Economic Impact of Climate Change and Ocean Acidification on Fisheries

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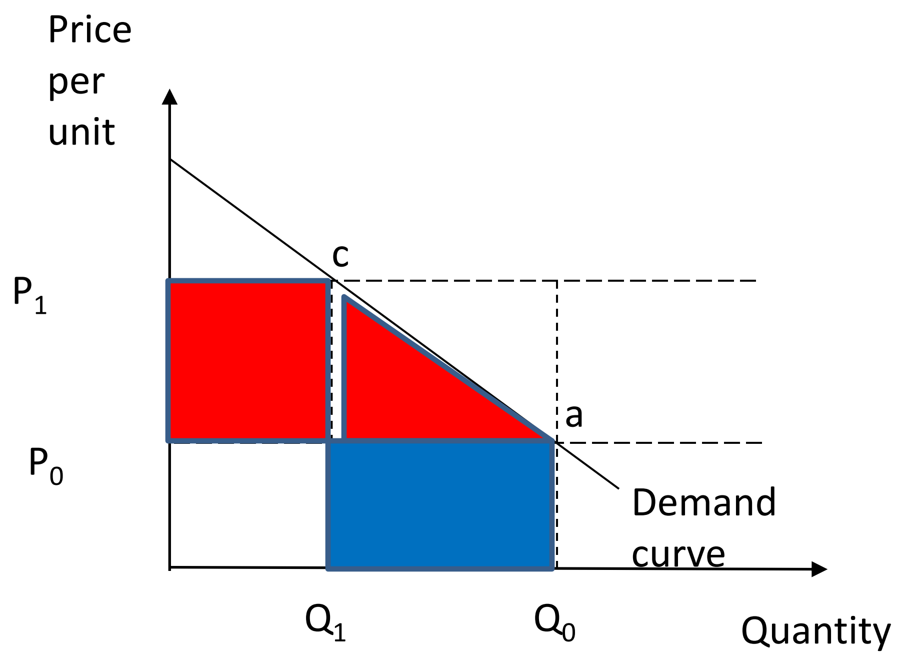
Ocean Acidification

- Past declines in ocean surface pH linked to mass extinction events
- Reduction in carbonate ion concentration
  - > reduction in calcium carbonate saturation
  - > impacts on marine calcifiers
  - >requires marine calcifying organisms to use more energy to form biogenic calcium carbonate
    - Hampered reef formation of corals, algaes
    - Hampered shell formation of oysters, clams and crabs

Economic consequences: S.R. Cooley and S.C. Doney. 2009. "Anticipating ocean acidification's economic consequences for commercial fisheries." *Environ. Res. Lett.*



•Calculated potential revenue losses from decreased mollusk harvests of 6%–25% from 2007 level were to occur in 2009, $75–187 million in direct revenue would be lost each year into the future, with a net NPV loss of $1.7–10 billion through 2060

•No direct connection between replacement costs and a useful welfare measure

Economic Consequences

- May disrupt provisioning of ecosystem services (ES)
- One of a class of "Materials Damages" problems studied in detail by Tom Crocker 25 years ago
- Human welfare is dependent on biological systems (material environment) that provide critical inputs to human activity
- Damages or improvements in material environment implies welfare changes

Assessment of Materials Damage Requires:

1. Characterization of the differential changes across time and space that environmental change causes in production and consumption opportunities
2. Determination of the responses of input and output market prices to these changes
3. Identification of the adaptations that affected agents can make to minimize losses or maximize gains from changes in opportunities and prices

Economic Effects:

- Perturbations in provisioning of ES change producers production possibilities
- Degradation may reduce production possibilities
- Perturbations in provisioning of ES may change costs facing households directly or indirectly (access costs)
- Objective functions and behavior towards new sets of production and consumption possibilities remains the same
- First key question: how do to bring these changes in possibilities into economic analysis?

Bringing Environmental Changes into the Economic Assessment

Reduced Form Representation:

- easy to fit to limited data
- gives good view of general processes

BUT

- aggregation can cause errors in economic estimates

(Kopp and Smith, 1980 BJE)

Structural Representation:

