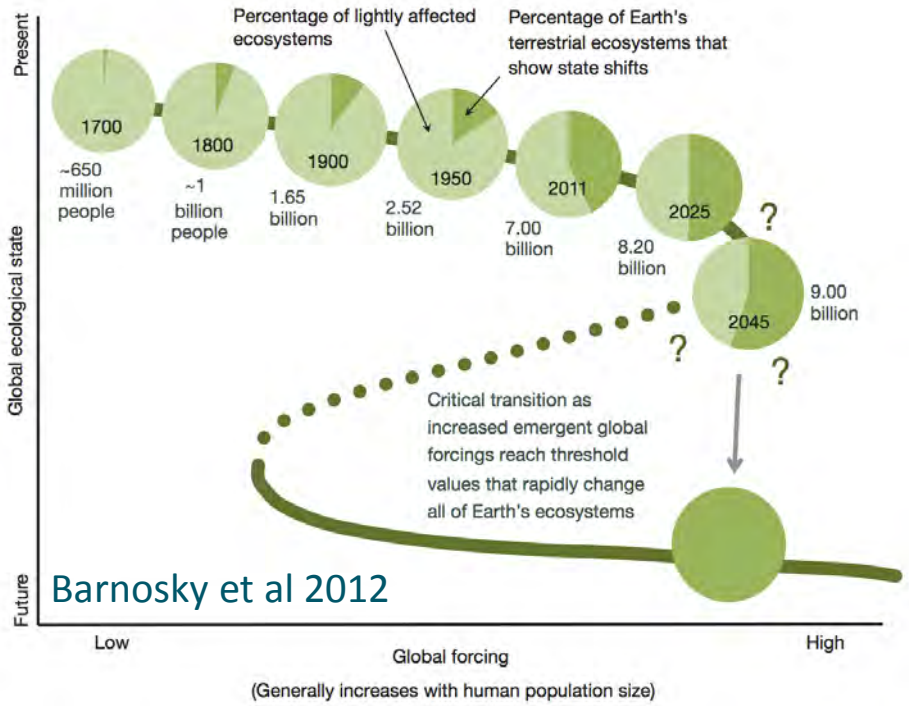
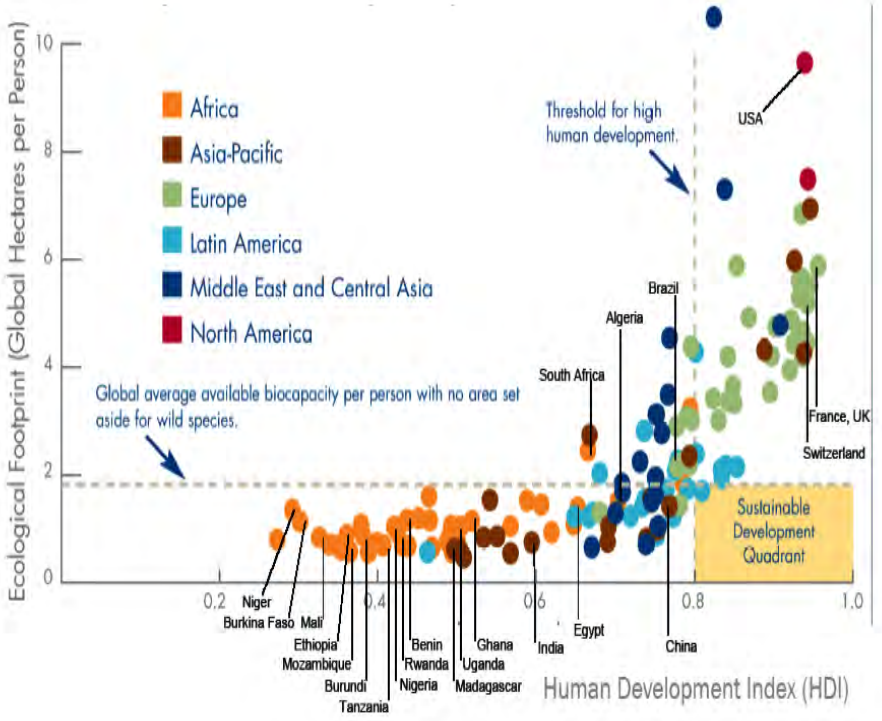


Barnosky et al 2012

Moran et al 2008



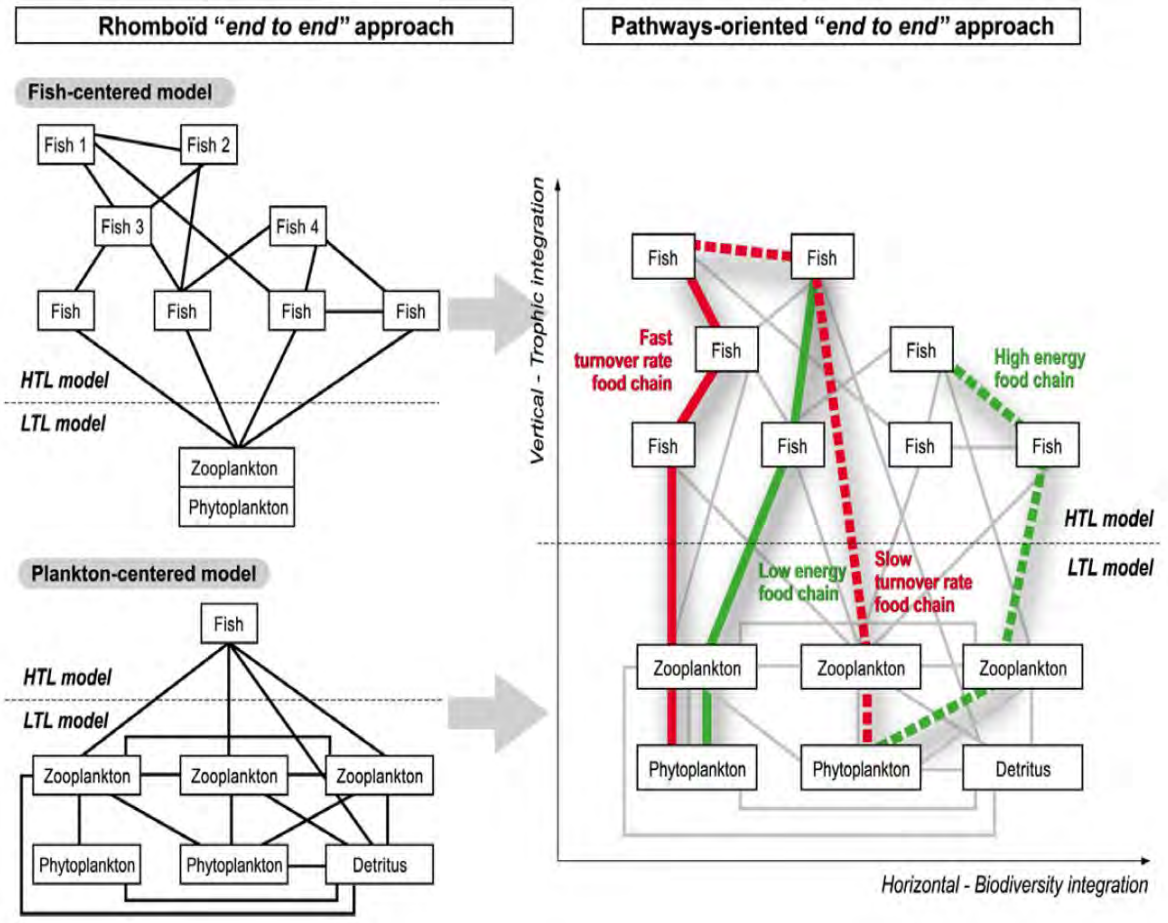
Modelling Change

Beth Fulton, Penny Johnson, Rebecca Gorton, Asta Audzijonyte, Gary Griffith

2014

Model flexibility

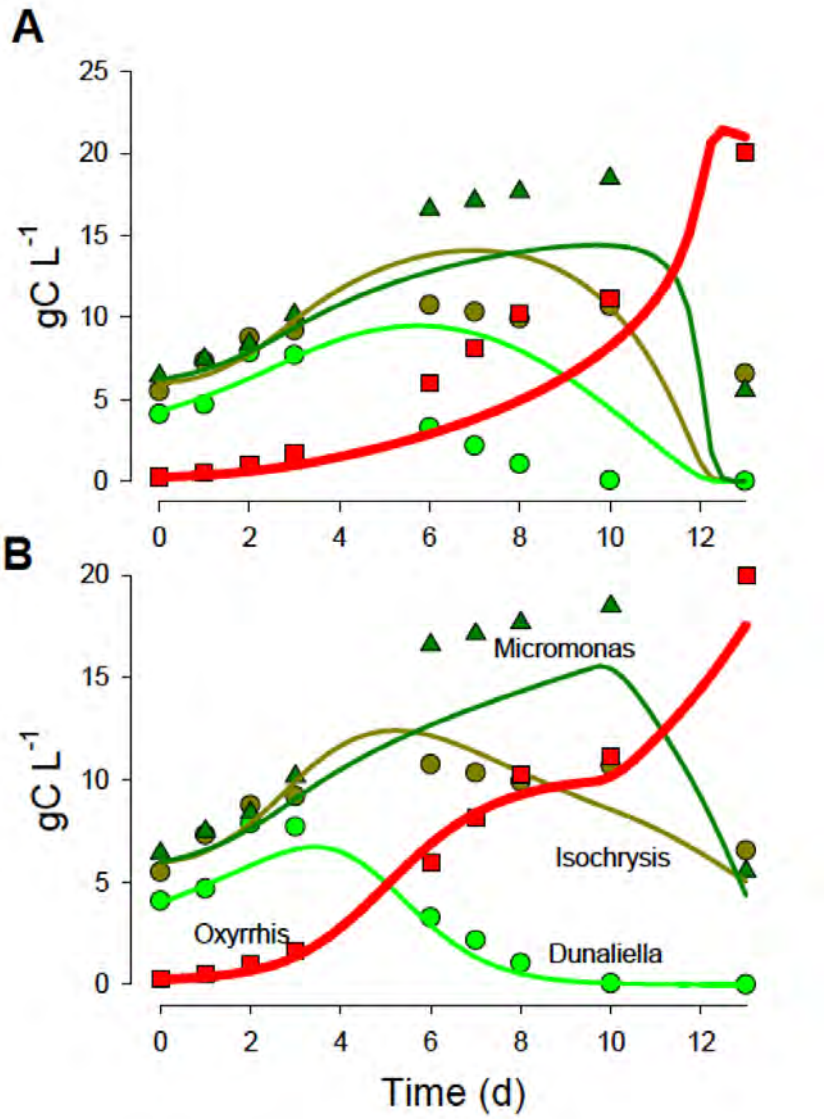
- Model structures that allow for multiple composition expression



