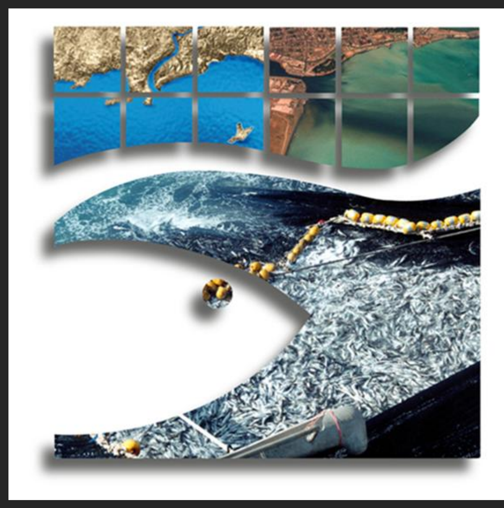

# PERFORMANCE OF HARVEST CONTROL RULES BASED ON STATIC AND DYNAMIC REFERENCE BIOMASS $B_{MSY}$ UNDER RECRUITMENT REGIME SHIFTS: The case of anchovy in the southern Humboldt ecosystem


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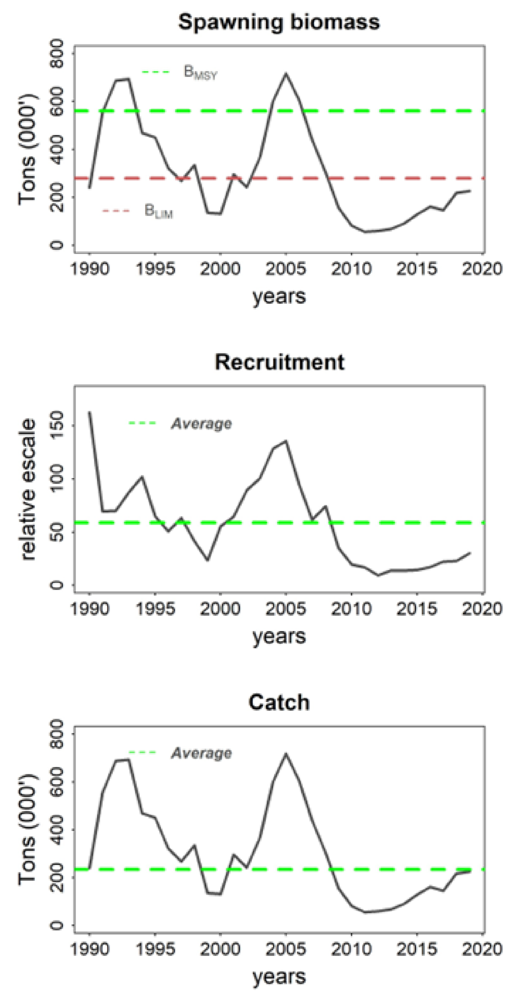
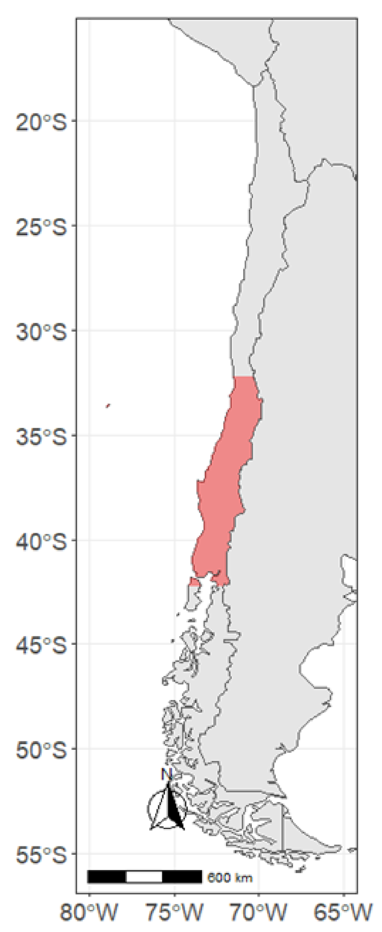
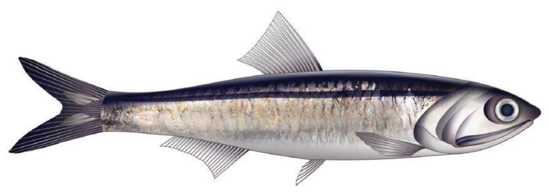
## INTRODUCTION





- Anchovy (*Engraulis ringens*) is an ecologically and economically important species
- Recruitment is a key driver of small pelagic fish population dynamics and strongly influences Reference Biomass (RB) used in fisheries management.

