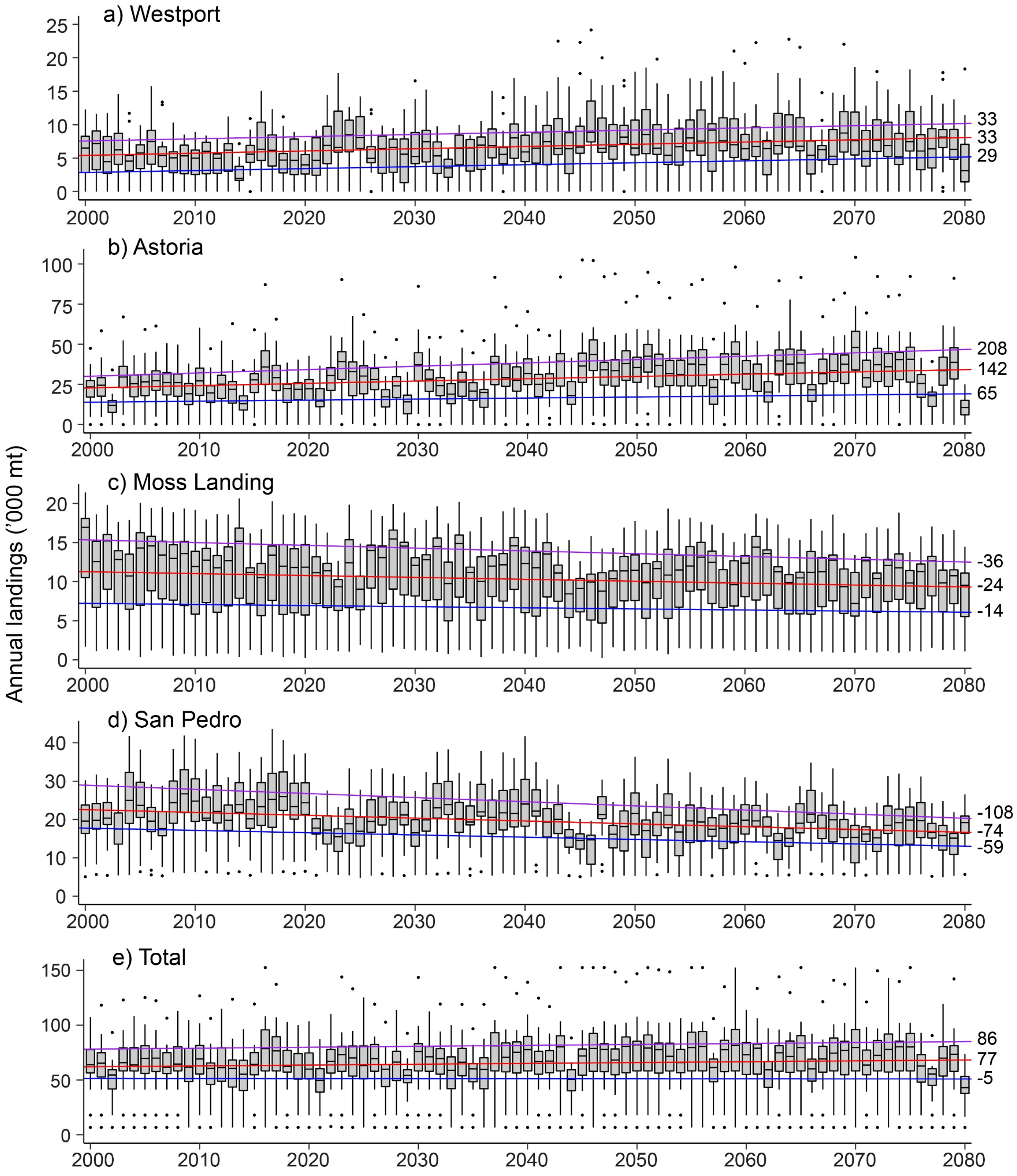
Step 4. Input future habitat into landings model