Shin et al 2010

Revise processes

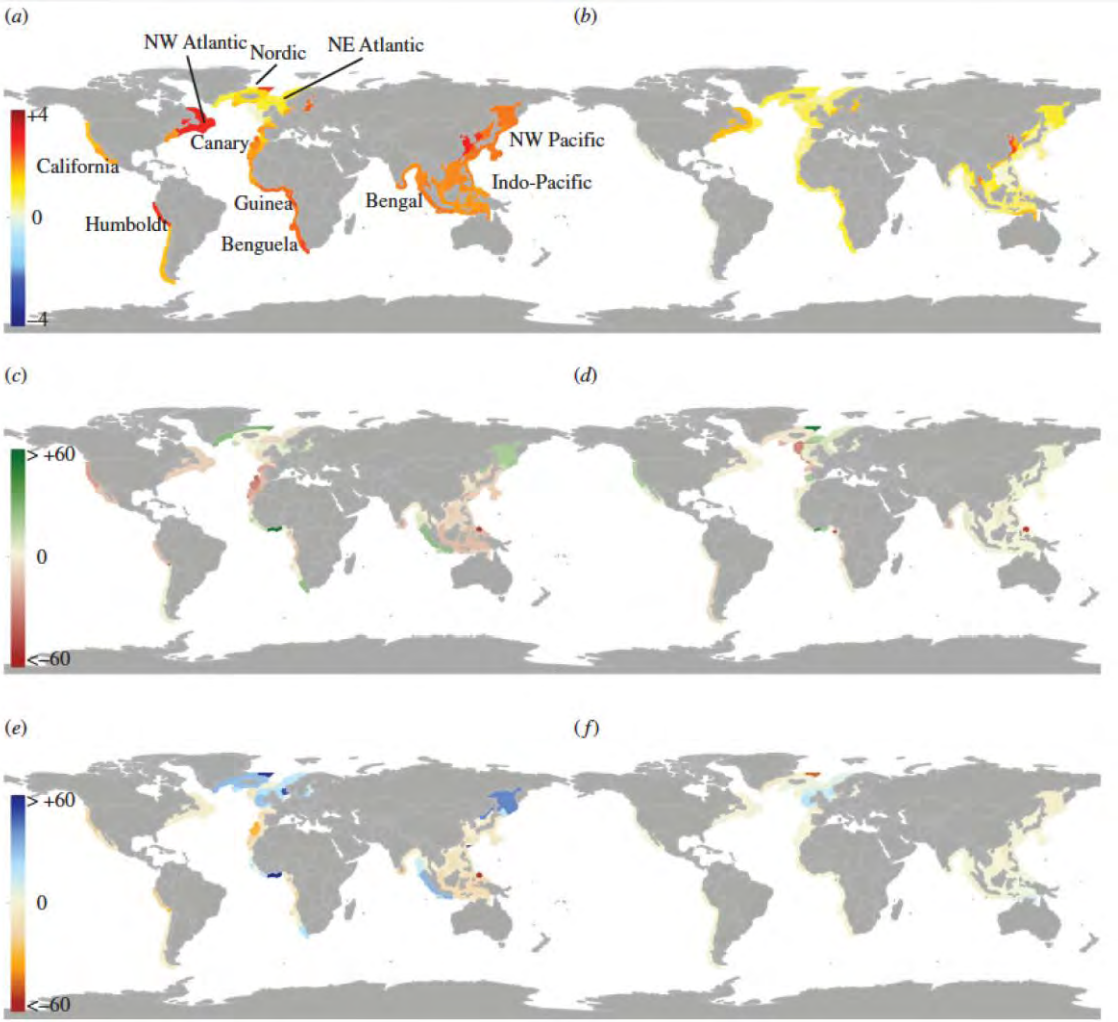
- Models reformulated with more knowledge
  - Multiple “errors” look like “truth”
  - “Right for right reasons” in case it influences dynamic shifts



