Tipping Points and Decision-Making: Why they matter, why they are hard, and practical things to do

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Why they matter

What do they do?

- They differentiate the area where there is resilience and buffering from the area where there vulnerability and amplification.
- On the safe (shallow) side of tipping points a (scaled) unit loss of the property has LESS than a unit loss in its function, service, or viability
- On the dangerous (steep) side the same unit loss of the property has MORE than a unit loss of function, service, and viability

Stock recruit curves

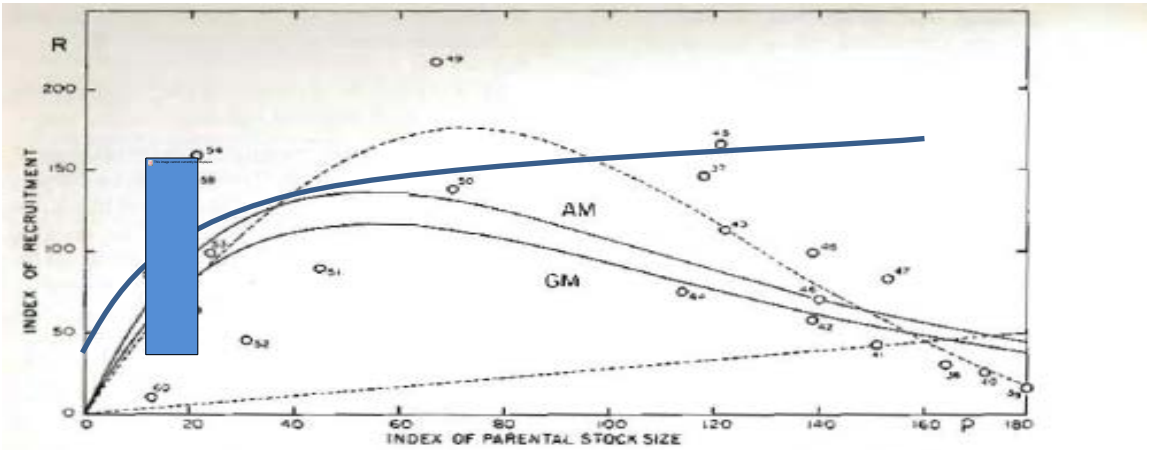
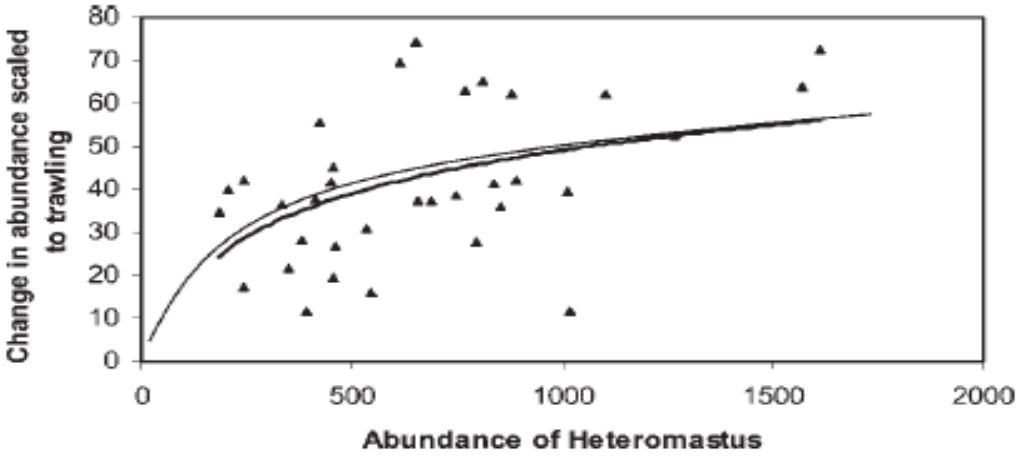


FIG. 11.3. Graph of recruitment against parental stock for Arcto-Norwegian cod. Solid curves—Ricker reproduction curves for geometric and arithmetic mean values; the broken curve is drawn freehand (see the text). (Data from Garrod 1967.)

