*Species On The Move Conference*
*Kruger National Park, South Africa*
*July 2019*

# A simulation comparing dynamic and static closures in a drift-gillnet swordfish fishery

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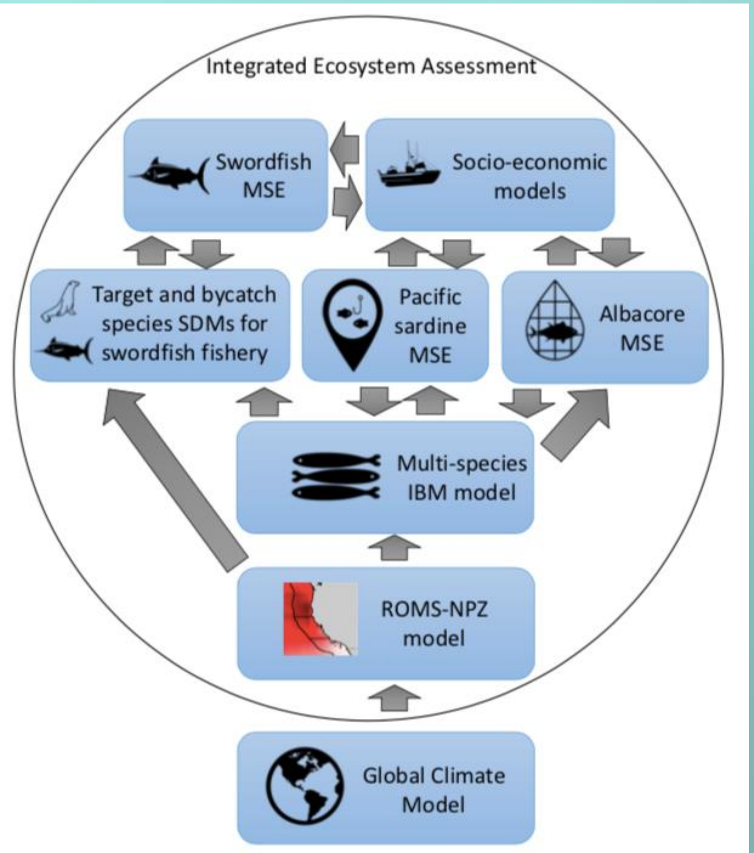
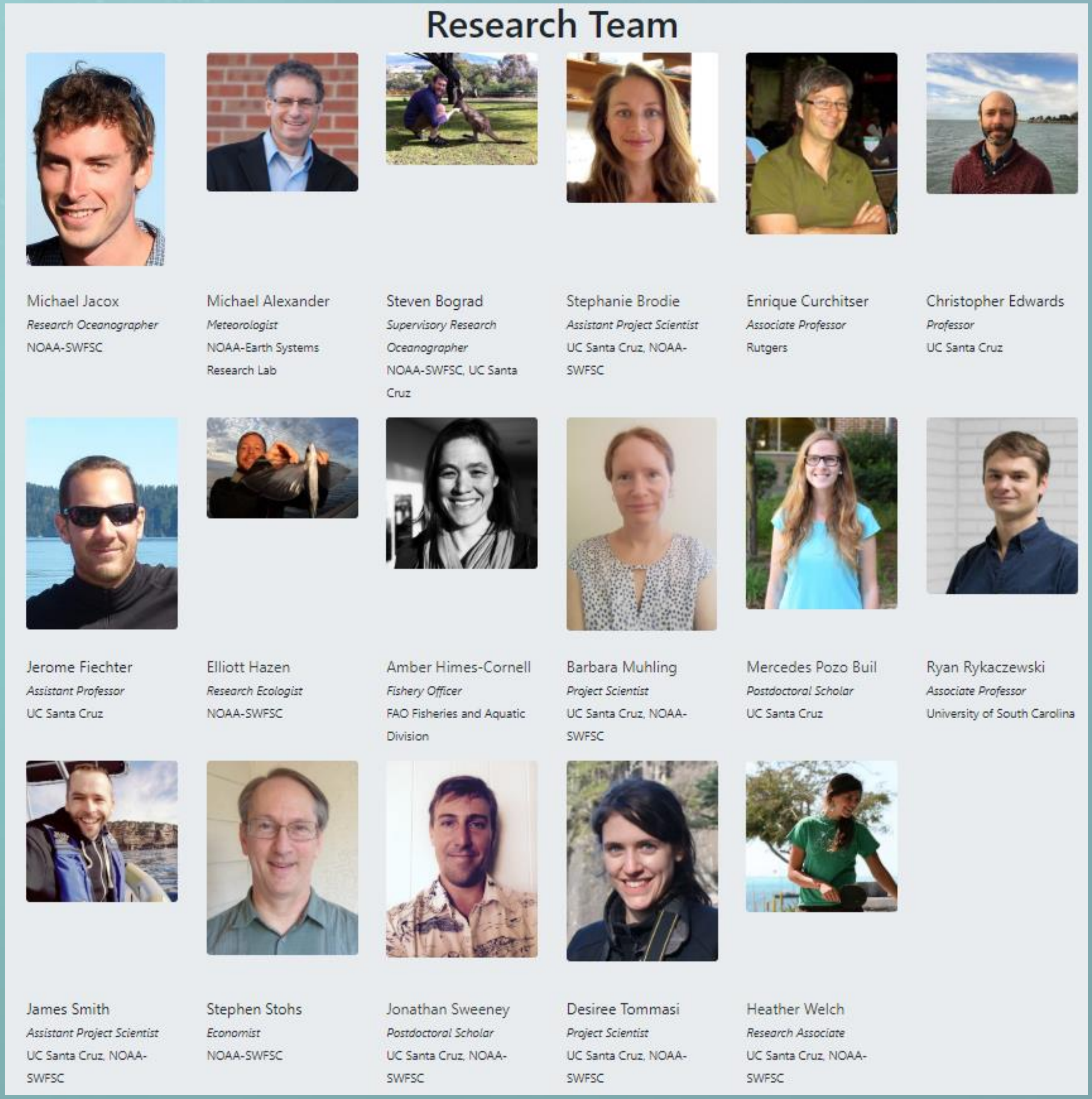
# 'FUTURE SEAS'

An end-to-end fisheries management strategy evaluation for future climate change in the California Current.




Plus numerous collaborators

# The DGN – fishery and closures

Mason et al 2019, Fish. Res.