Mitra & Flynn 2006

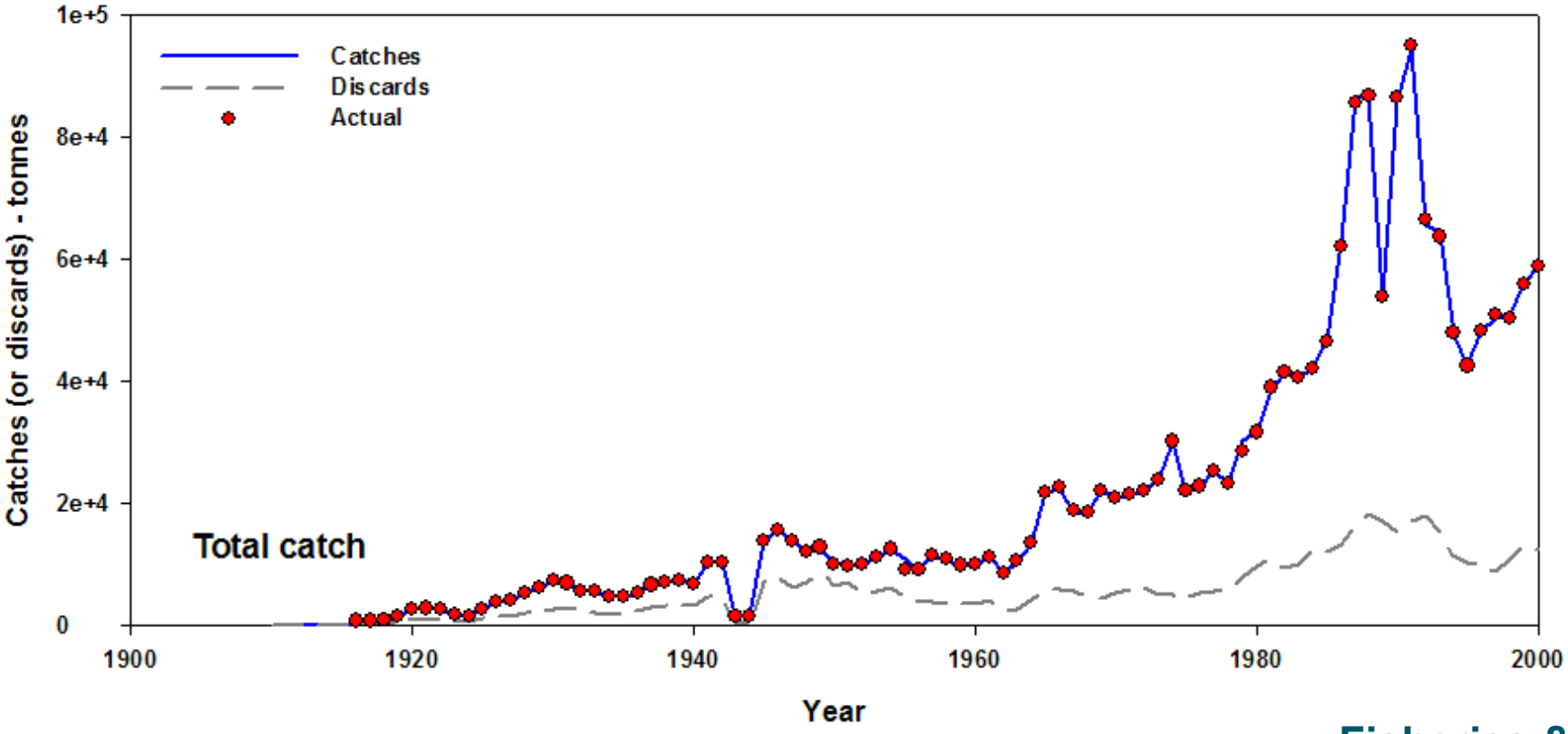
Go global

- Take existing model structures & apply variant on global scale



Blanchard et al 2010

Allow for evolution



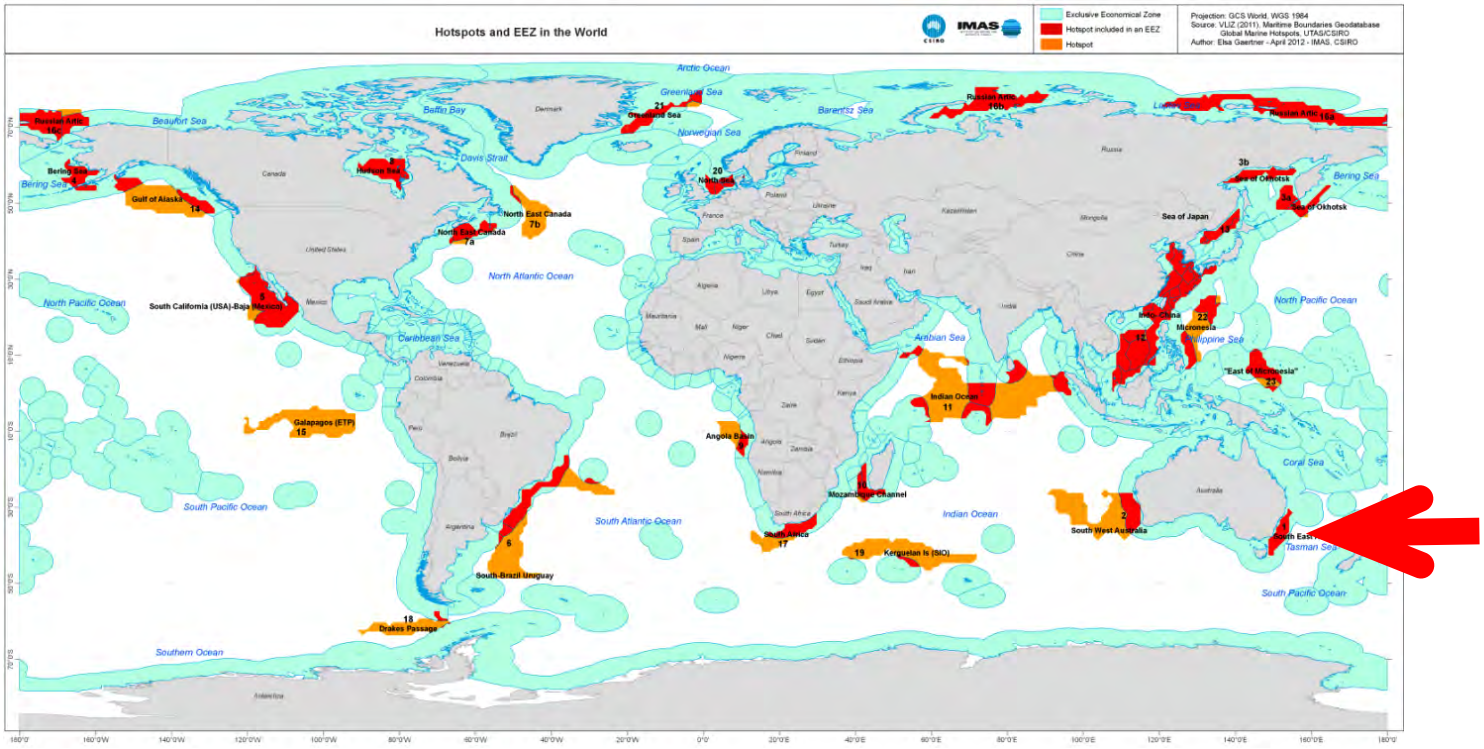
Fisheries & climate driven

Fisheries induced evolution

Fulton et al 2007

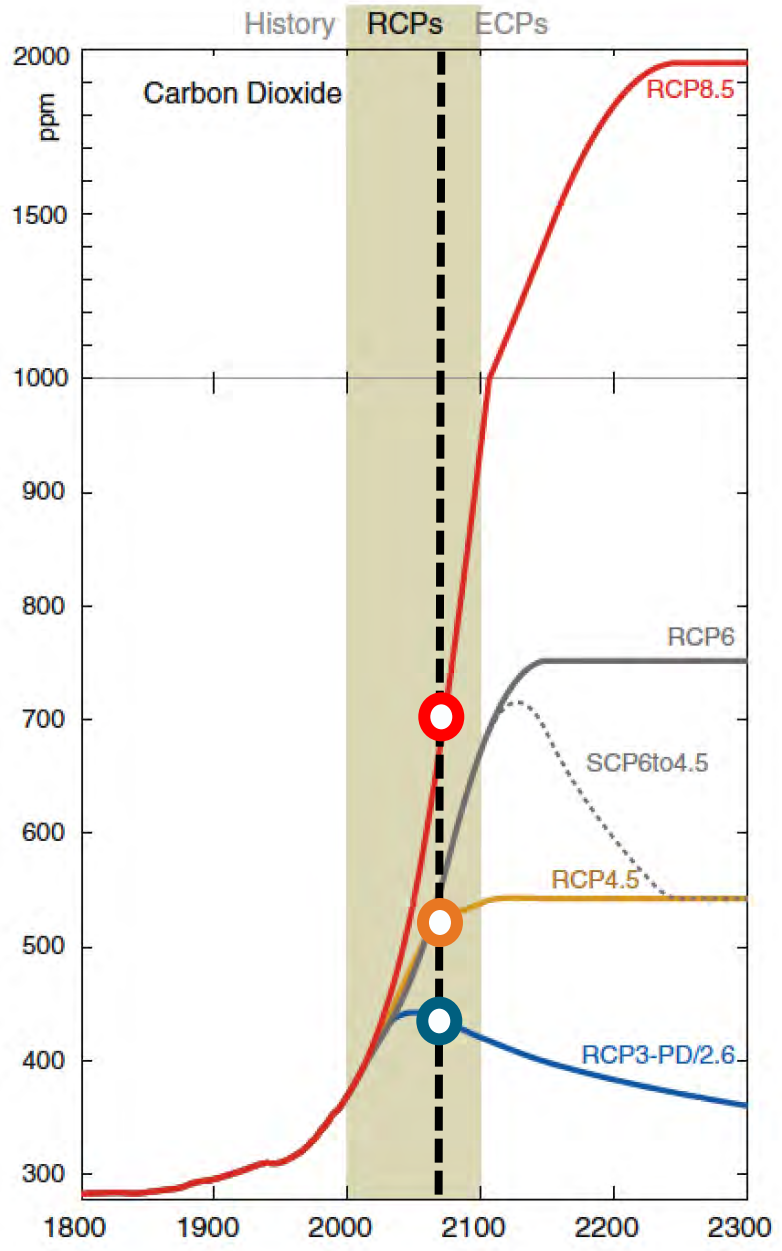
SEAP background

- SE Australia = hotspot of physical change
- Adaptation program (risk analysis, simulations etc)



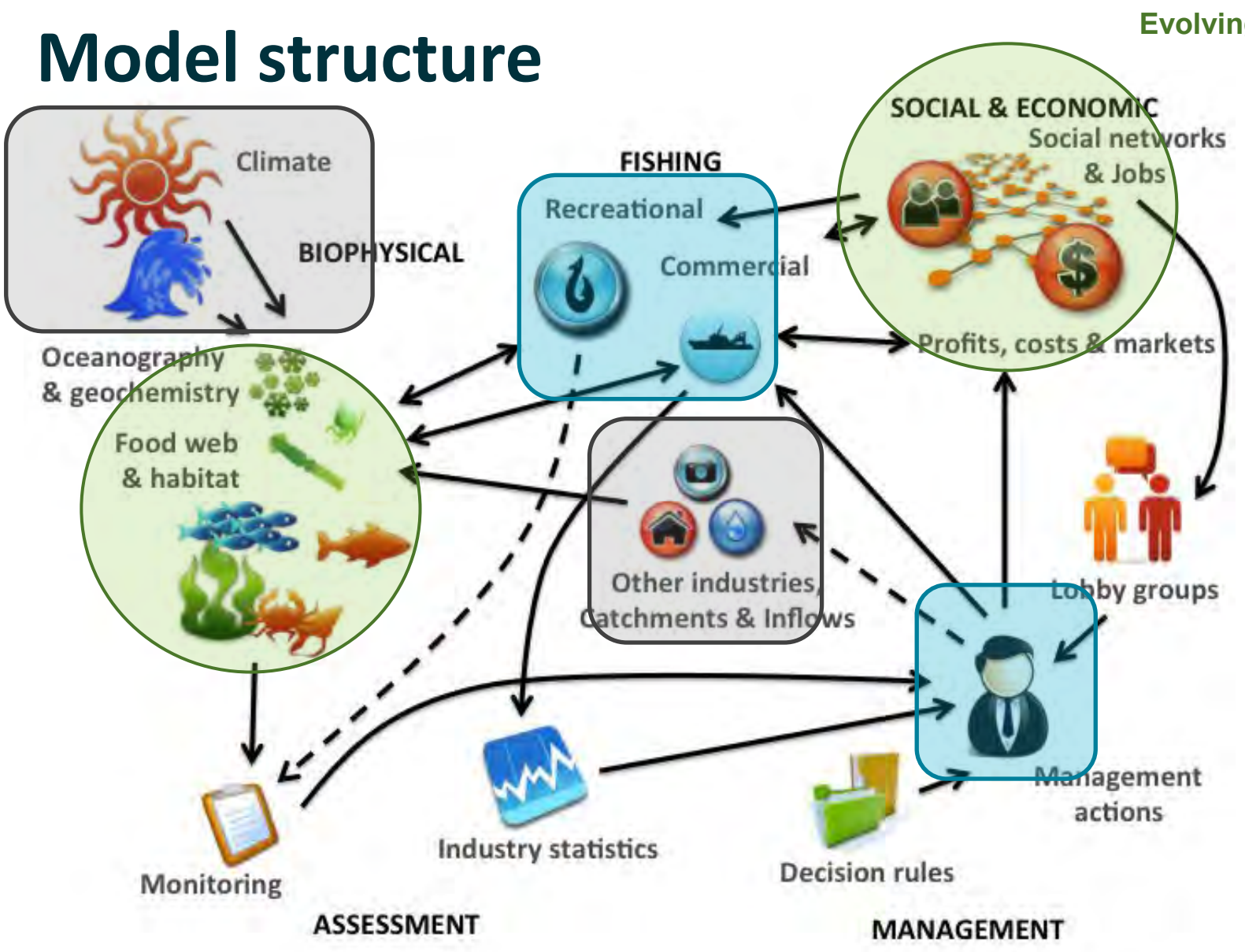
RCP context

- RCP 8.5, 4.5 and 3
- GCM derived forcing
  - Currents (horizontal & vertical)
  - Temperature, Salinity, pH, oxygen
- Extreme events (e.g. storms, pathogens)
- Changed level of other sectors (shipping, catchments, development aggregate mining etc.)