- can represent critical details explicitly
- capture within system adaptations

BUT

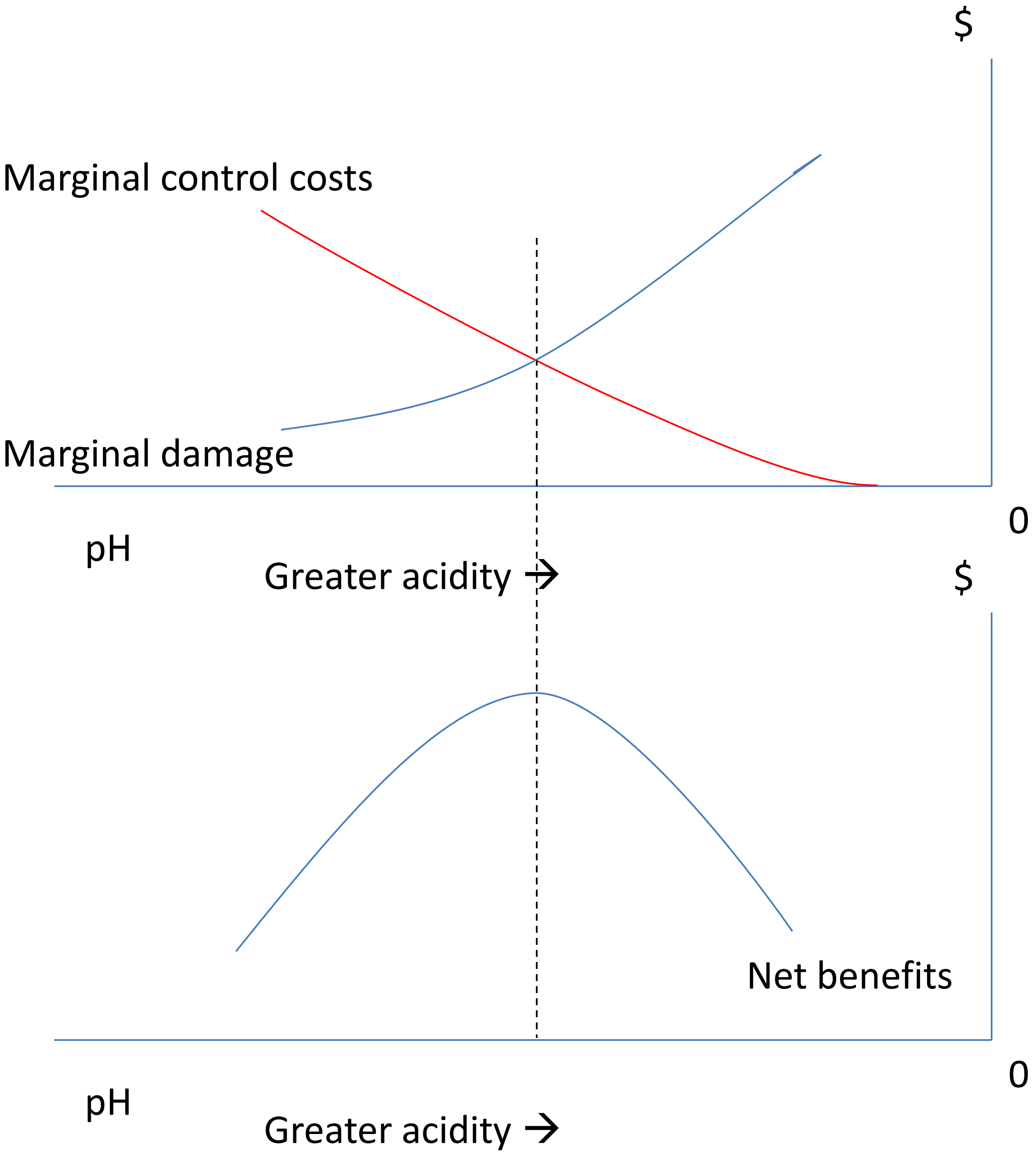
- contribution of additional natural science information declines rapidly

(Adams, Crocker and Katz, 1984 RESTAT)

Appropriate Balance?

