Modelling Change

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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

Fulton et al. 2007

Fisheries induced evolution

Fisheries & climate driven
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

- Climate
- Oceanography & geochemistry
- Food web & habitat

**BIOPHYSICAL**

**SOCIAL & ECONOMIC**

- Social networks & Jobs
- Profits, costs & markets
- Lobby groups

**FISHING**

- Recreational
- Commercial

**ASSESSMENT**

- Monitoring
- Industry statistics
- Decision rules

**MANAGEMENT**

- Management actions

**Evolving parameters**

**Dynamic responses**

**Forcing**
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

- Socio-economic
  - Land demand
- Land Use
- Use map
- Suitability
- Physical environment
  - Ecosystem state
- Zoning
- Infrastructure
- Employment
- Income
- Population
- Inter-sectoral demand
- Migration
- Domestic demand
- Imports
- External demand

Industry activities

- Habitats
- C Pool
- C Market
- Food web
- Climate

Modified from Engelen et al 1997
Management Options

- Objective remains sustainability; >100 options explore

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

- Increased pressure
- Many closures
- High compliance
- Many closures
- Integrated management
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- Increased flexibility
- Tech creep
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

- Integrated management
- Everyone does as they’re told
- No acclimation

% increase in number of overfished stocks

Integrated management

IM-Cumulative change
IM-Expanded forage fish demand
IM-Extreme events
IM-Gear switching
IM-High costs/low value
IM-Invasers
IM-High compliance
IM-Standard markets
IM-Tech creep
Cap
Centralised management
Fragmented management
Few closures
Many closures
No acclimation
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

- Piscivorous fish
  - Large sharks
  - Demersal fish
- Squid
- Forage fish
- Large zooplankton
- Mesopelagics
- Small zooplankton
- Bacteria
- Large phytoplankton
- Small phytoplankton
- Detritus
- Macrophytes
Biological adaptation: Facilitators of change

- Piscivorous fish
- Squid
- Forage fish
- Large zooplankton
- Small zooplankton
- Large phytoplankton
- Small phytoplankton
- Mesopelagics
- Benthic invertebrates
- Detritus
- Macrophytes
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

![Relative Catch Composition Chart]

- 2010
- Average acclimation
- No acclimation

- Maczoobenthos
- Filter feeders
- Squid
- Sharks and Rays
- Forage Fish
- Pelagic Fish
- Demersal Fish

-45%

>300%
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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