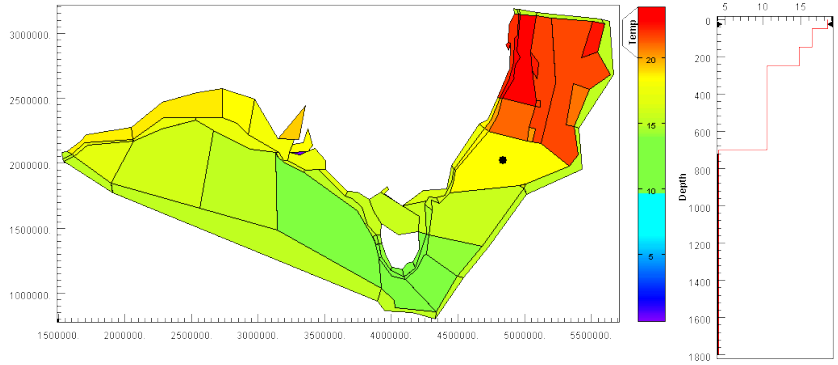
Meinshausen et al (2011)

Model structure

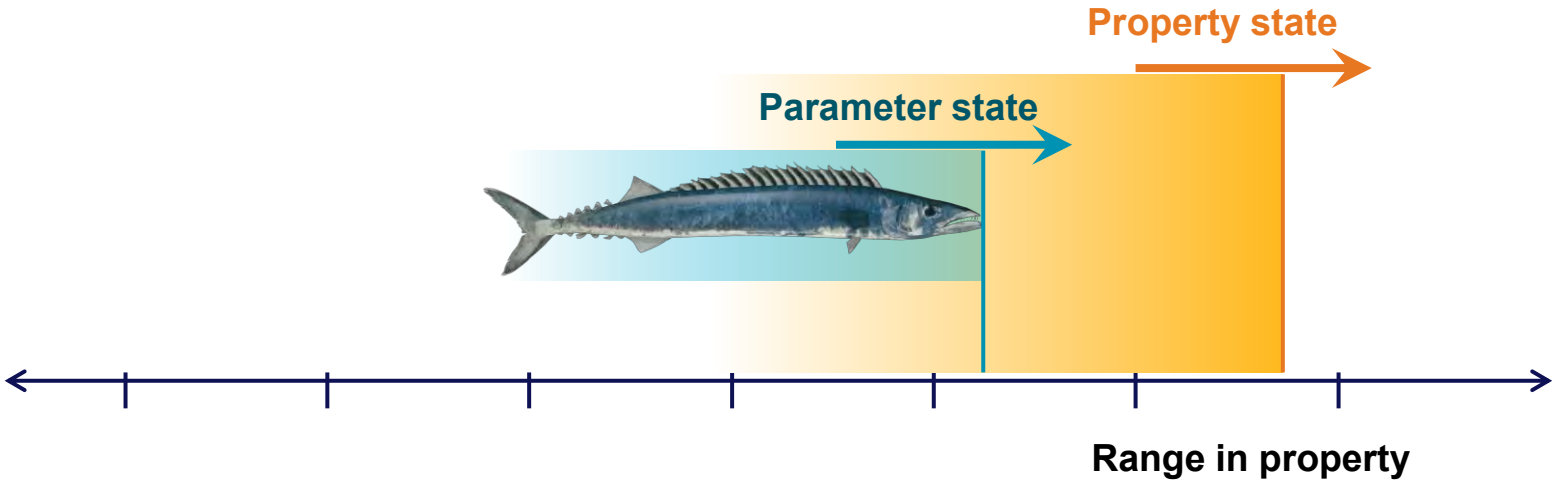


Acclimation

- Forage and density dependent geographic distributions



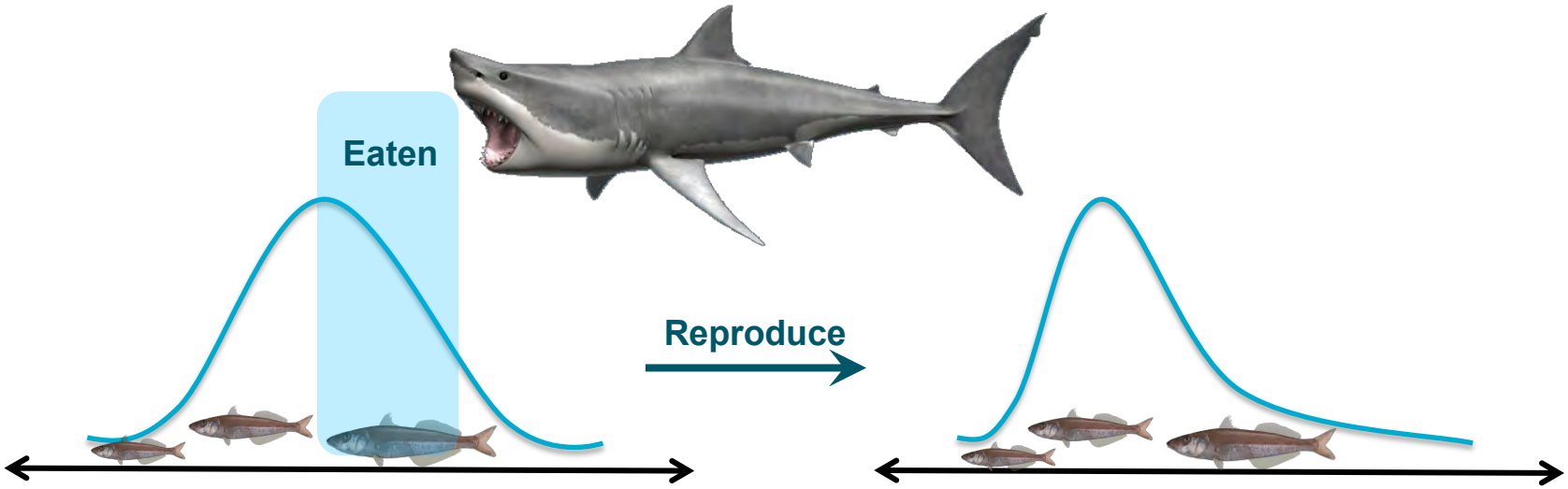
- Slow acclimation of parameterisation (to physical conditions; capped at observed laboratory & physiological ranges)



New optima = Old optima + (Gap between optima and new state) * rate of shift

Evolution & Biodiversity Turnover

- Size based feeding & reproduction
- Physiological rates, reproduction (and nutritional value) environmentally impacted
- Survivors reproduce (with heritability and stochasticity) so population's distribution of parameters evolves through time