- **Part of fisheries for more than half a century**
- **Root of ALL fishery reference points**
- **Fit to ALL data is rarely very convincing**
- **Point of maximum curvature is highly robust**

Concept is generalizable well beyond fisheries S – R relationships

From Rice
ICES JMS
2009



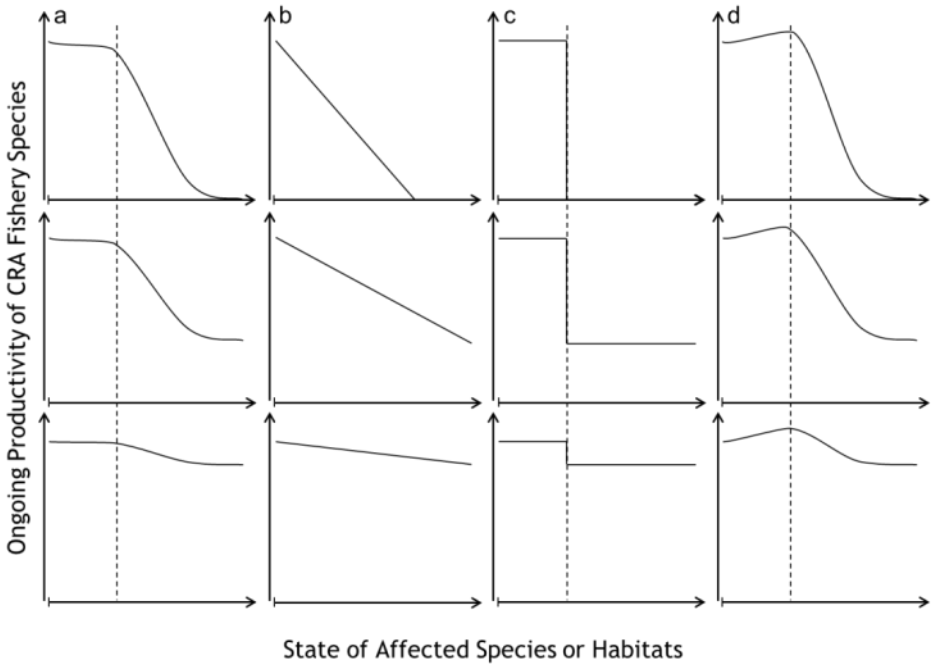
SAME properties of SHALLOW and STEEP Domains
Same robust region of transition between domains
X-axis – ANY measure of how much [temperature, biomass, duration, etc
Y-axis – Any measure of replacement, function, service
Same resilience in the shallow side, reactivity in steep side