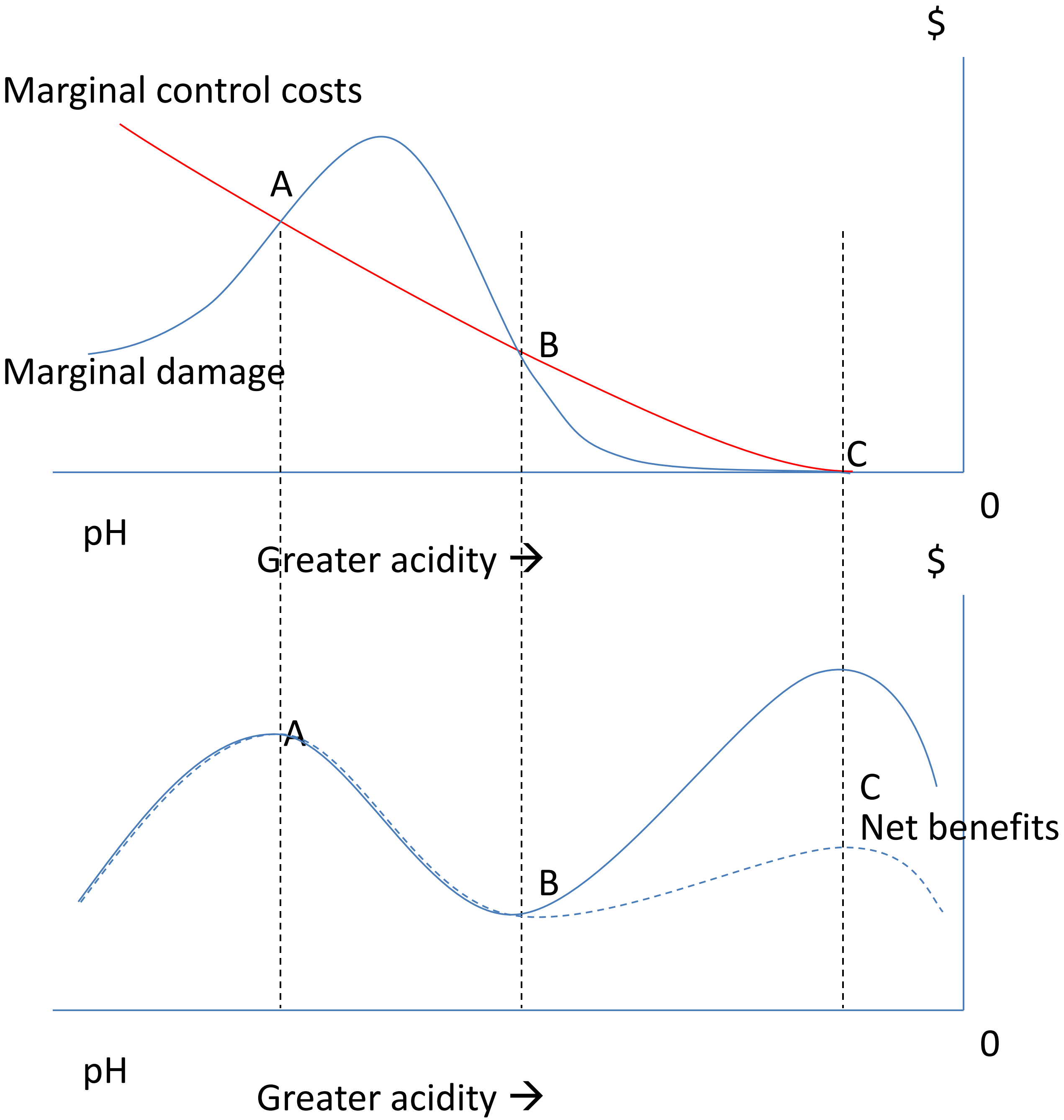
- in one dimension balance depends on potential of non-convexities
- If problems are convex reduced form representation likely sufficient
- If there are pervasive non-convexities high level of abstraction may lead to trouble – need to know the entire possibilities surface

Standard setting



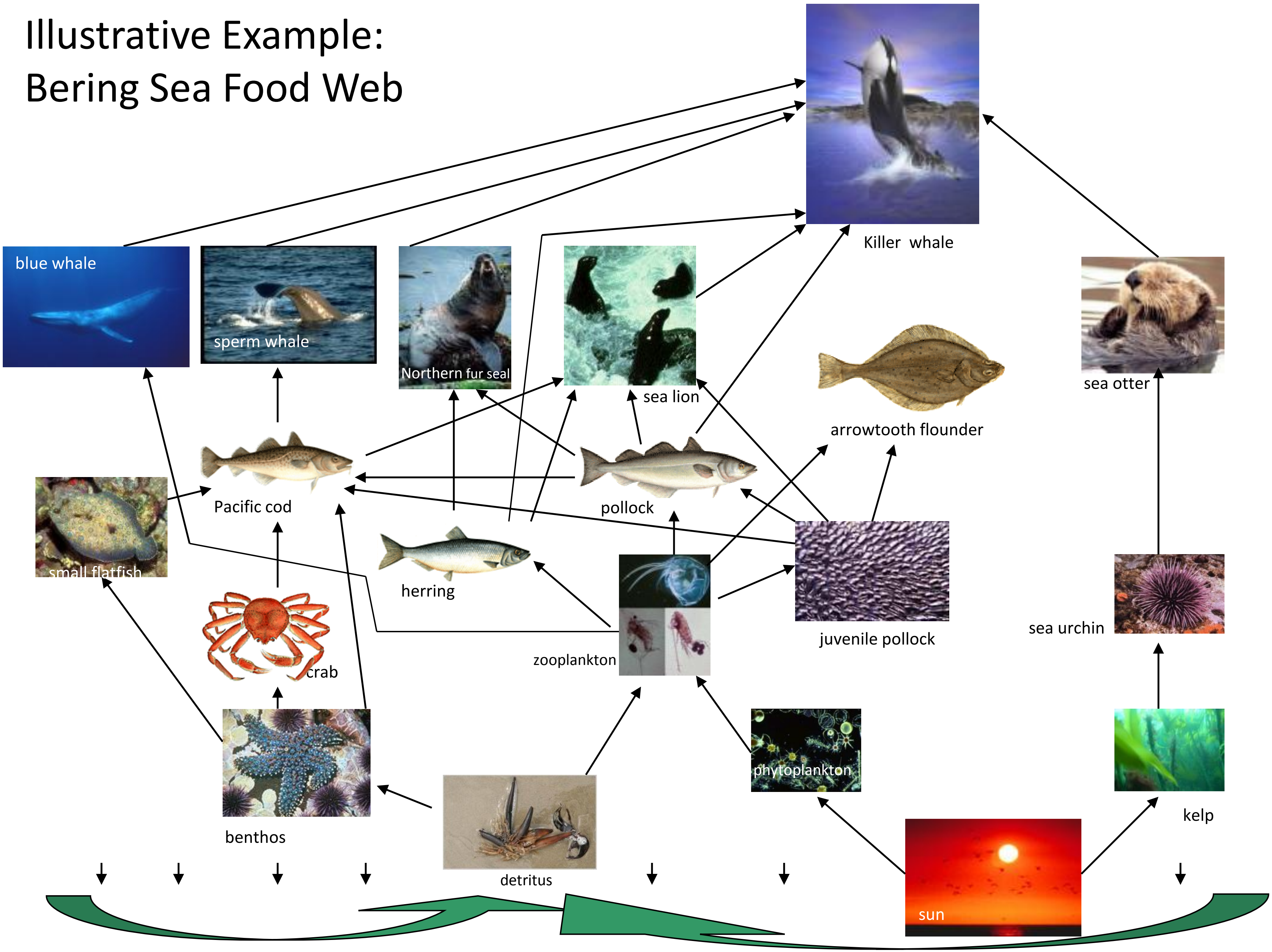
- single equilibrium
- marginal comparisons alone sufficient to signal how to max social net benefits