- Seeing 1-10cm drop in mean adult size over 50yrs

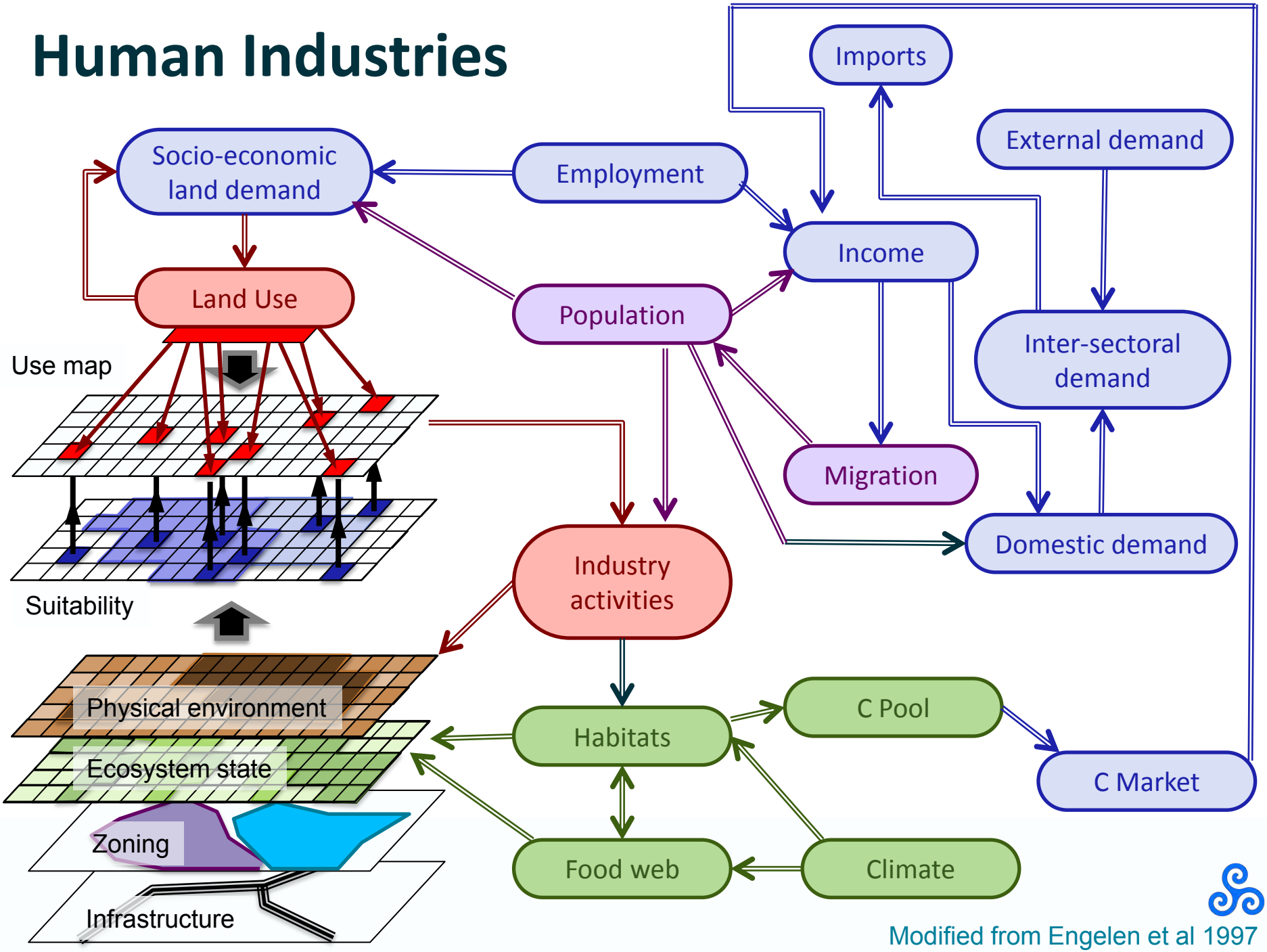
Human Industries

- Dynamic social and economic driven effort allocation decision model
  - can shift ports, trade quota, sell up, invest etc
  - Full MSE (adaptive management loop complete)




- One-way coupled marine and coastal industries model (human pressure along the coast line)

Human Industries



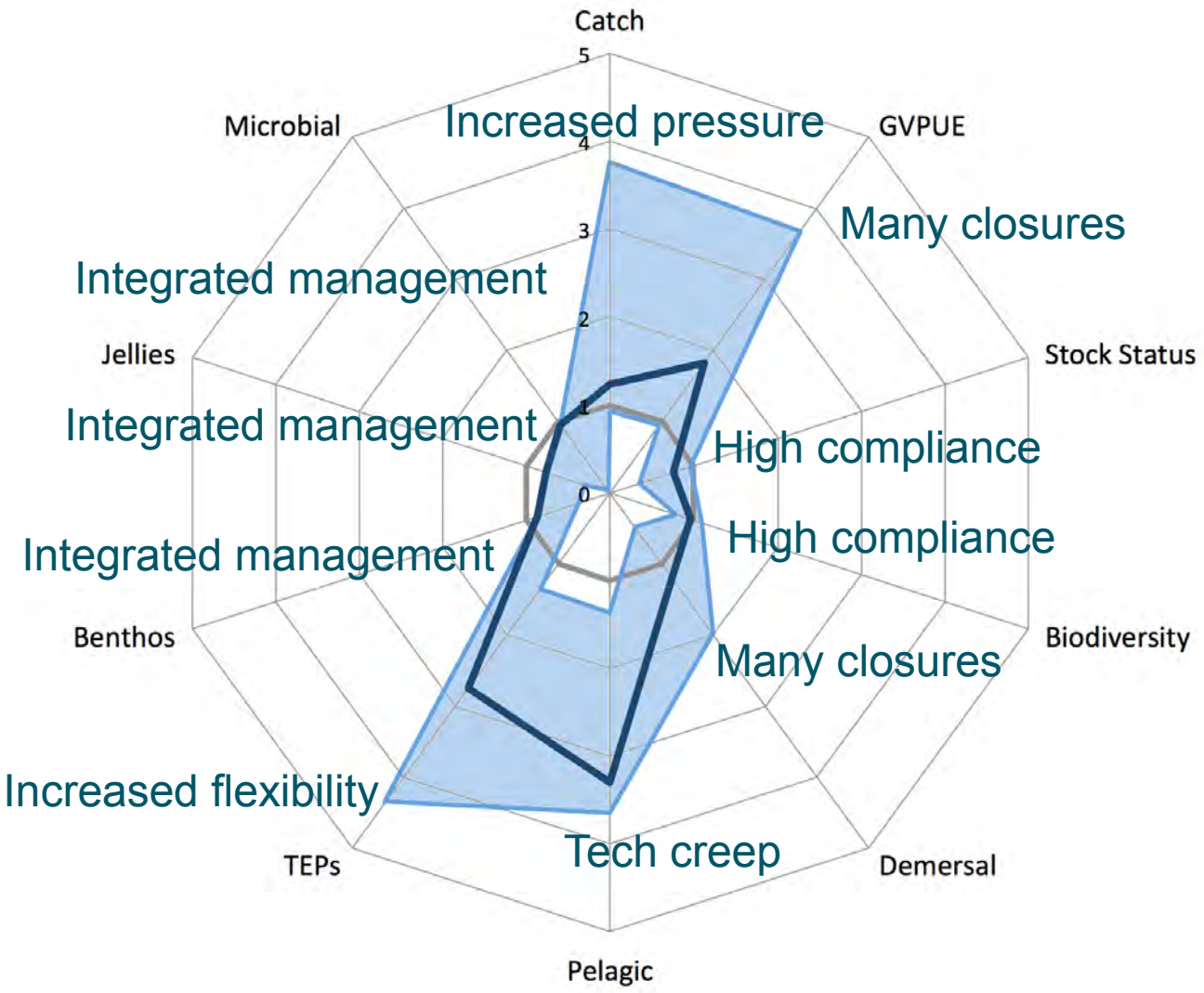
Modified from Engelen et al 1997

Management Options

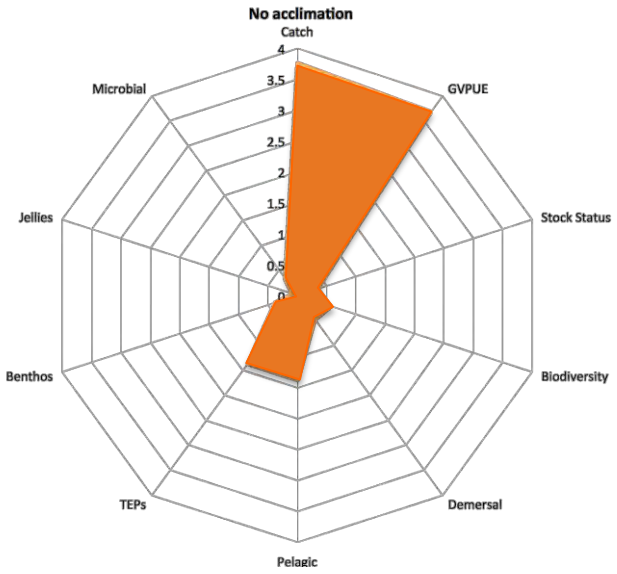
- Objective remains sustainability; >100 options explore

Class of management action
Governance: centralised, cross border co-op, “go it alone”
Spatial management: static, shifting, closures (10%, 30%, 75%)
Integrated management
Monitoring schemes: annual, periodic, per-state, coordinated
Management delays: short, long
Stock enhancement (including stocking densities for aquaculture)
Markets: classical, diversified
Costs: low, high (fisheries and aquaculture)
New fisheries (e.g. mesopelagics, immigrant species, biofuel)
Changing pressure (including tech creep, gear switching, compliance levels)

Tradeoffs – conservation & industry

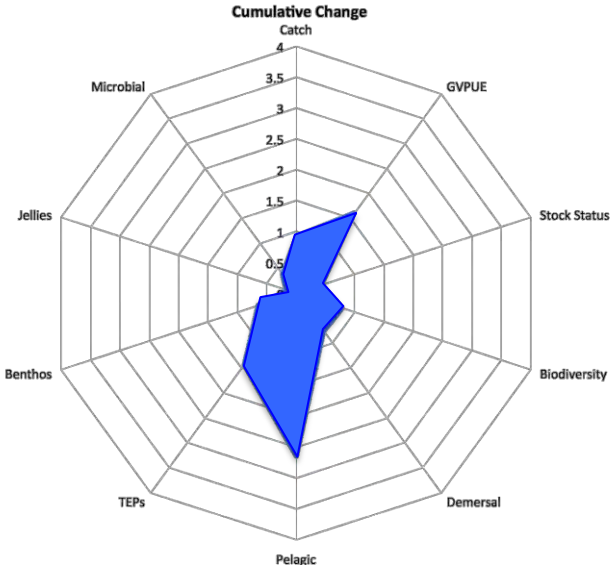


Adaptation



No acclimation

- Vertebrates suffer
- Some invertebrates explode (or crash)