Fish Habitat/FPP Framework

Same concept with the X-axis reversed

Shows flexibility of framework, covers ALL pathways of effect

ALL hinge on which side of the tipping point

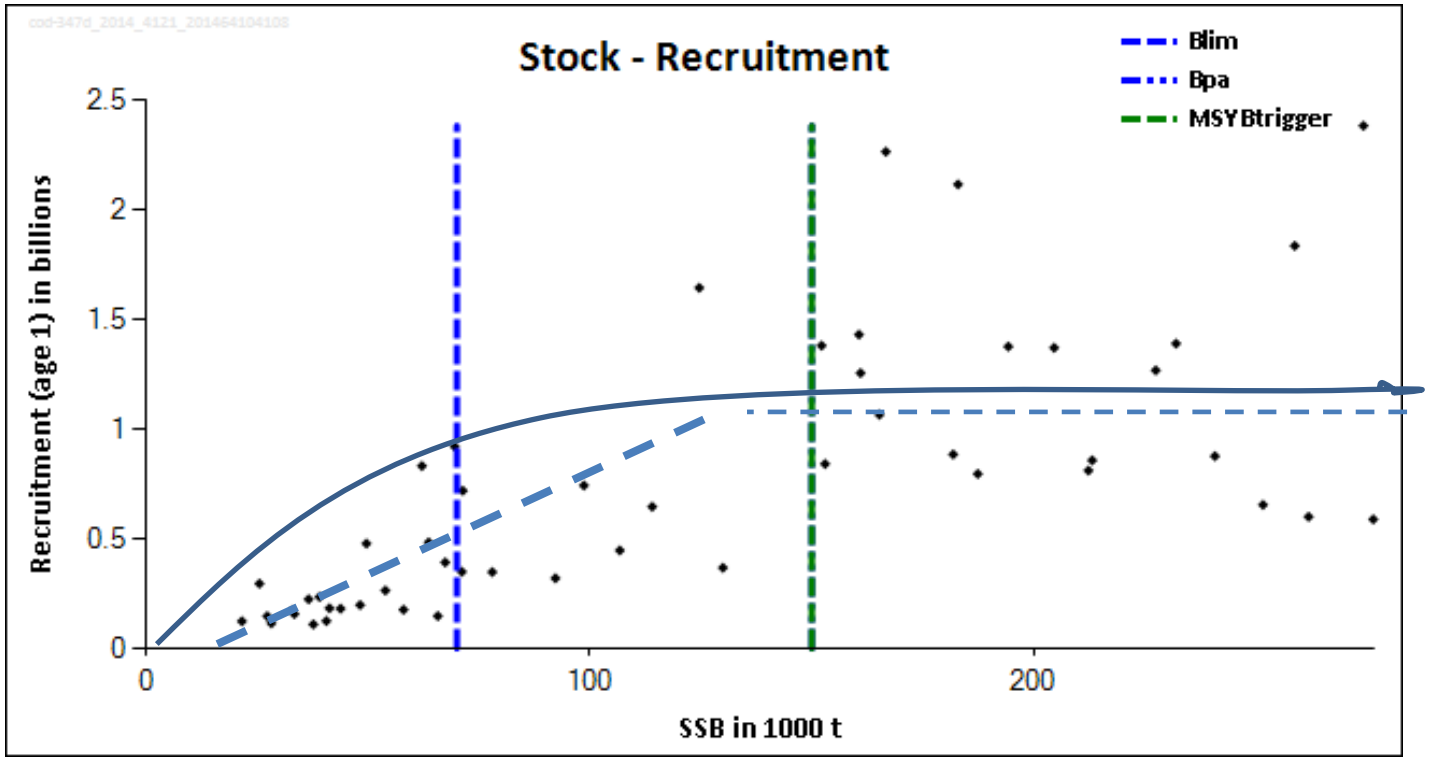


Why they are hard

We don’t focus on the tipping point

- Simple reason – they require contrast in the data
- More complex reasons - models mislead us
  - Fitting a full functional relationship shifts emphasis from locating tipping point to fitting all the data
  - Anchor at the origin and overestimate steepness in 43 of 47 ICES and Canadian stock assessments *
  - If points are less frequent at high X-axis values they, then they have high leverage on model parameters
  - If Y not strongly affected by X in shallow zone, other pressures may put lots of variance there and model will thy to explain THAT variance

North Sea cod show all of these challenges
Not Every model places tipping point in the same region – have to fit the data at least a bit
Data based linearizations have value