Non-convexities



- multiple equilibria
- natural and economic adjustments not as clear – requires an expansion of the scope of analysis
- marginal comparisons alone insufficient to signal how to max social net benefits
- need know the entire surface (across environmental change) to locate global optimum and understand how the marginal damages change

Illustrative Example:
Bering Sea Food Web



GEEM: Developed to track ecological adjustment

1) fitness net energy

$$R_i = \sum_{j=1}^{i-1} [e_j - e_{ij}] x_{ij} - \sum_{k=i+1}^{m} e_i [1 + t_i e_{ki}] y_{ik} (\sum_{j=1}^{i-1} x_{ij}) - f^i (\sum_{j=1}^{i-1} x_{ij}) - \beta_i$$

2) biomass transfers (similar to market clearing)

$$n_i x_{ij}(\mathbf{e}_i) \leq n_j y_{ji}(\mathbf{x}_j(\mathbf{e}_j))$$

3) population updating

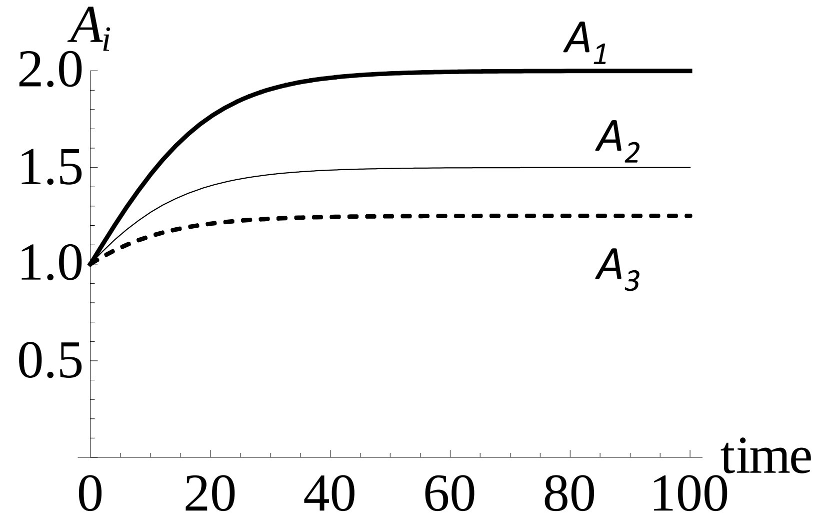
$$n_i^{t+1} = n_i^t + n_i^t \frac{1}{s_i} [\frac{R_i(\cdot) + v_i}{v_i^{ss}} - 1]$$