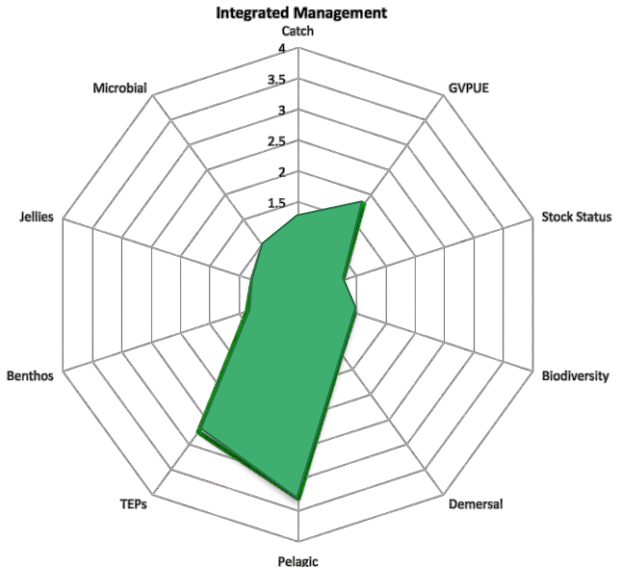


Cumulative impacts

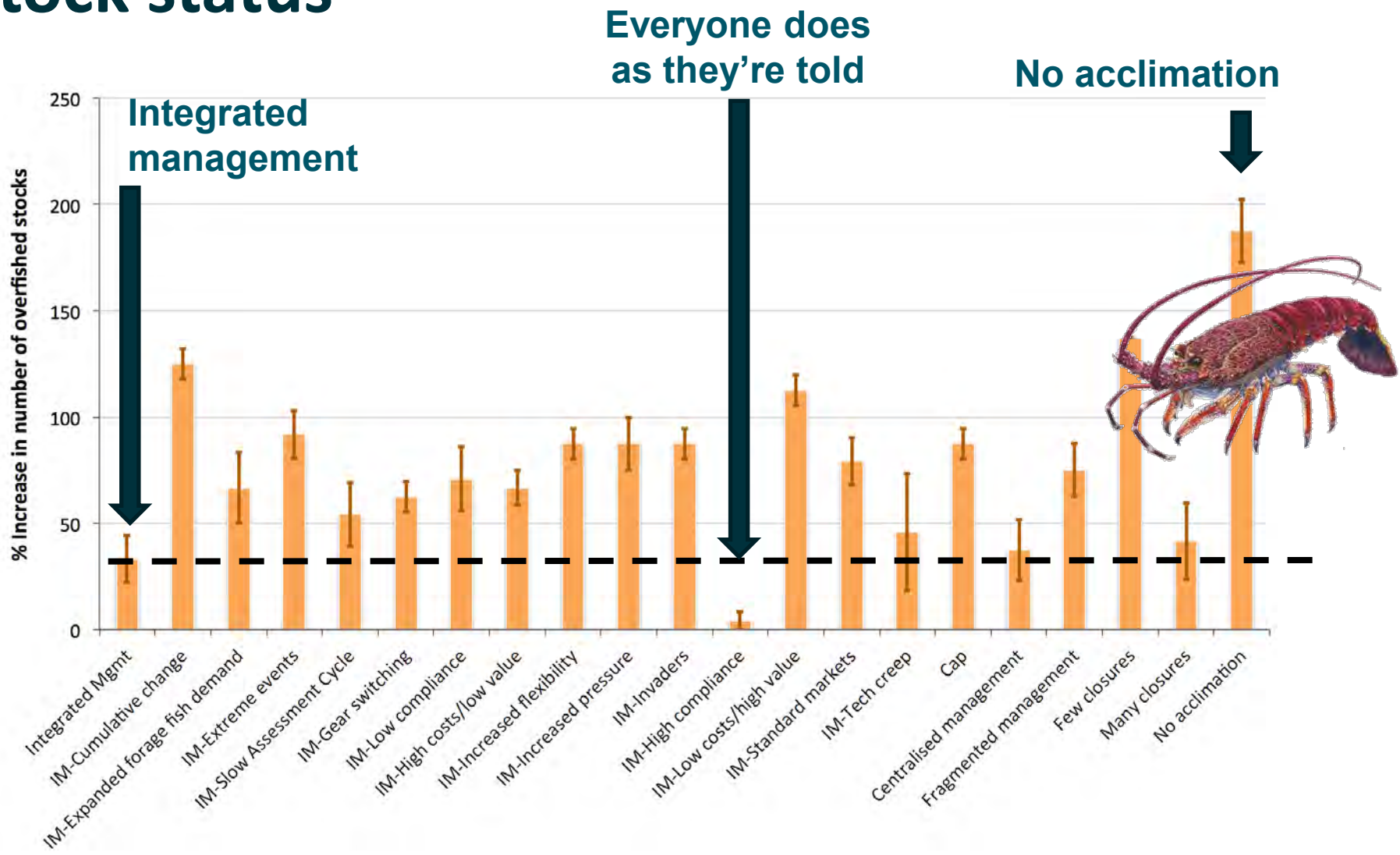
- Industries interfere
- End up with weedy system