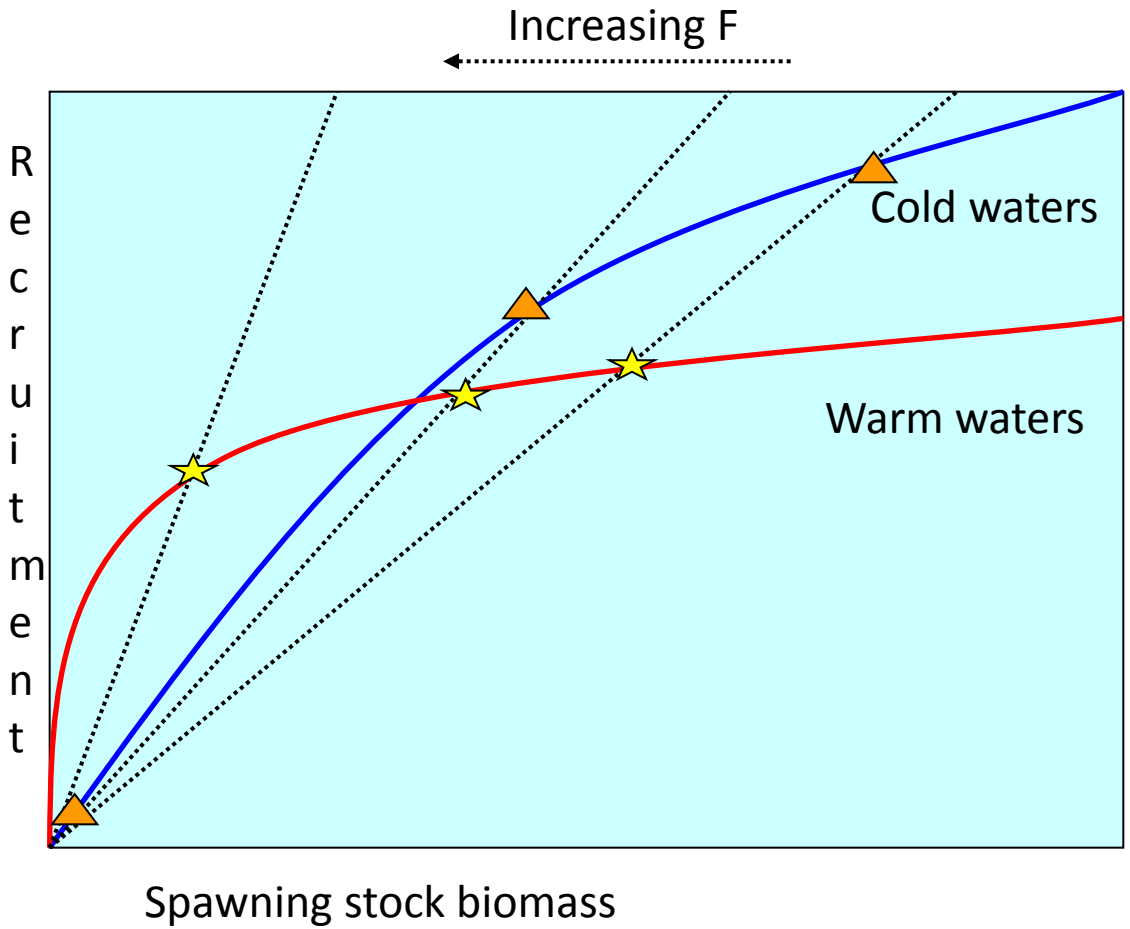
What should management do with tipping points

Decision making

AVIOD tipping points with high probability

- If decision-making has one dimension maximizing likelihood of achieving target rarely puts passing tipping point at risk
- FEW DECISIONS HAVE ONLY ONE DIMENSION
  - Ecological AND Social AND Economic considerations
  - Maximizing one often requires being close to or over tipping points on others (Trade offs)