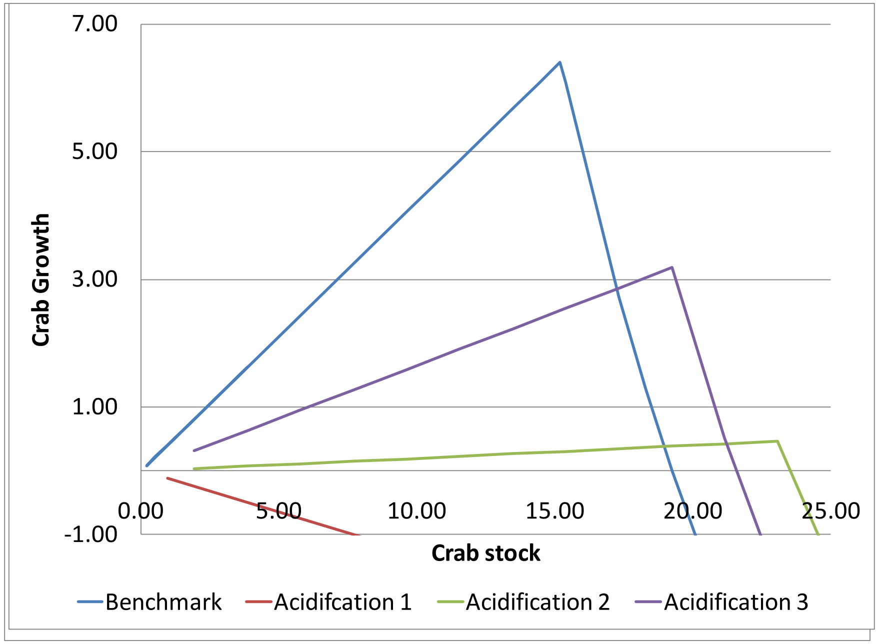
Acidification

Ad Hoc: Acidification increases variable respiration requirements of crabs for any level of biomass consumption