- This shows the projected change in habitat suitability near each port (SDM60)
- This is inputted into the landings GAM



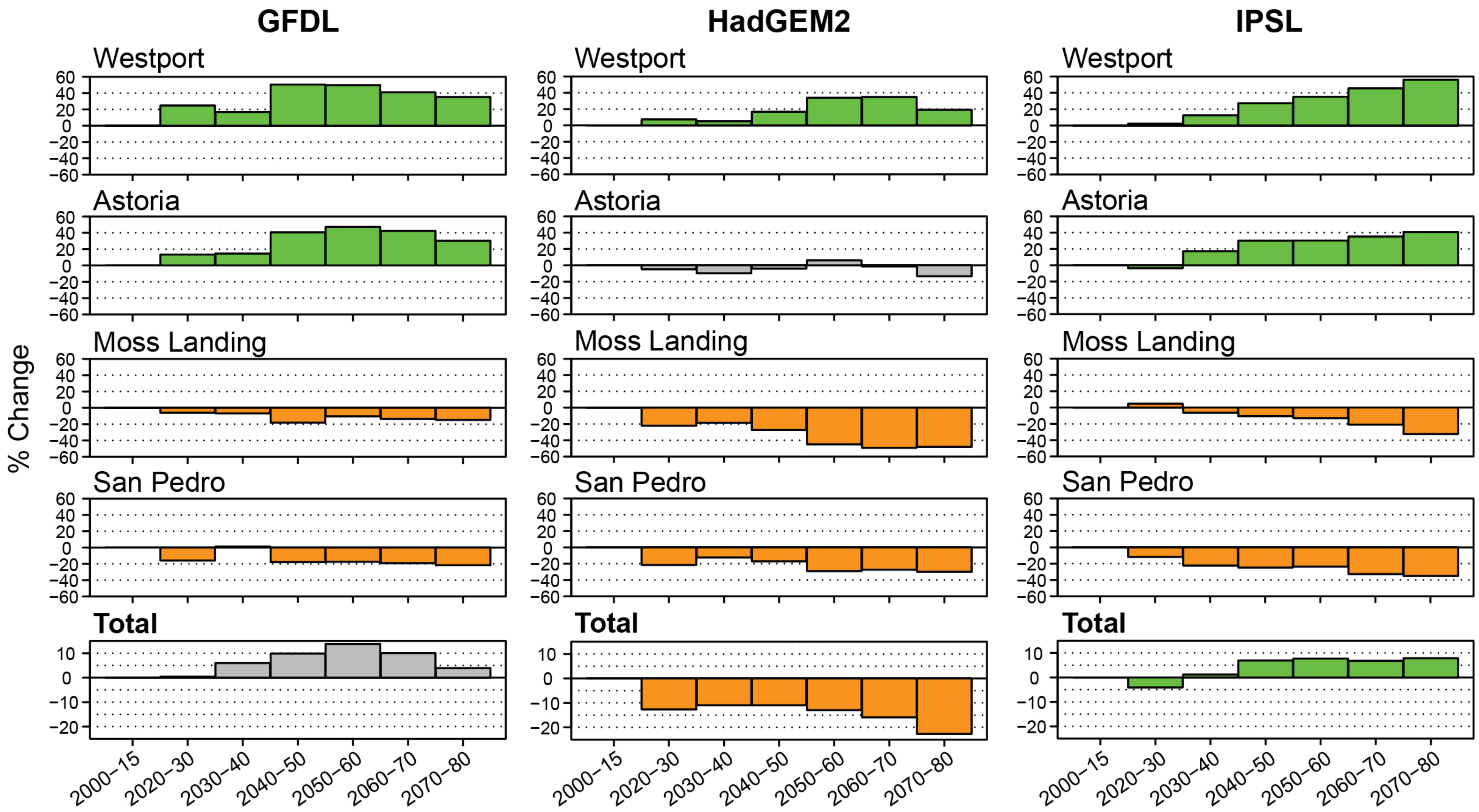
Step 5. Results

- This shows the range of landings expected in each year, based on habitat suitability near port, with everything else from the 2000-15 period
- The linear trend is due to change in habitat suitability only
- The relative (%) change in this trend is the key result