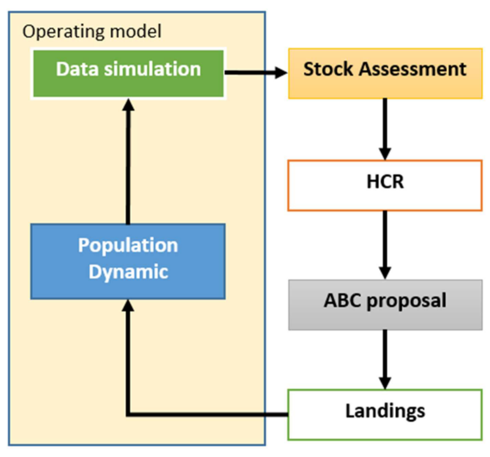
Reference biomass associated with MSY ($B_{MSY}$) is widely used to assess stock status and define catch limits through Harvest Control Rules. Although $B_{MSY}$ is commonly treated as time-invariant, evidence shows that recruitment variability and regime shifts can cause substantial changes in stock productivity. Consequently, choosing between fixed or dynamic $B_{MSY}$ can strongly influence management decisions and long-term fishery sustainability.

**STUDY OBJECTIVE**

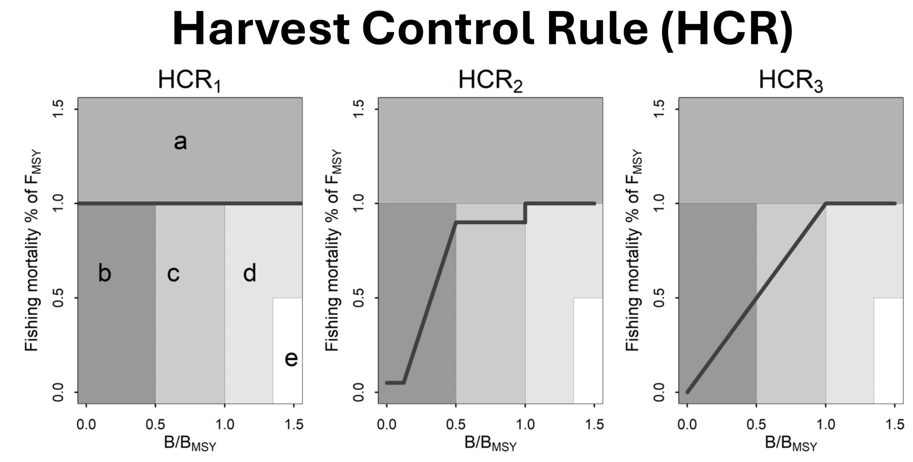
Considering the anchovy fishery of the southern zone of the Humboldt ecosystem as a case study and given the evidence of regime shifts in its recruitment, we evaluated the performance of HCRs and management performance conditioned on static and dynamic $B_{MSY}$ under regime shift scenarios.

## METHODOLOGY

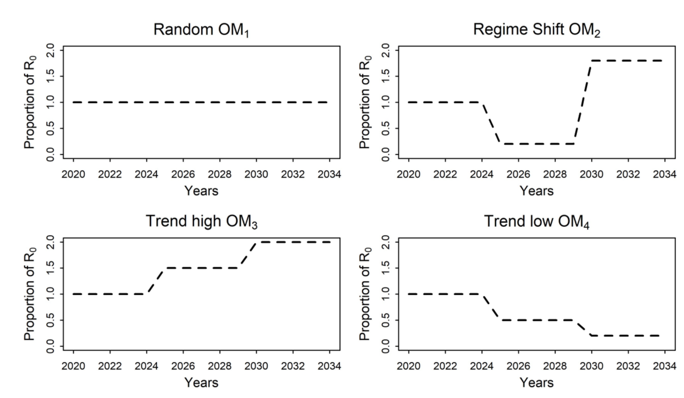
**Management Strategy Evaluation (MSE)**