$$f_{crab}(.) = \mathrm{A}_i \, \alpha_{crab} x^2_{crab,benth}$$

$$\mathrm{A}_i = \frac{a_i}{b_i + e^{-.1t}} \quad i = \{1,2,3\}$$




7.00
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Crab Growth
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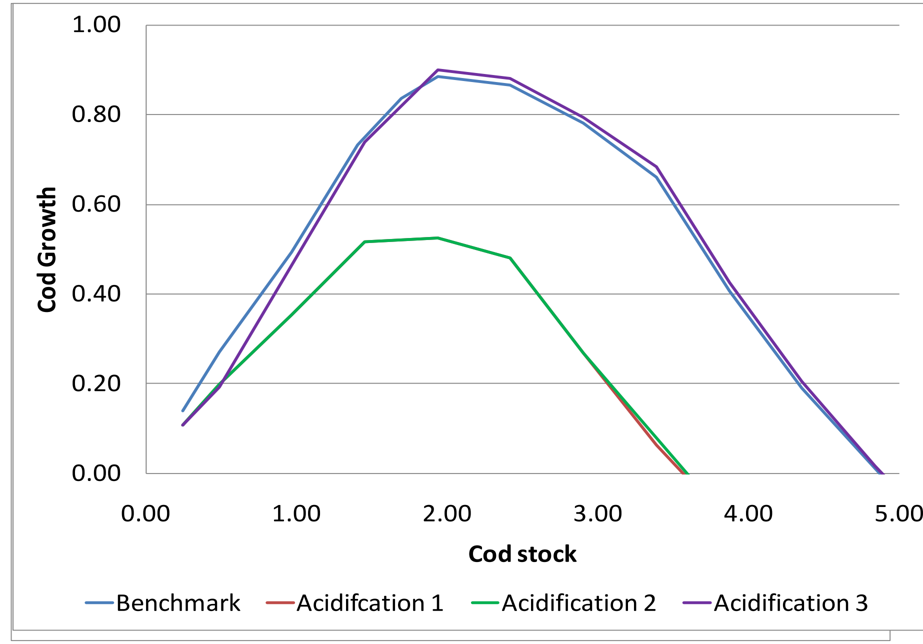
Crab stock
Benchmark
Acidifcation 1
Acidification 2