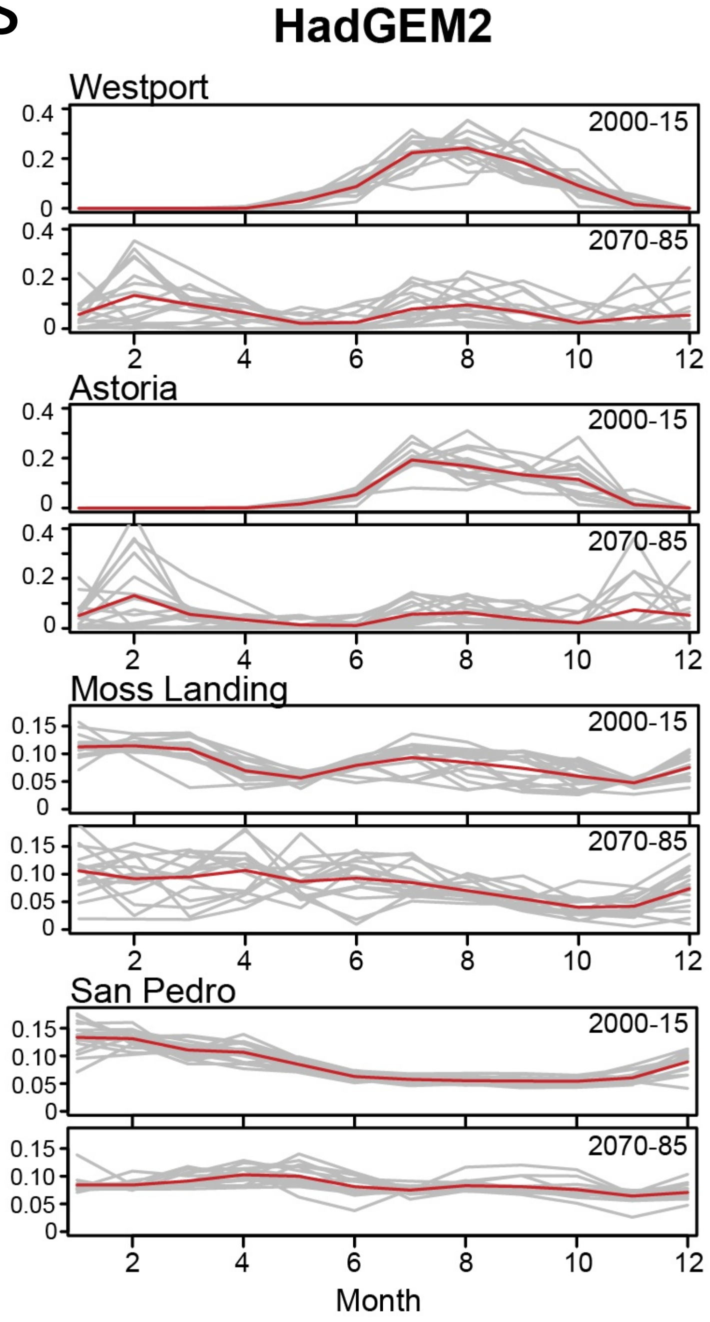
Step 5. Results

- Landings increase in the north, decrease in the south
- Total landings can do down (20%), go up (10%), or go up and then down