**Harvest Control Rule (HCR)**



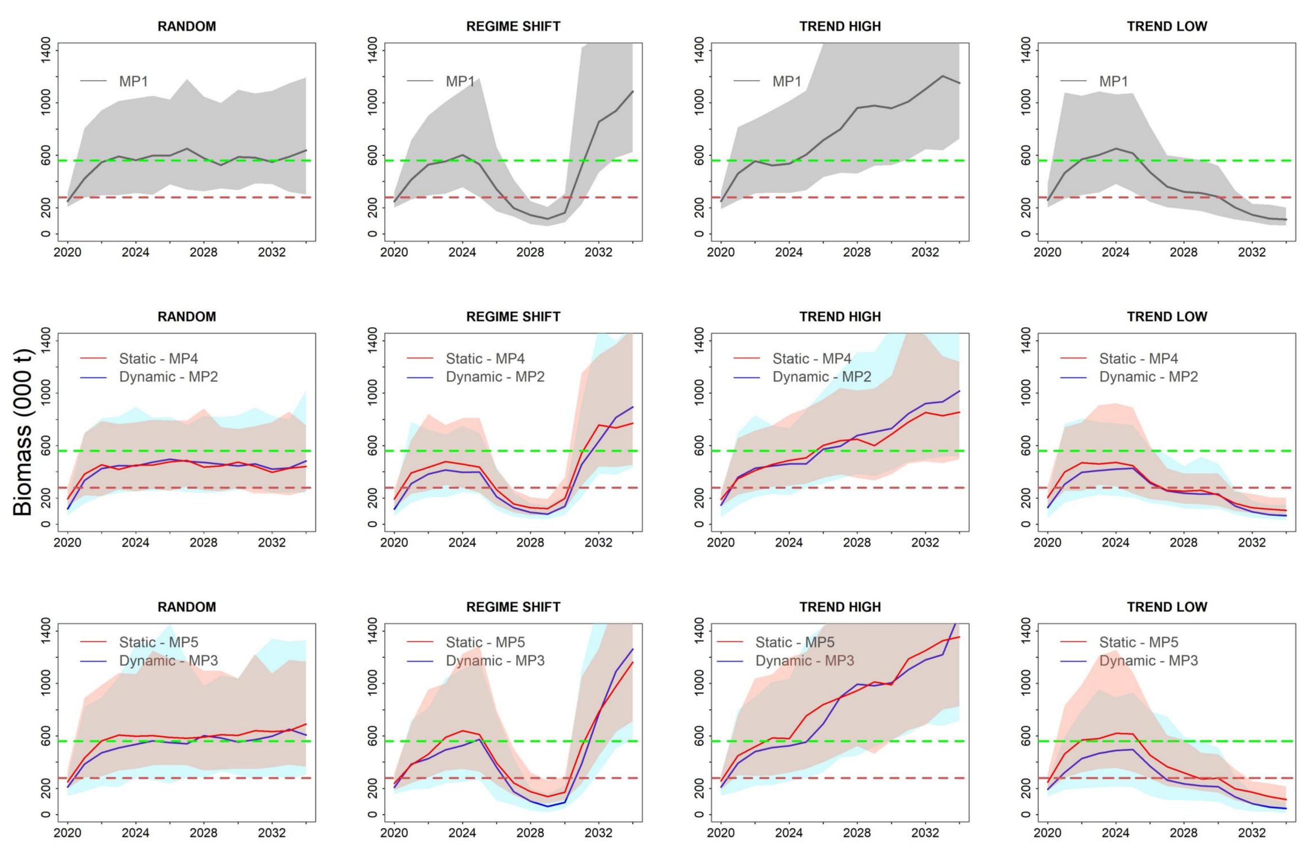
**Operating Models (OM)**



## RESULTS

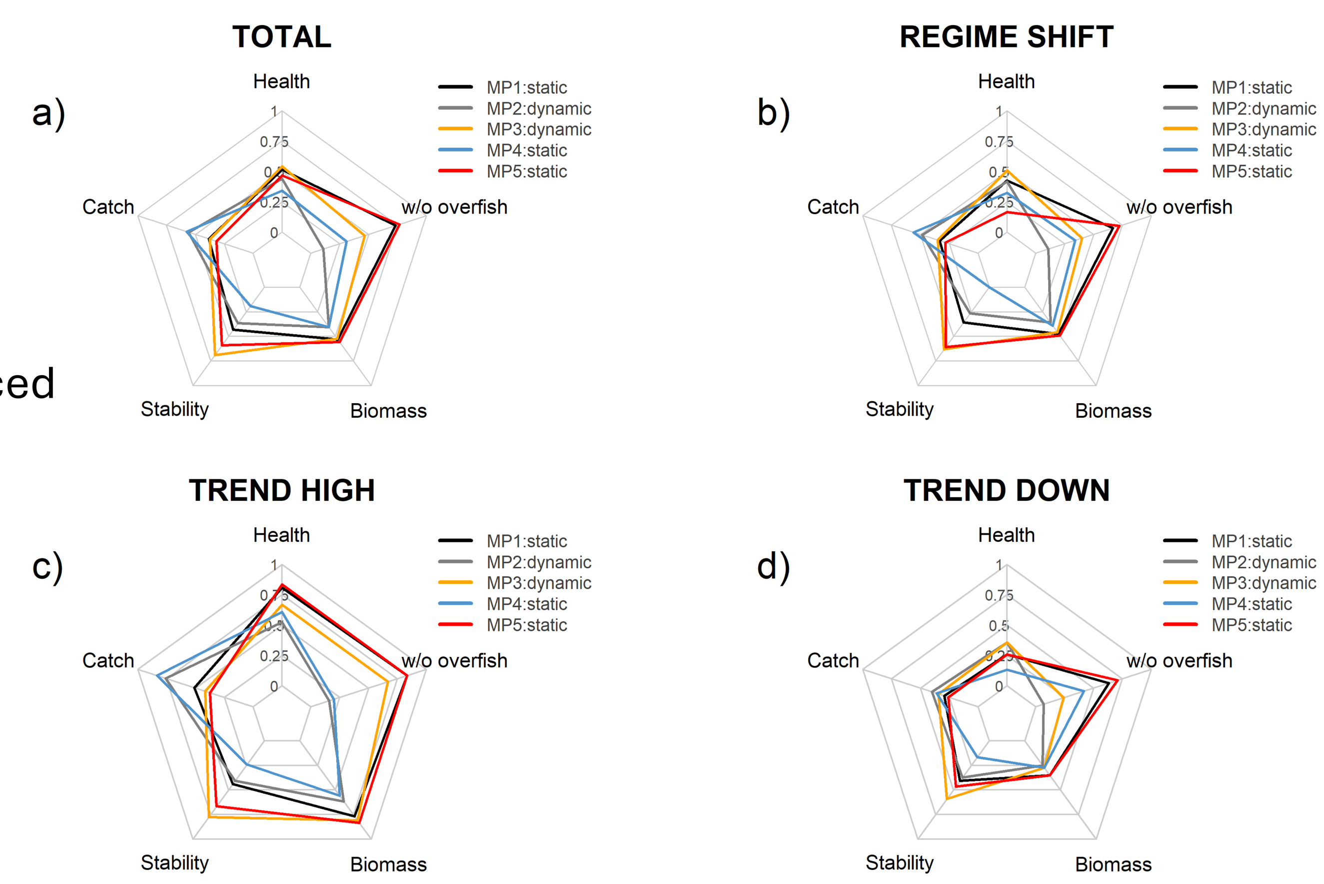
Performance variables of the population health index (without overexploitation), average catches, fishery variability (CV), average biomass, and no-overfishing index for different operating models (OM), management procedures (MP), and harvest control rules (HCR) of the anchovy fishery in the south-central zone of Chile The values represent the entire simulated period.