Acidification 3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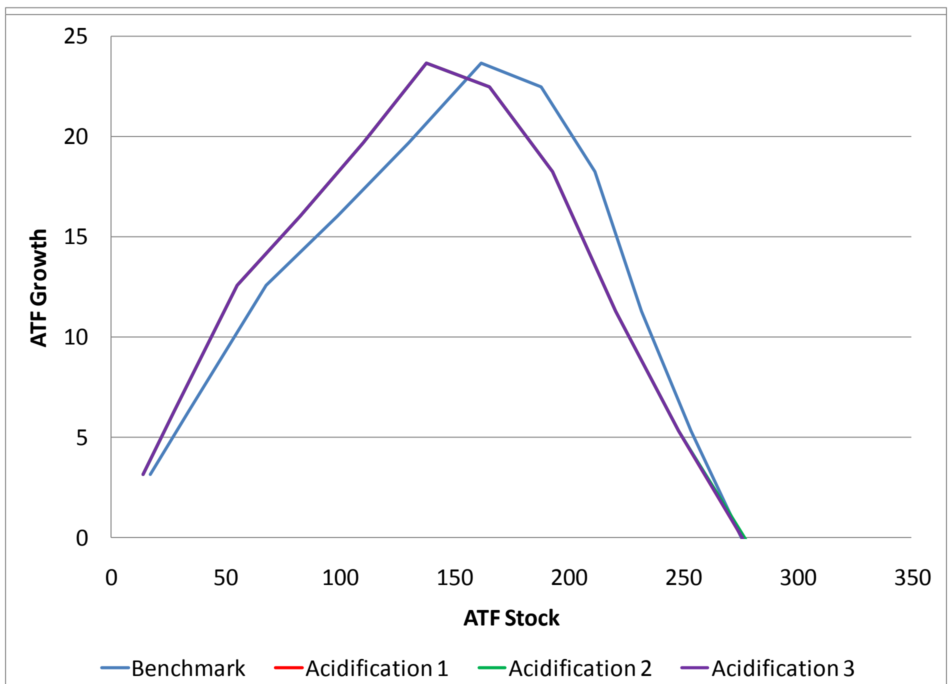
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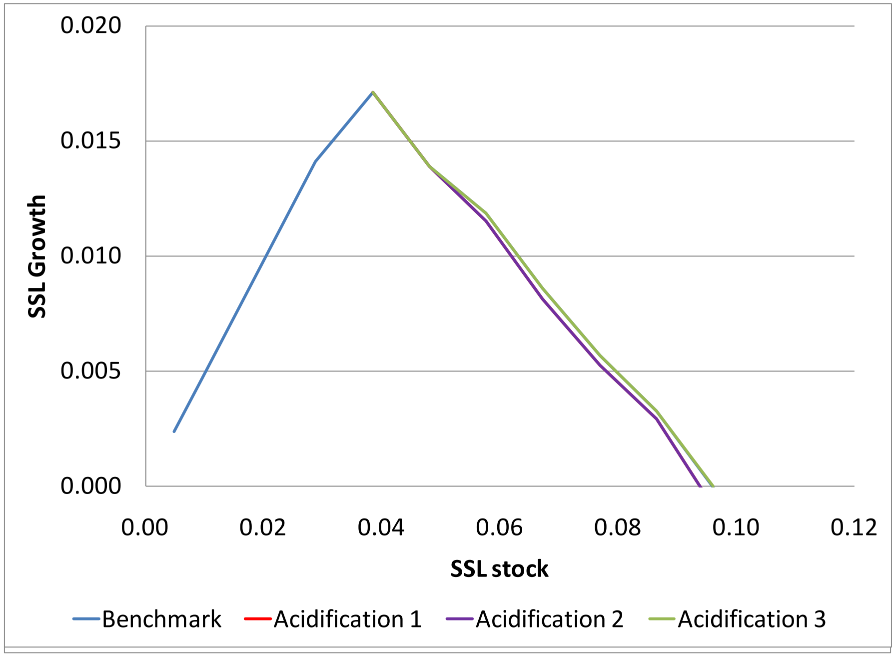
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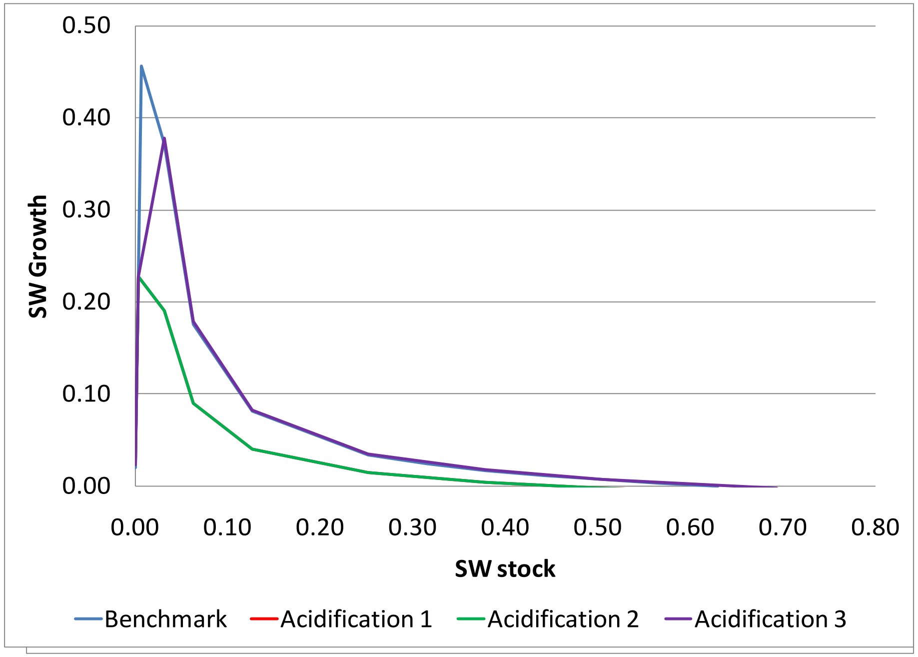
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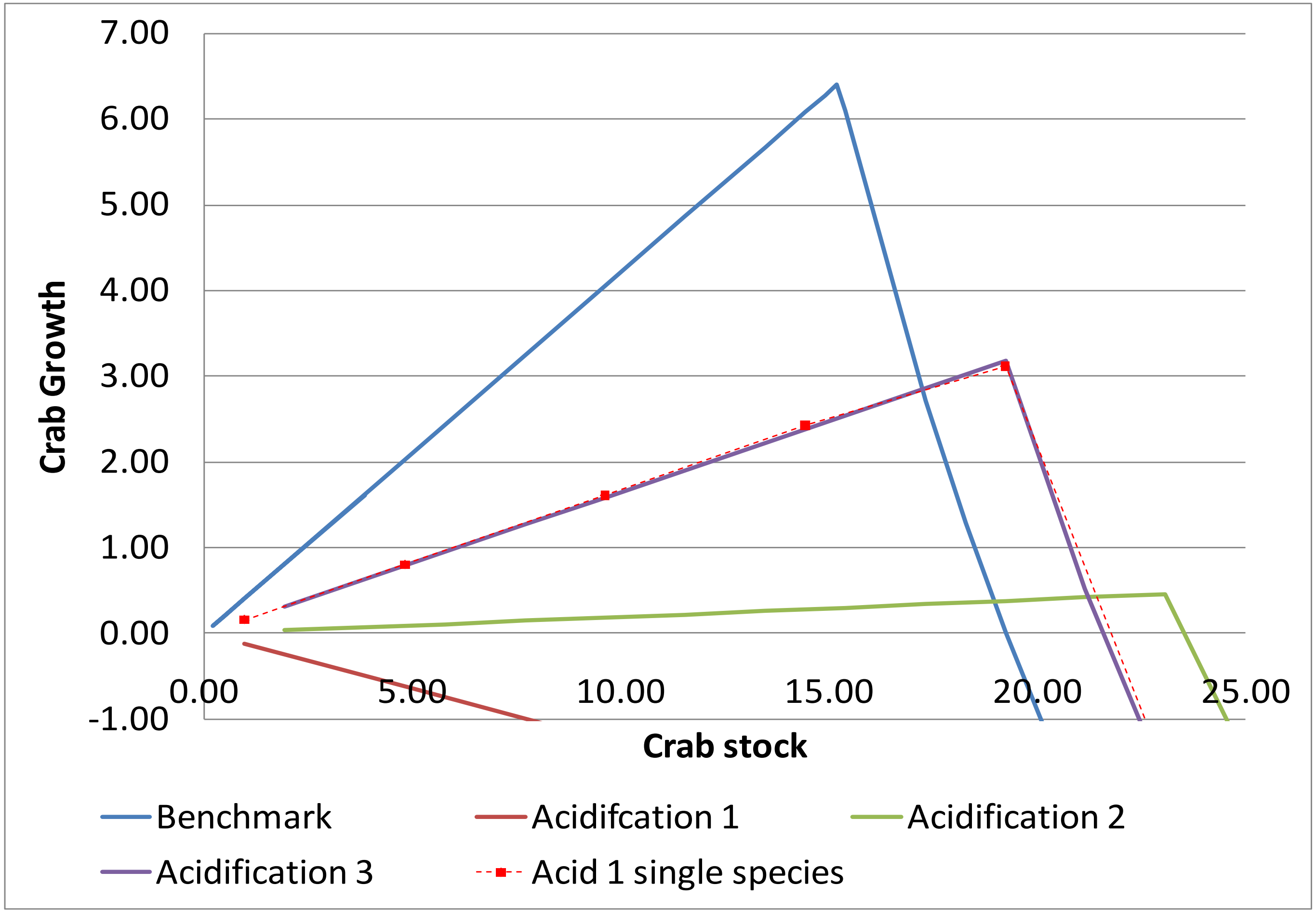
SW stock
Benchmark
Acidification 1
Acidification 2
Acidification 3