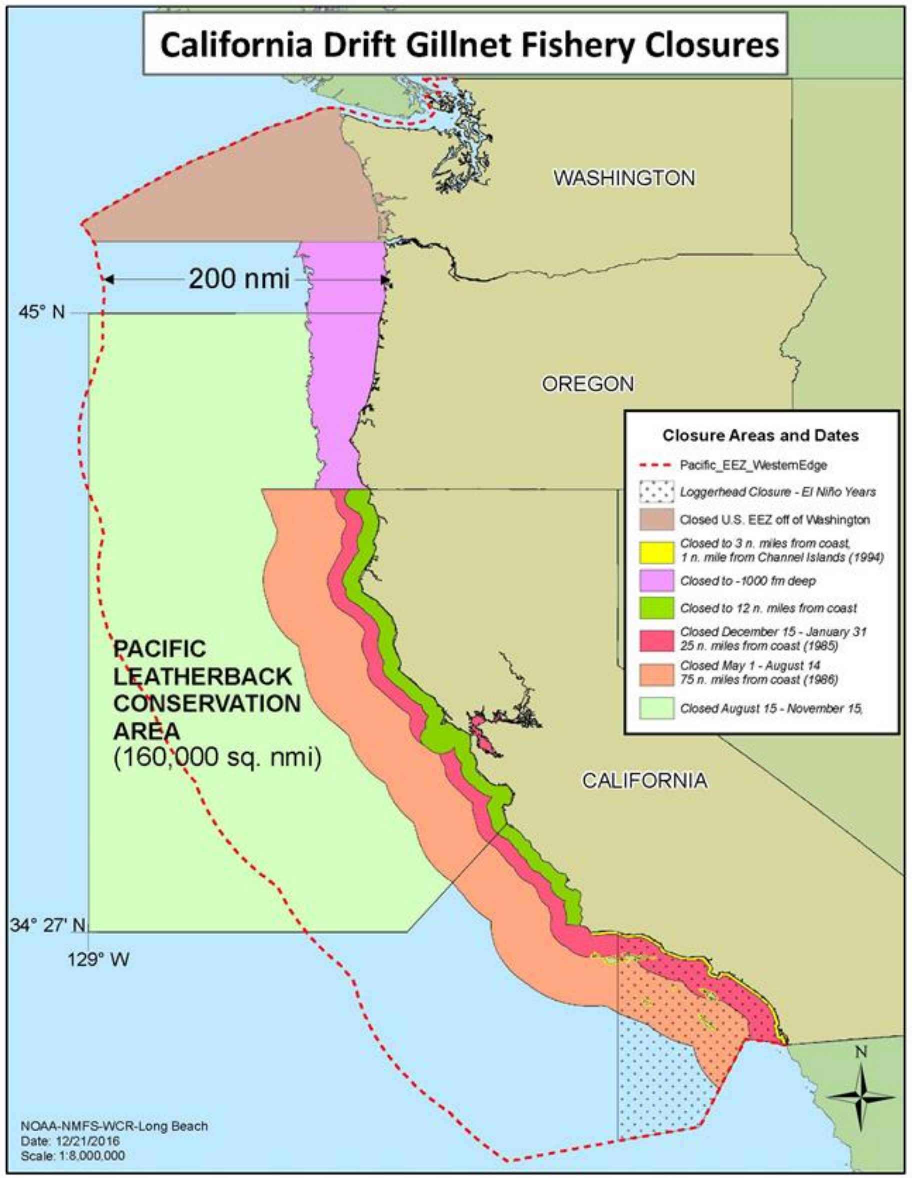



Table 1. Drift gillnet catch species referenced in this manuscript. Target species (defined as over 75% retained) icons are blue, while bycatch species icons are red. The percentage of total catch is calculated as number of individuals recorded in the observer data over total individuals of all species recorded. Analyses refer to the methods used in this study.

| Icon | Species | Common name | Number caught | % total catch | Analyses |
|---|---|---|---|---|---|
| | *Mola mola* | Common Mola | 55235 | 33.29 | Both |
| | *Prionace glauca* | Blue Shark | 22340 | 13.46 | Both |
| | *Xiphias gladius* | Broadbill Swordfish | 18502 | 11.15 | Both |
| | *Thunnus alalunga* | Albacore Tuna | 17382 | 10.48 | Both |
| | *Katsuwonus pelamis* | Skipjack Tuna | 9720 | 5.86 | DFA |
| | *Isurus oxyrinchus* | Shortfin Mako Shark | 8161 | 4.92 | Both |
| | *Alopias vulpinus* | Common Thresher Shark | 6632 | 4.00 | Both |
| | *Dermochelys coriacea* | Leatherback Turtle | 25 | $1.51 \times 10^{-4}$ | Both |

# EcoCast

- A ‘Dynamic Ocean Management’ decision support tool
- Combines occurrence probabilities to create a multi-species risk surface indicating fishing suitability
- Used in our simulation to determine dynamic closures, by indicating areas for fishers to *avoid*
- Weighted: 0.1 (SF), -0.7 (LB), -0.1 (SL), -0.1 (BS)

SCIENCE ADVANCES | RESEARCH ARTICLE

ECOLOGY

## A dynamic ocean management tool to reduce bycatch and support sustainable fisheries

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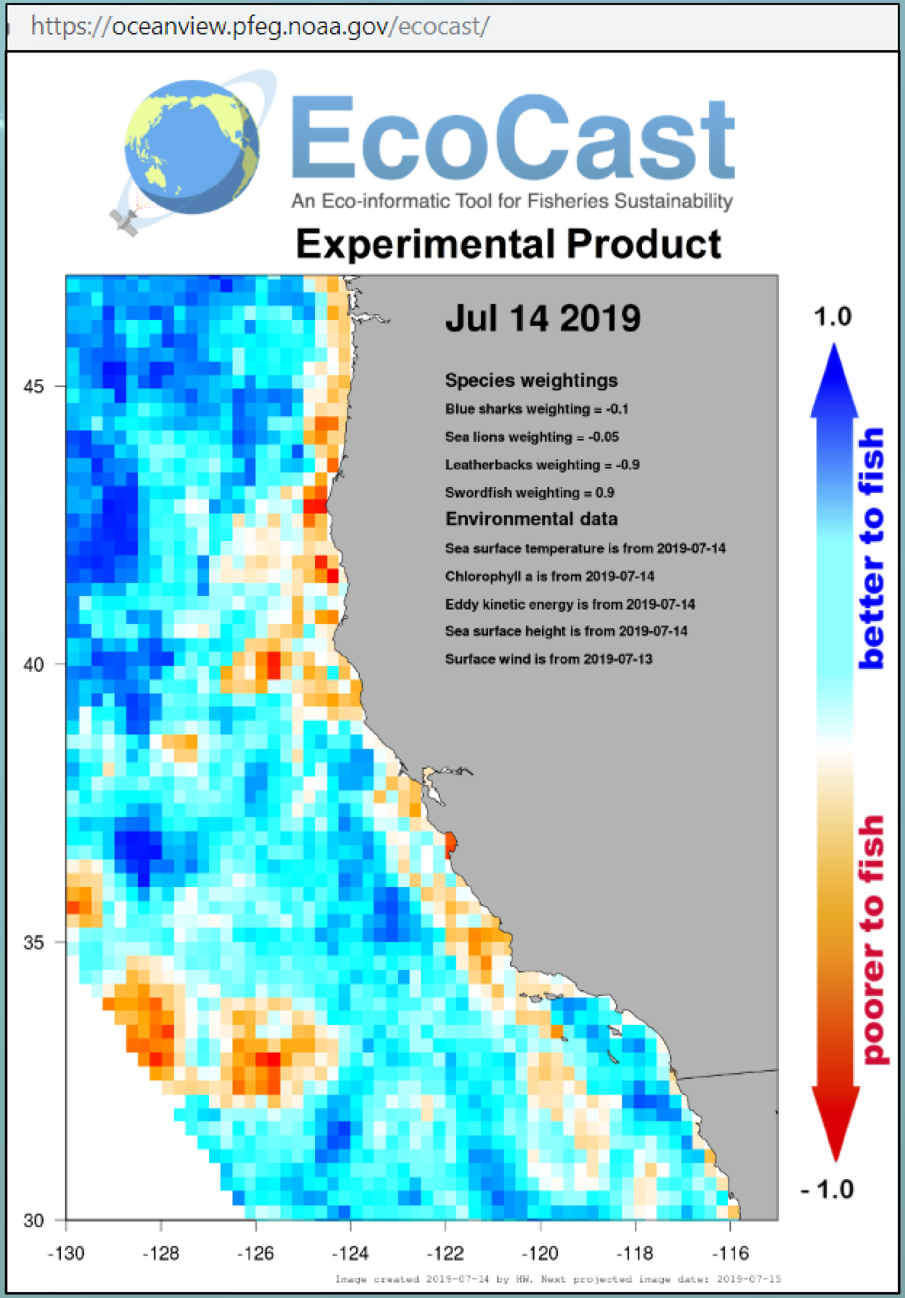
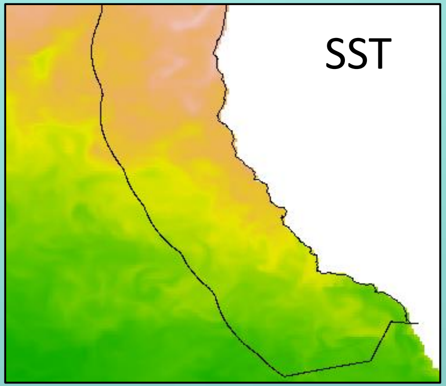


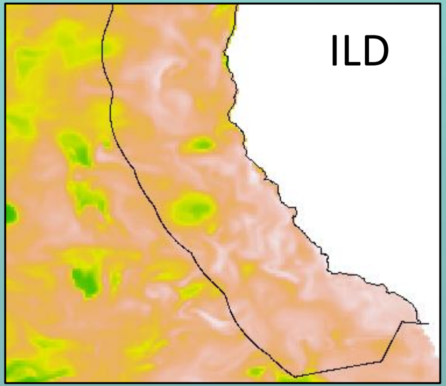
# Goal of this Simulation

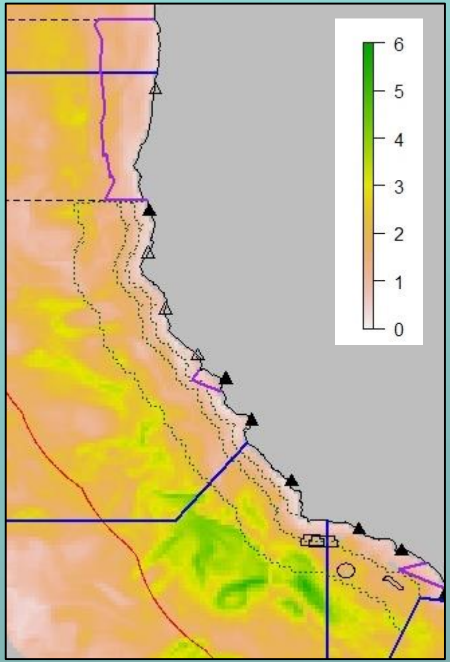
- Broadly: exploring climate-change resilient management strategies
- Specifically: an evaluation of Dynamic Ocean Management vs Static Closures, using the DGN as a model system
  - The 1990-2000 period was modelled to provide realistic pre-closure magnitude and distribution of fishing effort in the DGN