| OM | MP | HCR | $B_{MSY}$ | Health | Catch (000' t) | CV | Biomass (000' t) | w/o Overfish |
|---|---|---|---|---|---|---|---|---|
| random | 1 | 1 | Static | 0.48 | 158 | 0.43 | 621 | 0.83 |
| regime shift | 1 | 1 | Static | 0.36 | 136 | 0.67 | 549 | 0.69 |
| trend low | 1 | 1 | Static | 0.22 | 118 | 0.60 | 401 | 0.65 |
| trend high | 1 | 1 | Static | 0.68 | 204 | 0.55 | 884 | 0.86 |
| | | | **Mean** | **0.44** | **154** | **0.56** | **614** | **0.76** |
| random | 2 | 2 | Dynamic | 0.40 | 237 | 0.57 | 481 | 0.12 |
| regime shift | 2 | 2 | Dynamic | 0.35 | 196 | 0.80 | 412 | 0.11 |
| trend low | 2 | 2 | Dynamic | 0.30 | 161 | 0.65 | 290 | 0.07 |
| trend high | 2 | 2 | Dynamic | 0.44 | 305 | 0.60 | 707 | 0.16 |
| | | | **Mean** | **0.37** | **225** | **0.66** | **473** | **0.12** |
| random | 3 | 3 | Dynamic | 0.53 | 161 | 0.10 | 636 | 0.56 |
| regime shift | 3 | 3 | Dynamic | 0.43 | 141 | 0.28 | 526 | 0.41 |
| trend low | 3 | 3 | Dynamic | 0.30 | 138 | 0.34 | 312 | 0.25 |
| trend high | 3 | 3 | Dynamic | 0.56 | 167 | 0.08 | 930 | 0.69 |
| | | | **Mean** | **0.46** | **152** | **0.20** | **601** | **0.48** |
| random | 4 | 2 | Static | 0.27 | 219 | 0.69 | 468 | 0.28 |
| regime shift | 4 | 2 | Static | 0.27 | 227 | 1.18 | 450 | 0.35 |
| trend low | 4 | 2 | Static | 0.11 | 146 | 0.94 | 321 | 0.43 |
| trend high | 4 | 2 | Static | 0.51 | 337 | 0.84 | 645 | 0.21 |
| | | | **Mean** | **0.29** | **232** | **0.91** | **471** | **0.32** |
| random | 5 | 3 | Static | 0.52 | 140 | 0.28 | 651 | 0.82 |
| regime shift | 5 | 3 | Static | 0.14 | 114 | 0.32 | 570 | 0.75 |
| trend low | 5 | 3 | Static | 0.22 | 104 | 0.52 | 406 | 0.73 |
| trend high | 5 | 3 | Static | 0.70 | 152 | 0.24 | 960 | 0.86 |
| | | | **Mean** | **0.40** | **128** | **0.34** | **647** | **0.79** |



- ❑ Our results show that the performance of the HCRs varies depending on the $B_{MSY}$ criterion applied, and that the effectiveness of the status indicator is influenced by both the control rule (HCR) and the productivity scenario (OM).

- ❑ Stock management using an HCR adapted to a dynamic indicator improved fishing performance without compromising population sustainability.
- ❑ However, the dynamic index produced slightly lower average biomass compared to the static index, especially under low anchovy productivity scenarios




- ❑ Static reference biomass combined with ramp-type HCRs provide greater stability and lower overexploitation risk under high uncertainty, whereas dynamic references enhance adaptability to persistent productivity shifts when integrated with precautionary rules that buffer variability

## CONCLUSION

- We conclude that using a dynamic $B_{MSY}$ through a ramp-type HCR could improve the performance of the fishery without compromising the sustainability of the population. Nevertheless, under conditions of low anchovy productivity, the static approach proves to be more appropriate for effective fishery management.
- No single optimal strategy exists; fisheries management should adopt an integrated, adaptive approach that considers combinations among reference points, HCRs, and stock dynamics, considering periodic MSE with precautionary measures to ensure sustainability under variable productivity.

## ACKNOWLEDGMENT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