Implications:

- Consequences reverberate across system in varying degrees and magnitudes
- Seems to be a potential for non-convexities
  - Acidification a negative shock to crab optimization problem yet can see higher stocks (although less surplus growth)
  - Changes not always monotonic
  - Problems with reduced form aggregations

Representation of Environmental Changes:

Reduced Form Representation v's Structural Representation



Point:

- Bioeconomic harvests of fish and crab likely affected to varying degrees and magnitudes depending on location in food web
- Non-harvested stocks may or may not have cascading effects depending on location in foodweb
- To assess tradeoffs have to be able to access changes in flows and stocks simultaneously

Evaluating Environmental Changes: Do changes in relative prices matter?

Reduced Form / Partial Equilibrium Representation:

- other prices and incomes exogenous
- allows clear representation of optimal planning over long time horizons
- allows clear focus on effect of environmental dynamics on choices
- requires few parameters

BUT

- narrow viewpoint, omits all other adaptation
- typically omits a connection to welfare economics
- not clear how specific scientific information be included into lumped parameters

Structural / General Equilibrium Representation:

- prices and incomes endogenous
- system wide adaptation
- clear link to principles of welfare economics and inclusion of producer and consumer behavior
- Enough detail to include specific scientific information

BUT

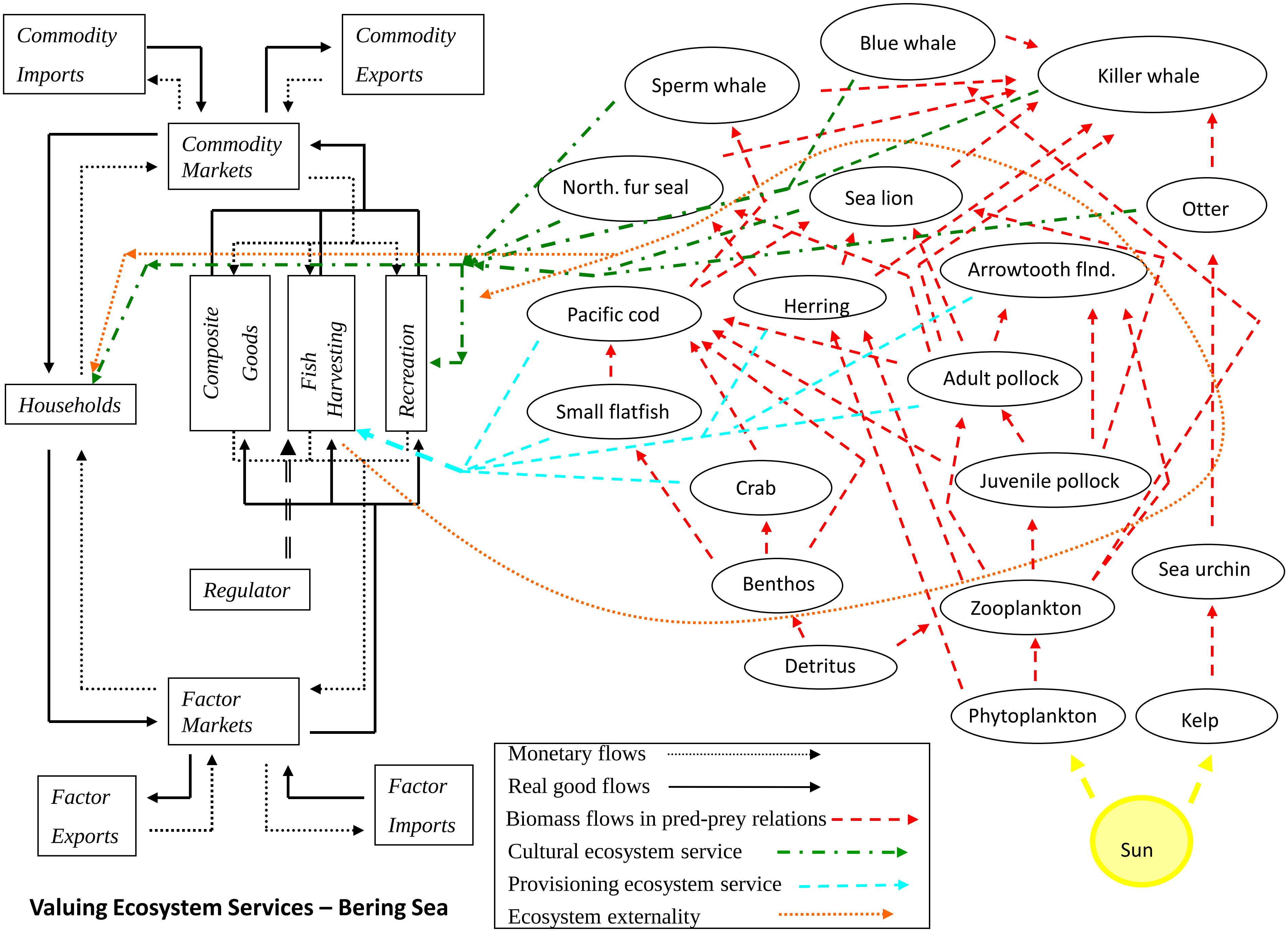
- requires numerous parameters
- hard to dynamically optimize
- broad viewpoint makes decomposing effects tricky
- influence of environmental dynamics obscured by economic responses

What is the Appropriate Balance????

Conclusions

Point: Welfare measurement of materials damages has some well known characteristics but for this problem a lot remains unresolved and work remains

1. Accurate assessments tricky, generalities seem to be lacking
2. Need a clear understanding of how production and consumption possibilities are affected by the problem in a consistent setting
   – dose response relationships of environmental change from the natural sciences are key, but how much detail is necessary for a good understanding remains to be resolved
3. If problems are convex or well behaved then aggregate representations of the natural science may be sufficient for good economic assessments
4. If problems have pervasive non-convexities then policy makers must expand the scope of their analysis for good economic assessments – marginal assessments on their own may lead to trouble (G. Brown, REE, forthcoming)



Valuing Ecosystem Services – Bering Sea

Valuing Ecosystem Services – Neuse River