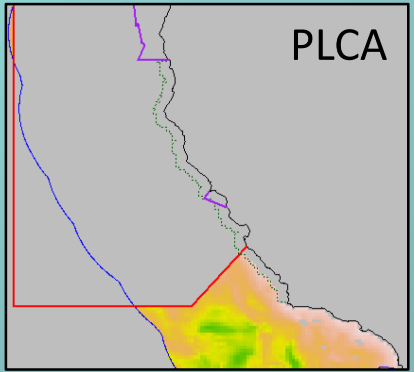
# Structure of Simulation

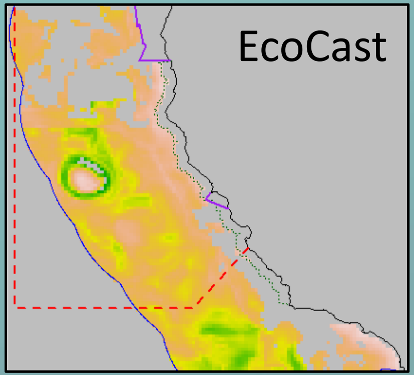
| What is the ocean doing | What can be caught | Which areas are closed | Simulate fishing | Catches and profits |
|---|---|---|---|---|
| **ROMS** | **Catch models**<br>Statistical models for SF and LBT, using Observer & ROMS | **3 closure scenarios**<br>1. All closures<br>2. No PLCA<br>3. Avoid with EcoCast | **2 effort models**<br>1. Fixed fishing effort<br>2. Dynamic effort (Agent-based model) | **Performance metrics**<br>*Compare closure scenarios* using catch, bycatch, profit, etc |

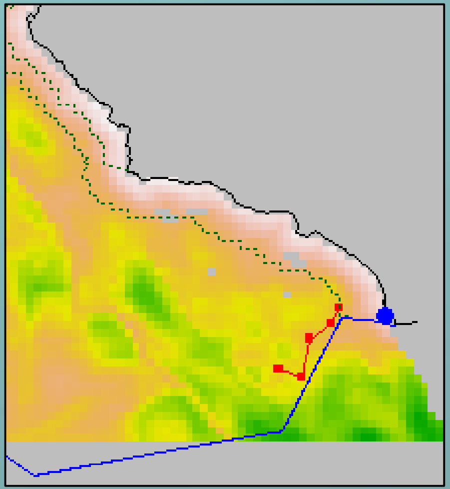


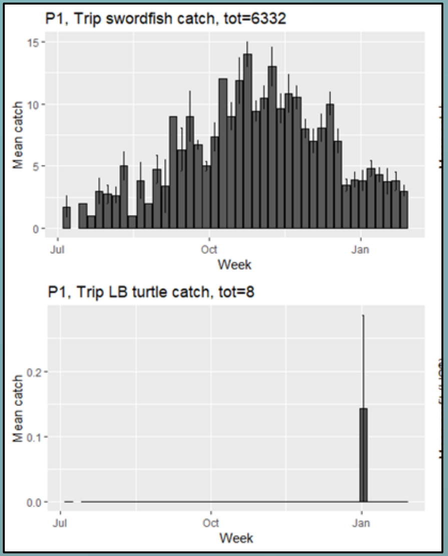





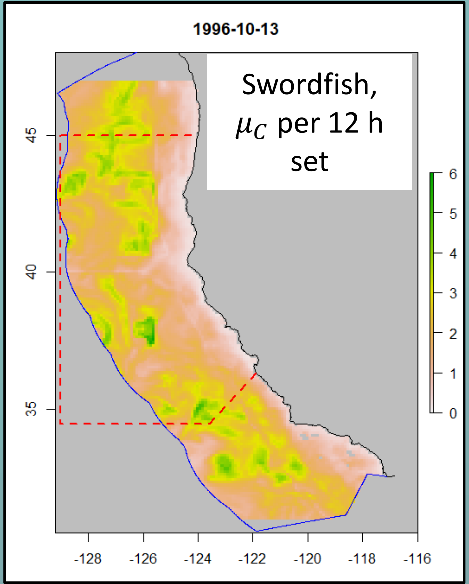


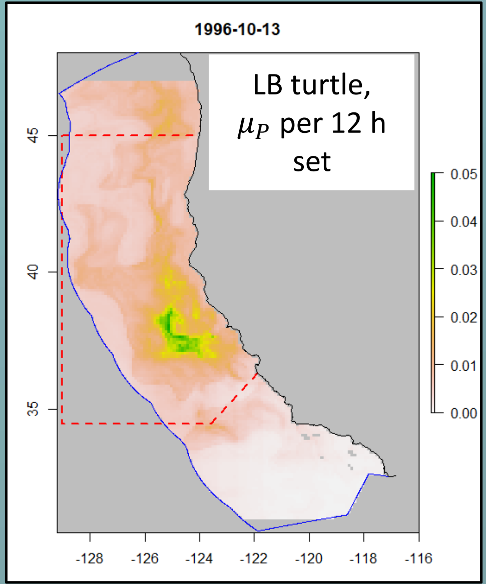
# Structure of Simulation

## *Catch models*

- Swordfish catch models are GAMMs and BRTs
- LB turtle catch models are Random Forests, *with down-sampling procedure*
- Fitted using Observer data from 1990-2000 (~5800 sets)
- Catch at each set determined by $NB(\mu_C, \theta), Pois(\mu_C),\ B(\mu_P)$

| | **Swordfish** | | | **Turtle** |
|---|---|---|---|---|
| | GAMM Env. | GAMM S-T | BRT | RF |
| SST | y | y | y | y |
| SST-sd | y | y | y | y |
| Dist-coast | y | | y | |
| Depth-sd | y | y | y | |
| ILD | y | y | y | |
| SSH | y | y | y | y |
| EKE | y | y | y | |
| FTLE | y | y | y | |
| Soak | y | y | y | y |
| Lat | | y (te, sf) | y | y |
| Lon | | y (te, sf) | | y |
| Time | | y (te, cr) | | |
| DOY | | y (cc) | | |
| Vessel | y (RE) | y (RE) | | |
| FAMILY | NB | NB | Pois | Prob. / B |
| Expl. Dev. | 26% | 41% | 46% | |
| OOB error | | | | 27% |