Integrated management

- Can deliver on sustainable objectives
- Social licence required for delivery

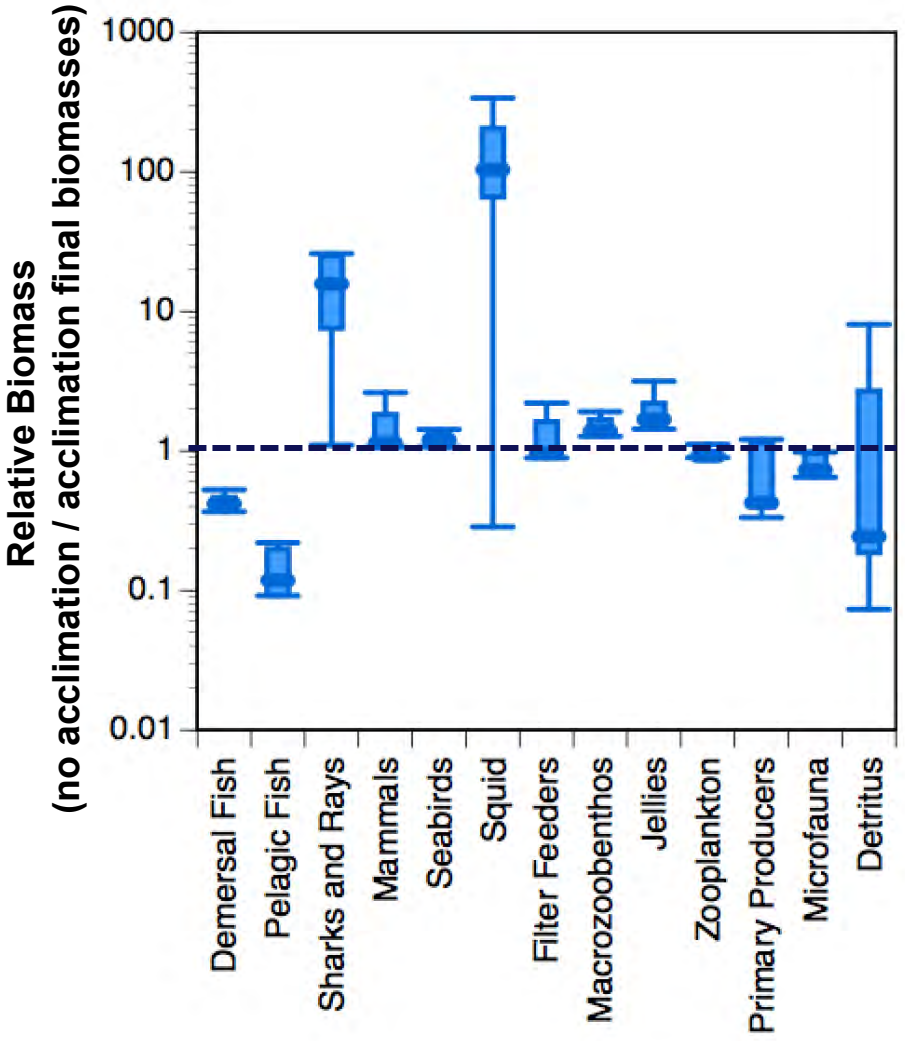


Stock status



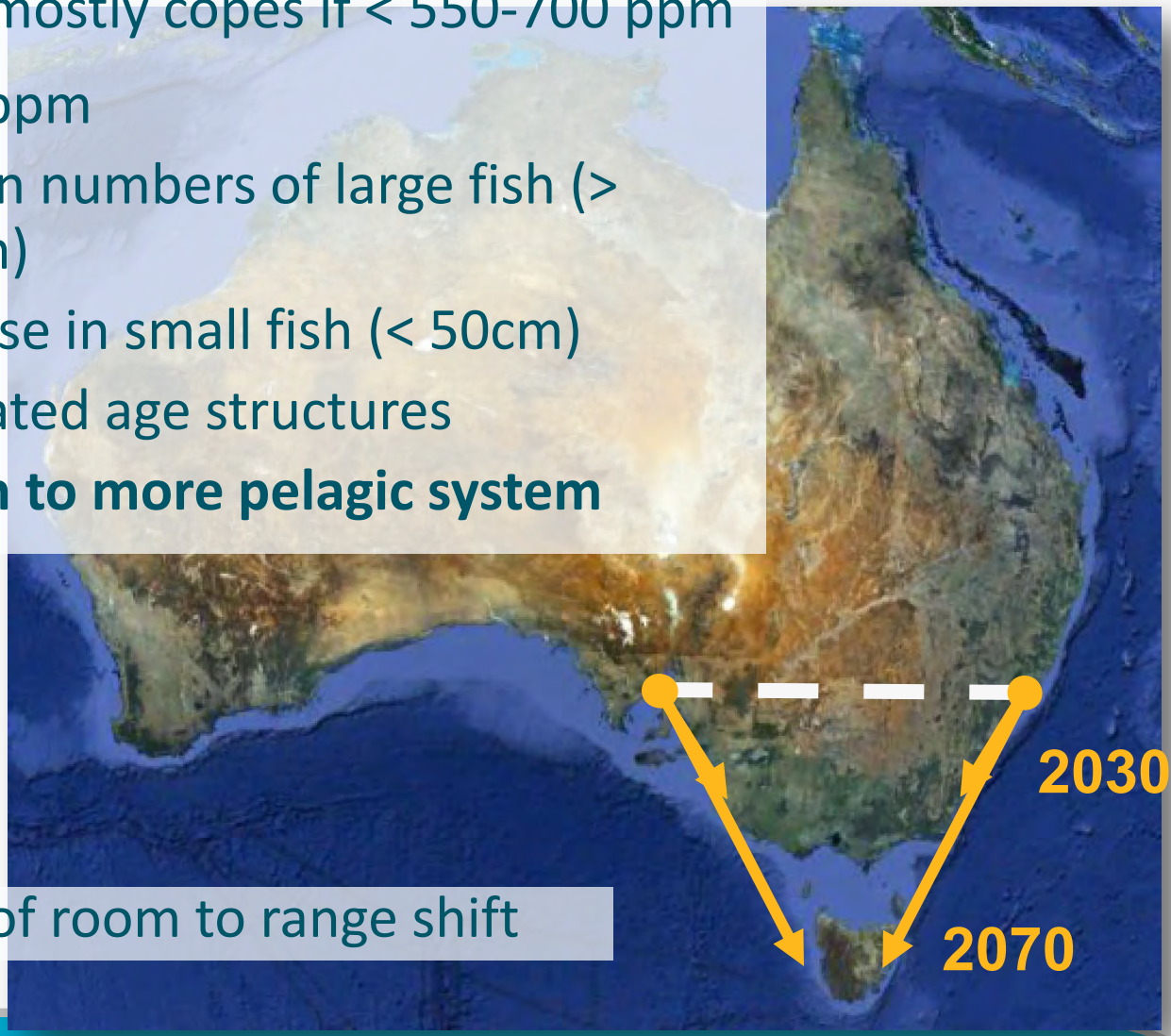
Not as dire with acclimation

- No acclimation
  - Squids boom/bust
  - Jellies & non-calcifiers win
  - Weedy & pelagic
  - Fast turnover system
- With acclimation & evolution
  - While system copes, little gross change (some turnover in dominant spp)
  - Tipping point exists

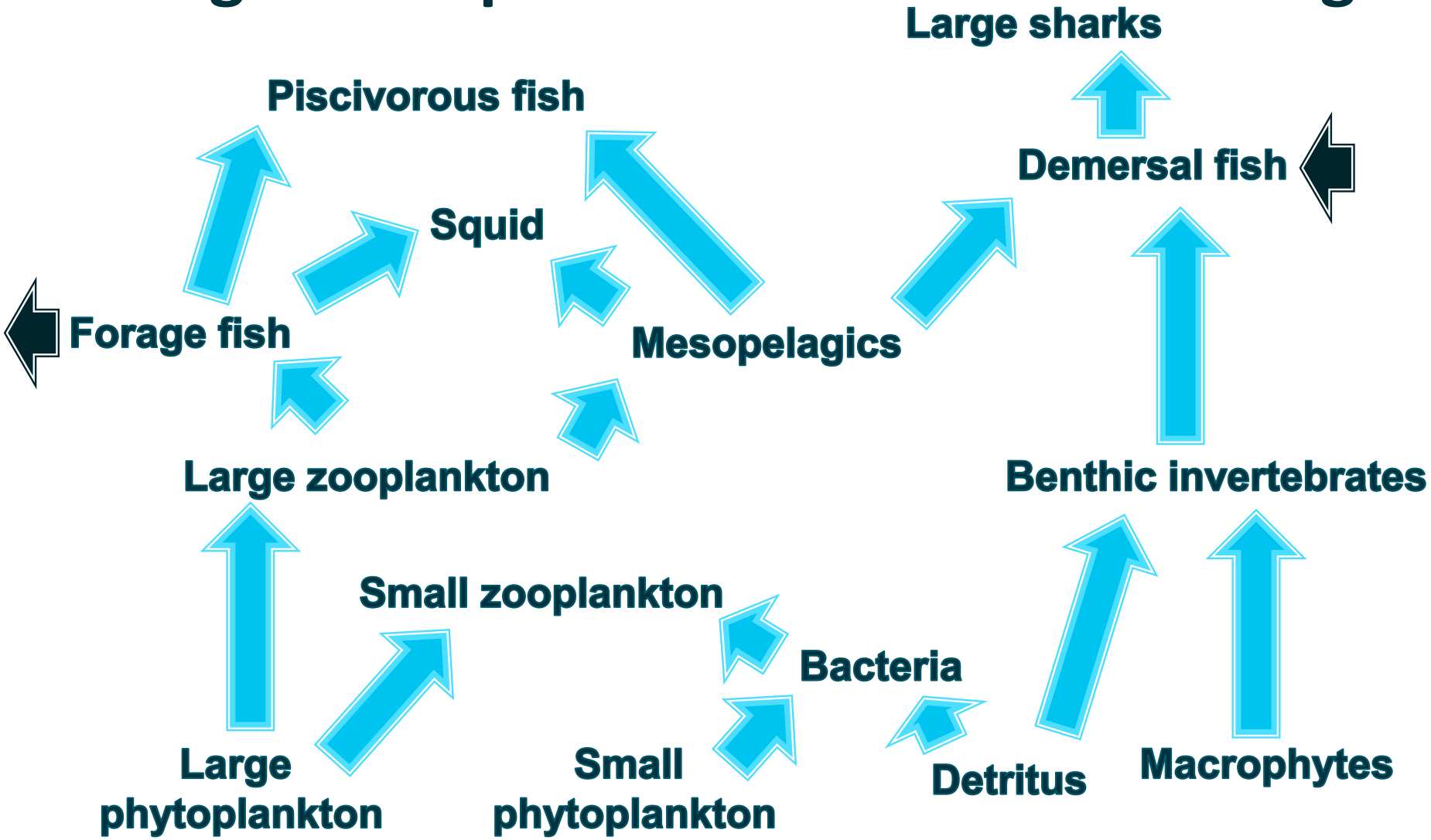


Biological adaptation: Shifting size & location

- Ecology mostly copes if < 550-700 ppm
- If > 700 ppm
  - Drop in numbers of large fish (> 450cm)
  - Increase in small fish (< 50cm)
  - Truncated age structures
  - **Switch to more pelagic system**
- Run out of room to range shift