There is Multi-dimensionality to the environment



Replacement lines

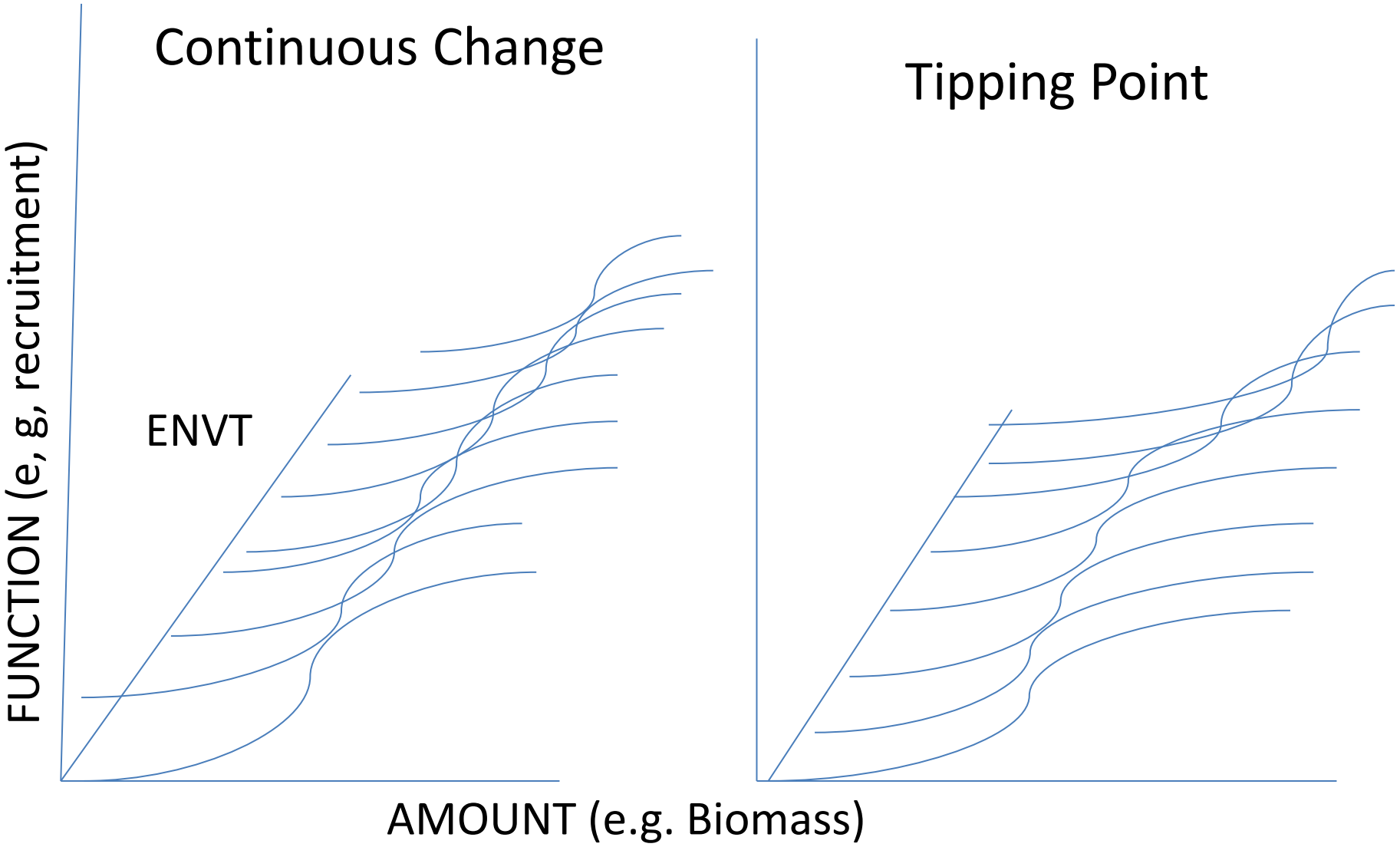
Recruitment in warm waters

Recruitment in cold waters

Private working group data for 6 cod stocks (Pope et al 2009)

Implications

- If temperature (or other environmental factor) has continuous normal variation then analyze for tipping points on two dimensions
  - Standard 3-D contours
- If influential factors have regimes or stages then one has hierarchical rules:
  - Which regime to use (“regime” tipping point)
  - Where is tipping point for the appropriate regime


Continuous Change
Tipping Point
ENVT
FUNCTION (e, g, recruitment)
AMOUNT (e.g. Biomass)

It matters what changes

- Per capita mortality
  - Density Independent; top down OR bottom up
- Per capita fecundity
  - Density independent; generally bottom up
- Ecosystem Carrying Capacity
  - Density DEPENDENT; more likely bottom up but predation regimes conceptually possible

Tipping point effects

- Increased density independent mortality
  - Tipping point moves RIGHT and less curved
- Decreased density independent fecundity
  - Tipping point moves right and less curved
- Both require MORE spawners to fill ecosystem space
- Lower density dependent carrying capacity
  - Tipping point likely reached sooner, so moves to the left and more curved; FEWER spawners

Conclusions

- Be aware of leverage in data sets when fitting models, not just overall fit
  - If the data suggest curvature, focus on maximum secodn derivative zone
- Manage to avoid all tipping points, not optimize on one dimension if the cost is “dancing near the edge” on the other
- When you do have an (environmental) tiping point exceeded, you need to understand what happened to make the right management choice