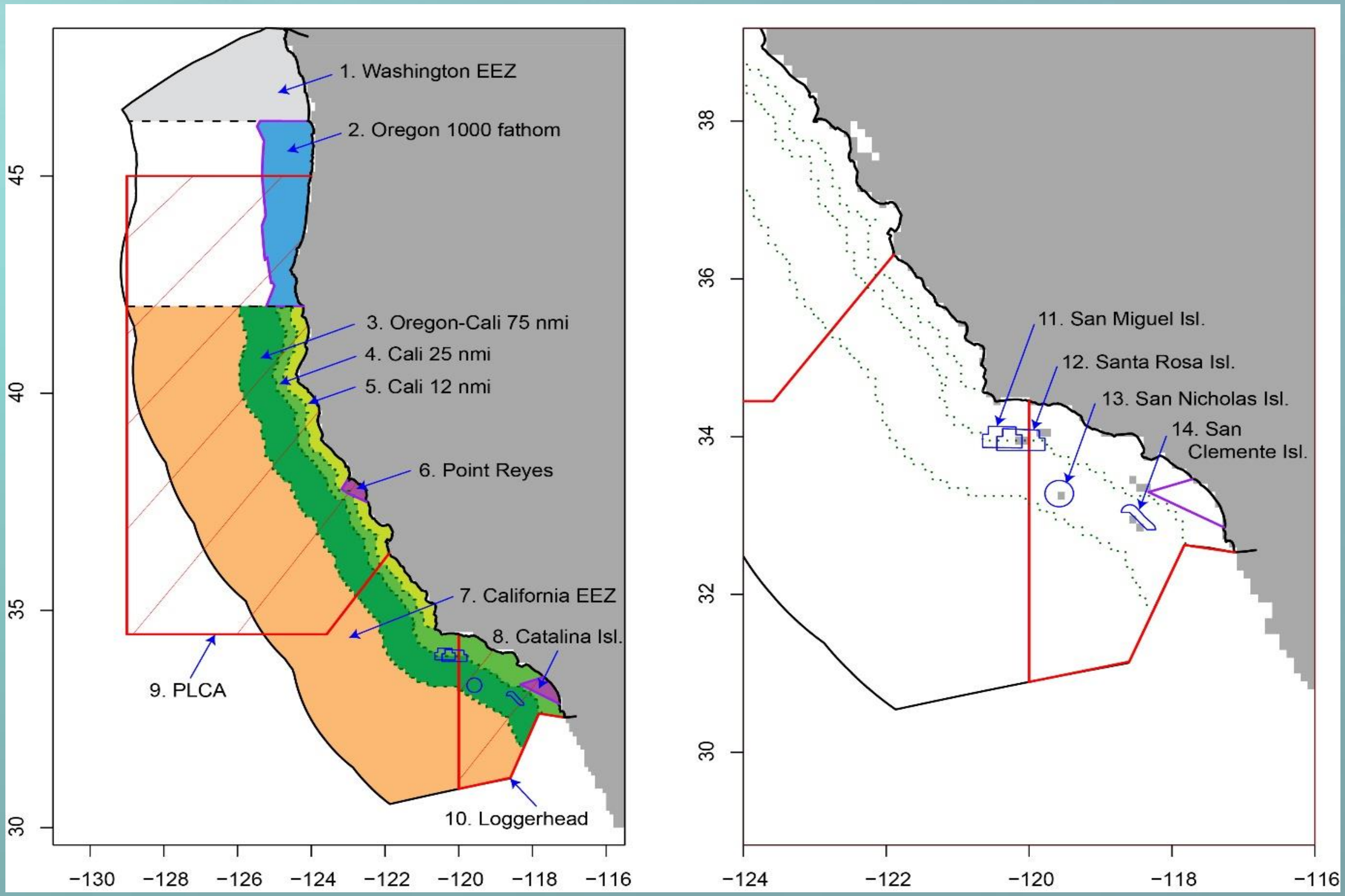


# Structure of Simulation

## *Closure scenarios*

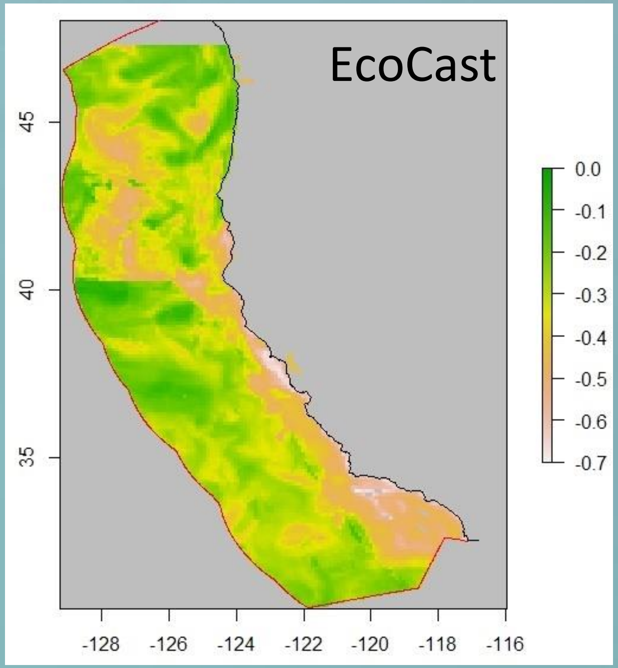
- The simulation tracks 14 closures
- Only the PLCA varied among scenarios

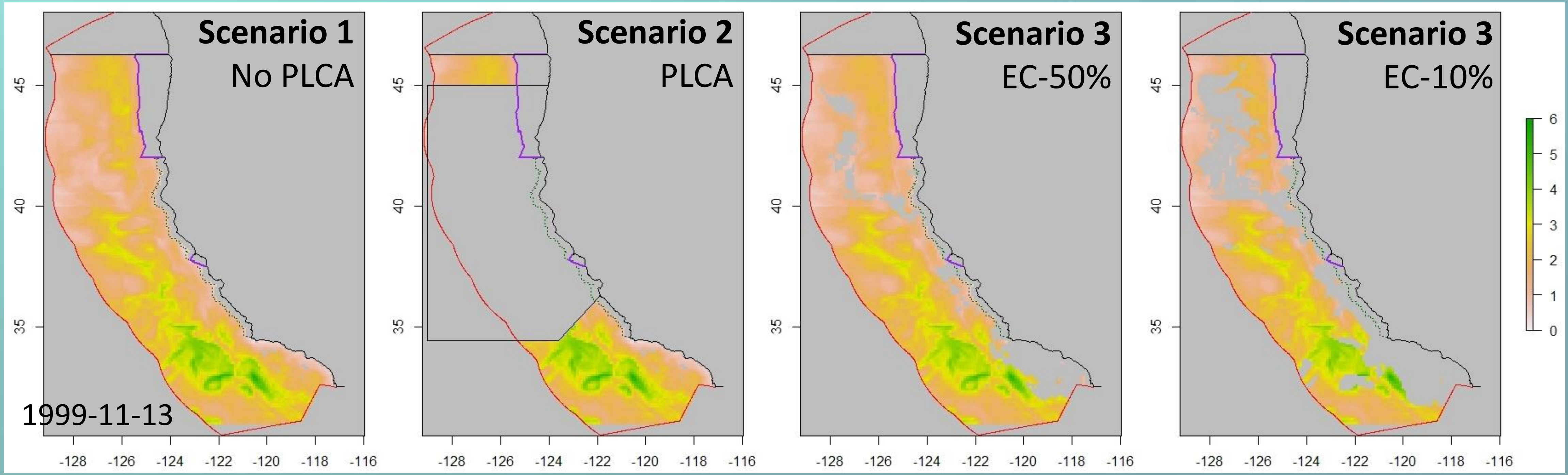


# Structure of Simulation

## *Closure scenarios*

- Three 'avoid with EcoCast' thresholds: 50% allowable catch risk for LB turtles, 10%, <10%
  - A 50% catch risk means that 50% of >0.5 occurrence LB habitat is above a closure threshold value (i.e. open to fishing)