Biological adaptation: Facilitators of change



Biological adaptation: Facilitators of change

Large sharks

Piscivorous fish

Demersal fish

Squid

Forage fish

Mesopelagics

Large zooplankton

Benthic invertebrates

Small zooplankton

Bacteria

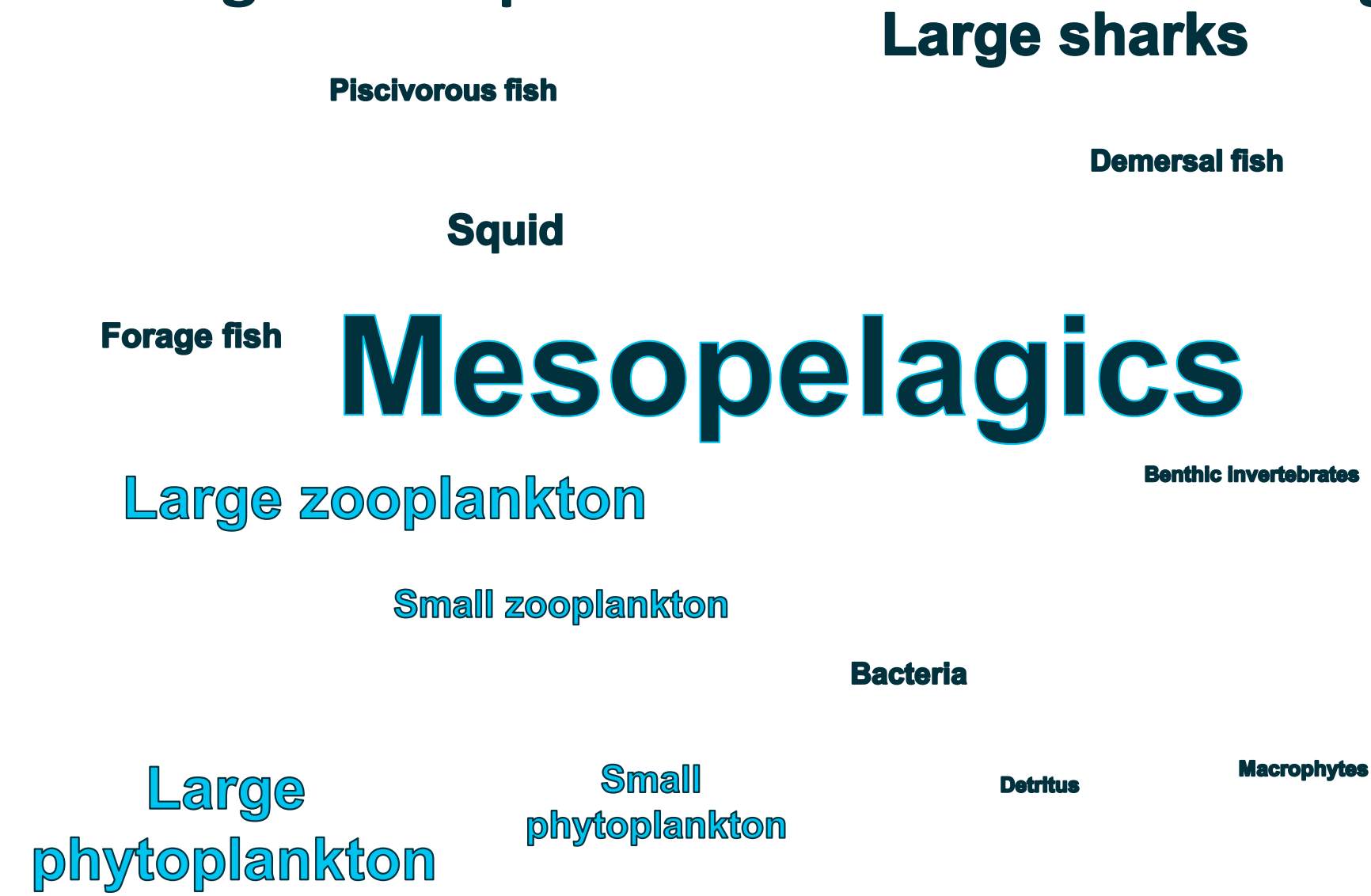
Large phytoplankton

Small phytoplankton

Detritus

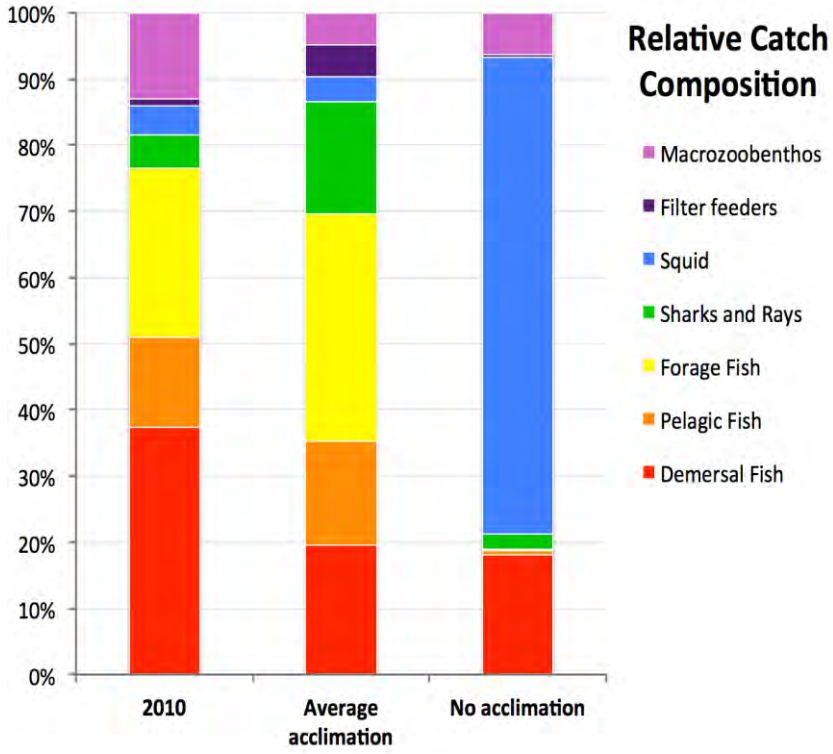
Macrophytes

Biological adaptation: Facilitators of change



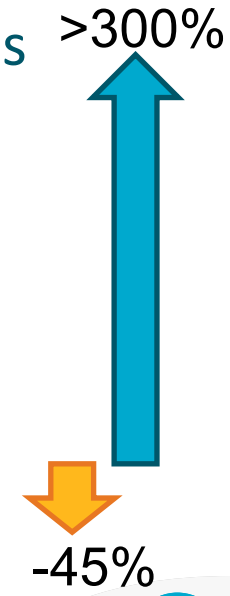
Social & economic change

- Compositional change (interaction ecology, value, ease of access)



- Cost structures shift (extreme events exposure, sunk costs, transit costs)
- Differential outcomes across jurisdictions (& fleets)
- **VPUE** outcome variable
- **Employment** halved

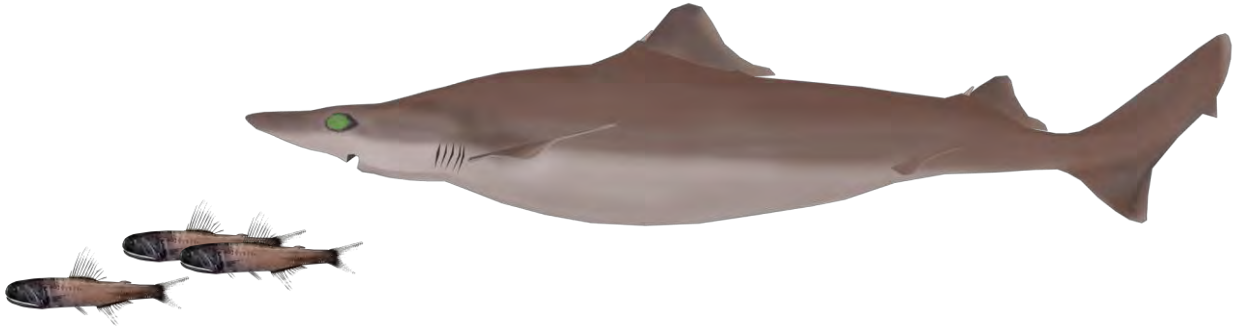
  Larger vessels more robust



Barriers to adaptation

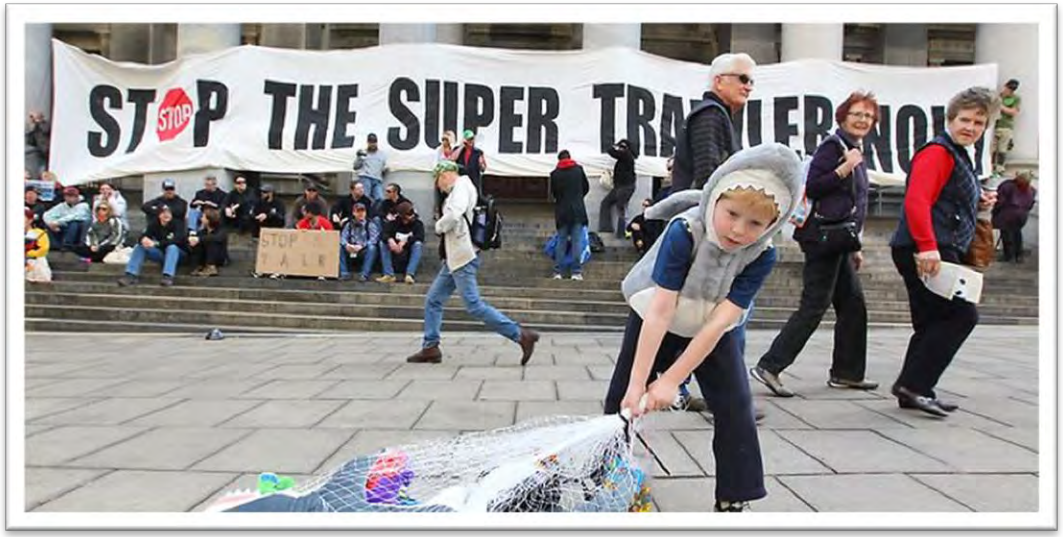
1. **Biological and ecological**
   - distribution, composition & productivity change; thresholds
2. **Behavioural, cognitive and social**
   - flexibility & personality; intuition & perception; cultural influence
3. **Governance and regulation**
   - supportive vs constraints & delays (hardship potential)
4. **Economic and markets**
   - compound barriers; larger operators typically have more capacity
5. **Technological**
   - facilitate change vs lock in maladaptive behaviour; info access
6. **Scientific**
   - remaining gaps; more change focus needed

Barriers to modelling & implementation



- Data gaps
  - physiological adaptation of higher trophic levels
  - human responses (e.g. institutional dynamics)

- Social licence



Summary

- Real world systems are non-stationary
- Models and management often based on equilibrium (or at least stationary parameterisations)
- Get a different picture if include acclimation
- Many of ecological key players are not focus of regulation
- Most effective management = integrated & adaptive
- Barriers to adaptation
  - Biology copes through until 550+ ppm
  - Human barriers to adaptation = major blocks

Thank you

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