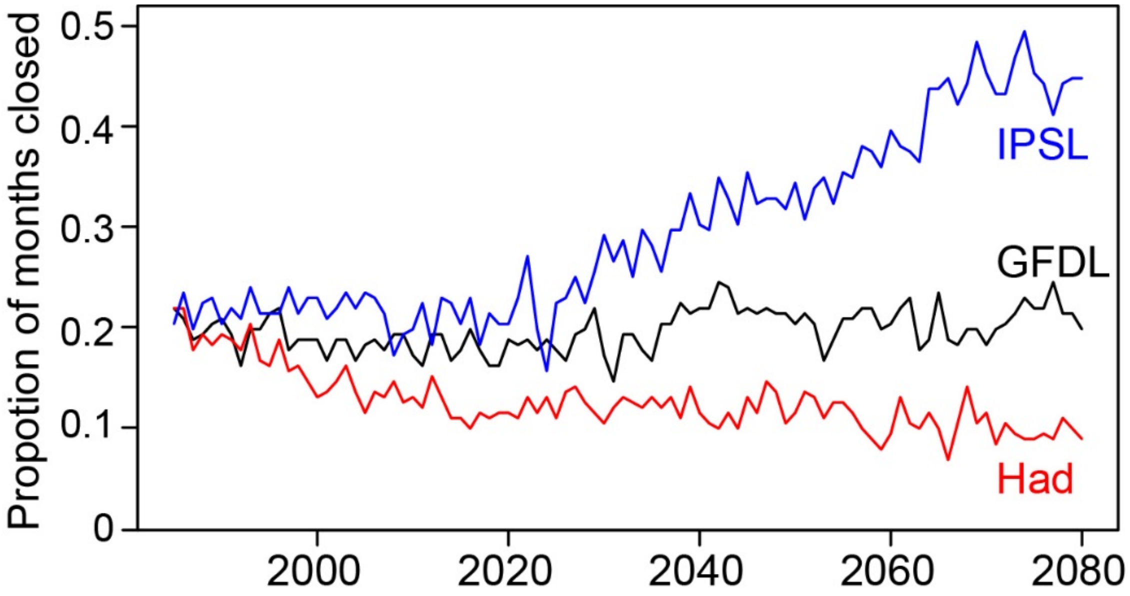


Step 5. Results

- Fishing season may start earlier and get longer



- Fishing closures may become more frequent (ACL reached earlier)



Sardine 3 ways – benefits and limitations

	SDM-Landings	IBM	MICE
Benefits	- SDMs are robust for long term projection - Avoids projecting sardine abundance or management - Explores interplay of fishery constraints (e.g. other species, quota allocation)	- Mechanistic understanding of bottom up effects on population dynamics - Represents age structure and early life stages explicitly - Includes growth, mortality, reproduction, behavior explicitly	- Age-structured population dynamics - Environmental driving of biological processes - Fine time-step (1 week) - Fast run-time - Uncertainty and sensitivity analyses
Limitations	- Estimates only relative change in landings (%) - Uses correlative models, so less insight into processes and assumes past correlations persist - Doesn't yet propagate all uncertainty through to results	- Typically underestimates observed variability - Calibration of many biological parameters can be time intensive - Population dynamics can be overly sensitive to early life mortality	- Coarse/simplified spatial resolution - No individual-level processes - No detailed fleets/ports (yet?)

Sardine 3 ways – results summary

	SDM / landings	IBM	MICE
Sardine distribution	Northward shift (Nth subpop)	Northward shift	Northward shift (rule-based forcing)
Biomass trends	*Does not project sardine biomass*	Multi-decadal variability in adult biomass; periods of higher biomass in 2000-20 and 2080-2100, lower in 2040-60	General increasing trend in biomass; interannual variability same or higher; more biomass and uncertainty for HAD & IPSL
Total catch trends	Increases (IPSL), decreases (HAD), or increases then decreases (GFDL) [to 2080]	Follows trend of biomass	Follows trend of biomass
Catch distribution	Increase in the north, decrease in the south	Increase in the north, decrease in the south (GFDL) and central (HAD, ISPL)	*Catches not resolved at region/port level*
Main drivers	Temperature and Chl; seasonal ACL allocation; timing of other CPS	Temperature through increased early life survival; Prey availability through reproductive output	Temperature, prey availability