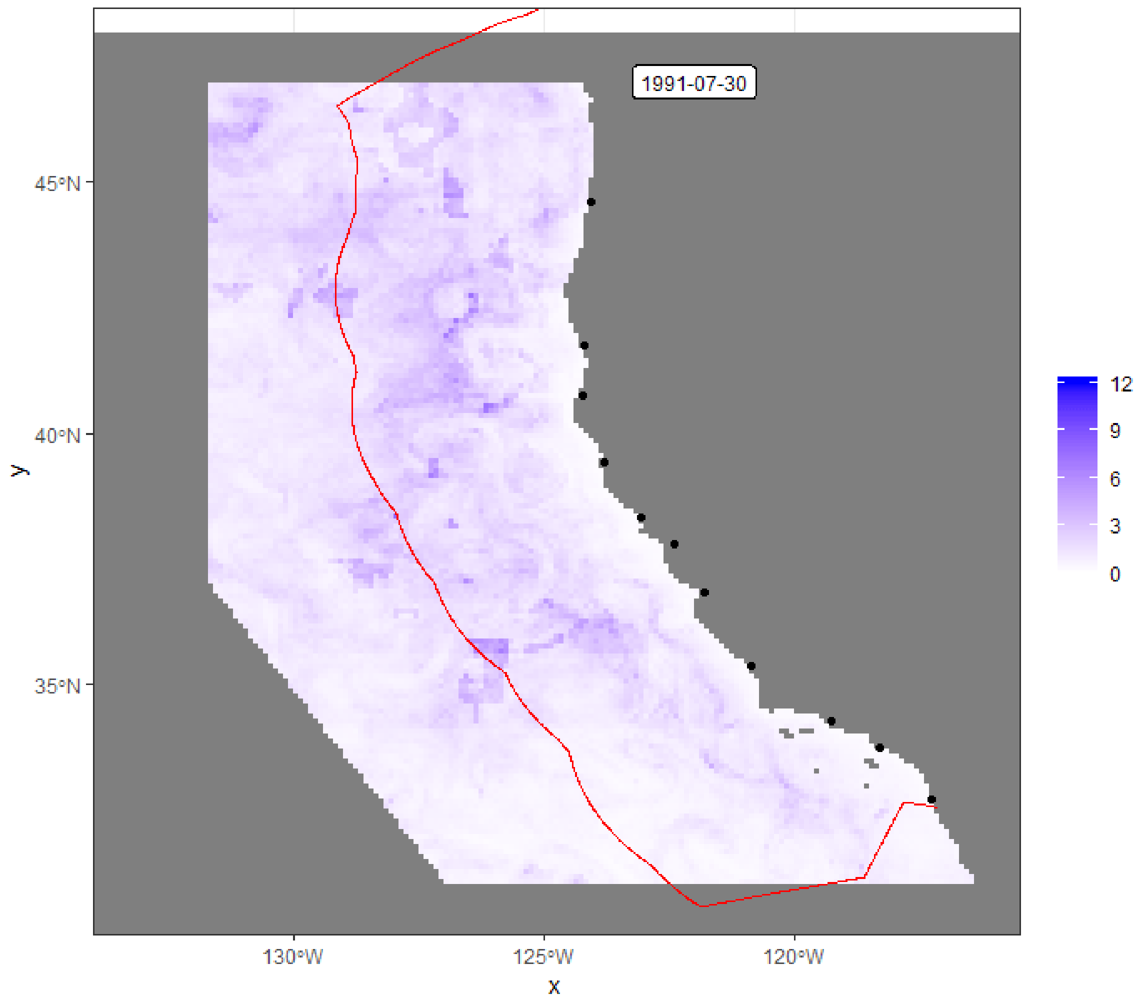


# Structure of Simulation

## *Simulate fishing: Agent-based Model*

- Vessels will move outside closures if they can reasonably do so
- Search by profit-maximizing
- Land catch at nearest port
- Move according to travel speeds, 12-h sets, catch-dependent step distances
- Tuned so modelled ≈ observed



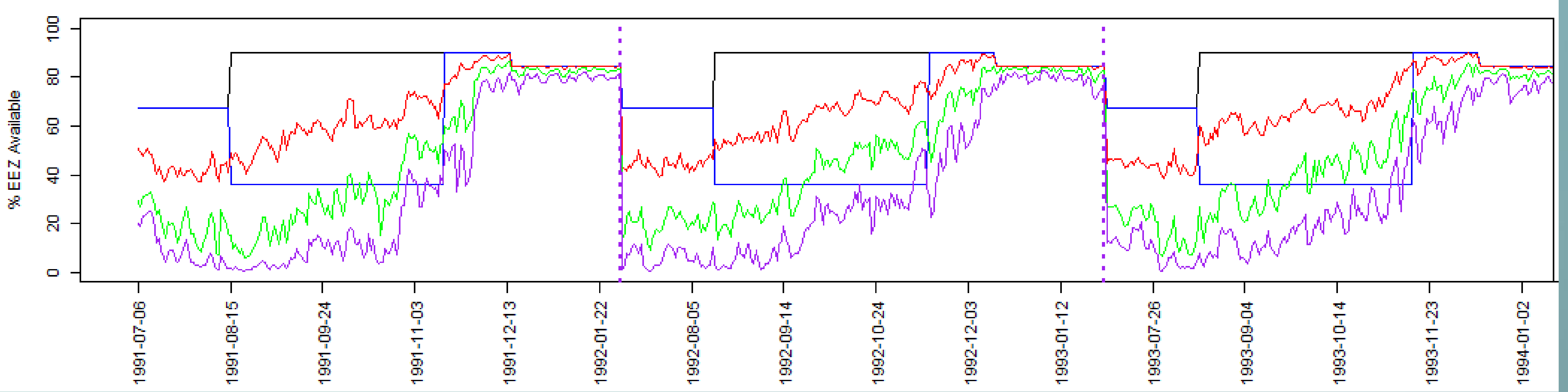

animation of fishing behaviour

# Results – area available

- We can track the area available to fishing
  - EC-50 opens more area to fishing, EC-10 is similar to PLCA
  - With EC, more area opens over time as risk of LB bycatch decreases

No Closure
PLCA
EC50
EC10
ECs

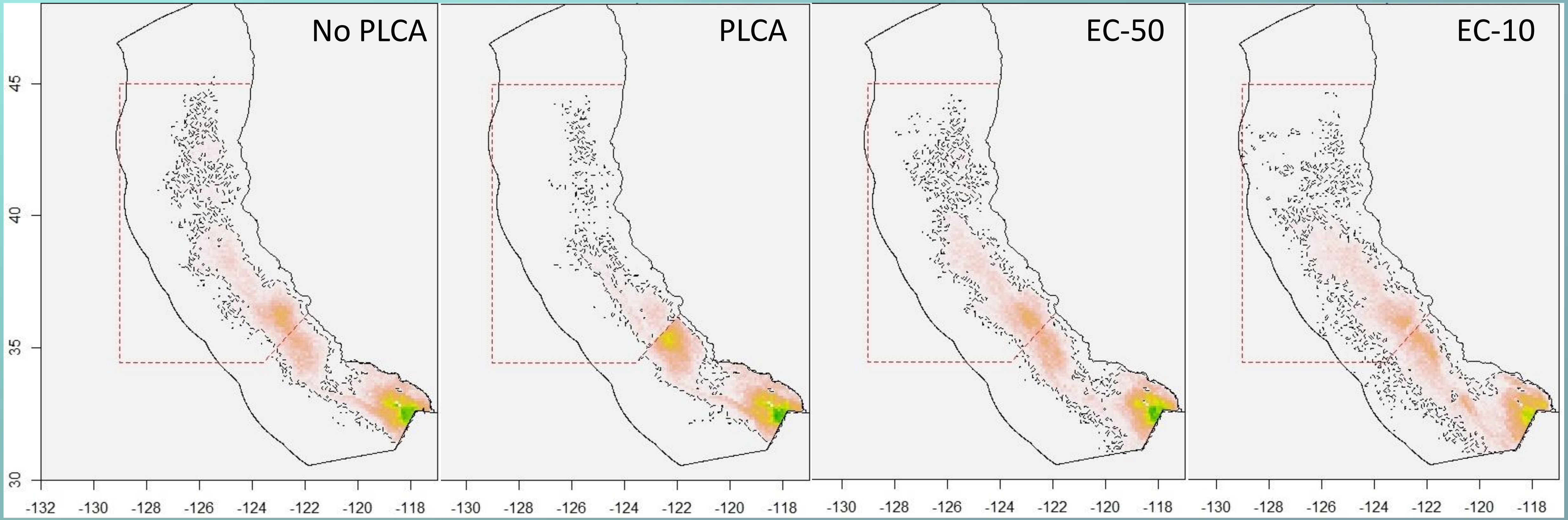
**First three fishing seasons: area open to fishing**



# Results – effort distribution

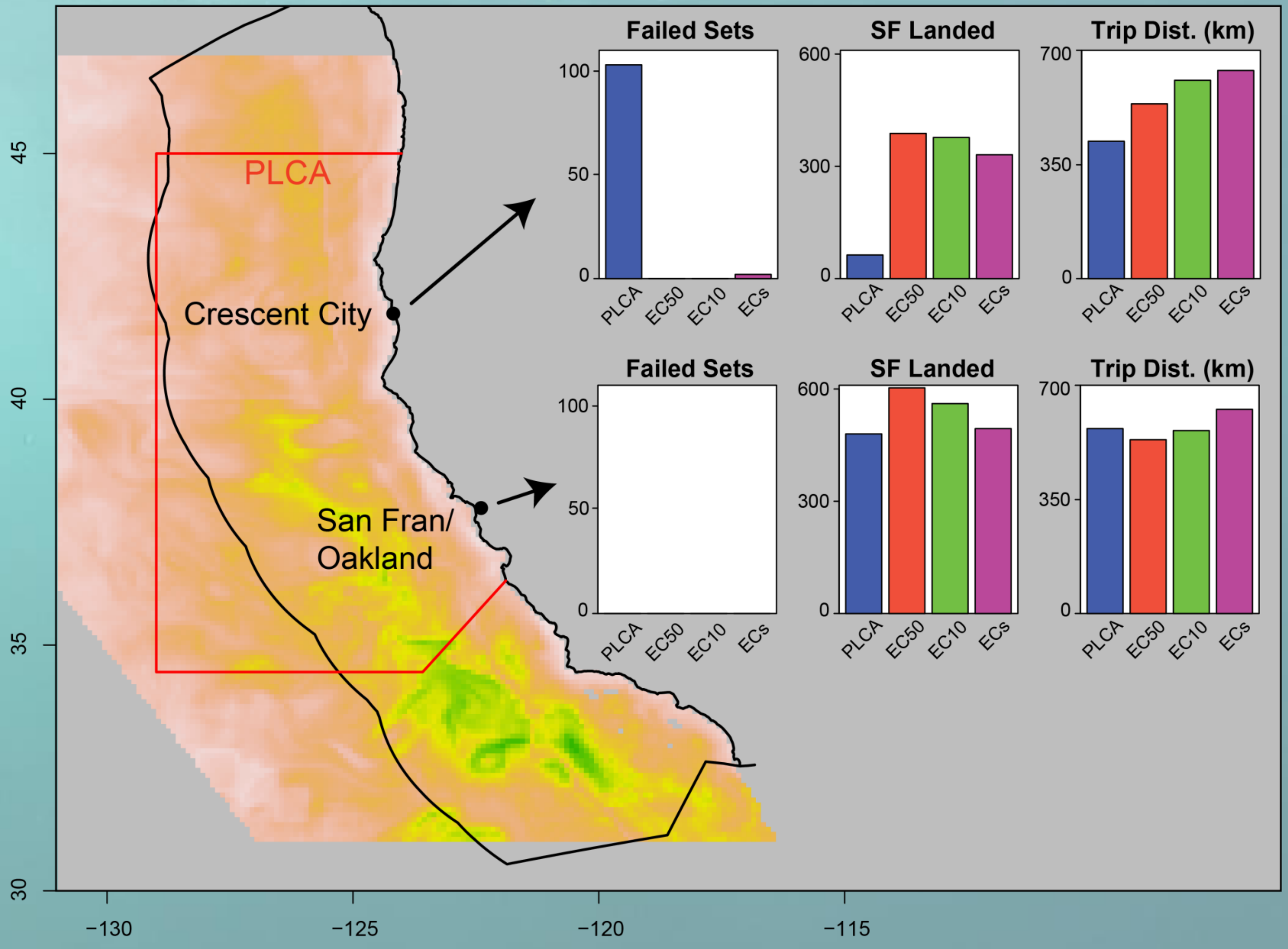
- We can examine the distribution of total simulated fishing effort
  - EC allows broader effort distribution, but EC-10 moves vessels farther offshore

GAMM S-T



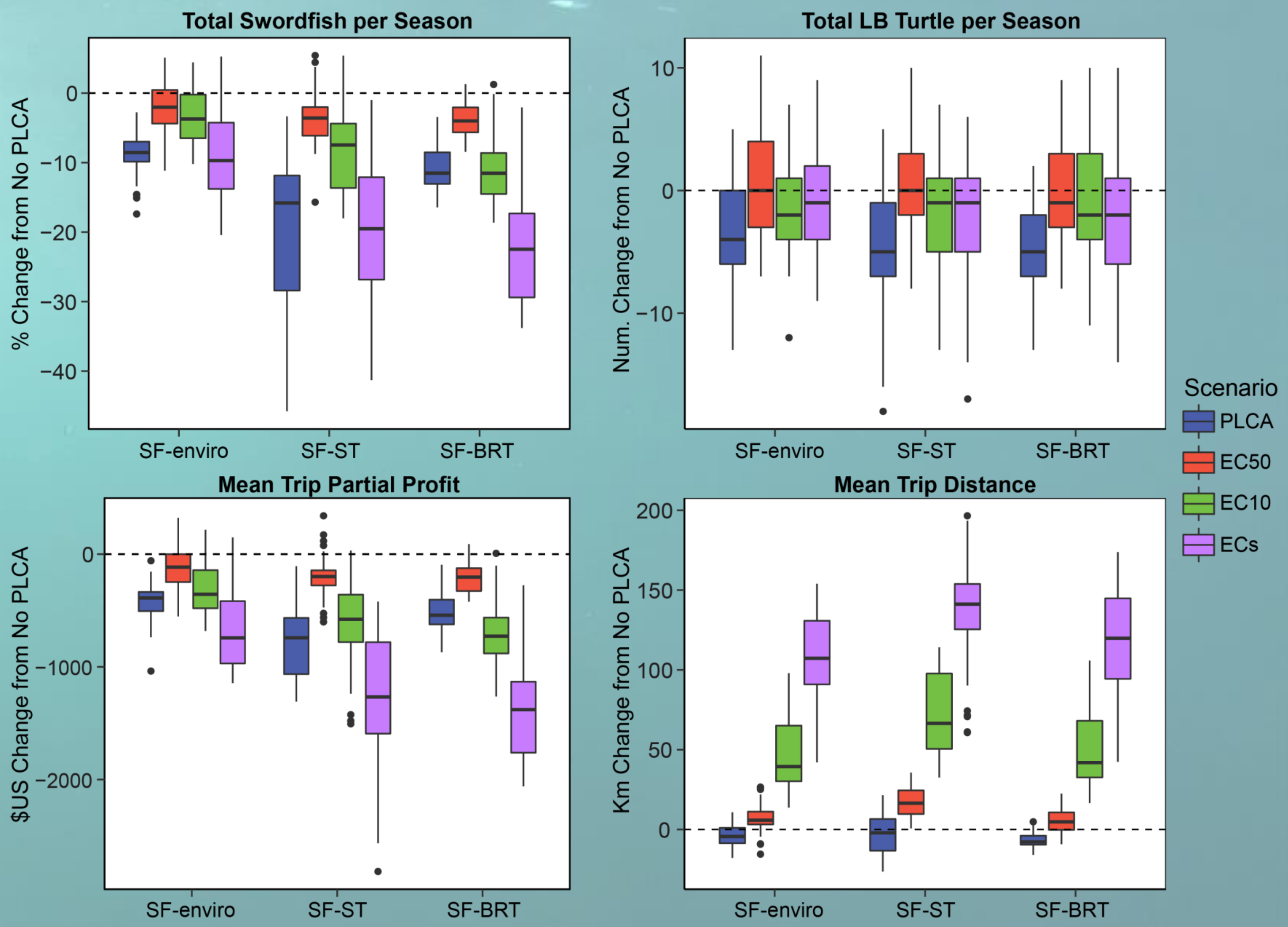
# Results – port effects

- Effects vary by port
- Using EcoCast, Crescent City has increased opportunity and SF caught, but vessels travel farther
- San Fran/Oakland has increased SF caught



# Results – fleet-wide effects

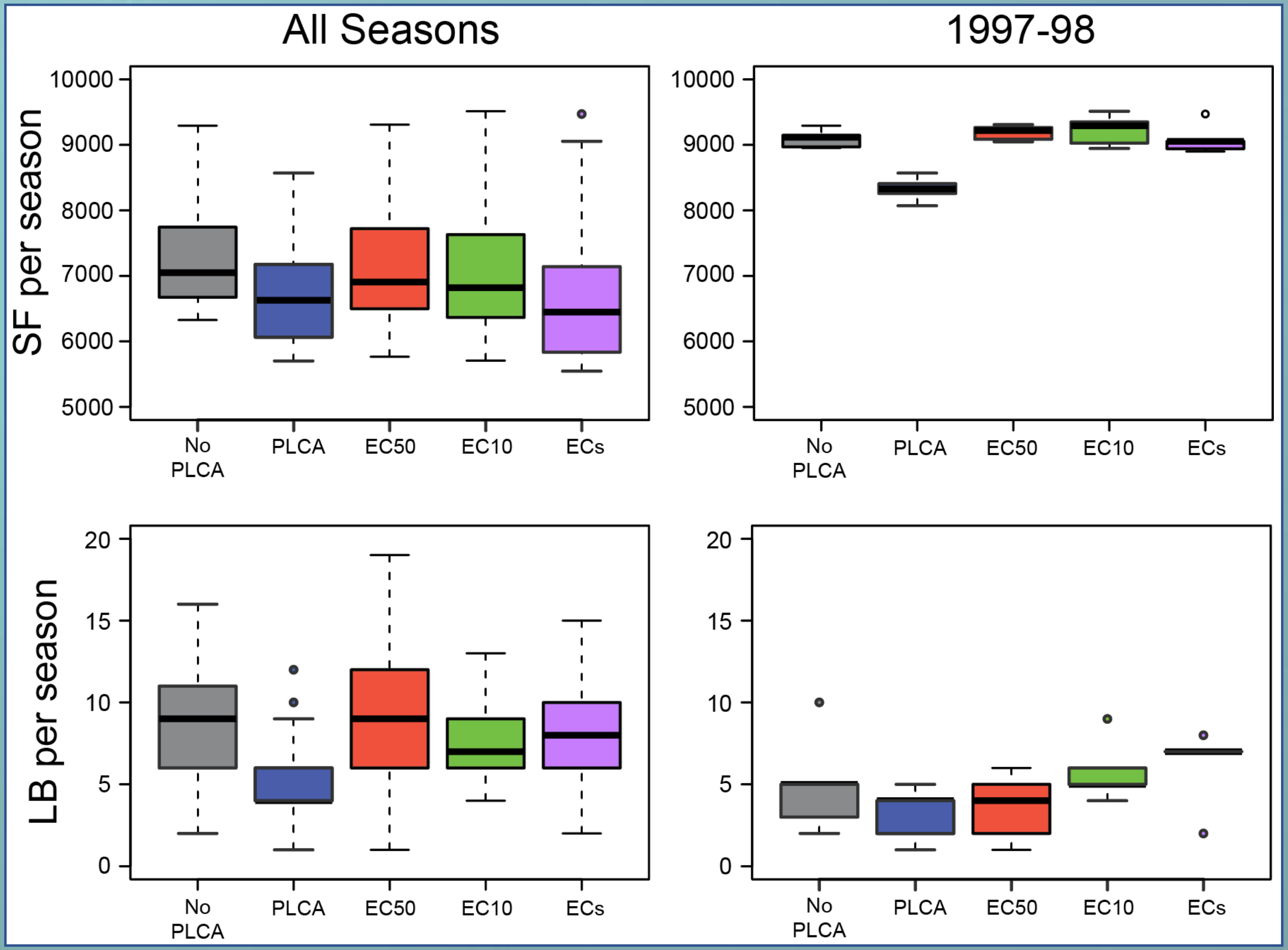
- EC50 and EC10 increased SF catch (up to 17% more) and profit
- <u>High uncertainty in LB bycatch</u>, but some evidence that the PLCA performs a little better (2-4 fewer LBs per y, or with 2019 effort, 1-2)



# Results – year-specific effects

- 1997-98 an El Nino year
- EcoCast identified this as a less risky year and closed less area, and had better performance
- Highly productive area in the PLCA was made available

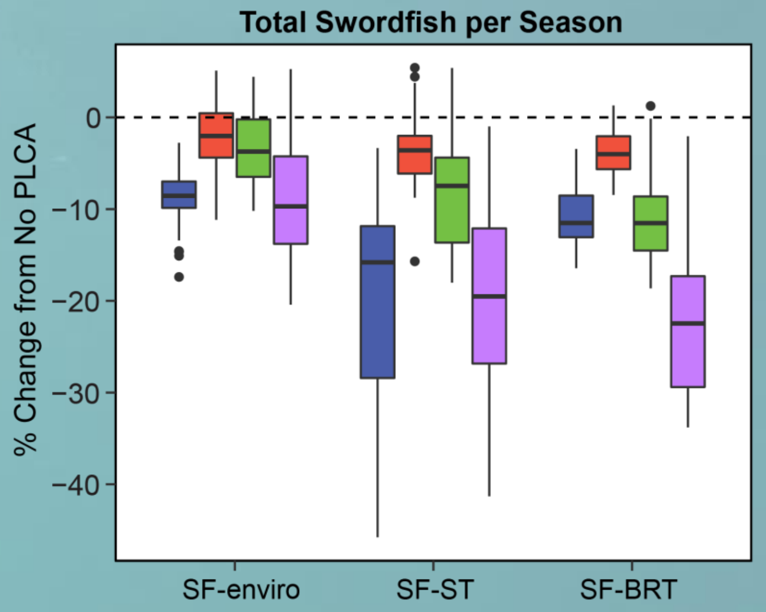
| EC50,10 > PLCA | All Seasons | 1997-98 |
|---|---|---|
| SF catch | + 460 (6.9%) | + 880 (10.6%) |
| LB catch | + 3.3 | + 1.5 |
| EEZ open | + 0% | + 7% |

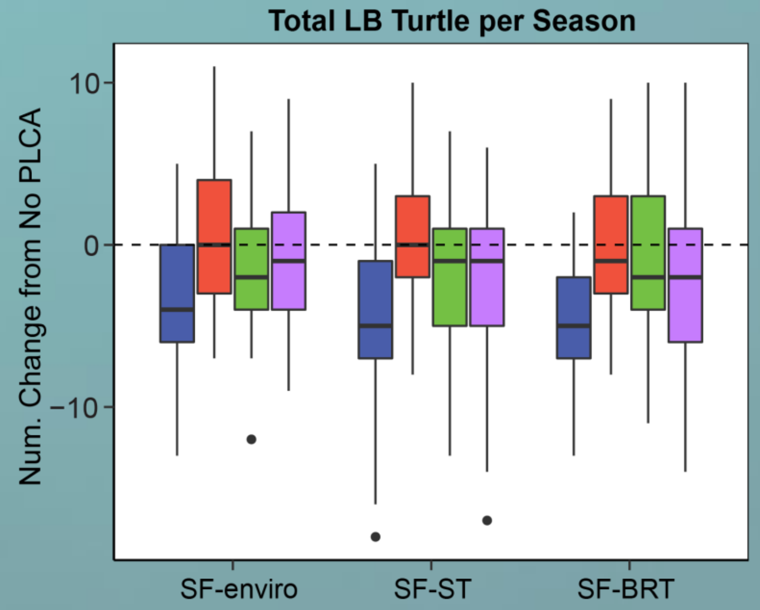


# Simulation of Dynamic vs Static Closures

## *Summary*

- Our simulation illustrates the potential trade-off using DOM
  - ➢ Using EC led to more SF and fishing opportunity (esp. northern ports and in 'good' years), but also more LB bycatch
- Why is the LB result so uncertain?
  - ➢ Very low catch rate
  - ➢ Our RF model is diffuse: LBs can be caught just about anywhere

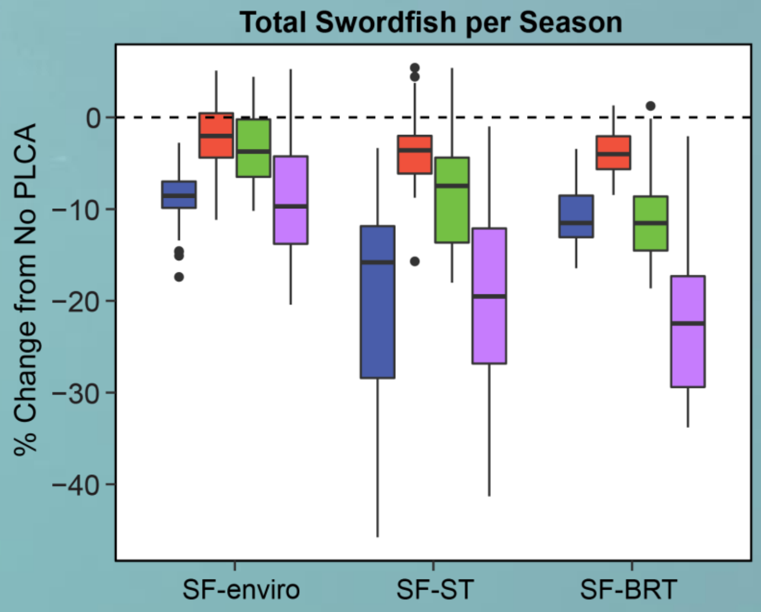


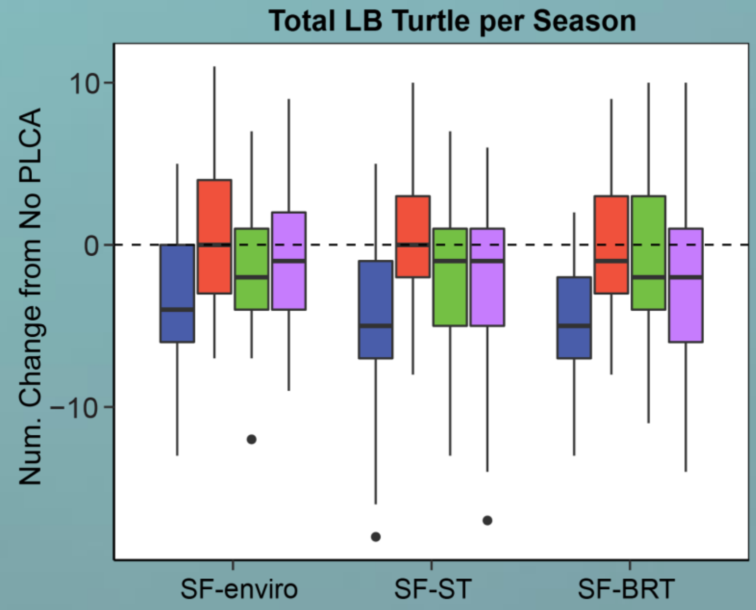



# Simulation of Dynamic vs Static Closures

## *Summary*

- Why was the PLCA better at reducing LB bycatch?
  - The very large static closure was more robust to fine-scale uncertainty
  - EC is multi-species & acts to also reduce sea lion and blue shark bycatch

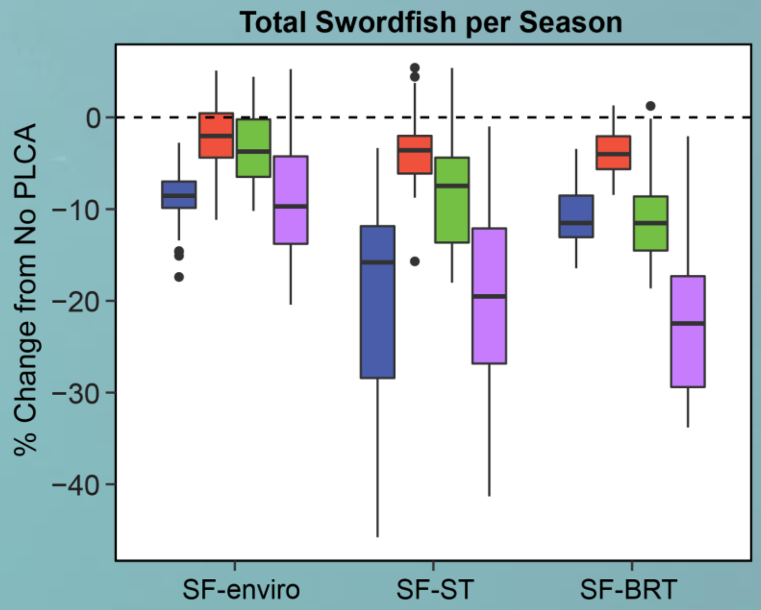


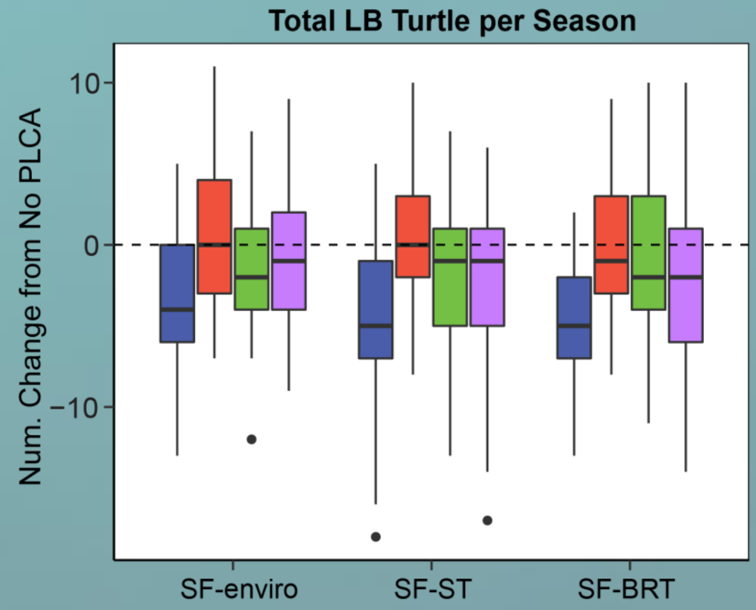



# Simulation of Dynamic vs Static Closures

## *Food for thought*

- It's very challenging to evaluate spatial management tools for species rarely encountered in their habitat
  - ➢ This was a *tough* challenge for DOM (size of PLCA, rarity and broad distribution of LB turtles)
  - ➢ DOM's performance (*and our ability to test it*) would likely improve given more info on LBs, but telemetry data may not be enough (it lacks catchability)

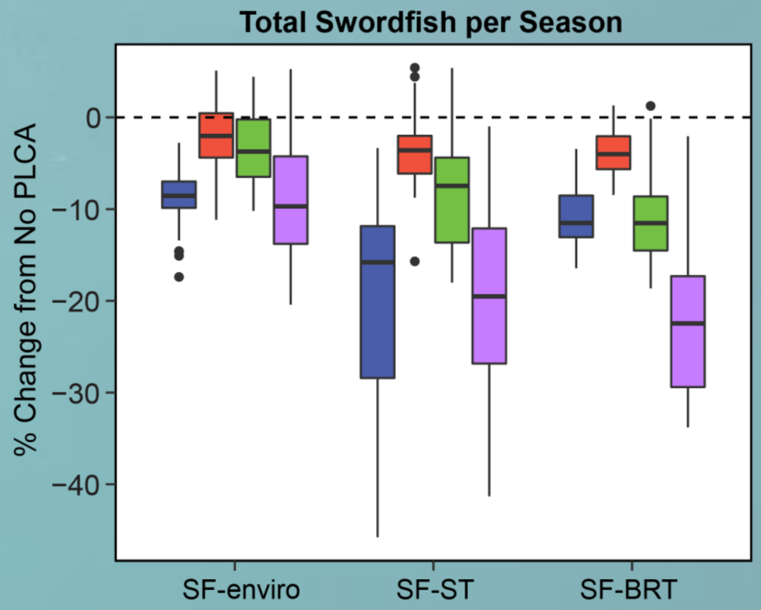


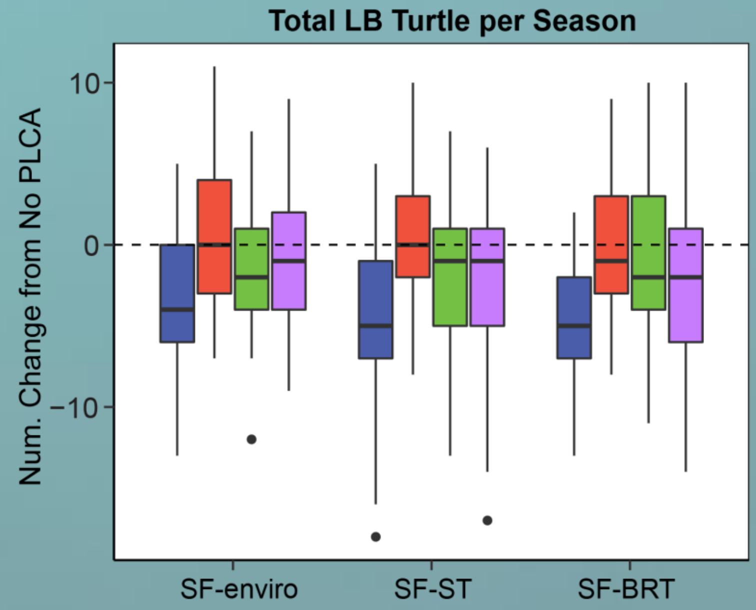



# Simulation of Dynamic vs Static Closures

*Food for thought*

- Can we base the <u>resolution</u> of spatial-temporal DOM on the <u>uncertainty</u> of the species distributions?
- ➢ When we know very little, is coarser better?



# Thanks!

OCEAN SCIENCES MEETING | 16-21 FEBRUARY 2020 SAN DIEGO, CA, USA

*Responses of Fishing Communities to Ocean Change*

"This session will highlight innovations and challenges in modeling responses of fishers and fishing communities to ocean variability. We welcome contributions on methodological advances in coupled biological-economic models, environmentally informed economic models of fisher behavior, climate-informed fishing community vulnerability indices, and integration of economic models and metrics into management strategy evaluations."

https://www2.agu.org/ocean-sciences-meeting/

Submission deadline September 11, 2019